Pipeline Toolbox - 2014
Presentation Guide

INTEGRATED SOFTWARE TOOLS FOR PIPELINE PROFESSIONALS
What Is In The Pipeline Toolbox?

An integrated suite of over 75 pipeline engineering software tools that are:

• Available in Gas, Liquid and Enterprise (Gas & Liquid) versions
• User Customizable
• In English or Metric units (since 2011 Version)
• Field Tested and Proven software
• Used by Federal and State Pipeline Inspectors
Pipeline Engineering tools and support documents supplanted by the Toolbox
Examples of the Software Subjects

- Hydraulics, Facilities & Design Calculations
- Gas Mixture & Liquid Properties
- Meter/Regulator/Relief Valve Sizing
- Steel & PE Pipe Design & Stress Analysis
- Testing & Maintenance
- Corrosion & Cathodic Protection
- API 1102/Crossings/Wheel & Track Load
- DOT/PHMSA Pipeline Regulations & Forms
- Document & Applications Management
Software Positioned in the Pipeline Toolbox
Comparable to Tools in a Mechanic's Tool Chest
ORDER OF PRESENTATION

1. User Interface and Support Features
2. Applications for Design of Gas Service Features
3. Applications for Design of Liquid Service Features
4. Applications for Design of Gas or Liquid Lines
5. Problem Analysis Applications: Stress, Damage, Corrosion
6. Applications for Operating and Testing Measurements
7. Polyethylene Pipe
User Interface and Support Features

• Toolbars
• Files/Projects: Creating, Organizing, Saving and Re-Opening
• F1 Key
• Utilities Modules
  - Document Management System
  - External Application Integration
  - Pipe Data Bases
  - Physical Properties of Fluids
  - Engineering Units Conversion
  - Current Standards, Regulations and DOT Forms

Help Modules
  - Searchable Menus
  - Access to Technical Toolbox Support
View Upon Opening the Pipeline Toolbox:
Title Bar: Notice of Edition (Gas or Liquid) and Revision, Subject Category, Icon Bars, and the “Desk Top”
TOOLBARS

**Subject Category Bar** for access to subject related modules

File
Pipeline Facilities
Hydraulics
Steel Pipe - Design & Stress Analysis
Steel Pipeline Crossings
ECDA & Corrosion Control
Polyethylene Pipe - Design & Stress Analysis
Utilities

**Icon Bar** for direct access to an application. For ENTERPRISE Editions the Edition Button provides a switch between GAS and LIQUID Editions
Basic User Steps if Hard Copy of a “Project” is Wanted
PRINTABLE PROJECT REPORTS

• Example project screen and printable report in “Word” format accessible from the Report button.

Completed projects may also be saved in the Toolbox Edition by the “Save” or “Saved As” button.
Access to Saved Completed Projects for Retrieval or Deleting (File)
WINDOW FUNCTION (Window)
To Organize Multiple Screens Open On the Desktop

Screens after Cascade Tiling
Example Subject Help References Accessible by the **F1 Key** when Executing the Subject Application

**Design Pressure - Steel Pipe**

\[ P = \frac{2S}{D} F T \]

- \( P \): Design pressure, psig
- \( S \): Specified minimum yield strength, psi
- \( D \): Nominal outside diameter, inches
- \( t \): Nominal wall thickness, inches
- \( F \): Design factor
- \( T \): Longitudinal joint factor
- \( T \): Temperature derating factor

**Installation of Pipelines by Horizontal Directional Drilling**

The calculation procedure in this module is based on Pipeline Research Council International, Inc. (PRCI) report number PR-227-9424 “Installation of Pipelines by Horizontal Directional Drilling, an Engineering Design Guide” Research report in electronic form is included for easy reference. In order to access report, please select and click on “PRCI Design Guide” button.
Utilities Modules for Embedding Documents and External Applications in the Toolbox (Utilities)

Document Management System

The purpose of the Document Management System (DMS) is to allow the user to customize his/her own Toolbox with commonly used documents such as Design Guidelines, Company Recommended Practice, etc... One sample document has been included in your Document Management System to get you started. Any document can be added to your Toolbox by simply clicking on the DMS icon to reveal the following screen:

External Applications Integration

This feature provides the user with the capability to integrate external applications with the Pipeline Toolbox program suite. Applications can be added or deleted as determined by the individual user. Please see the Document Management System HELP for detailed procedures.

The only file formats that can be integrated are spreadsheets (*.xls) and application executables (*.exe).
Pipe Database and Physical Properties of Fluids

Information Modules (Utilities)

Partial showing of 22 columns of API 5L pipe specs for .125” to 80” diameters

Partial List of 33 Properties of 215 Fluids
### Engineering Units Conversion Module (Utilities)

#### English/Metric Units Conversion
- **Mass and Weight**
  - **To convert**
    - Slug
    - 1000
  - **Into**
    - Kilograms [kg]
    - 14590

#### Units Conversion - Oil Volume
- **To convert**
  - Barrels [bbls]
  - 1000
- **Into**
  - Cubic meters [m³]
  - 158.99

#### Gas Standard Volume Units Conversion
- **To convert**
  - Standard cu feet [scf]
  - 1000
- **Into**
  - Standard cu meters [m³ std]
  - 28.32784

**Standard U.S.A. Conditions**
- $t = 60°F$, $P = 14.73$ psia

**Standard Metric Conditions**
- $t = 15°C$, $P = 1.013$ bar
Regualtions and Standards

Pipeline Safety Laws
DOT Code, Part 190, Pipeline Safety Programs
DOT Code, Part 191, Annual Reports, Incident Reports and Safety Related Condition Reports
DOT Code, Part 192, Transportation of Natural Gas and Other Gases by Pipeline
DOT Code, Part 193, Liquified Natural Gas Facilities
DOT Code, Part 194, Onshore Oil Pipelines
DOT Code, Part 195, Transportation of Hazardous Liquids by Pipeline
DOT Code, Part 196, State Grants
Canadian Standards Association, Code 266-07, Oil and Gas Pipeline Systems

Part 192 - Transportation of Natural Gas
Current through Amendment 192-117 of June 16, 2011

This Code Part

Service Line Drawings
Jurisdictional LPG Drawings
OPS Forms
Disclaimers

Subpart A Sections 1-16 General
Subpart B Sections 51-65 Materials
Subpart C Sections 101-125 Pipe Design
Subpart D Sections 141-203 Design of Pipeline Components
Subpart E Sections 221-245 Welding of Steel in Pipelines
Subpart F Sections 271-287 Joining of Materials Other Than by Welding
Subpart G Sections 301-328 General Construction Requirements for Transmission Lines and Mains
Subpart H Sections 351-383 Customer Meters, Service Regulators, and Service Lines
Subpart I Sections 451-491 Requirements for Corrosion Control
Subpart J Sections 501-517 Test Requirements

§192.327 Cover.
(a) Except as provided in paragraphs (c), (e), (f), and (g) of this section, each buried transmission line must be installed with a minimum cover as follows:

<table>
<thead>
<tr>
<th>Location</th>
<th>Normal soil</th>
<th>Consolidated rock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1 locations</td>
<td>30 (762)</td>
<td>18 (457)</td>
</tr>
<tr>
<td>Class 2, 3, and 4 locations</td>
<td>36 (914)</td>
<td>24 (610)</td>
</tr>
<tr>
<td>Drainage ditches of public</td>
<td>36 (914)</td>
<td>24 (610)</td>
</tr>
<tr>
<td>roads and railroad</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(b) Except as provided in paragraphs (c) and (d) of this section, each buried main must be installed with at least 24 inches (610 millimeters) of cover.
(c) Where an underground structure prevents the installation of a transmission line or main with the minimum cover, the transmission line or main may be installed with less cover if it is provided with additional protection to withstand anticipated external loads.
(d) A main may be installed with less than 24 inches (610 millimeters) of cover if the law of the State or municipality:
   (1) Establishes a minimum cover of less than 24 inches (610 millimeters);
   (2) Requires that mains be installed in a common trench with other utility lines; and,
   (3) Provides adequately for protection of the pipe by external forces.
(e) Except as provided in paragraph (c) of this section, all pipe installed in a navigable river, steam, or harbor must be installed with a minimum cover of 48 inches (1,219 millimeters) in soil or 24 inches (610 millimeters) in consolidated rock between the top of the pipe and the underwater natural bottom (as determined by recognized and generally accepted practices).
Help Topics (Help)

- Searchable menus for factors required for a Toolbox Application or wanted for references providing an understanding of the basis for an Application’s computed results.

Example Search for soil property E’n

Values of E’n Native Soil Modules of Soil Reaction

<table>
<thead>
<tr>
<th>Granular</th>
<th>Cohesive</th>
<th>E’n [psi]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Std Penetration</td>
<td>Description</td>
<td>Unconfined Compressive Strength (TSF)</td>
</tr>
<tr>
<td>ASTM D1586</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blow/ft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.15</td>
<td>very, very loose</td>
<td>&gt; 0 - 0.125</td>
</tr>
<tr>
<td>1 - 2</td>
<td>very loose</td>
<td>0.125 - 0.25</td>
</tr>
<tr>
<td>2 - 4</td>
<td>very loose</td>
<td>0.25 - 0.50</td>
</tr>
<tr>
<td>4 - 8</td>
<td>loose</td>
<td>0.50 - 1.00</td>
</tr>
<tr>
<td>8 - 15</td>
<td>slightly compact</td>
<td>1.00 - 2.00</td>
</tr>
<tr>
<td>16 - 30</td>
<td>compact</td>
<td>2.00 - 4.00</td>
</tr>
<tr>
<td>30 - 50</td>
<td>dense</td>
<td>4.00 - 8.00</td>
</tr>
<tr>
<td>&gt;50</td>
<td>very dense</td>
<td>&gt;6.00</td>
</tr>
<tr>
<td>Rock</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Help Modules (Help)
For access to Technical Toolboxes Home Page & Support

Online Support Screen for emails to Support Personnel
Applications for Design of Gas Service Features

or analysis of existing features as applicable

• Hydraulics
• Design Pressure and Wall Thickness
• Pipeline Compressors and Station Piping
• Reinforcement of Welded Branch Connection
• Meters and Regulator Station Sizing
• Relief Valve Sizing
• Hot Tap Sizing
• Relief Valve Reactive Force
Hydraulics

Screen for selecting 1 of 4 unknowns to be calculated by 1 of 11 Flow Equations

Panhandle A and B
Weymouth
A.G.A. Fully Turbulent Flow
Colebrook White
FM-Fundamental Equation
IGT Distribution Equation
Mueller- High and Low Pressure
Pittsburg
Splitzglass
**Examples: Panhandle A and B for Downstream Pressure (Hydraulics)**

