Modernizing Pipelines
Presentation Outline

The Challenges
The Company
The Products
The Benefits
The Applications
The Success Stories
The Complete Solution
What are your Pipelining Challenges?

- Installation?
- Economics of pipeline projects?
- Corrosion or Reliability issues?
- Environmental footprint?
Presentation Outline

The Challenges

The Company

The Products

The Benefits

The Applications

The Success Stories

The Complete Solution
Flexpipe Systems

- Founded in 2001; joined ShawCor in 2008
- Manufacture and sell corrosion resistant, high temperature and high pressure, spoolable composite linepipe
- Over 15,000 km pipeline in service; products have excellent track record
- Rated as the most trusted supplier that delivers the overall best customer value in the market\(^1\)
- Cost effective alternative to steel; more durable than fiberglass; most reliable spoolable composite product in the market

\(^1\): As per an independent third party survey conducted by Welling and Company in Dec 11’ & March 12’
### Flexpipe Systems at a Glance

<table>
<thead>
<tr>
<th>Category</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing, sales and service facilities worldwide</td>
<td>10</td>
</tr>
<tr>
<td>Employees worldwide</td>
<td>&gt;300</td>
</tr>
<tr>
<td>Enforceable Patents</td>
<td>8</td>
</tr>
<tr>
<td>Number of Researchers</td>
<td>15</td>
</tr>
</tbody>
</table>

- **Plant (Calgary, Alberta, Canada)**
- **Solution Centers** (Canada: Estevan, Saskatchewan, Grande Prairie, Alberta; United States: Grand Junction, Colorado, Midland, Texas, Big Wells, Texas)
- **Stocking Centers** (United States: Myton, Utah, Bakersfield, California)
- **Strategic Sales Partners** (United States: Milford Pipe, Midland, Texas, Ken Miller Supply, Ohio)
- **Sales Offices** (Canada: Calgary, Alberta; United States: Houston, Texas)
ShawCor at a Glance

- Global ranking in pipe coatings and services: #1
- Manufacturing, sales and service facilities worldwide: >70
- Employees worldwide: >5,000
- Market capitalization: >$2.0B

1 As of January 6, 2012
### One of 7 ShawCor Business Units

#### PIPELINE & PIPE SERVICES

<table>
<thead>
<tr>
<th>Bredero Shaw</th>
<th>Flexpipe</th>
<th>Guardian</th>
<th>Shaw Pipeline Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Coatings</td>
<td>- Flexible composite pipe for:</td>
<td>- Drill pipe/tubular inspection</td>
<td>- Weld inspection</td>
</tr>
<tr>
<td>- corrosion protection</td>
<td>- oil and natural gas gathering lines</td>
<td>- Inventory management services</td>
<td>- radiographic</td>
</tr>
<tr>
<td>- insulation</td>
<td>- oilfield water applications</td>
<td></td>
<td>- ultrasonic</td>
</tr>
<tr>
<td>- weight / protective</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- internal flow efficiency</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Canusa-CPS | | |
|------------|---|
| - Joint protection | |
| - Pipe coating materials | |

| Shaw Pipeline Services | |
|------------------------|
| - Weld inspection | |
|  - radiographic | |
|  - ultrasonic | |

#### PETROCHEMICAL & INDUSTRIAL

<table>
<thead>
<tr>
<th>DSG-Canusa</th>
<th>ShawFlex</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Heat shrink tubing for sealing and protection</td>
<td>- Control, instrumentation cable</td>
</tr>
</tbody>
</table>
State of the art manufacturing facility (~140,000sq. ft.)

Raw Materials | Liner | Fiberglass | Jacket | Cooling | Print String | Reeling | Finished Goods
---|---|---|---|---|---|---|---
Pipe Identification

Meters length, run number, Flexpipe logo, product identifier, manufactured date, made in Canada
Record of Successful Execution

Over 15,000 km pipeline in service
Variety of Applications

- Flow lines or gathering lines for transfer of:
  - Crude Oil,
  - Gas,
  - Water,
  - Condensate,
  - Emulsion,
  - Sour Applications (H₂S),
  - Gases or liquids containing CO₂

- EOR injection line

- Source water and disposal lines for SAGD

- Fuel Gas lines or Gas lift lines

- Rehabilitation of failed pipeline through liner-pulls

- Well test temporary surface line (re-spool and re-use)

- Waste water disposal line
Presentation Outline

- The Challenges
- The Company
- **The Products**
- The Benefits
- The Applications
- The Success Stories
- The Complete Solution
Industry Leading Solutions

FlexPipe Linepipe

FlexPipe HT Linepipe

FlexCord Linepipe

*Flexpipe System’s products are patented by US Patents 6,889,716, 6,902,205, 7,946,629 B2 and 8,042,252 B2 by Canada Patent 2,513,506, 2,513,468 and 2,562, 823 and by European Patent 1592908. Additional patents are pending.*
FlexPipe Linepipe

