Successful Oil and Gas Production Well
Applications of Thermoplastic Lined Downhole Tubing: Protecting Horizontal Well Tubing and Pumping Around the Bend

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What is a Poly Liner?

- A specially formulated polymer tube that is inserted inside new or used tubing, to reduce failures due to corrosion and/or rod on tubing wear (Patents in USA and pending in Canada).
- A unique procedure is followed to cover the pin ends
- Seamless mechanical-bonded liner (no adhesive required)
- API Couplings are coated with a high performance polymer to protect against corrosion in the J-area.
Introduction

- Poly liners have a proven history in down hole applications in over 30,000 wells for the last 22 years reducing corrosion failures in injection and disposal wells; artificially lifted wells like plunger lift wells, submersible pumped wells, gas lifted wells; and flow lines.

- The cost savings being realized are fewer work-overs, increased tubing life, continuous production/injection service, reduction in energy requirements during lifting/injection, and reduction or elimination of corrosion inhibitor use.

- Poly liner products have been particularly effective for mitigating corrosion in water injection wells and rod on tubing wear in beam and progressive cavity pumped wells including deviated and dog-legged holes without the use of rod guides and/or special rod boxes.
Falcon Polycore™ is a high-density polyethylene liner as specified by the Plastic Pipe Institute’s specification PE 3608. This patented product is highly abrasion resistant which accounts for its success in the elimination of tubing rod wear, wire line, mechanical, and handling damage. HDPE is a highly chemical resistant barrier. The mechanically bonded seamless tube is tolerant to minor surface damage and eliminates concerns with holidays or voids as in adhesive or thermally bonded liners and coatings.

Falcon Enertube™ is a liner manufactured from a specially formulated blend of polyolefins. This liner is similar in mechanical properties to the field proven Falcon Polycore™ liner with a moderate increase in tensile strength and temperature resistance. This second generation of Falcon liners is specifically designed to limit (not stop) the permeability of acid gases such as CO₂ and H₂S. Enertube™ is a seamless mechanically bonded liner providing a smooth tubing ID surface.
Specifications

- Coated couplings protect J-area against corrosion.
- Minimum API torque recommended for tubing connection make-up.
- No special position make-up or coupling inserts required.
- Can currently line 1.900-inch to 7-inch with designed capability to line up to 16-inch.

- Maximum operating temperature is 160\(^\circ\)F in oil production and 180\(^\circ\)F in aqueous service.

- Maximum operating temperature is 210\(^\circ\)F
Falcon Ultratube™ is a liner composed of an engineering thermoplastic (PPS) that can withstand downhole temperatures exceeding 320ºF. This polymer is highly abrasion and chemical resistant. The mechanically bonded seamless tube is tolerant to minor surface damage and the base resin has been proven in other downhole applications for over twenty years.
Western Falcon’s Seamless Engineering Thermoplastic Liner Made From VICTREX® PEEK™ Polymer To Reduce Downhole Failures

Thermoplastic liners have proven effective in drastically reducing well operating costs associated with rod-on-tubing wear and tubing corrosion failures. The mechanically bonded liners provide cost savings. The unique Western Falcon bonding process, together with the remarkable properties of VICTREX® PEEK™ polymer used as a protective barrier, allows for the use of low-cost carbon steel in environments that previously required expensive alloys of nickel, chrome, and/or molybdenum.

Western Falcon, a major manufacturer of tubular linings, has introduced a new seamless engineering thermoplastic liner called Falcon Extremetube™. Made from VICTREX PEEK polymer, the Extremetube liner is designed to line production tubing used in oil and gas production to extend the life of standard steel tubing. It offers a significant increase in temperature stability, tensile strength, outstanding long term creep and aging properties, and is highly abrasion and chemically resistant to well fluids, drilling fluids, and hydrocarbon mixtures with extremely low permeability (1E-19, CG).