<table>
<thead>
<tr>
<th>Project</th>
<th>Panhandle A</th>
<th>Panhandle B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Additional Gas Edition App</td>
<td>Additional Gas Edition App</td>
</tr>
<tr>
<td>Date</td>
<td>11/8/2012</td>
<td>11/9/2012</td>
</tr>
</tbody>
</table>

**Temperature base [°F]**
- Panhandle A: 60.0 °F
- Panhandle B: 60.0 °F

**Pressure base [psia]**
- Panhandle A: 14.71 psia
- Panhandle B: 14.71 psia

**Gas flowing temperature [°F]**
- Panhandle A: 60.0 °F
- Panhandle B: 60.0 °F

**Gas specific gravity**
- Panhandle A: 0.60
- Panhandle B: 0.60

**Compressibility factor**
- Panhandle A: 1.00
- Panhandle B: 1.00

**Pipeline efficiency factor**
- Panhandle A: 0.98
- Panhandle B: 0.98

**Upstream pressure [psig]**
- Panhandle A: 890.0 psig
- Panhandle B: 535.6 psig

**Flow rate [MCFD]**
- Panhandle A: 230,000.0 MCFD
- Panhandle B: 230,000.0 MCFD

**Internal pipe diameter [inches]**
- Panhandle A: 12.75
- Panhandle B: 12.75

**Length of pipeline [miles]**
- Panhandle A: 10.0
- Panhandle B: 10.0

**Upstream elevation [feet]**
- Panhandle A: 0.0
- Panhandle B: 0.0

**Downstream elevation [feet]**
- Panhandle A: 0.0
- Panhandle B: 0.0
Examples: Colebrook White and FM Fundamental for Flow Rate (Hydraulics)
Examples: Muellar High > 1 psig and Low Pressure Distribution for Internal Pipe Diameter

(General Hydraulics)

Mueller - High Pressure [Internal Pipe Diameter]

- **Project:** City of Houston
- **Location:**
- **Date:** 10/9/2013

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upstream pressure [psig]</td>
<td>100</td>
</tr>
<tr>
<td>Flow rate [MCFH]</td>
<td>1000</td>
</tr>
<tr>
<td>Downstream pressure [psig]</td>
<td>50</td>
</tr>
<tr>
<td>Gas specific gravity</td>
<td>0.60</td>
</tr>
<tr>
<td>Length of pipeline [feet]</td>
<td>2000</td>
</tr>
</tbody>
</table>

Results:
- Internal pipe diameter [inches] | 5.80 |

Mueller - Low Pressure [Internal Pipe Diameter]

- **Project:** City of Houston
- **Location:**
- **Date:** 10/9/2013

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upstream pressure [psig]</td>
<td>1</td>
</tr>
<tr>
<td>Flow rate [MCFH]</td>
<td>3</td>
</tr>
<tr>
<td>Downstream pressure [psig]</td>
<td>0.5</td>
</tr>
<tr>
<td>Gas specific gravity</td>
<td>0.60</td>
</tr>
<tr>
<td>Length of pipeline [feet]</td>
<td>100</td>
</tr>
</tbody>
</table>

Results:
- Internal pipe diameter [inches] | 2.83 |
B31.8 Design Pressure & Minimum Wall Thickness
(Steel Pipe-Design & Stress Analysis)
(Steel Pipeline-Design & Stress Analysis)
Centrifugal Compressors

Adiabatic Head & Adiabatic Required HP

(Pipeline Facilities)(Pipeline Compressors)
### Centrifugal Compressor - Fan Laws

### Reciprocating Compressor – Cylinder Capacity & HP

(Pipeline Facilities)(Pipeline Compressors)

#### Centrifugal Compressor - Fan Laws

- **Project:** User Guide 2 - Centrifugal Compressor - Fan Laws
- **Location:** Additional Gas Edition Applications
- **Date:** 11/8/2012

**Input Parameters:**
- Q1 - Initial Flow Rate [MMSCFD]
- H1 - Initial Compressor Head [ft lb]/lbm
- BHP1 - Initial Shaft Horsepower [HP]
- N1 - Initial Impeller Rotational Speed [rpm]
- N2 - Final Impeller Rotational Speed [rpm]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>1040</td>
</tr>
<tr>
<td>H1</td>
<td>17000</td>
</tr>
<tr>
<td>BHP1</td>
<td>11000</td>
</tr>
<tr>
<td>N1</td>
<td>1500</td>
</tr>
<tr>
<td>N2</td>
<td>2250</td>
</tr>
</tbody>
</table>

**Results:**
- G2 - Final Flow Rate [MMSCFD]
- H2 - Final Compressor Head [ft lb]/lbm
- BHP2 - Final Shaft Horsepower [HP]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>G2</td>
<td>1.8311</td>
</tr>
<tr>
<td>H2</td>
<td>36.6465</td>
</tr>
<tr>
<td>BHP2</td>
<td>35.1005</td>
</tr>
</tbody>
</table>

#### Reciprocating Compressor Capacity and HP

- **Project:** User Guide 2 - Recip Compressor Capacity and HP
- **Location:** Additional Gas Edition Applications
- **Date:** 11/8/2012

**Input Parameters:**
- Base Pressure [psia]: 14.73
- Base Temperature [°F]: 60.0
- Select Piston Acting Compression Type: Single-Acting Piston Compressing on the Outer End Only
- Bore/Cylinder Inside Diameter [in]: 6.00
- Stroke/Travel Length of Piston [in]: 12.00
- Rotational Speed [rpm]: 200
- Cylinder Clearance [%]: 12.00
- Suction Pressure [psig]: 200.0
- Suction Temperature [°F]: 110.0
- Discharge Pressure [psig]: 1,000.0
- Gas Specific Gravity (Relative to Air): 0.640
- Gas Specific Heat Ratio: 1.300
- Compressor Mechanical Efficiency: 0.900

**Results:**
- Piston Displacement [ft³/min]: 39.27
- Discharge Temperature [°F]: 355.68
- Z1 - Compressibility Factor at Suction: 0.8713
- Z2 - Compressibility Factor at Discharge: 0.8878
- Volume Efficiency [%]: 59.40
- Cylinder Capacity [ft³/min]: 23.3
- Equivalent Capacity [MMSCFD]: 0.460
- Cylinder Brake Horsepower Required [HP]: 45.4

[Pipe Diagram]

[Compressor Diagram]
Compressor Station Piping
Diameter and Minimum Wall Thickness
(Pipeline Facilities) (Pipeline Compressors)

Note: Gas velocity should not exceed 2,000 [ft/min]. Greater velocities generate excessive turbulent flow.
Meters and Regulators – Station Sizing
(Pipeline Facilities)(Meters & Regulators)
Applications for Design of Liquid Service Features
or problem solving as applicable

• Hydraulics
• Design Pressure and Minimum Wall Thickness
• Pipeline Pumps and Station Piping
• B31.4 Reinforcement of Welded Branch Connection
• Relief Valve Sizing and Reactive Force
Hydraulics (Liquid Pipeline Hydraulics)

Screen for selecting a wanted unknown to be calculated by 1 of 6 Flow Equations

- Darcy – Weisbach
- Colebrook White
- Hazen-Williams
- Heltzel
- T.R. Aude
- Shell/MIT
Examples: Darcy-Weisbach and Colebrook-White for Upstream Pressure (Hydraulics)
Examples: Hetzel and Hazen-Williams for Internal Pipe Diameter (Hydraulics)

### Hetzel [Internal Pipe Diameter] (Revision: 10.0.0)

| Project: User Guide 2 - Hetzel for Internal Pipe diameter |
| Location: Additional Liquid Edition Application: Date: 11/12/2012 |

| Liquid flowing temperature [°F] | 60.0 |
| Liquid Specific Gravity [lbs/cu.ft] | 0.74 |
| Flow rate [bbls/h] | 3,000.0 |
| Upstream Pressure [psig] | 1,000.0 |
| Downstream Pressure [psig] | 50.0 |
| Length of Pipeline [miles] | 50.0 |
| Kinematic Viscosity [sq ft/sec] | 0.8800 |
| Upstream Elevation [ft] | 500.0 |
| Downstream Elevation [ft] | 0.0 |

### Hazen - Williams [Internal Pipe Diameter] (Revision: 10.0.0)

| Project: User Guide 2 - Hazen-W for Internal Pipe diameter |
| Location: Additional Liquid Edition Applications: Date: 11/12/2012 |

| Reference for Hazen-Williams Coefficient: |
| Depending on liquid: | Depending on pipe material: |
| Gasoline 150 | Normal service scaled pipe 100 |

| Liquid Flowing Temperature [°F] | 60 |
| Liquid Specific Gravity - Relative to H2O | 0.74 |
| Flow rate [bbls/h] | 3000 |
| Upstream Pressure [psig] | 1000 |
| Downstream Pressure [psig] | 50 |
| Length of Pipeline [miles] | 50 |
| Hazen - Williams Coefficient | 100 |
| Upstream Elevation [ft] | 500 |
| Downstream Elevation [ft] | 0 |
Examples: T.R. Aude for Flow Rate and Shell/MIT for Downstream Pressure (Hydraulics)
For a Wanted psi/mile Pressure drop

Darcy-Weisbach Equation (Hydraulics)
Pipeline Pumps: Required Horsepower based on Total Head or Differential Pressure
(Pipeline Facilities)(Pipeline Pumps)
Pump Specific Speed, Suction Specific Speed and Temperature Rise Due to Pumping
(Pipeline Facilities)(Pipeline Pumps)
Reciprocating Pumps: Capacity, Acceleration Head and Piston Rod Load
(Pipeline Facilities)(Pipeline Pumps)

### Reciprocating Pump - Displacement and Actual Capacity

<table>
<thead>
<tr>
<th>Project</th>
<th>UG 4-6 Reciprocating Pump Displacement &amp; Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Addit Liquid</td>
</tr>
<tr>
<td>Notes</td>
<td></td>
</tr>
<tr>
<td>Select Type</td>
<td>Single-Acting Pump</td>
</tr>
<tr>
<td>Piston/Plunger Diameter [in]</td>
<td>6.00</td>
</tr>
<tr>
<td>Stroke Length [in]</td>
<td>12</td>
</tr>
<tr>
<td>Rotational Speed [rpm]</td>
<td>1800</td>
</tr>
<tr>
<td>Number of Pistons/Plungers</td>
<td>2</td>
</tr>
<tr>
<td>Volumetric Efficiency (Fraction)</td>
<td>0.98</td>
</tr>
<tr>
<td>Results:</td>
<td></td>
</tr>
<tr>
<td>Pump Displacement/Theoretical Capacity [gpm]</td>
<td>587.5</td>
</tr>
<tr>
<td>Pump Actual Capacity [gpm]</td>
<td>2.002</td>
</tr>
</tbody>
</table>