- **Bimodal HDPE resin and Dry Fiberglass**
- **Operating Temp**: -50°F to 140°F (-46°C to 60°C)
- **Available in**:
  - 2”, 3” and 4” ID
  - Pressure Ratings: 300 to 1500psi
- **Lengths**: 600 to 2,000 meters per reel
- **20 years Service Life**

**Design**
- Thermoplastic Jacket
- Thermoplastic Liner
- Structural Layers (Fiber Reinforcement)

*Designed in accordance with API RP 15S and CSA Z662-07*
FlexPipe HT Linepipe

- Bimodal HDPE-RT and Dry Fiberglass
- Operating Temp: -13°F to 180°F (-25°C to 82°C)
- Available in:
  - 2”, 3” and 4” ID
  - Pressure Ratings: 750 to 1500psi
- Suitable for 25% aromatic and cycloalkane content (by volume)
- Suitable for temperature excursions at 93°C (200°F) for 500hrs
Pressure Profile

Mean Pressure: 115 psi

Peak-to-Peak: 20 psi (17 %)

Frequency: 70 cycles/min.
FlexCord Linepipe

- Bimodal HDPE resin with Galvanized Steel Cords
- Operating Temp: 32°F to 140°F (0°C to 60°C)
- Available in:
  - 3” and 4” ID
  - Pressure Ratings: 2000psi
- Lengths: 525 to 615 meters per reel
- Designed for severe cyclic conditions

Designed in accordance with CSA Z662-07 and applicable standards of API 17J
FlexCord Linepipe

- **Large Amplitude Pressure Cycles**
  - Up to 10 cycles per day from 0 – 1,500 psi

- **Pulsations of Positive Displacement Pumps**
  - Up to 200 psi peak-to-peak

- **Pump Jack (Rod Pump) Service**
  - Operating pressures up to 500 psi

- **Excellent solution for CO₂ EOR application**
Pressure Profile-Duplex Pump

Mean Pressure: 390 psi
Peak-to-Peak: 180 psi (46.2 %)
Frequency: 60 cycles/min.
Coil Pipe

- Available for FlexPipe and FlexPipe HT Linepipe
- Available in 2”, 3”, and 4” ID sizes
- Lengths: Up to 2,000 meters per coil depending on pipe size
Coil Pipe Benefits

- No Reel Deposits or Reel Returns
- More Pipe Footage on a Truck
- No Over Height Restrictions
- Easily Deployed
- Easy to Handle in the Field
- Fewer connections
Joining System
Standard Fittings

Pipe to Pipe Coupler  Flanged End Fitting  Weldneck Fitting

- Same style fitting system for FlexPipe Linepipe, FlexPipe HT Linepipe and for FlexCord Linepipe, the difference is the fitting length
- Available in Nickel coated and Stainless Steel
Risers for Entering or Exiting a Trench
Hydraulic Crimping System

MI/Hydraulic Press

Hydraulic Crimper
Installation Equipment
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The Benefits—“The BIG 5”

- BENEFITS USING FLEXPIPE OR FLEXCORD LINEPIPE

1. Reliability
2. Speed of installation
3. Ease of installation
4. Corrosion resistance
5. Cost savings
Reliability

- Most reliable linepipe solution for the onshore market
- Over 15,000 km of installed pipeline
- Over 70,000+ installed fittings
- Sold to over 500+ customers
Reliability

Failure Statistics

Km's @ Start of Year

2005 2006 2007 2008 2009 2010 2011 2012

Failures (S&T) 6 9 32 34 38 26 32 16
Cumulative km 517 1.327 2.609 4.194 6.964 8.384 10.091 13.283
Failure per 1000 km 11.6 6.8 12.3 8.1 5.5 3.1 3.2 1.2

* 2012 Data as of June
Reliability of Fittings

Successfully installed over 70,000 fittings
Reliability of Fittings

- Industry leading repeatability and reliability
- Energization pressure is controlled by hydraulic pressure regulation rather than applying torque with large wrenches
- Crimper dies move independently to allow for variations in pipe wall thickness
- The combination of fitting design and thermoplastic materials eliminates the need for precise fit up and reaming
Reliability

Ratio of Cut-Out Burst Pressure to Burst Pressure at Time of Manufacture

Cut-Out Number

80% is Acceptable Limit
Speed of Installation

Install 2X faster than Steel

21 km (13 miles) of Steel and Flexpipe stringed

✓ Steel: 8 days
✓ Flexpipe: 3 days
Speed of Installation

Need another Good Example
Ease of Installation

- Trenching
- Plowing
- Chain Ditching
- Liner-Pulls
Ease of Installation
Ease of Installation
Corrosion Resistant

- No corrosion or cracking in FlexPipe and FlexCord
- Life expectancy of pipe: 20 years service life
- No need for chemical and batching programs
- Less downtime means increased production
Corrosion Resistant
Installation Cost Savings
FlexPipe Installation vs Steel Video
Installation Cost Savings

Where do you save cost?

