Response of Petro Pipelines to Longwall Subsidence

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INTRODUCTION
OUTLINE

- Longwall Mining
- Subsidence Movements
- Subsidence Response
- Subsidence Damage
- Subsidence Damage Mitigation
LONGWALL MINING
MINING METHODS – LONGWALL MINING

SCHEMATIC OF LONGWALL MINING TECHNIQUE (MARK, 1990)
MINE SUBSIDENCE
MINE SUBSIDENCE

- TENSILE CRACKS
- COMPRESSION RIDGES
- DRAW LINE
- BREAK LINE
- SPAL ROCK
- LONGWALL PANEL

TROUGH SUBSIDENCE
MINE SUBSIDENCE

SUBSIDENCE PROFILE OF A LONGWALL PANEL
MINE SUBSIDENCE

CHARACTERISTICS ACROSS A SUBSIDENCE PROFILE
LONGWALL SUBSIDENCE

Finish

Central

Start

Maximum subsidence

Rib

Mining
MINE SUBSIDENCE

PIPELINE PERPENDICULAR TO LW PANELS

PIPELINE PARALLEL TO LW PANELS

PIPELINE DIAGONAL TO LW PANELS

PIPELINE

FACE

LARGE DIAMETER
MINE SUBSIDENCE

DISTANCE ALONG THE PANEL

LONGWALL DIRECTION
MINE SUBSIDENCE

DISTANCE ACROSS THE PANELS

SUBSIDENCE

PANEL

PANEL

PANEL
# MINE SUBSIDENCE

<table>
<thead>
<tr>
<th>Location</th>
<th>$H_{\text{max}}/S_{\text{max}}$</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illinois Basin</td>
<td>0.11-0.41</td>
<td>Lin, et al., 1996</td>
</tr>
<tr>
<td></td>
<td></td>
<td>O’Rourke, T.D. and Turner S.M., 1979</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Van Roosndall, D.J., et al., 1997</td>
</tr>
<tr>
<td>Wyoming</td>
<td>0.23-0.28</td>
<td>Inhouse files</td>
</tr>
<tr>
<td>U.S. Appalachian Field</td>
<td>0.3</td>
<td>Peng and Geng, 1982</td>
</tr>
<tr>
<td>Germany</td>
<td>0.35-0.45</td>
<td>Brauner, 1973</td>
</tr>
<tr>
<td>USSR</td>
<td>0.3-0.35</td>
<td>Brauner, 1973</td>
</tr>
<tr>
<td>France</td>
<td>0.4</td>
<td>Brauner, 1973</td>
</tr>
<tr>
<td>Great Britain</td>
<td>0.04-0.32</td>
<td>Breeds, 1976</td>
</tr>
</tbody>
</table>

Averages: 0.22 all

- 0.15 limestone classes
- 0.24 others

**MAXIMUM HORIZONTAL TO VERTICAL DISPLACEMENT RATIOS, $H_{\text{MAX}}/S_{\text{MAX}}$ FROM LONGWALL MINING**
SUBSIDENCE RESPONSE
TYPICAL LONGWALL SUBSIDENCE INDUCED STRESSES
SUBSIDENCE RESPONSE/PREDICTION

SUBSIDENCE PROFILE ANALYSIS

MODEL OUTPUT

EMPIRICAL RANGE
SUBSIDENCE RESPONSE/PREDICTION

MAXIMUM SLOPE

THE NUMBERS INDICATE SOIL COVER (FT.)

RANGE: 5 TIMES

LW TRANVERSE DATA
LW LONGITUDINAL DATA
R & P DATA

2(\text{SPW})S'_{\text{max}} \text{ [MAXIMUM SLOPE]}
SUBSIDENCE RESPONSE/PREDICTION

THE NUMBERS INDICATE SOIL COVER (FT.)

4(PSW)^2S''_max [MAXIMUM CURVATURE]  

RANGE: 20 TIMES
MINE SUBSIDENCE RESPONSE

VERTICAL DISPLACEMENT

HORIZONTAL DISPLACEMENT

PIPELINE

SUBSIDENCE INDUCED LONGITUDINAL PIPELINE STRESSES
MINE SUBSIDENCE RESPONSE

RESIDUAL STRENGTH CONDITIONS ALONG PIPELINE

PEAK STRENGTH

RESIDUAL STRENGTH

HORIZONTAL SLIP

PIPELINE
MINE SUBSIDENCE RESPONSE

SATURATED COHESIVE FILL

SATURATED SAND FILL

(assuming same effective friction angle)
MINE SUBSIDENCE RESPONSE

SUBSIDENCE INDUCED PIPELINE STRESSES
<table>
<thead>
<tr>
<th>Alert Level</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderate Stress</td>
<td>More frequent/close monitoring of survey/strain readings with modeling to better understand pipeline response and to identify magnitude(s) and location(s) of peak stress.</td>
</tr>
<tr>
<td>High Stress</td>
<td>For better accuracy monitoring based on modeled peak stress conditions. If necessary, perform effective decoupling. Lowering operating pressure to maintain stress level below acceptable limit at least until mitigation measures are in place, if needed.</td>
</tr>
<tr>
<td>Threshold</td>
<td>Based on modeled peak stress conditions. Where reduction to minimum operating pressure is inadequate, possible line shutdown until decoupling of pipeline, and lower pipe stress verified.</td>
</tr>
</tbody>
</table>
SUBSIDENCE DAMAGE
SUBSIDENCE DAMAGE MITIGATION
SUBSIDENCE DAMAGE MITIGATION