### Reciprocating Pump - Acceleration Head

<table>
<thead>
<tr>
<th>Project</th>
<th>UG 4-6 Recip Pump Acceleration Head</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Addit Liquid App</td>
</tr>
<tr>
<td>Notes</td>
<td></td>
</tr>
<tr>
<td>Select Pump Type for C Factor</td>
<td>Duplex Double Acting</td>
</tr>
<tr>
<td>Select Liquid for K Factor</td>
<td>Most Hydrocarbons</td>
</tr>
<tr>
<td>C - Empirical Constant for Type of Pump</td>
<td>0.115</td>
</tr>
<tr>
<td>K - Factor Related to Liquid Compressibility</td>
<td>2.00</td>
</tr>
<tr>
<td>Length of Suction Line [m]</td>
<td>712</td>
</tr>
<tr>
<td>Average Liquid Velocity [m/s]</td>
<td>3.7</td>
</tr>
<tr>
<td>Pump Speed [rpm]</td>
<td>480</td>
</tr>
<tr>
<td>Results:</td>
<td></td>
</tr>
<tr>
<td>Acceleration Head [m]</td>
<td>1935</td>
</tr>
</tbody>
</table>

### Reciprocating Pump - Piston Rod Load

<table>
<thead>
<tr>
<th>Project</th>
<th>UG-46 Piston Rod Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Addit Liquid</td>
</tr>
<tr>
<td>Notes</td>
<td></td>
</tr>
<tr>
<td>Piston Diameter [in]</td>
<td>6.0</td>
</tr>
<tr>
<td>Maximum Allowable Pressure [psi]</td>
<td>680.8</td>
</tr>
<tr>
<td>Results:</td>
<td></td>
</tr>
<tr>
<td>Piston Rod Load [lb]</td>
<td>4322.3</td>
</tr>
</tbody>
</table>

[Image of reciprocating pump]
Pump Station Piping: Pipe Wall Thickness, Average Flow Velocity per Pipe Internal Diameter
(Pipeline Facilities)(Pipeline Pumps)
ASME B31.4 Reinforcement of Welded Branch Connection (Pipeline Facilities) (Reinforcement)
Applications for Design Gas or Liquid Line Features or problem analysis as applicable

- Pipe Buoyancy
- Allowable Pipe Span Length
- Pipe Anchoring
- Flume Design
- HDD Crossing Stresses
- Highway and Railroad Crossings
- Cathodic Protection
Buoyancy - Concrete Coating Requirements
(Steel Pipe-Design & Stress Analysis)(Steel Pipeline-Design & Stress Analysis)

**Buoyancy Analysis & Concrete Coating Requirements (Revision: 10.00)**

<table>
<thead>
<tr>
<th>Project: Buoyancy Analysis &amp; Concrete Coating Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location: Common App</td>
</tr>
<tr>
<td>Date: 11/4/2012</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Notes:</th>
</tr>
</thead>
</table>

**Pipe and Operational Data:**

- **Line Pipe - API Specification 5L**
  - Standard Steel Pipe - ASTM - ANSI B36.10
  - Line Pipe API 5L
    - **Nominal Pipe Size:** 24
    - **Wall Thickness [in.]:** 0.250

<table>
<thead>
<tr>
<th>Water Density [lbs/ft³]</th>
<th>62.42</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete Density [lbs/ft³]</td>
<td>140</td>
</tr>
<tr>
<td>Corrosion Coating Density [lbs/ft³]</td>
<td>Thin Film</td>
</tr>
</tbody>
</table>

**Input and Selected Data:**

- **Nominal Outside Diameter [in.]:** 24.00
- **Nominal Wall Thickness [in.]:** 0.250
- **Design Specific Gravity Ratio:** 1.15
- **Corrosion Coating Thickness [MIL]:** 25
- **Pipe Length [ft./Joint]:** 40.0

**Results:**

- **Pipe Weight [lbs/ft.]:** 86.91
- **Total Volume [ft³]:** 5.19
- **Corrosion Coating Volume [ft³]:** 0.01
- **Concrete Coating Volume [ft³]:** 3.40
- **Concrete Coating Volume [ft³]:** 2.04
- **Weight of Pipe in Air [lbs/ft]:** 352.91
- **Weight of Water Displaced [lbs/ft]:** 321.01
- **Weight of Submerged Pipe [lbs/ft]:** 40.00
- **Weight per Joint [lbs/Joint]:** 1,491.45

![Concrete Coating Application](image)
Buoyancy Requirements - Spacing of Concrete Weights (Steel Pipe-Design & Stress Analysis)(Steel Pipeline-Design & Stress Analysis)
Maximum Allowable Pipe Span Length
(Steel Pipe-Design & Stress Analysis)
(Steel Pipeline-Design & Stress Analysis)
## Pipe Anchor Force Analysis

### (Steel Pipe-Design & Stress Analysis)(Steel Pipeline-Design & Stress Analysis)

<table>
<thead>
<tr>
<th>Project</th>
<th>UG 2-2 Pipe Anchor Force Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Common App</td>
</tr>
<tr>
<td>Date</td>
<td>11/4/2012</td>
</tr>
</tbody>
</table>

### Select Pipe Properties:

- **Line Pipe - API Specification 5L**
- **Standard Steel Pipe - ASTM - ANSI B36.10**

#### Line Pipe API 5L
- **Nominal Pipe Size**: 12 3/4
- **Wall Thickness [in.]**: 0.219

### Poisson's Ratio
- 0.30

### Young's Modulus of Elasticity [psi]
- 29,000,000

### Thermal Expansion Coefficient [in./in.°F]
- 0.000000650

### Pipe and Operational Data:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Pressure [psig]</td>
<td>1,440.0</td>
</tr>
<tr>
<td>Nominal Outside Diameter [in.]</td>
<td>12.75</td>
</tr>
<tr>
<td>Nominal Wall Thickness [in.]</td>
<td>0.219</td>
</tr>
<tr>
<td>Installation Temperature [°F]</td>
<td>55.0</td>
</tr>
<tr>
<td>Operating Temperature [°F]</td>
<td>60.0</td>
</tr>
</tbody>
</table>

### Results:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hoop Stress [psi]</td>
<td>40,478</td>
</tr>
<tr>
<td>Compressive Stress Due to Temperature Change [psi]</td>
<td>943</td>
</tr>
<tr>
<td>Net Longitudinal Stress at Point A [psi]</td>
<td>11,201</td>
</tr>
<tr>
<td>Net Longitudinal Stress at Point B [psi]</td>
<td>20,239</td>
</tr>
<tr>
<td>Net Longitudinal Strain at Point B [in./in.]</td>
<td>0.000312</td>
</tr>
<tr>
<td>Soil Resistance [lbf./ft.]</td>
<td>90.3</td>
</tr>
<tr>
<td>Length of the Transition Zone A-B [ft.]</td>
<td>862.8</td>
</tr>
<tr>
<td>Total Pipe Movement at Point B [in.]</td>
<td>1.613</td>
</tr>
<tr>
<td>Anchor Force [lbf.]</td>
<td>77,921</td>
</tr>
</tbody>
</table>
HDD: Pull Force and Installation Stress Analysis

133 Page: PRCI – Design Guide Imbedded in APP
(Steel Pipe-Design & Stress Analysis)(Steel Pipeline-Design & Stress Analysis)
HDD: Pull Force and Stress Analysis Screens

<table>
<thead>
<tr>
<th>Pipe Weight in Air [lbs/ft]</th>
<th>33.38</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe Exterior Volume [ft³/ft]</td>
<td>0.89</td>
</tr>
<tr>
<td>Pipe Interior Volume [ft³/ft]</td>
<td>0.62</td>
</tr>
<tr>
<td>Weight of Water [lbs/ft]</td>
<td>0.00</td>
</tr>
<tr>
<td>Displaced Mud Weight [lbs/ft]</td>
<td>79.62</td>
</tr>
<tr>
<td>Effective Weight of Pipe [lbs/ft]</td>
<td>-46.245</td>
</tr>
</tbody>
</table>

**Straight Section "A - B" Downslope:**
- Friction from Soil [lbs]: 1,514
- Drag Forces from Mud [lbs]: 2,790
- Tension on Section [lbs]: 6,140
- Cumulative Pull Load [lbs]: 6,140

**Curved Section "B - C" Downslope:**
- Normal Force [lbs]: 13,136
- Friction from Soil [lbs]: 3,941
- Drag Forces from Mud [lbs]: 6,990
- Tension on Section [lbs]: 19,075
- Cumulative Pull Load [lbs]: 25,215

**Total Pull Force [lbs]: 65,757**

<table>
<thead>
<tr>
<th>Point: &quot;E&quot;</th>
<th>Tensile Stress [psi]</th>
<th>632</th>
<th>46,800</th>
<th>PASS/FAIL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bending Stress [psi]</td>
<td>0</td>
<td>35,682</td>
<td>PASS</td>
</tr>
<tr>
<td></td>
<td>External Hoop Stress [psi]</td>
<td>631</td>
<td>6,767</td>
<td>PASS</td>
</tr>
<tr>
<td></td>
<td>Unity Check: Tensile &amp; Bending Stress</td>
<td>0.01</td>
<td>1.00</td>
<td>PASS</td>
</tr>
<tr>
<td></td>
<td>Unity Check: Tensile, Bending &amp; Hoop Stress</td>
<td>0.01</td>
<td>1.00</td>
<td>PASS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Point: &quot;C&quot;</th>
<th>Tensile Stress [psi]</th>
<th>2,568</th>
<th>46,800</th>
<th>PASS/FAIL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bending Stress [psi]</td>
<td>15,938</td>
<td>35,682</td>
<td>PASS</td>
</tr>
<tr>
<td></td>
<td>External Hoop Stress [psi]</td>
<td>1,590</td>
<td>6,767</td>
<td>PASS</td>
</tr>
<tr>
<td></td>
<td>Unity Check: Tensile &amp; Bending Stress</td>
<td>0.01</td>
<td>1.00</td>
<td>PASS</td>
</tr>
<tr>
<td></td>
<td>Unity Check: Tensile, Bending &amp; Hoop Stress</td>
<td>0.30</td>
<td>1.00</td>
<td>PASS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Point: &quot;D&quot;</th>
<th>Tensile Stress [psi]</th>
<th>4,500</th>
<th>46,800</th>
<th>PASS/FAIL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bending Stress [psi]</td>
<td>0</td>
<td>35,682</td>
<td>PASS</td>
</tr>
<tr>
<td></td>
<td>External Hoop Stress [psi]</td>
<td>1,590</td>
<td>6,767</td>
<td>PASS</td>
</tr>
<tr>
<td></td>
<td>Unity Check: Tensile &amp; Bending Stress</td>
<td>0.10</td>
<td>1.00</td>
<td>PASS</td>
</tr>
<tr>
<td></td>
<td>Unity Check: Tensile, Bending &amp; Hoop Stress</td>
<td>0.98</td>
<td>1.00</td>
<td>PASS</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Point: &quot;E&quot;</th>
<th>Tensile Stress [psi]</th>
<th>6,968</th>
<th>46,800</th>
<th>PASS/FAIL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bending Stress [psi]</td>
<td>13,281</td>
<td>35,682</td>
<td>PASS</td>
</tr>
<tr>
<td></td>
<td>External Hoop Stress [psi]</td>
<td>1,024</td>
<td>6,767</td>
<td>PASS</td>
</tr>
<tr>
<td></td>
<td>Unity Check: Tensile &amp; Bending Stress</td>
<td>0.50</td>
<td>1.00</td>
<td>PASS</td>
</tr>
<tr>
<td></td>
<td>Unity Check: Tensile, Bending &amp; Hoop Stress</td>
<td>0.27</td>
<td>1.00</td>
<td>PASS</td>
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</table>