- 3 men crew versus 10-12 men crew
- Less equipment on site
  - No need for side booms, extra pickers, welding trucks
- Can be installed 2X faster than steel
- Couplings required every 1,722 to 6,562 feet. Welding, inspection and associated costs are ELIMINATED
- Smaller ROW
Installation Cost Savings

Where do you save cost?

- Eliminates the need for special sections of pipe for bends
- No lost time to do field bends

<table>
<thead>
<tr>
<th>Pipe Diameter</th>
<th>Minimum bend radius OPERATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(m)</td>
</tr>
<tr>
<td>2”</td>
<td>1.2</td>
</tr>
<tr>
<td>3”</td>
<td>1.8</td>
</tr>
<tr>
<td>4”</td>
<td>2.1</td>
</tr>
</tbody>
</table>
Installation Cost Savings

Where do you save cost?

- No need for Sand Padding to protect our pipe and fittings
Freight Cost Savings

Up to 6+ km (3.75 miles) of pipe per truck load
Freight Cost Savings

Up to 9.2+ km (5.7 miles) of pipe per truck load
Proven Cost Savings

20%-30% Cost Savings

Ratio of Installed Costs - Comparison of Flexpipe and Steel (3" - 3km)

Chart-To-be Updated
Operation Cost Savings

Where do you save cost?

- Immune to corrosion so less inspections are necessary
- Minimizes the need for chemical and batching programs
- Low friction factors means higher flow rates
- Smoother flow characteristics reduce pressure drops saving on the wear and tear of rotating equipment
- No need for external coating; no need for anodes
- Simple Pigging or Hot Oiling Program
  - Paraffin takes longer to build up in a FlexPipe or FlexCord application as compared to steel
  - Using Flexpipe’s disk pigs or our hot oiling procedure is an easy way to mitigate build-up in line
Advantages of using tandem 4” Flexpipe lines

- Flow characteristics for two 4” Flexpipe lines are comparable to single 6” steel line
- Tandem pipeline systems can provide more flexibility for operation:
  - Ability to isolate one line for tie-ins, pigging or other maintenance without interrupting production
  - Ability to adapt system to changing operational requirements by converting one line to different use
- Two Flexpipe lines can be plowed simultaneously with minimal increase in cost
Operation Cost Savings

Slide will be updated with a bar chart
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# The Applications

<table>
<thead>
<tr>
<th></th>
<th>FlexPipe Linepipe/FlexPipe HT Linepipe</th>
<th>FlexCord Linepipe</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Oil Gathering</strong></td>
<td>- Typical pump jack, PCP, ESP</td>
<td>- Aggressive pump jack, PCP, ESP</td>
</tr>
<tr>
<td></td>
<td>- Pump Jack upstroke to down stroke differential up to 50 psig</td>
<td>- Pump Jack upstroke to down stroke differential up to 500 psig</td>
</tr>
<tr>
<td></td>
<td>- H₂S up to 5%</td>
<td>- H₂S up to 3000 PPM</td>
</tr>
<tr>
<td></td>
<td>- CO₂ up to 100%</td>
<td>- CO₂ up to 100%</td>
</tr>
<tr>
<td><strong>Gas Gathering</strong></td>
<td>- Reciprocating compressor</td>
<td>- Reciprocating compressor</td>
</tr>
<tr>
<td></td>
<td>- H₂S up to 50 KPa partial pressure</td>
<td>- H₂S up to 800 PPM</td>
</tr>
<tr>
<td></td>
<td>- CO₂ up to 100%</td>
<td>- CO₂ up to 100%</td>
</tr>
<tr>
<td><strong>Water</strong></td>
<td>- Centrifugal pumps up to 1,500 psi</td>
<td>- All pumps up to 2,000 psi</td>
</tr>
<tr>
<td></td>
<td>- Piston pumps up to 750 psig (50% de-rate)</td>
<td>- Pulsations &lt; 150 psi</td>
</tr>
<tr>
<td></td>
<td>- Pulsations &lt; 30 psi</td>
<td>- Several start/stops per day</td>
</tr>
<tr>
<td></td>
<td>- Few start/stop per week</td>
<td></td>
</tr>
</tbody>
</table>
Field Layout

GAS OUT – Methane (CH₄), CO₂ and H₂S

VENT GAS – Methane (CH₄), CO₂, H₂S

~100 psi

OIL OUT (further processing)