**Benefits of Extremetube™ Liners**
- Mitigates rod on tubing wear
- Controls corrosion
- Reduces well servicing frequency and cost
- Reduces corrosion inhibitor requirements
- Reduces friction and peak polished rod load
- Eliminates rod guides
- No stabilizing guides or special coupling inserts required
- No field technical service required

**Applications**
- Steam flood
- Gas lift wells
- Plunger lift wells
- Disposal
- Water injection
- Flow lines
- Deep, high temperature producing wells
- Submersible pumped wells
- Beam pumped wells
- Acid gas injection
- Coal bed methane
- Solution mining

**General Properties of VICTREX PEEK Polymer**
- **High Temperature Resistance** — Can withstand continuous operating temperatures of up to 260°C (500°F). Also maintains short-term mechanical properties at temperatures approaching its melting point of 340°C (644°F).
- **High Abrasion Resistance** — Combined with low friction properties over wide ranges of pressures, velocities, temperatures and counterfacial roughness.
- **Mechanical Properties** — Excellent strength, stiffness and long-term properties, such as creep and fatigue, retained over a wide range of temperatures and environments.
- **Chemical Resistance** — Exhibits outstanding resistance to a wide range of chemical and corrosive environments, even at elevated temperatures up to 300°C (572°F).
- **Hydrolysis Resistance** — Retains high levels of mechanical properties and dimensional stability when continuously operating in water, brine or steam at elevated temperatures and pressures.
- **Dimensional Stability** — Remarkably stable, resisting changes to its properties due to temperature, moisture, chemical attack or physical stress.
- **Rapid Gas Decompression** — Highly resistant to the damaging effects of rapid gas decompression.
Advantages of Poly Liner

- Corrosion Protection – to mitigate corrosion failures of tubing surface ID
- Abrasion resistant – to mitigate tubing wear in rod pump and PCP wells – w/o rod guides
- Chemically inert (stimulation fluids), flexible, lightweight, and recyclable
- Control of Surface Deposits – Scale and Paraffin
Advantages of Poly Liner

- Mechanically bonded – No adhesive, filler, etc., needed
- Increases service life of tubing; reduces lifting, completion, and workover costs
- Allows reuse of lower quality tubing (yellow, blue, green band tubes)
- Can line over previously ID coated tubing without cost of removing coating.
- Liner reduces friction of rods on tubing – Recent study completed by ConocoPhillips.
ConocoPhillips Rod Friction Test
Summary – Drag Ratio

- Plotting the drag ratios vs. temp. yields the relationship on the right
- Testing funded and supported by ConocoPhillips

\[ y = 0.0020x + 0.3197 \]

\[ R^2 = 0.9963 \]
Surface Roughness
Pressure Drop Due to Friction – Basic Fluid Dynamics

- Western Falcon Polycore lined tubing is 30 Times smoother than NEW bare tubing (0.00006 vs. 0.0018 inches)
- New BARE tubing typically will become approximately 30 to 35 Times rougher (than new) during service from corrosion
PRESSURE DROP EXAMPLE

FRICCTION COMPONENT

- Flow Rate: 2,500 bpd of water using Hazen Williams equation
- C-Factor of 160 for Western Falcon Poly Lined tubing and 100 for NEW bare tubing
- Compare bare and lined API tubing in both 2.875-inch and 3.500-inch
- Bare pressure drops are 3.5 & 1.4 psi per 100 ft. at velocities of 4.9 & 3.3 ft/sec.
- Poly Lined pressure drops are 2.5 & 0.8 psi per 100 ft. at velocities of 6.3 & 3.7 ft/sec.
Pressure Drop in Lined Tubing

- Lined tubing ID is approx. 0.30-inch less than bare pipe
- Even at higher velocities and same flow rate, the smoothness of the liner overcomes the ID restriction of the liner.