<table>
<thead>
<tr>
<th>Point: &quot;F&quot;</th>
<th>Tensile Stress [psi]</th>
<th>6,688</th>
<th>46,800</th>
<th>PASS/FAIL</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Bending Stress [psi]</td>
<td>0</td>
<td>35,682</td>
<td>PASS</td>
</tr>
<tr>
<td></td>
<td>External Hoop Stress [psi]</td>
<td>0</td>
<td>6,767</td>
<td>PASS</td>
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<tr>
<td></td>
<td>Unity Check: Tensile &amp; Bending Stress</td>
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<td>1.00</td>
<td>PASS</td>
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<tr>
<td></td>
<td>Unity Check: Tensile, Bending &amp; Hoop Stress</td>
<td>0.93</td>
<td>1.00</td>
<td>PASS</td>
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</tbody>
</table>
Operating Stress Analysis of a Crossing Installed by HDD

Project: UG Guide - HDD Operating Stress Analysis
Location: Comm App  Date: 8/1/2013
Notes:

Select Pipe Properties:
- Line Pipe - API Speciification 5L
- Standard Steel Pipe - ASTM - ANSI B36.10

- Line Pipe 5L
  - Nominal Pipe Size: 1/8
  - Wall Thickness: 0.063
  - Grade: A25

Pipe and Operational Data:
- Operating Pressure [psig]: 1,272.0
- Pipe Outside Diameter [in.]: 12.75
- Pipe Wall Thickness [in.]: 0.312
- Specified Minimum Yield Strength [psi]: 52,000
- Installation Temperature [°F]: 75.0
- Operating Temperature [°F]: 65.0
- Depth of the Pipe at Horizontal Section [ft]: 25.0
- Groundwater Table below Datum [ft]: 20.0
- Shortest Radius of Curvature [ft]: 1,000.0

Results:
- Bending Stress [psi]: 15,930
- Hoop Stress [psi]: 25,946
- Thermal Stress [psi]: 1,950
- Total Longitudinal Compressive Stress [psi]: -6,204
- Maximum Shear Stress [psi]: 16,075
- Maximum Allowable Shear Stress (45% of SMYS) [psi]: 23,400

Operating Conditions: ACCEPTABLE

Buttons: PRCI - Design Guide, Save, Report, Calculate
API 1102: Design of Highway and Railroad Crossings
(Steel Pipeline Crossings)

1st - Pipe and Operational Characteristics Screen Identical for Highway and Railroad Crossings less than 42 inches O.D.

- Liquid Edition App does not require Location class, Temperature or Longitudinal Factors
Crossing Installation & Site Characteristics
Highways and Railroads Screens

Pipe and Operational Characteristics

Soil Characteristics:
- Soft to medium clays and silts with high plasticities
- E' - Modulus of Soil Reaction [ksi] = 0.2
- Er - Resilient Modulus [ksi] = 5.0
- Average Unit Weight of Soil [lb/ft³] = 120.0

Installation Characteristics:
- Pipe Depth [ft] = 4.00
- Bored Diameter [in] = 14.00
- Installation Temperature [°F] = 60.0
- Design Wheel Load from Single Axle [kips] = 12.00
- Design Wheel Load from Tandem Axles [kips] = 10.00

Pavement Type:
- Flexible
- Rigid
- None

Impact Factor Method:
- ASCE - Highway
- User Defined

Results

Stress Check:
- GRI/Cornell Guidelines (PC-PISCES)
- API 1102 Procedure

GRI/Cornell Recommended Safety Factors:
- Safety Factor for Effective Stress - Location Class 3 = 1.25
- Safety Factor for Girth Welds - Location Class 3 = 1.10
- Safety Factor for Longitudinal Welds - Location Class 3 = 1.10

API 1102 - Gas Pipeline Crossing Railroad (Revision: 10.0.0)

Soil Characteristics:
- Soft to medium clays and silts with high plasticities
- E' - Modulus of Soil Reaction [ksi] = 0.2
- Er - Resilient Modulus [ksi] = 5.0
- Average Unit Weight of Soil [lb/ft³] = 120.0

Installation Characteristics:
- Pipe Depth [ft] = 6.00
- Bored Diameter [in] = 14.8
- Installation Temperature [°F] = 60.0
- Distance of Girth Weld from Track Centerline [ft] = 0.0
- Number of Tracks (1 or 2) = 1.0

Rail Loading:
- Cooper E-80
- Other
- Applied Design Surface Pressure [psi] = 13.900

Results

Stress Check:
- GRI/Cornell Guidelines (PC-PISCES)
- API 1102 Procedure

Clear Calculate
Stress and Fatigue Factor Results
Highways and Railroads Screens
## GPTC Guide—Design of Uncased Crossings
(Steel Pipeline Crossings)

### Select Pipe And Location Data:
- **Line Pipe - API Specification 5L**
- **Standard Steel Pipe - ASTM - ANSI B36.10**

#### Line Pipe API 5L
- **Nominal Pipe Size:** 20
- **Nominal Outside Diameter [in.]:** 20.00
- **Nominal Wall Thickness [in.]:** 0.250
- **Grade:** A25

#### Design Factor:
- **Location Class:** 1
- **Longitudinal Joint Factor:** API 5L Seamless
- **Temperature Derating Factor:** Temperature [°F], 250 or less

#### Uniform Support Under Pipe ['] and Crossing Conditions:
- **30° - Open Trench**

### Soil Type:
- Gravel/filling materials before trench or setting

### Pipe and Operational Data:
- **Nominal Pipe Size:** 20
- **Nominal Outside Diameter [in.]:** 20.00
- **Nominal Wall Thickness [in.]:** 0.250
- **Grade:** A25
- **Specified Minimum Yield Strength [psi]:** 46,000
- **Design Factor:** 0.72
- **Longitudinal Joint Factor:** 1.000
- **Temperature Derating Factor:** 1.000
- **Modulus of Elasticity for Steel [psi]:** 30,000,000
- **Unit Weight of Soil [lbs/ft²]:** 120
- **Deflection Parameter:** 0.108
- **Bending Parameter:** 0.235
- **Impact Factor:** 1.5
- **Pipeline Internal Pressure [psig]:** 828
- **Wheel Load [lbs]:** 16,000
- **Width of Pipe Trench or Diameter of Bore [ft]:** 4.0
- **Height of Soil over Pipe [ft]:** 4.0

### Load Coefficient
- **Total External Load [lbs/linear inch of pipe]:**
- **Hoop Stress due to Internal Pressure [psi]:**
- **Hoop Stress due to External Loading [psi]:**

### Total Calculated Combined Stress [psi]

**Note:** The total calculated combined stress should not exceed 100% of SMYS.
Estimated Weight of a Single Magnesium Anode
(ECDA & Corrosion Control)(Cathodic Protection)

Assumed Life of a Magnesium Anode [Year] 12.0
Electrical Current Flow from the Anode to the Pipe [A] 0.2
Polarized Potential Difference between Pipe and Reference Electrode [V] -1.3
Polarized Potential Difference between the Anode and same Reference Electrode [V] -1.8
Average Soil Resistivity [ohm-cm] 1,000.0

Result:
Estimated Weight of a Magnesium Anode [lbs.] 19.28
Problem Analysis Applications

- Stress
- Damage
- Corrosion
Problem Analysis - Stress

- Internal Pressure per Percent of SMYS
- Hoop & Longitudinal Stress
- Bending Stress and Deflection
- Linear Thermal Expansion
- Stress Caused by Fluid Flowing Around Pipe
- Requirements to Move Unpressurized Pipe
  Movement of In Service Pipelines
- PipeBlast Module – Blasting Analysis
- Heavy Loads Crossing a Pipeline
- Stresses on Restrained or Unrestrained Gas and Liquid Lines
- Liquid Line: Surge Analysis
Internal Pressure-Percent of SMYS

(Steel Pipe-Design & Stress Analysis)

Hoop & Longitudinal Stress

Internal Pressure - Percent of SMYS (Revision: 10.0.0)

Select Pipe:
- Line Pipe - API Specification 5L
- Standard Steel Pipe - ASTM - ANSI B36.10

Nominal Pipe Size: 24
Well Thickness [in.]: 0.312
Grade: X42

Specified Minimum Yield Strength [psi]: 42,000
Percent of SMYS [%]: 72

Input and Selected Data:
- Nominal Pipe Size: 24
- Nominal Outside Diameter [in.]: 24.00
- Nominal Wall Thickness [in.]: 0.312
- Internal Pressure [psig]: 785.0

Results:
- Hoop Stress [psi]: 30,230.8
- Longitudinal Stress [psi]: 15,115.4

Project: UG 2-1 Hoop & Longitudinal Stress
Location: Common App
Date: 6/5/2013
Notes:

Pipe Properties:
- Line Pipe - API Specification 5L
- Standard Steel Pipe - ASTM - ANSI B36.10

Nominal Pipe Size: 24
Wall Thickness [in.]: 0.312

Save | Report | Calculate
# Bending Stress and Deflection

## Project Information

<table>
<thead>
<tr>
<th>Location:</th>
<th>Comm App</th>
<th>Date:</th>
<th>8/28/2013</th>
</tr>
</thead>
</table>