~ ½ psi

~ 1000 psi – up to 300 ppm (0.3%) H₂S

To injection well for EOR or disposal
## The Applications

<table>
<thead>
<tr>
<th></th>
<th>FlexPipe Linepipe/FlexPipe HT Linepipe</th>
<th>FlexCord Linepipe</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>H₂S</strong></td>
<td>- 5% H₂S by volume in liquids (oil and/or water) or multiphase; - 7.25 psi partial pressure of H₂S in gas. - 2% for 150 ANSI - 1% for 300 ANSI - 0.5% for 600 ANSI</td>
<td>- 3000 PPM (0.3%) of H₂S for liquids and gases</td>
</tr>
<tr>
<td><strong>CO₂</strong></td>
<td>- Approved for use in gas or liquid applications containing 100% CO₂</td>
<td>- Approved for use in gas or liquid applications containing 100% CO₂</td>
</tr>
<tr>
<td><strong>H₂O</strong></td>
<td>- Water applications which are not susceptible to severe pressure fluctuations</td>
<td>- Excellent option for water transfer and disposal lines</td>
</tr>
</tbody>
</table>
## The Applications

<table>
<thead>
<tr>
<th></th>
<th>FlexPipe Linepipe</th>
<th>FlexPipe HT Linepipe</th>
<th>FlexCord Linepipe</th>
</tr>
</thead>
</table>
| Aromatic & Solvents | - Compatible with (by volume)  
• 25% up to 20^\circ C  
• 5% up to 40^\circ C  
• 1% up to 60^\circ C | - Compatible with (by volume)  
• 25% up to 82^\circ C  
• 5% up to 40^\circ C  
• 1% up to 60^\circ C | - Compatible with (by volume)  
• 25% up to 20^\circ C  
• 5% up to 40^\circ C  
• 1% up to 60^\circ C |
| Chemical Injection | - Compatible with corrosion inhibitors, biocides, scale inhibitors, paraffin dispersants, etc.  
- Compatible with batch treatment or continuous dosing | -                                                    | -                                                        |
| Methanol          | - Compatible with both batch treatment and continuous dosing                      | - Compatible with both batch treatment and continuous dosing | - Compatible. Batch treatment preferred                      |
| Hot Oiling        | Limited to MAOP/Temperature                                                       | -500 hrs at 93^\circ C (200^\circ C) over the life of the product | Limited to MAOP/Temperature                                   |
## The Applications

<table>
<thead>
<tr>
<th>FlexPipe Linepipe/FlexPipe HT Linepipe</th>
<th>FlexCord Linepipe</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PUMP</strong></td>
<td></td>
</tr>
<tr>
<td>Centrifugal</td>
<td>Piston (Triplex, etc)</td>
</tr>
<tr>
<td>Gear</td>
<td>Diaphragm</td>
</tr>
<tr>
<td>Progressive cavity (PC)</td>
<td>• Mini on-off flow, large pressure pulsations with each shaft revolution</td>
</tr>
<tr>
<td>Screw</td>
<td></td>
</tr>
<tr>
<td>• Constant flow, pulsations negligible</td>
<td></td>
</tr>
<tr>
<td><strong>ON/OFF CYCLES</strong></td>
<td></td>
</tr>
<tr>
<td>Somewhat limited in on/off apps</td>
<td>Virtually unlimited in on/off apps</td>
</tr>
<tr>
<td><strong>PUMP JACKS</strong></td>
<td></td>
</tr>
<tr>
<td>Typical Pump Jacks</td>
<td>Aggressive Pump Jacks</td>
</tr>
<tr>
<td>• max 50 psi up/down delta (this includes up to 90% of all operating pump jacks)</td>
<td>• Large up/down delta</td>
</tr>
<tr>
<td></td>
<td>• Unusual, poor system design or maintenance</td>
</tr>
</tbody>
</table>
Application Review

S-N Curves → Goodman Diagrams → Application Review

Field Monitoring* → Application Review

* For existing systems
<table>
<thead>
<tr>
<th>Test Description</th>
<th>Applicable Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression pressure testing</td>
<td>ASTM D2992 Procedure B</td>
</tr>
<tr>
<td></td>
<td>API RP 15S Section 5.1.2.3</td>
</tr>
<tr>
<td>Short term burst pressure testing</td>
<td>ASTM D1599 Procedure A</td>
</tr>
<tr>
<td></td>
<td>API RP 15S Section 5.1.2.3</td>
</tr>
<tr>
<td>Minimum bend radius pressure testing</td>
<td>API RP 15S Section 5.3.2</td>
</tr>
<tr>
<td>Elevated temperature pressure testing</td>
<td>API RP 15S Section 5.2.1</td>
</tr>
<tr>
<td>Low temperature pressure testing</td>
<td>ASTM D1599 Procedure A</td>
</tr>
<tr>
<td>Axial load testing</td>
<td>API RP 15S Section 5.3.3</td>
</tr>
<tr>
<td>External load testing</td>
<td>ASTM D2412</td>
</tr>
<tr>
<td>Impact resistance testing</td>
<td>API RP 15S Section 5.5.2</td>
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Qualification Testing
# Qualification Testing