Bar chart showing PSI per 100 ft. for API tubing sizes 2 7/8 and 3 1/2, with bars for Bare and Poly Lined tubing.
Recommendations

- API MINIMUM torque for makeup
- Reduced corrosion inhibitor requirement – only need to protect rods
- No Stabbing Guide required
- No inserts or connection “donuts” required
- No Field Service Tech. required
Thermoplastic Lined Premium Thread – Flush ID Joint Coupled Connection
Limitations of Poly Liners

- See [www.westernfalcon.com](http://www.westernfalcon.com) for handling procedures
- Must select proper polymer liner chemistry for well and servicing environment
- TEMPERATURE
- USE Thread Protectors
- Special procedures – fishing, cutting, etc...
- Adds slight amount of weight to string
- Creates ID restriction
### ID Restriction and Weight Increase

<table>
<thead>
<tr>
<th>Size</th>
<th>ID (inch)</th>
<th>Weight (#/ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 3/8 – inch</td>
<td>1.71</td>
<td>0.40</td>
</tr>
<tr>
<td>2 7/8 – inch</td>
<td>2.16</td>
<td>0.47</td>
</tr>
<tr>
<td>3 1/2 - inch</td>
<td>2.67</td>
<td>0.64</td>
</tr>
</tbody>
</table>

**Notes:**
- Drift sizes of 1.60”, 2.00”, and 2.50” for the respective tubing sizes above.
- Hydraulic benefit of reduced surface roughness in liner typically exceeds pressure loss due to ID restriction. Western Falcon is pleased to offer technical assistance specific to your well conditions.
16 Successful Case Histories of Thermoplastic Lined Production Tubing
Case 1: Heavy Oil Production; South America

- Over six years of service in more than 40 wells using 4 ½-inch EUE tubing to solve rod on tubing and corrosion failures
- First wells installed in late 2000 and have already lasted over 14 times the life of bare tubing and still operational today
- Producing significant amounts of formation sand and operate at temperatures of 150° F and depths up to 5,000 feet
- Water cuts from one to seventy percent
- Lifted using reciprocating beam pumps and rotating PC pumps
Case 2: Artificially Lifted Wells; Alberta, Canada

- HDPE lined 3 ½-inch tubing in over 200 wells producing sour light oil since March of 2007 (over 66 months to date).
- No operational issues or leaks in lined tubing
- Beam and PC pumped horizontally drilled wells up to 4,000 feet deep
- Scale, paraffin, wear and corrosion issues in tubing have been solved using TPL tubing
- Increased pump life by 50 to 100 percent.
- Bare tubing lasted less than 6 months.
Case 3: Directionally Drilled Wells; Pacific Coast, USA

- 600 + Beam & PC Pumped wells with over 150,000 joints of TPL 2 7/8 and 3 ½-inch tubing
- Have used PPS, Falcon Enertube™ and HDPE TPL
- Pumps set in horizontal section of wellbore
- Producing significant amounts of formation sand
- First wells lined in 2002 to replace new tubing that failed in less than 100 days. **Over 30X improvement in service life**
- Most of the TPL tubing has been used tubing to optimize economic benefit
Case 4: McElroy Field; Permian Basin, USA

- High water cut sour crude beam pumped oil wells up to 3,000 feet deep
- Bare tubing lasted approximately 116 days
- First TPL tubulars installed in 1996. Some are still in service today, over 15 years later. 45X service life extension.
- Producing from corrosive San Andres formation
- 17 well TPL study documented in SPE 39815
Case 5: Western Canada

- Over 300 wells in Southern Alberta with HDPE lined 2 7/8-inch and 3 1/2-inch tubing
- Field under polymer injection since 2003
- Mostly beam pumped but some PC pumped wells
- Wells up to 4,000 ft deep with high water cuts
- Tubing lasted 3 to 4 months with rod guides
- Boron treated steel tubing was not successful
- For the past 5 years, TPL tubing has been used to mitigate severe corrosion and wear
Case 6: Colorado, USA

- Major operator using HDPE lined 2 7/8 and 3 1/2-inch tubing since April, 2002 to dewater gas wells

- “S” shaped well bores that cause tubing to fail as quickly as one week and commonly in 6 months

- Poly lined tubing ran for over 6 years (over 20 million strokes) and no measurable wear found with caliper survey. That is 12X longer than bare steel with rod guides that failed - holes in tubing.