## Pipe Properties

- **Line Pipe - API Specification 5L**
- **Standard Steel Pipe - ASTM-ANSI B36.10**

### Nominal Pipe Size

| 24 |

### Wall Thickness [in.]

| 0.344 |

## Results

### Fixed Ends Support

| Maximum Bending Stress [psi] | 13,137.1 |
| Maximum Deflection [ft] | 0.31 |

### Simple Support

| Maximum Bending Stress [psi] | 19,705.7 |
| Maximum Deflection [ft] | 1.53 |

### Cantilever Support

| Maximum Bending Stress [psi] | 78,022.8 |
| Maximum Deflection [ft] | 14.68 |

## Selected and Input Data

| Pipe Outside Diameter [in.] | 24.00 |
| Pipe Wall Thickness [in.] | 0.344 |
| Pipe Length [ft] | 150 |
| Modulus of Elasticity [psi] | 300,000,000 |
Linear Thermal Expansion (or Contraction)

Bending Stress Caused by Fluid Flowing Around Pipe
Requirements to Move Unpressurized Pipe

Project: UG 2-8 Requirements to Move Unpressured Pipe
Location: Common App
Date: 11/5/2012

Input and Selected Data:
- Maximum Deflection at the Pipe End (in.): 120.0
- Nominal Outside Diameter (in.): 18
- Nominal Wall Thickness (in.): 0.281
- Specified Minimum Yield Strength (psi): 46000
- Percentage of SMYS [%]: 60

Pipe Properties:
- Line Pipe - API Specification 5L
- Standard Steel Pipe - ASTM - ANSI B36.10

Line Pipe API 5L:
- Nominal Pipe Size: 18
- Wall Thickness [in.]: 0.281
- Grade: X46

Young's Modulus of Elasticity (psi): 30,000,000

Results:
- Maximum Stress Allowed [psi]: 27,600.0
- Total Exposed Pipe Required [ft]: 156.39
- Maximum Load at the Pipe End [lbs]: 1,003.4
- Section Modulus: 68.2
- Moment of Inertia: 614.0
- Moment [lb-ft]: 156,920.0

Save   Report   Calculate
## Movement of in Service Pipelines – API RP 1117 slide 1 of 2

### Design & Operational Parameters

<table>
<thead>
<tr>
<th>Project</th>
<th>UG 2-9 API 1117 Movement of In-Service Pipelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Common App</td>
</tr>
<tr>
<td>Notes</td>
<td></td>
</tr>
</tbody>
</table>

### Pipe Properties:

- Lina Pipe - API Specification 5L
- Standard Steel Pipe - ASTM - ANSI B36.10

<table>
<thead>
<tr>
<th>Liner Pipe API 5L</th>
<th>Nominal Pipe Size</th>
<th>Wall Thickness [in]</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1/8</td>
<td>0.063</td>
<td>A25</td>
</tr>
</tbody>
</table>

### Results: Preferred Trench Profile for Lowering & Table

<table>
<thead>
<tr>
<th>Input and Selected Pipe Properties:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Pipe Size</td>
</tr>
<tr>
<td>Outside Pipe Diameter [in]</td>
</tr>
<tr>
<td>Pipe Wall Thickness [in]</td>
</tr>
<tr>
<td>Inside Pipe Diameter [in]</td>
</tr>
<tr>
<td>Specified Minimum Yield Strength [psi]</td>
</tr>
<tr>
<td>Modulus of Elasticity of Steel [psi]</td>
</tr>
<tr>
<td>Poisson's Ratio for Steel</td>
</tr>
</tbody>
</table>

### Design and Operational Data:

- Desired Vertical Deflection of the Pipe [ft]: 6.0
- Maximum Operating Pressure [psi]: 1,185.0
- Installation Temperature of the Pipe [°F]: 75.0
- Operating Temperature of the Pipe [°F]: 70.0
- Pipe Design Factor: 0.80
- S - Longitudinal Stress due to Pipe Elast. Curvature [psi]: 0.0

![Image of excavation site with equipment and workers]
APR 1117 - Movement of In-Service Pipelines (Revision: 10.0.0)

**Design & Operational Parameters**

<table>
<thead>
<tr>
<th>Design &amp; Operational Parameters</th>
<th>Results, Preferred Trench Profile for Lowering &amp; Table</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sp</strong> - Longitudinal Stress due to Internal Pressure [psi]</td>
<td>3,065</td>
</tr>
<tr>
<td><strong>St</strong> - Longitudinal Stress due to Temperature [psi]</td>
<td>343</td>
</tr>
<tr>
<td><strong>Se</strong> - Existing Longitudinal Stress [psi]</td>
<td>10,008</td>
</tr>
<tr>
<td><strong>L</strong> - Minimum Required Trench Length [ft]</td>
<td>401</td>
</tr>
<tr>
<td><strong>Ss</strong> - Longitudinal Stress due to its Elongation [psi]</td>
<td>12,063</td>
</tr>
<tr>
<td><strong>Sa</strong> - Longitudinal Stress Available for the Bending [psi]</td>
<td>15,369</td>
</tr>
<tr>
<td><strong>Ls</strong> - Maximum Allowable Support Spacing [ft]</td>
<td>55.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Station-x [ft]</th>
<th>Deflection [ft]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00</td>
</tr>
<tr>
<td>2</td>
<td>0.01</td>
</tr>
<tr>
<td>3</td>
<td>0.06</td>
</tr>
<tr>
<td>4</td>
<td>0.10</td>
</tr>
<tr>
<td>5</td>
<td>0.18</td>
</tr>
<tr>
<td>6</td>
<td>0.27</td>
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<tr>
<td>7</td>
<td>0.36</td>
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<td>8</td>
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<td>9</td>
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<td>10</td>
<td>0.80</td>
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<tr>
<td>11</td>
<td>0.95</td>
</tr>
<tr>
<td>12</td>
<td>1.12</td>
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**Preferred Trench Profile of the Lowering**

-5.046

Deflection [ft]

<table>
<thead>
<tr>
<th>Trench Length [ft]</th>
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<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>50</td>
</tr>
<tr>
<td>100</td>
</tr>
<tr>
<td>150</td>
</tr>
<tr>
<td>200</td>
</tr>
<tr>
<td>250</td>
</tr>
<tr>
<td>300</td>
</tr>
<tr>
<td>350</td>
</tr>
<tr>
<td>400</td>
</tr>
</tbody>
</table>

-5.046
PipeBlast- Blasting Analysis (A Tool Kit of Special Apps and Project Files within the Tool Box for stresses from five potential arrangements of explosive charges)

Screens for a Single Explosive Charge and a Parallel Grid of Charges
Wheel Load Analysis (Steel Pipeline Crossings)
## Track Load Analysis
(Steel Pipeline Crossings)

### Track Load Analysis (Revision: 10.0.0)

<table>
<thead>
<tr>
<th>Project</th>
<th>LGC 2-20 Track Load Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Common App</td>
</tr>
<tr>
<td>Date</td>
<td>11/5/2012</td>
</tr>
<tr>
<td>Notes</td>
<td></td>
</tr>
</tbody>
</table>

- **Line Pipe - API Specification 5L**
  - Nominal Pipe Size: 1/8
  - Wall Thickness [in]: 0.063
  - Grade: A25

- **Standard Steel Pipe - ASTM - ANSI B36.10**
  - Line Pipe API 5L

### Pipe and Operational Data
- Pipe Outside Diameter [in]: 8.630
- Pipe Wall Thickness [in]: 0.203
- Specified Minimum YIELD Strength [ksi]: 42,000
- Maximum Allowable Internal Stress [%]: 72
- Maximum Allowable Combined Stress [%]: 80

- **Friction Force Coefficient (K)**: 0.1920
- **Weight per Unit of Backfill [lbs/ft]**: 100.0
- **Impact Factor**: 1.50

- **Operating Weight (Object with Tracks) [lbs]**: 80,000
- **Width of Standard Track Shoe [in]**: 24
- **Length of the Track on the Ground [ft]**: 15.00

- **Bending Coefficient (K)**: 0.235
- **Deflection Coefficient (K)**: 0.108

- **Pipe Internal Pressure [ksi]**: 1.422.0
- **H - Vertical Depth of the Soil Cover [ft]**: 3.0
- **B - Trench Width [ft]**: 3.00

### Results
- **C_d - Load Coefficient**: 0.630
- **W_c - Load due to Overburden [lbs]**: 62.25
- **m - Influence Factor**: 0.30
- **n - Influence Factor**: 2.50
- **I_c - Influence Coefficient(m,n)**: 0.355
- **Q_d - Max Static Pressure [lbs/ft]**: 473.33
- **W_T - Total Track Load [lbs]**: 42,550
- **W_T - Total Load [lbs]**: 104,800

- **S_b - Longitudinal Bending Stress [psi]**: 0
- **S_c - Circumferential Stress [psi]**: 6,968
- **S_h - Hoop Stress [psi]**: 30,226
- **S_t - Total Circumferential Stress [psi]**: 37,194
- **S_t - Total Combined Stress [psi]**: 37,194

- **Percent of SMYS**: 88.56

**NOT SAFE TO CROSS PIPELINE**
### Stress Analysis

**Restrained and Unrestrained Gas Pipelines**

#### Restrainted Gas Pipeline - Stress Analysis

<table>
<thead>
<tr>
<th>Project</th>
<th>JG 3-16 Restained Gas Pipeline Stress Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Additional Gas Edition Applications</td>
</tr>
<tr>
<td>Notes</td>
<td>Date</td>
</tr>
</tbody>
</table>

**Pipe and Operational Data**
- Pipe Internal Pressure (psig): $495.0$
- Nominal Outside Diameter (in): $16.00$
- Nominal Wall Thickness (in): $0.250$
- Grade: $A42$
- Specified Minimum Yield Strength (psi): $70.000$
- Temperature Derating Factor: $1.60$
- Pipe Installation Temperature (°F): $80.0$
- Pipe Operating Temperature (°F): $110.0$
- Nominal Bending Stress (psi): $2,430.0$
- Stress due to Axial Loading (psi): $80.0$
- k-Load Factor: $0.9$

**Results**
- Hoop Stress (psi): $10,240.0$
- Longitudinal Stress due to Internal Pressure (psi): $8,972.0$
- Longitudinal Stress due to Thermal Expansion (psi): $2,335.0$
- Net Longitudinal Stress (psi): $17,592.0$
- Maximum Permitted Longitudinal Stress (psi): $31,500.0$
- Combined Biaxial Stress (psi): $26,233.7$
- Maximum Permitted Combined Biaxial Stress (psi): $37,000.0$