<table>
<thead>
<tr>
<th>Test Description</th>
<th>Applicable Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyclic pressure testing</td>
<td>API RP 15S Section 5.1.5.1</td>
</tr>
<tr>
<td>Vent testing - gases venting from annulus</td>
<td>API RP 15S Section 5.3.1</td>
</tr>
<tr>
<td>Fitting gas leak testing</td>
<td>API RP 15S Section 5.3.1</td>
</tr>
<tr>
<td>Aromatics exposure</td>
<td></td>
</tr>
<tr>
<td>Corrosion Testing and Design Pressure (FLEXCORD)</td>
<td>API 17J</td>
</tr>
<tr>
<td>Corrosion Protection</td>
<td>CSA Z662</td>
</tr>
<tr>
<td>Thermal Expansion and Pressure Expansion Testing</td>
<td>API RP 15S Sections 5.5.4 and 5.5.5</td>
</tr>
</tbody>
</table>
Qualification Testing
Presentation Outline

The Challenges

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The Success Stories

The Complete Solution
Classy pipe Linepipe

Marble Point: Canada based junior oil and gas producer

<table>
<thead>
<tr>
<th>Project Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project Scope</strong></td>
</tr>
<tr>
<td><strong>Application</strong></td>
</tr>
<tr>
<td><strong>Location</strong></td>
</tr>
<tr>
<td><strong>Length</strong></td>
</tr>
<tr>
<td><strong>Pipe</strong></td>
</tr>
<tr>
<td><strong>Installation Method</strong></td>
</tr>
<tr>
<td><strong>Date</strong></td>
</tr>
</tbody>
</table>

“The install costs for Flexpipe Linepipe are substantially lower compared to steel linepipe. A smaller footprint, lower labor requirements, and less equipment make Flexpipe a very attractive option. We drilled, completed, and tied in over 120 wells in 108 days.”

…..Ken Younger (Operations Manager)
Flexpipe HT Linepipe

Santos: Australia’s leading energy producer

---

**Project Details**

<table>
<thead>
<tr>
<th>Project Scope</th>
<th>High Temp Linepipe required to connect 2 wells</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>Oil gathering system</td>
</tr>
<tr>
<td>Location</td>
<td>Near Moomba</td>
</tr>
<tr>
<td>Length</td>
<td>5.4km or 3.35 miles</td>
</tr>
<tr>
<td>Pipe</td>
<td>3” 601 HT</td>
</tr>
<tr>
<td>Installation Method</td>
<td>Plowed</td>
</tr>
<tr>
<td>Date</td>
<td>June 2011</td>
</tr>
</tbody>
</table>

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“The speed at which Flexpipe Systems was able to support our needs was impressive; their expertise is what sets them apart from the competition.”

…..Rory Burnell (Project Lead)
**FlexCord Linepipe**

**Project Details**

<table>
<thead>
<tr>
<th>Project Scope</th>
<th>FlexCord Linepipe injection of produced water to flush $\text{H}_2\text{S}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>Water Injection</td>
</tr>
<tr>
<td>Location</td>
<td>Ronalane pipeline near Hayes, Alberta</td>
</tr>
<tr>
<td>Length</td>
<td>1.5 km/4900 ft</td>
</tr>
<tr>
<td>Pipe</td>
<td>3&quot; 600 ANSI FlexCord</td>
</tr>
<tr>
<td>Installation Method</td>
<td>Trenched</td>
</tr>
<tr>
<td>Date</td>
<td>August 2010</td>
</tr>
</tbody>
</table>

“Some of the options were to go to steel or fiberglass, but you get into corrosion issues with steel and fiberglass is fragile. FlexCord address all of those concerns. Going forward, we are going to keep FlexCord in mind for any application where we need a 1500 psi pressure rating and have pulsation issues.”

…..Ben VanRootselaar (VP Engineering)
Presentation Outline

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The Complete Solution

Provide end to end solution for your individual needs

15,000+ km installed pipeline

Confirm product fit

70,000+ installed fittings

500+ customers

115+ certified contractors
Thank You!

*Flexpipe has an 15,000+ km installed base.*

Questions?
Appendix
Regulations and Standards

CSA - Flexpipe products meet the requirements of CSA Z662-07, “Oil and Gas Pipeline Systems”, which covers the design, construction, operation, and maintenance of oil and gas industry pipeline systems.

ISO - Flexpipe Systems has been certified as meeting the requirements of ISO 9001:2000, “Quality management systems – Requirements”.

DOT - The United States Department of Transportation considers the use of Flexpipe in regulated applications through waiver applications submitted to the Office of Pipeline Safety.