- Reduced lifting cost by large reductions in peak polish rod load
Case 7: Midcontinent, USA

- Falcon Enertube and PPS lined 3 ½-inch L-80 tubing in 14 highly deviated wells 7,500 ft deep
- Bare tubing failed in less than 1 mo. w/ rod guides.
- Producing 300 to 600 BFPD (approx. 85% water) & 400 MCFD of gas
- Horizontally drilled wells lifted with beam pumps
- Up to 20 degrees per 100 ft. build
- Lined tubing in wells exceeding 2 years, already a 24X improvement
- Operator states field not “pumpable” without TPL
Case 8: Louisiana, USA

- PPS lined 2 7/8-inch L-80 tubing in 11,000 ft deep well installed in July, 2007
- 230° F BHT at 2,500 psi producing 700 MCFD gas with 5% CO₂ and 150 BWPD
- Beam pumped gas well previously suffered severe tubing wear and ID corrosion
Case 9: Deviated Wells; South America

- 25 South American beam and PC pumped wells with HDPE lined 3 ½-inch and 4 ½-inch tubing
- First lined tubing installed October, 2007 – 12X improvement and still operating
- Using bare steel tubing and rod guides, wells failed every 4 to 5 months.
- Very mature waterflooded field with varying amounts of CO₂ present in the wells.
Case 10: Nebraska, USA

- 3 experimental HDPE lined wells installed September, 2004
- Beam pumped 1,150 m deep wells that failed every 100 days prior to TPL installation
- All three wells still in service today – Over 29 X prior tubing life extension
Case 11: Wyoming, Rocky Mountains, USA

- PC pumped dogleg well that suffered tubing leaks every 30 days from wear and corrosion
- Produces 1,300 BFPD plus formation sand at 65 Hz
- HDPE lined tubing solved tubular corrosion and wear issues. Pump replaced one year after TPL installation then initial lined tubing reinstalled and still in service today
Case 12: PC Pumped Wells; South Texas, USA

- Two PC pumped 3,000 feet deep wells with tubing failures every 120 to 150 days
- Installed Falcon Enertube™ lined tubing in March, 2003
- Occasionally hot oil these wells for paraffin
- Lined tubing still in service today and has lasted over 25 times the life of bare tubing with rod guides
Case 13: West Texas, USA

- HDPE, PPS and Falcon Enertube™ lined tubulars in 25 different sour fields for one operator to solve corrosion and wear problems in production tubing.

- Depths between 4,000 ft and 13,000 ft and most wells lifted with reciprocating beam pumps

- Tubing failures in 150 to 400 days prior to using TPL


- TPL tubulars still operating today
Case 14: Beam Pumped Well; Midcontinent, USA

- Corkscrew deviated well over 13,000 feet deep
- Falcon Enertube™ lined 2 7/8-inch L-80 tubing installed over four years ago
- BHT over 200° F, producing 60 MCFD gas, 50 BFPD (40% oil cut), at over 2,300 psi BHP
Case 15: Lloydminster, Canada

- 30 wells operating with HDPE lined 4 ½-inch J-55 tubing in PC pumped wells to 5,000 ft deep
- Heavy oil wells with low water cuts
- Bare tubing averaged 7 months to failure
- First TPL string installed February, 2007 and still operating today, over 67 months later (9X improvement).
- Lined tubing allowed an increase in pump angle and higher production rates in these wells
Case 16: Southern Saskatchewan, Canada

- Over 50 wells completed with HDPE lined 3 ½-inch tubing since November, 2007, 58 months ago.
- Producing light API oil with high water cuts using PC pumps.
- Bare steel tubing with rod guides failed in 9 months.
- TPL has allowed operator to increase their pump angle by ten degrees increasing production capability.
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