#### Unrestrained Gas Pipeline - Stress Analysis

<table>
<thead>
<tr>
<th>Project</th>
<th>JG 3-16 Unrestrained Gas Pipeline Stress Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Additional Gas Edition Applications</td>
</tr>
<tr>
<td>Notes</td>
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</tr>
</tbody>
</table>

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- Maximum Permitted Longitudinal Stress (psi): $31,500.0$
Stress Analysis
Restrained and Unrestrained Liquid Pipelines
Surge Analysis – Water Hammer- Slide 1 of 2 (Liquid – Hydraulics)

Analysis of surge in 10 miles of 24 inch line flowing 15000 BPH - Screens 1 & 2 of 5

### Surge Analysis - Water Hammer (Revision: 10.0.0)

**Surge Analysis Input**

- **Project:** UG 4-17 Surge Analysis
- **Location:** Additional Liquid Edition Applications
- **Date:** 11/14/2012

**Select Specific Gravity and Viscosity from Database:**

- Crude Oil 40° API

**Select Pipe Dimensions:**

- Line Pipe - API Specification 5L
- Standard Steel Pipe - ASTM - ANSI B36.10

**Nominal Pipe Size:**

- 24

**Wall Thickness [in.]:**

- 0.281

**Internal Pipe Diameter [in.]:**

- 23.438

**Absolute Pipe Roughness [in.]:**

- 0.00180

**Flowing Temperature [°F]:**

- 60.0

**Specific Gravity:**

- 40.00

**Upstream Pressure Rel. to H2O 60/60°F [psi]:**

- 786.0

**Flowrate [bbl (US, petrol)/h]:**

- 15,000.0

**Pipeline Length [miles]:**

- 10

**Kinematic Viscosity [cSt]:**

- 9.700

**Valve Closing Time [sec]:**

- 3.0

**Simulation Time [sec]:**

- 200.0

**Intermediate Results:**

- Friction Factor: 0.0172
- Average Adiabatic Bulk Modulus [psi]: 225,688.1
- Average Wave Speed in Pipeline [ft/sec]: 3,533.9

**Surge Analysis - Water Hammer (Revision: 10.0.0)**

<table>
<thead>
<tr>
<th>Time [sec]</th>
<th>Q(1)</th>
<th>Q(2)</th>
<th>Q(3)</th>
<th>Q(4)</th>
<th>Q(5)</th>
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---

89
Surge Analysis – Water Hammer - Slide 2 of 2

Analysis of surge in 10 miles of 24 inch line flowing 15000 BPH - Screen 3

Screens 4 and 5: Graphs of Flow and Pressure per Duration of Surge
Problem Analysis - Damage

- Maximum Impact Load & Penetration Depth
- Potential Impact Radius
- Gas Line Rupture Analysis
- Accidental Gas & Liquid Pipeline Releases
# Maximum Impact Load & Penetration Depth (Steel Pipe-Stress Analysis)

<table>
<thead>
<tr>
<th>Project</th>
<th>UG 2-6 Maximum Impact Load &amp; Penetration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Common App</td>
</tr>
<tr>
<td>Notes</td>
<td></td>
</tr>
</tbody>
</table>

## Input Parameters:

- **Weight of Falling Object [lbs]**: 200,000
- **Drop Height [ft]**: 15.0
- **Impact Area Diameter [ft]**: 6.0
- **Unit Weight of Soil [lbs/ft³]**: 11.00
- **Poisson’s Ratio for Soil**: 0.37
- **Shear Wave Velocity of Near Surface Soil [in./sec]**: 10,000.0

## Empirical Coefficient of Penetration:

- **Soft Soil**: 0.0732

## Results:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Shear Modulus [psi]</td>
<td>1.647</td>
</tr>
<tr>
<td>Maximum Load at the Soil Surface [lbs]</td>
<td>3,316,527</td>
</tr>
<tr>
<td>Impact Velocity [ft/sec]</td>
<td>31.08</td>
</tr>
<tr>
<td>Impact Pressure [ksi]</td>
<td>815</td>
</tr>
<tr>
<td>Weight per Unit of Impact Area [psi]</td>
<td>49</td>
</tr>
<tr>
<td><strong>Penetration Depth [ft]</strong></td>
<td>1.01</td>
</tr>
</tbody>
</table>

[Graphs and images showing impact scenarios]
Potential Impact Radius (ECDA & Corrosion Control) (ECDA Toolset) (PIR&DCVG)

Gas Pipeline Rupture Analysis (Steel Pipe-Design & Stress Analysis)
Accidental Gas Release thru small hole
Problem Analysis – Corrosion
(ECDA & Corrosion Control)

- RSTRENG for Windows Module
- External Corrosion Direct Assessment Toolset and Remaining Life of Corroded Pipe
- ANSI B31G-1991 Evaluation of MAOP
- ANSI B31G Maximum Allowable Longitudinal Corrosion
- Current Flow & Resistance Equations
RSTRENG-New File Data Input Screens
RSTRENG Calculations Screen: Calculated analysis of the profile after entering the longitudinal spacing and depths of the measured increments.

CORROSION PROFILE - Houston

<table>
<thead>
<tr>
<th>Increment [in]</th>
<th>Pit Depth [Mil]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0</td>
</tr>
<tr>
<td>2</td>
<td>50.0</td>
</tr>
<tr>
<td>3</td>
<td>90.0</td>
</tr>
<tr>
<td>4</td>
<td>60.0</td>
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<tr>
<td>5</td>
<td>60.0</td>
</tr>
<tr>
<td>6</td>
<td>100.0</td>
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<tr>
<td>7</td>
<td>70.0</td>
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<tr>
<td>8</td>
<td>120.0</td>
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<tr>
<td>9</td>
<td>50.0</td>
</tr>
<tr>
<td>10</td>
<td>0.0</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective Area</td>
<td>742</td>
<td>1031</td>
<td>1.29</td>
</tr>
<tr>
<td>0.85dL Area</td>
<td>628</td>
<td>873</td>
<td>1.09</td>
</tr>
<tr>
<td>ASME B31G</td>
<td>647</td>
<td>899</td>
<td>1.12</td>
</tr>
</tbody>
</table>

P = 2STF/D [psig] - Calculated Pressure: 619.936

Established MAOP [psig]: 600

Pipe Outside Diameter [in]: 20.00
Pipe Wall Thickness [in]: 0.219
SMYS [psi]: 52,000
Total Length [in]: 7
Start [in]: 0.50
End [in]: 6.30

Max. Depth/Wall Thickness: 0.55
After closing the analysis can be saved in the RSTRENG module available for re-opening and analyzing a different profile of the corroded site.

Run Multiple Scenarios in the Help App of the RSTRENG Module provides guidance for entering data, calculating and saving the analysis of multiple profiles of a corroded site.
EXTERNAL CORROSION DIRECT ASSESSMENT TOOLSET
Module with Separate User Interface

- FILE: for direct access to completed RSTRENG projects

- UNITS and Set Operator/Inspector Data: screens for setting up an RSTRENG project.

- PRCI Research Reports module provides direct access to reports explaining the basis and validation of RSTRENG as a procedure for evaluating the remaining strength of corroded pipe.

- ECDA
  A. Remaining Life of Corroded Pipe
  B. Practical Guidelines for Conducting ECDA Program
     123 page instructional report
  C. ECDA – Direct Examination Worksheet – 8 page template

- PIR & DCVG
  Potential Impact Radius
  DCVG-%IR Drop
## ECDA

### A. Remaining Life of Corroded Pipe

<table>
<thead>
<tr>
<th>General Project Information:</th>
</tr>
</thead>
<tbody>
<tr>
<td>RSTRENG Project</td>
</tr>
<tr>
<td>Station/Mile Post</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pipe Properties &amp; Operational Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe Outside Diameter</td>
</tr>
<tr>
<td>Pipe Wall Thickness [in]</td>
</tr>
<tr>
<td>SMYS [psi]</td>
</tr>
<tr>
<td>P = 2SFT/D [psig] - Calculated Pressure</td>
</tr>
<tr>
<td>Established MAOP [psig]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Calculated Failure Pressures</th>
</tr>
</thead>
<tbody>
<tr>
<td>RSTRENG - Effective Area [psig]</td>
</tr>
<tr>
<td>RSTRENG - 0.85dL Area [psig]</td>
</tr>
<tr>
<td>ASME B31G [psig]</td>
</tr>
</tbody>
</table>

### Results:

| Pipeline Operating Stress Level [% SMYS] | 60 |
| Hoop Stress/Yield Pressure [psig]       | 1,461 |
| Failure Pressure Ratio for RSTRENG - Effective Area | 0.764 with Safety Margin 0.154 |
| Failure Pressure Ratio for RSTRENG - 0.85dL | 0.830 with Safety Margin 0.029 |
| Failure Pressure Ratio for ASME B31G | 0.701 with Safety Margin 0.101 |

| Time Until Failure: RSTRENG - Effective Area [years] | 2.4 |
| Time Until Failure: RSTRENG - 0.85dL Area [years]    | 0.4 |
| Time Until Failure: ASME B31G [years]                | 1.5 |

### REMAINING LIFE:

- Remaining Life based on RSTRENG - Effective Area [years] | 2.4 |
- Remaining Life based on RSTRENG - 0.85dL Area [years]    | 0.4 |
-Remaining Life based on ASME B31G [years]                | 1.5 |

### RE-ASSESSMENT INTERVAL for ECDA region:

- Re-Assessment Interval based on RSTRENG - Effective Area [years] | 1.2 |
- Re-Assessment Interval based on RSTRENG - 0.85dL Area [years]    | 0.2 |
- Re-Assessment Interval based on ASME B31G [years]                | 0.8 |

### B. Practical Guidelines for Conducting ECDA Program:
- 123 page instructional report

### C. ECDA – Direct Examination Worksheet – 8 page template
PIPELINE CORROSION

ANSI B31G – 1991 Evaluation of MAOP in Corroded Areas

Location: Common App
Date: 11/6/2012

Select Pipe And Location Data:
- Line Pipe - API Specification 5L
- Standard Steel Pipe - ASTM - ANSI B36.10

Pipe and Operational Data:
- Maximum Depth of Corroded Area [in.]: 0.15
- Longitudinal Extent of Corroded Area [in.]: 1.4
- Pipe Outside Diameter [in.]: 24
- Nominal Pipe Wall Thickness [in.]: 0.312
- Specified Minimum Yield Strength - SMYS [psi]: 42000
- Appropriate Design Factor ANSI B.31.8 Code: 0.72
- Temperature Derating Factor ANSI B.31.8 Code: 1.0
- Longitudinal Joint Factor ANSI B.31.8 Code: 1.900
- Maximum Operating Pressure - MOP [psi]: 786