ERCB - The Energy Resources Conservation Board allows FPLP and FCLP applications to be processed as routine for fresh water, salt water, multiphase, crude oil/LVP, and natural gas service.

API - FlexPipe products are designed, qualified, and manufactured in accordance with API RP 15S and FLEXCORD complies with API 17J.


ASME - Flanges incorporated in Flexpipe Flanged Fittings are compliant with the requirements of ASME B16.5, “Pipe Flanges and Flanged Fittings”.
Procedure for Determining Max Operating Pressure

PSF = 0.67 as per API 15S,
SFF = 0.67 as per CSA Z662
Challenges with CO2 EOR Applications

- Corrosion
- Permeation and Collapse
- Blistering
- Pressure Pulsations and Cycling
- Others?

Solution: FlexCord Linepipe
Corrosion Resistance-Pipe

- Liner and jacket do not corrode
- The galvanized steel cord reinforcements have been proven to be resistant to corrosion due to permeated gases for a lifetime of 20 years
- Completed testing includes cord corrosion tests in combined water/CO2/H2S environments, and long-term full-scale pipe tests at maximum service temperature with brine and CO2
- Supporting reports include internal reports as well as third-party reports and testing by Corrmet, IRIS-NDT, and University of Calgary
Corrosion Resistance-Fittings

- Fitting options and accessories:
  - Alloy steel with high-phosphorus nickel plating
  - Custom magnesium anodes
  - Duplex stainless steel

- Fittings are resistant to corrosion for 20 years in wet CO2 and H2S environments depending on temperature and brine chloride content
Collapse and Blistering Resistance

- Pipe and fitting design allows the low levels of gases that permeate through the liner to rapidly vent to atmosphere.
- Proven rapid communication of gas pressure through vent system.
- No blistering or collapse observed after 20 cycles of rapid decompression at 1000 psi/minute.
- No decrease in burst pressure after rapid decompression.
- No restrictions on de-pressurization rate.
FlexCord Linepipe has been specifically designed and tested for applications with severe pressure pulsations and cycles.

- Provides a 20 year service life for applications with 200 psi peak-to-peak pulsations (example: triplex pump) combined with up to 10 cycles per day of 0 to 1,500 psi with a 10x safety factor (standard requirement).

- Goodman Diagram and Miner’s Rule are used in Engineering Application Reviews to evaluate suitability of specific applications.
Custom Fittings

Tee Joint  Y Lateral  Y Lateral
## Fitting Materials

<table>
<thead>
<tr>
<th>Part</th>
<th>Material type</th>
<th>Material grade(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mandrel</td>
<td>Alloy steel&lt;sup&gt;a&lt;/sup&gt;</td>
<td>AISI 4130 or 4140</td>
</tr>
<tr>
<td>Sleeve</td>
<td>Carbon steel&lt;sup&gt;a&lt;/sup&gt;</td>
<td>ASTM A106, A333, A513, or A519</td>
</tr>
<tr>
<td>Flange (flanged fittings only)</td>
<td>Carbon steel</td>
<td>ASTM A105 or ASTM A350 LF2</td>
</tr>
<tr>
<td>Weld neck fitting welding end</td>
<td>Carbon steel&lt;sup&gt;a&lt;/sup&gt;</td>
<td>ASTM A106 or A333</td>
</tr>
<tr>
<td>Flow joints</td>
<td>Carbon steel&lt;sup&gt;a&lt;/sup&gt;</td>
<td>ASTM A234 WPB or ASTM A420 WPL6</td>
</tr>
<tr>
<td>O-rings</td>
<td>Viton&lt;sup&gt;b&lt;/sup&gt;</td>
<td>75 Durometer</td>
</tr>
<tr>
<td>Coatings&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Electroless Nickel or uncoated</td>
<td></td>
</tr>
</tbody>
</table>

Other materials such as Duplex 2205 SS, etc. are also available

<sup>a</sup>Meets requirements of NACE MR0175 for sour service

<sup>b</sup>Special o-rings are available for high-pressure CO₂ service

<sup>c</sup>Weld neck fittings are not coated
45 Degree Riser

NOTES:
1. INSTALL THE RISER SUPPORT FIRST, THEN ANY CONNECTED STEEL PIPES
2. FPLP IS NOT TO BE LOADED BY EXTERNAL PIPING
3. U-BOLTS SHOULD BE SNUG. DO NOT OVER-TIGHTEN!
4. RUBBER PADS ARE TO BE PLACED BETWEEN FPLP AND THE RISER SUPPORT END AND BETWEEN FPLP AND EACH OF THE U-BOLTS
5. WRAP ABOVE-GROUND FPLP AND FITTINGS WITH INSULATION OR LIGHT-COLOURED TAPE AFTER INSTALLATION