Results:
- Maximum Safe Pressure - Corroded Area [psi]: 421.34
- Design Pressure - ANSI B.31.8 [psi]: 786.24
- Intermediate factor A: 4.57

ANSI B31G – 1991 Maximum Allowable Longitudinal Corrosion

Project: User Guide 2 - Max Allowable Extent of Corrosion
Location: Common App
Date: 11/6/2012

Maximum depth of corroded area [in.]: 0.16
Pipe outside diameter [in.]: 24
Nominal pipe wall thickness [in.]: 0.312

Result:
- Maximum allowable longitudinal extent of corrosion [in.]: 2.24
**Rate of Current Flow through the Corrosion Cell**

| Potential of the Cathode with Respect to a Reference Electrode [V] | -1.2 |
| Potential of the Anode with Respect to the same Reference Electrode [V] | .8 |
| Total Resistance to Electrical Current Flow through the Cell [ohm] | 50 |

**Relationship between Resistance and Resistivity**

| Electrolyte Resistivity [ohm-cm] | 500 |
| Distance through the Electrolyte Travelled by the Current [cm] | 50 |
| Cross Sectional Area through which the Current Flows [sq.cm] | 10000 |

**Electrolyte Resistance from from Surface of an Electrode**

| Electrolyte Resistivity [ohm-cm] | 500 |
| Distance from the Central Electrode [cm] | 10 |
| Geometry Factor for the Central Electrode | 0001 |

**Electrical Resistance of a Conductor**

| Length of the Conductor [cm] | 1000 |
| Cross Sectional Area of the Conductor [sq.cm] | 2 |
| Conductor Resistivity [ohm-cm] | 0002 |

**Ohm’s Law for Corrosion Current**

| Potential Difference between the Polarized Cathode and Reference Electrode [V] | -1.7 |
| Potential Difference between the Polarized Anode and the Same Reference Electrode [V] | .8 |
| Geometry Factor for a Cathode | 1 |
| Geometry Factor for an Anode | 10000 |
| Average Soil Resistivity [ohm-cm] | 500 |

**Result:**

- Electrolyte Resistance [ohm] = 421.92
- Electrical Resistance of a Conductor [ohm] = 1.00
- Corrosion Current [A] = 0.05
DCVG-%IR Drop  (ECDA & Corrosion Control)(Toolset)

**Project:** User Guide

**Location:** Common App | **Date:** 11/6/2012

**Notes:**

---

**Input Parameters:**

- Voltage Swing at Pipe [mV]
- Voltage Swing at Last Test Station [mV]
- Voltage Swing at Next Test Station [mV]
- Distance to Last Test Station [ft]
- Distance to Next Test Station [ft]

---

**Result:**

DCVG - %IR Drop

---

**Report** | **Calculate**
Applications for Operating and Testing Measurements

- Hydrostatic Testing
- Weld Imperfection Assessment
- Gas Property Calculations
- Liquid Property Calculations
- Orifice Meter Flow Rate Calculations
Hydrostatic Testing
Volume to Fill & Test and Max Pressure Drop
(Steel Pipe-Design & Stress Analysis) (Pipeline Testing & Miscellaneous)

Pipeline Hydrostatic Testing
- Project: UG 2-13 Pipeline Hydrostatic Testing
- Location: Common App
- Notes:

Selected Pipe:
- Line Pipe - API Specification 5L
- Standard Steel Pipe - ASTM - ANSI B36.10
- Line Pipe API 5L
  - Nominal Pipe Size: 1/8
  - Wall Thickness [in]: 0.668

Pipe and Operational Data:
- Outside Diameter [in.]: 3.50
- Wall Thickness [in]: 0.231
- Internal Diameter [in]: 2.438
- Test Pressure [psig]: 1,200.0
- Test Temperature [°F]: 70.0
- Pipeline Length [miles]: 10.0

Results:
- Correlation Factors for:
  - Water: 10036.795
  - Volume Change due to Increase of Pressure: 1.0025275
  - Volume Change due to Temperature Change: 1.0001820
  - Thermal Change in the Specific Volume of Water: 1.0010384
  - Volume Change Ratio Pipe/Water: 0.9991465

Pipeline Fill Volume [gallons]: 813.349
Volume Required for Hydrotesting [gallons]: 816.191
Incremental Volume Required for Hydrotesting [gallons]: 4.442
Compressibility Factor for Water [mHg]/psig X 10-6: 1.39
Pressure Change [gpa/°F]: 10

Initial test pressure [psig]: 1200
Shut-in time [hr]: 8
Internal pipe diameter [in.]: 12.25

Result:
- Acceptable pressure loss [psig]: 0.03

Gas Pipeline Pressure Testing - Max. Pressure Drop
- Project: UG Max Pressure Drop
- Location: Comm App
- Notes:

Initial test pressure [psig]: 1200
Shut-in time [hr]: 8
Internal pipe diameter [in.]: 12.25

Result:
- Acceptable pressure loss [psig]: 0.03

CAUTION HYDROSTATIC TEST IN PROGRESS

Pipeline Hydrostatic Testing
- Project: UG 2-13 Pipeline Hydrostatic Testing
- Location: Common App
- Notes:

Selected Pipe:
- Line Pipe - API Specification 5L
- Standard Steel Pipe - ASTM - ANSI B36.10
- Line Pipe API 5L
  - Nominal Pipe Size: 1/8
  - Wall Thickness [in]: 0.668

Pipe and Operational Data:
- Outside Diameter [in.]: 3.50
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- Test Pressure [psig]: 1,200.0
- Test Temperature [°F]: 70.0
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Pressure Change [gpa/°F]: 10

Initial test pressure [psig]: 1200
Shut-in time [hr]: 8
Internal pipe diameter [in.]: 12.25

Result:
- Acceptable pressure loss [psig]: 0.03

CAUTION HYDROSTATIC TEST IN PROGRESS
API 1104 – Appendix A: Option 2
Weld Imperfection Assessment
(Steel Pipe-Design & Stress Analysis) (Pipeline Testing & Miscellaneous)

Numerous welding flaws in pipeline
A new report from the National Transportation Safety Board says that the natural gas pipeline that exploded in San Bruno in September had more than 100 locations where welds were inadequate — reducing the amount of pressure the pipe could safely hold.

Section flaws
Within a 44-foot section of the damaged pipeline were six smaller pieces, known as “pups,” all welded together as part of its installation in 1956.

Lengthwise flaws
The report also found numerous longitudinal welds that penetrated as little as 47 percent of the way through the steel pipe. The welds should go all the way through the pipe wall to be safe, experts say.

<table>
<thead>
<tr>
<th>Nominal Pipe Size</th>
<th>36</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Outside Diameter [in.]</td>
<td>36.00</td>
</tr>
<tr>
<td>Nominal Wall Thickness [in.]</td>
<td>0.344</td>
</tr>
<tr>
<td>Grade</td>
<td>X60</td>
</tr>
<tr>
<td>Specified Minimum Yield Strength [psi]</td>
<td>60,000</td>
</tr>
</tbody>
</table>

Minimum CTOD Toughness [in.] 10019
Applied Stress [ksi] 6,000
# Gas Mixture Property Calculations

**17 Properties per 3 Base Conditions**

(Utilities)

## Mole Fraction:

<table>
<thead>
<tr>
<th>Component</th>
<th>Mole Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane (CH4)</td>
<td>0.8157</td>
</tr>
<tr>
<td>Ethane (C2H6)</td>
<td>0.0732</td>
</tr>
<tr>
<td>Propane (C3H8)</td>
<td>0.0431</td>
</tr>
<tr>
<td>Isobutane (iC4H10)</td>
<td>0.0082</td>
</tr>
<tr>
<td>n-Butane (C4H10)</td>
<td>0.0106</td>
</tr>
<tr>
<td>Isopentane (iC5H12)</td>
<td>0.0030</td>
</tr>
<tr>
<td>n-Pentane (C5H12)</td>
<td>0.0025</td>
</tr>
<tr>
<td>n-Hexane (C6H14)</td>
<td>0.0029</td>
</tr>
<tr>
<td>n-Heptane (C7H16)</td>
<td>0.0000</td>
</tr>
<tr>
<td>n-Octane (C8H18)</td>
<td>0.0000</td>
</tr>
<tr>
<td>n-Nonane (C9H20)</td>
<td>0.0000</td>
</tr>
<tr>
<td>n-Decane (C10H22)</td>
<td>0.0000</td>
</tr>
<tr>
<td>Hydrogen (H2)</td>
<td>0.0000</td>
</tr>
<tr>
<td>Helium (He)</td>
<td>0.0003</td>
</tr>
<tr>
<td>Water (H2O)</td>
<td>0.0174</td>
</tr>
<tr>
<td>Carbon Monoxide (CO)</td>
<td>0.0000</td>
</tr>
<tr>
<td>Nitrogen (N2)</td>
<td>0.0031</td>
</tr>
<tr>
<td>Oxygen (O2)</td>
<td>0.0000</td>
</tr>
<tr>
<td>Hydrogen Sulfide (H2S)</td>
<td>0.0000</td>
</tr>
<tr>
<td>Argon (Ar)</td>
<td>0.0000</td>
</tr>
<tr>
<td>Carbon Dioxide (CO2)</td>
<td>0.0198</td>
</tr>
</tbody>
</table>

## Conditions:

- **Base Temperature for Heating Value [°F]**: 60.0
- **Base Temperature for Relative Density [°F]**: 60.0
- **Base Operating Pressure [psia]**: 14.7

## Results:

- **Molar Mass**: 20.200
- **Molar Mass Ratio**: 0.69747
- **Relative Density**: 0.69972
- **Compressibility Factor**: 0.99641
- **Gross Heating Value [Btu/lb]**: 21,613.22
- **Gross Heating Value-Ideal [Btu/scf]**: 1,150.81
- **Gross Heating Value-Real [Btu/scf]**: 1,154.96
Liquid Property Calculations (Utilities)