DETAIL A

FLANGE SLEEVE
U-BOLT & RUBBER PAD
FLEXPIPE
RISER EXTENSION
WELD EXTENSION TO RISER TRACK
RISER TRACK
FINISHED GRADE

U-BOLT & RUBBER PAD
WELD RISER TRACK TO PILE

THERE MUST BE A MINIMUM OF 7M / 23FT OF STRAIGHT PIPE BEFORE THE BOTTOM OF THE RISER

VIRGIN SOIL:
RUBBER PAD
PILE
PILE
90 Degree Riser

NOTES:

1. INSTALL THE RISER SUPPORT FIRST THEN THE CONNECTED PIPES
2. FPLP IS NOT TO BE LOADED BY EXTERNAL PIPING
3. U-BOLTS SHOULD BE SNUG, DO NOT OVERTIGHTEN!
5. WRAP ABOVE GROUND FPLP AND FITTINGS WITH INSULATION OR LIGHT-COLOURED TAPE AFTER INSTALLATION
“S” Bend Riser

NOTES:

1. INSTALL FPLP RISER SUPPORT FIRST, THEN ANY CONNECTED STEEL PIPES
2. TO ATTACH PIPE
   A) LAY PIPE WITH NATURAL CURVATURE IN SAME DIRECTION AS BOTTOM PORTION OF RISER
   B) ATTACH U-BOLTS IN ORDER INDICATED BY NUMERALS
3. U-BOLTS SHOULD BE SNUG. DO NOT OVER-TIGHTEN!
4. USE CAUTION WHEN PULLING PIPE DOWN TO AVOID KINKING
5. FPLP IS NOT TO BE LOADED BY EXTERNAL PIPING
6. RUBBER PADS ARE TO BE PLACED BETWEEN THE FPLP AND THE RISER SUPPORT END AND BETWEEN FPLP AND EACH OF THE U-BOLTS
7. WRAP ABOVE-GROUND FPLP AND FITTINGS WITH INSULATION OR LIGHT-COLOURED TAPE AFTER INSTALLATION
Corrosion Protection for Fittings

- **External Corrosion Protection** – Option for ribbon anode kit covered with paste and tapes

- **Internal Corrosion Protection** - High-phosphorus electroless nickel plating with a fluoropolymer sealer on all wetted surfaces of the fitting excluding weldnecks.
Field Monitoring System
Example to show how we use Goodman Diagram and Miner’s Rule
A pump jack runs at:

- 10 cycles per minute
- Upstroke pressure 250 psi
- Down stroke pressure 200 psi
- Presco switch set at 450 psi
- ESD event every month

\[
\text{Upstroke pressure} = \frac{250 + 200}{2} = 225 \text{ psi}
\]

\[
\text{Down stroke pressure} = \frac{250 - 200}{2} = 25 \text{ psi}
\]

- Is FlexPipe Linepipe a good fit?
Goodman Cyclic Life Predictor

Goodman Diagram 3" FP301

Mean Pressure (psi)

Alternating Pressure (psi)

y = -0.2798x + 537.97
y = -0.1827x + 351.37
y = -0.1602x + 306.86
y = -0.0825x + 158.61
y = -0.056x + 107.78
y = -0.0376x + 72.348
y = -0.0253x + 48.697
y = -0.0166x + 31.845

Alternating Pressure (psi)

Mean Pressure (psi)
Pump Jack Application Example

Goodman Diagram

• 10 MMM cycles from 200-250 psi
• 1 MM cycles from 0-450 psi

Considering a service life of 50 years:

• The pump jack will have 263 MM cycles 200-250 psi
• The pump jack will have 600 ESD events
The suitability of FPLP for a service of 50 years is evaluated using Miner’s rule as follows:

\[
10 \times \frac{N_{1a}}{N_{1U}} + 10 \times \frac{N_{2a}}{N_{2U}} \leq 1
\]

\[
10 \times \frac{263MM}{10MMM} + 10 \times \frac{600}{1MM}
\]

0.263 + 0.006

0.269 \leq 1 \therefore FP301Suitable
Operation Cost Savings

Our Flow Rate is Higher Transporting Liquids

Representative Pressure Drop Comparison: Water at Various Flow Rates
*Calculations based on 1 mile of pipe length, with fresh water at 30˚C

Flow Rate (bbls/day) vs. Pressure Drop (PSI)

- 2” Flexpipe
- 2” Sch 40 Steel
- 3” Flexpipe
- 3” Sch 40 Steel
- 4” Flexpipe
- 4” Sch 40 Steel
Operation Cost Savings

Our Flow Rate is Higher Transporting Gas

Representative Pressure Drop Comparison: Methane at Various Flow Rates
*Calculations based on 1 mile of pipe length, with methane at 20°C (68 F) compressed to 500 PSI
### Permeability Calculations