Database of Liquid Specifications

Volume Correction Factors

- Viscosity Temperature Relations
- cSt/Saybolt -°API/Baume Specific Gravity

**Database of Liquids Commonly Transferred by Pipeline**

<table>
<thead>
<tr>
<th>Liquid Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude Oil 40° API</td>
</tr>
<tr>
<td>Crude Oil 35.5° API</td>
</tr>
<tr>
<td>Crude Oil 32.5° API</td>
</tr>
<tr>
<td>Crude Oil 48° API</td>
</tr>
<tr>
<td>Diesel Fuel Oil No. 1</td>
</tr>
<tr>
<td>Diesel Fuel Oil No. 2</td>
</tr>
<tr>
<td>Diesel Fuel Oil No. 3</td>
</tr>
<tr>
<td>Diesel Fuel Oil No. 4</td>
</tr>
<tr>
<td>Diesel Fuel Oil No. 5</td>
</tr>
<tr>
<td>Gas Oils</td>
</tr>
<tr>
<td>Gasoline A</td>
</tr>
<tr>
<td>Gasoline B</td>
</tr>
<tr>
<td>Hexane</td>
</tr>
<tr>
<td>Heptane</td>
</tr>
<tr>
<td>Kerosene</td>
</tr>
<tr>
<td>Methylene Chloride</td>
</tr>
<tr>
<td>Octane n</td>
</tr>
<tr>
<td>Octane n</td>
</tr>
<tr>
<td>Naphtha</td>
</tr>
</tbody>
</table>

**API 2540 - Volume Correction Factors (Revision: 10.0.0)**

- Results
  - Coefficient of Thermal Expansion: 0.0009445
  - Volume Correction Factor for Thermal Expansion: 0.9983056
  - Corrected Specific Gravity: 0.6578

**ASTM D 341 Viscosity - Temperature Relations for Hydrocarbons**

**ASTM 2161 cSt/Saybolt Viscosity and °API/Baume/Specific Gravity Conversion**
Liquid Property Calculations

Adiabatic Bulk Modulus for Hydrocarbons

Wave Speed in Pipeline

Hydrocarbons Compressibility

API MPMS Ch.12 - Compressibility Factor for Hydrocarbons: 0 - 90°API

Project: User Guide 2 - Compressibility Factor for Hydrocarbons
Location: Additional Liquid Edition Apps
Date: 11/10/2012

- Determine Volume at Equilibrium (Bubble Point) Pressure
- Determine Compressibility Factor

Input:
- Liquid Specific Gravity
- Temperature at Metering Conditions (°C or °F)
- Pressure at Metering Conditions (psi)
- Volume of the Meter Pressure (bbl)
- Equilibrium (Bubble Point) Pressure (psi)

Results:
- Compressibility Factor
- Volume at Equilibrium (Bubble Point) Pressure [bbl]
Orifice Meters: Flow Rate Calculations
AGA 3 Methods 1 and 2
(Pipeline Facilities) (Meters & Regulators)

Screen 1 of 2: Input Data (Identical screen for both Methods)

Screen 2 of 2: Method 1 — Results of Calculation

Method 2 — Calculates Base Flow Rate of 608,476.9 SCHF
Polyethylene Pipe

• PE Pipe Design & PE Pipeline Crossings
• Installation of PE Pipelines by Horizontal Directional Drilling
**PE Pipe Design & PE Pipeline Crossings**

**Design Pressure – Polyethylene Pipe**

\[ P = \frac{2S}{(D - t)^{0.32}} \]

\[ P = \frac{2S}{(SDR - 1)} \]

- **P** – Design pressure, gauge, kPa (psig)
- **S** – Thermoplastic pipe long-term hydrostatic tensile strength (MPa, psi)
- **t** – Specified wall thickness, mm (in.)
- **D** – Specified outside diameter, mm (in.)
- **SDR** – Standard dimension ratio

**Minimum Wall Thickness Polyethylene Pipe**

\[ t = \frac{119}{1250} \times 0.2137 \]

For Nominal Size 6:
- **0.234**
- **0.204**
Distributed Static Surcharge Load: PE Pipe Directly & Not Directly Beneath

Unit Weight of Soil [lb/ft²]:
- N: 120
- M: 120
- M1: 126

Soil Height above Pipe Crown [ft]:
- N: 4
- M: 4
- M1: 4

Bed - Trench Width at Pipe Crown [ft]:
- N: 3
- M: 3
- M1: 3

For Soil:
- Softened Clay: Friction Force Coefficient Kf = 0.11
- M = 0.10
- M1 = 0.10
- Deflection Leg Factor (Typically 1.0 - 1.5) = 1.5
- Bedding Factor (Typically 0.1) = 0.1

Results:
- Vertical Pressure due to Earth Load [lb/ft²]:
  - N: 444.00
  - M: 159.00
  - M1: 159.00
- Vertical Pressure by Surcharge Load [lb/ft²]:
  - N: 6.00
  - M: 6.00
  - M1: 6.00

P = Soil Support Factor
- N: 0.44
- M: 0.44
- M1: 0.44

Deflection as % of Pipe Diameter [%]:
- N: 40
- M: 40
- M1: 40

Compressive Stress [psi]:
- N: 226
- M: 226
- M1: 226
Live Loads: Aircraft Landings and Highway Traffic
Live Single Wheel Load on Buried PE Pipe

Live Multiple Wheel Load over Buried PE Pipe
Live Loads on PE Pipe
Distributed Surface Load over Unpaved Road – Timoshenko’s Equation

Reference: ASTM F 1992 - 05, Table X1.1

HDPE
HDPE Typical Apparent Modulus of Elasticity:
Duration Time: Short-Term

Reference: Allowable Compressive Stress
For PE Pipe Material Designation Code: PE 2406
Allowable Compressive Stress at 73°F = 800 [psi]

Reference: Safe Deflection Limits for Pressurized Pipe
Pipe DR or SDR: 32.5
Safe Deflection as % of Pipe Diameter: 7.5 [%]

Reference: Typical Impact Factors for Paved Roads
For Cover Depth (ft) 4
Impact Factor = 1.20
For unpaved roads, impact factor of 2.0 or higher may occur, depending on the road surface.

Select Earth/Dead Load Calculation Method:

Prism Load

Vertical Pressure due to Earth Load [lb/ft²]: 430.00
Equivalent Radius [ft]: 0.47
Vertical Pressure due to Live Load [lb/ft²]: 930.00
Bd/Do: 6.60
En/E:
Fs - Soil Support Factor: 1.00
Deflection as % of Pipe Diameter [%]: 1.03
Compressive Stress [psi]: 160

Pipe Data:
Do - PE Pipe Outside Diameter [in]: 6
PE Pipe DR or SDR: 32.5
PE Pipe Apparent Modulus of Elasticity [psi]: 110000

Live Load Data:
Wheal Load [lb]: 16000
Wheal Imprint/Contact Area [in²]: 100
Impact Factor (2.0 or Higher): 2
Live Load: Cooper E-8- Railroad Load on Buried PE

<table>
<thead>
<tr>
<th>Input Data:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Pipe Envelope Data:</td>
</tr>
<tr>
<td>Unit Weight of Soil (lbs)</td>
</tr>
<tr>
<td>Soil Height above Pipe Crown (ft)</td>
</tr>
<tr>
<td>Bd - Trench Width at Pipe Crown (ft)</td>
</tr>
<tr>
<td>For Soil:</td>
</tr>
<tr>
<td>Saturated Clay</td>
</tr>
<tr>
<td>Friction Force Coefficient Kf1</td>
</tr>
<tr>
<td>E' - Modulus of Soil Reaction [psi]</td>
</tr>
<tr>
<td>E'Í - Native Soil Modulus of Soil Reaction [psi]</td>
</tr>
<tr>
<td>Deflection Lag Factor (Typically 1.0 - 1.5)</td>
</tr>
<tr>
<td>Building Factor (Typically 0.1)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pipe Data:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do - PE Pipe Outside Diameter [in]</td>
</tr>
<tr>
<td>PE Pipe DR or SDR</td>
</tr>
<tr>
<td>PE Pipe Apparent Modulus of Elasticity [psi]</td>
</tr>
<tr>
<td>Deflection as % of Pipe Diameter (%)</td>
</tr>
<tr>
<td>Compressive Stress [psi]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Results:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical Pressure due to Earth Load [lb/ft²]</td>
</tr>
<tr>
<td>Vertical Pressure due to Cooper E-8 Load [lb/ft²]</td>
</tr>
<tr>
<td>Ed/Do</td>
</tr>
<tr>
<td>E'Í/E'</td>
</tr>
<tr>
<td>Fs - Soil Support Factor</td>
</tr>
<tr>
<td>Deflection as % of Pipe Diameter (%)</td>
</tr>
<tr>
<td>Compressive Stress [psi]</td>
</tr>
</tbody>
</table>

Reference: ASTM F 1962 - 05, Table X1.1
- HDPE
- MDPE
- HDPE Typical Apparent Modulus of Elasticity:
  - Duration Time: Short-Term, 110,000 [psi]

Reference: Allowable Compressive Stress
- For PE Pipe Material Designation Code: PE 2408 [psi]
- Allowable Compressive Stress at 73°F = 800 [psi]

Reference: Safe Deflection Limits for Pressurized Pipe
- Pipe DR or SDR: 32.5 [in]
- Safe Deflection as % of Pipe Diameter = 7.5 [%]

Select Earth/Dead Load Calculation Method:
- Prism Load
- Mortar Load
- Combined Prism and Mortar Load

Note: Impact Factor included.

(ECDA & Corrosion Control)
Installation of PE Pipelines by HDD

Allowable Tensile Load (ATL) for PE Pipe During Pull-In Installation (Revision 12.0.0)

Input Variables:
- Pipe Outside Diameter (in)
- Pipe Dimension Ratio
- Tensile Yield Design Safety Factor
- Time Under Tension Design Safety Factor
- Tensile Yield Strength [psl]

Result:
ATL - Allowable Tensile Load [lb]

PE Pipe Post-Installation Loads, Deflection, & Unconstrained Collapse (Revision 12.0.0)

Input Parameters:
- Internal Borehole Diameter (in)
- Depth of Borehole Below Ground Surface [ft]
- Unit Weight of Fluid in Borehole [lb/ft³]
- Unit Weight of Soil [lb/ft³]
- Internal Friction Angle at Soil [°]
- Pipe Outside Diameter (in)
- Standard Dimension Ratio
- Percent of Odometry
- Apparent Modulus of Elasticity [psl]
- Poisson’s Ratio
- Radius of Curvature [ft]
- Live Load [lb/ft]

Safe Long-Term Deflection Design values for Buried Pressurized Polyethylene Pipe

DR or SDR | Safe Deflection as % of Diameter
--- | ---
21 | 7.5
17 | 6.0
13.6 | 6.0
11 | 5.0
9 | 4.0
7.3 | 3.0

Check Avoid Tensile Stress vs. Allowable Tensile Stress During Pullback:

ATL | [lb]
--- | ---
100 | PASS
200 | PASS
300 | PASS
400 | PASS
500 | PASS

Maximum Load (MPL) [lb]

Static Load Factor [psl]

Pressurized Load Factor [psl]

Deflection due to Presessuer Effect [%]

Critical Collapse Pressure (No Safety Factor) [psl]

Safety Factor against Buckling

125