<table>
<thead>
<tr>
<th>Fluid/Permeability</th>
<th>Permeability coefficient at 40°C (104°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(cm³/cm·sec·MPa)</td>
</tr>
<tr>
<td>Methane</td>
<td>$1 \times 10^{-7}$</td>
</tr>
<tr>
<td>H₂S</td>
<td>$1 \times 10^{-7}$</td>
</tr>
<tr>
<td>CO₂</td>
<td>$5.5 \times 10^{-7}$</td>
</tr>
</tbody>
</table>

Coefficients are based on experiments with unreinforced polyethylene. Field testing has shown the actual rates are insignificant.
Pressure/Head Loss at Fittings/Pigging

Pressure Loss

\[ \Delta P_{fitting} = K \frac{\rho V^2}{2} \]

Pressure Head Loss

\[ h_{fitting} = K \frac{V^2}{2g} \]

Where:

- \( \rho \) = fluid density
- \( V \) = fluid velocity
- \( g \) = acceleration due to gravity
- \( K \) = from flow theory and calculations

<table>
<thead>
<tr>
<th>Fitting size</th>
<th>K factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>2”</td>
<td>0.16</td>
</tr>
<tr>
<td>3”</td>
<td>0.15</td>
</tr>
<tr>
<td>4”</td>
<td>0.12</td>
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</tbody>
</table>
Surface Lines
Tracer Wire

Used to Locate Buried Lines
Pipe Refurbishment

Liner Pull and Maximum Pulling Force

<table>
<thead>
<tr>
<th>Pipe Size (nominal)</th>
<th>Maximum pull force</th>
</tr>
</thead>
<tbody>
<tr>
<td>(in)</td>
<td>(kgf)</td>
</tr>
<tr>
<td>2</td>
<td>1000</td>
</tr>
<tr>
<td>3</td>
<td>2040</td>
</tr>
<tr>
<td>4</td>
<td>2720</td>
</tr>
</tbody>
</table>

200 kilometers installed as of 2011
Can pull multiple lines at one time
Record is 4 reels in one pull
Fastest install time is 4 kms/day
Free standing liner
Pull Tools

Tools for Pulling Flexpipe Products Off the Reel or Through Road bores and Failed Steel Lines

Internal

External
## Pipe Clearances for Liner Pulls

<table>
<thead>
<tr>
<th>Conduit</th>
<th>3&quot; Steel</th>
<th>4&quot; Steel</th>
<th>6&quot; Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FPLP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2&quot; FP301</td>
<td>P</td>
<td>P</td>
<td>PF</td>
</tr>
<tr>
<td>2&quot; FP601</td>
<td>N</td>
<td>P</td>
<td>PF</td>
</tr>
<tr>
<td>3&quot; FP150</td>
<td>N</td>
<td>N</td>
<td>P</td>
</tr>
<tr>
<td>3&quot; FP301</td>
<td>N</td>
<td>N</td>
<td>P</td>
</tr>
<tr>
<td>3&quot; FP601</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>4&quot; FP150</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>4&quot; FP301</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>4&quot; FP601</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
</tbody>
</table>
Repairing Flexpipe

Use a Hydrovac Truck to Expose Lines
Repairing Flexpipe

Pre-made Pup

Repair a damaged line in less than an hour once the line is exposed.
Benefits vs. Thermoset Spoolable Pipe

1. Larger flow capacities
2. Superior durability and impact resistance
3. High fitting reliability
4. Faster installation and lower total installed cost
Benefit 1 – Flow Capacity

- Large internal diameters provide high flow capacities
- Allows for flexibility to handle future increases in flow volumes
- Similar inner diameters as steel pipe simplifies pigging
Benefit 2 – Durability

- Impact Resistance: FlexPipe provides industry leading impact resistance over a wide temperature range
- Crack resistance: FlexPipe Linepipe is manufactured using only highly crack resistant thermoplastic resins, which do not exhibit micro-cracking or delamination
- External damage to Flexpipe Linepipe is readily identifiable reducing the risk of rupture during pressure testing or operation

Impact test conducted at -4°F (-20°C) with 20 lb weight dropped
Benefit 3 – Fitting Reliability

- Flexpipe fittings have industry leading repeatability and reliability
- Fitting energization pressure is controlled by hydraulic pressure regulation by fitting installation equipment rather than applying torque with large wrenches
- Crimper dies move independently to allow for variations in pipe wall thickness
- The combination of fitting design and thermoplastic materials eliminates the need for precise fit up and reaming
- One-piece fitting increases ease of fitting installation
Benefit 4 – Cost Savings

- The total installed cost of FlexPipe Linepipe is lower and the installation rate is faster
  - Lighter and smaller reels are less expensive to transport to site and can be handled with smaller equipment on site
  - Higher flexibility increases ease of handling around corners and plowing
  - Smaller right of ways due to reel size and flexibility
  - Sand padding typically not required

- Flexpipe has a large certified contractor base and a strong Contractor Development Program