- IMPLEMENTED APPROACHES: A FUNCTION OF RISK TOLERANCE
SUBSIDENCE DAMAGE MITIGATION

- SURFACE METHODS
- UNDERGROUND MEASURES
## SUBSIDENCE DAMAGE MITIGATION

### PIPELINE MITIGATION ALTERNATIVES – LONGWALL

<table>
<thead>
<tr>
<th>TYPE</th>
<th>MEASURES</th>
</tr>
</thead>
<tbody>
<tr>
<td>MINE LEVEL</td>
<td>• Leave protection block of trona.</td>
</tr>
<tr>
<td></td>
<td>• Void fill behind longwall by grouting.</td>
</tr>
<tr>
<td></td>
<td>• Reduce extraction height.</td>
</tr>
<tr>
<td></td>
<td>• Reduce panel face and increase chain pillar support.</td>
</tr>
<tr>
<td></td>
<td>• Leave room and pillar protection area.</td>
</tr>
<tr>
<td></td>
<td>• Panel Orientation</td>
</tr>
<tr>
<td>TYPE</td>
<td>MEASURES</td>
</tr>
<tr>
<td>------</td>
<td>----------</td>
</tr>
</tbody>
</table>
| SURFACE: MOVE LINE | • Relocate pipe outside subsidence area.  
| | • Install temporary line above ground surface on ROW - segment and monitor permanent pipe - monitor in place pipe.  
| | • Install temporary line above ground surface on ROW, install expansion joints or sleeves at predetermined intervals, and reconnect to permanent line - monitor pipe and reduce fluid pressure as needed. |
## Subsidence Damage Mitigation

### Pipeline Mitigation Alternatives – Longwall

<table>
<thead>
<tr>
<th>Type</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pipe Decoupling</strong></td>
<td>• Uncover all or portions of the pipeline and monitor. Reduce internal pressure if necessary.</td>
</tr>
<tr>
<td></td>
<td>• Install protective cover and backfill pipe - monitor pipe. Reduce internal pressure if necessary.</td>
</tr>
<tr>
<td></td>
<td>• Install &quot;slip&quot; interface around pipe - monitor pipe and reduce internal pressure if necessary.</td>
</tr>
<tr>
<td><strong>Pipe Deflection Control</strong></td>
<td>• Uncover pipe in severe subsidence curvature areas. Support and control deflection of pipe with cribbing/airbags. Reduce internal pressure if necessary.</td>
</tr>
<tr>
<td></td>
<td>• Uncover pipe in severe subsidence curvature areas. Undercut subgrade where required to control deflections. Monitor pipe. Reduce internal pressure if necessary.</td>
</tr>
<tr>
<td></td>
<td>• Suspending pipe off twin steel beam across the trench via hanging rods which are bolted to a steel hoop secured around the pipe. Rods are treading to allow vertical adjustment. Also use of bracing to prevent lateral movement inside the trench. Monitor pipe. Reduce internal pressure if necessary.</td>
</tr>
<tr>
<td></td>
<td>• Uncover pipe in severe curvature areas. Preset pipeline elevations prior to subsidence to control resulting subsidence-induced bending. Monitor pipe. Reduce internal pressure if necessary.</td>
</tr>
</tbody>
</table>
## Subsidence Damage Mitigation

### Pipeline Mitigation Alternatives – Longwall

<table>
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<tr>
<th>Type</th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Future Pipeline Installations</strong></td>
<td>• Relocate pipe outside subsidence area.</td>
</tr>
<tr>
<td></td>
<td>• Install expansion/contraction sleeves or joints along pipeline - monitor pipe.</td>
</tr>
<tr>
<td></td>
<td>• Install protective cover/&quot;slip&quot; interface - monitor pipe.</td>
</tr>
</tbody>
</table>
SURFACE METHODS

Antenna
900 MHZ interface
Control datalogger
To phone line/internet connection

Solar Panel/Power Supply
AVW206 900 MHz Wireless Vibrating Wire Interface
AM16/32B Relay

Strain Gauge
Interconnecting cables
SUMMARY

- MORE ADVANCED ASPECTS DISCUSSED
- USE OF ADVANCED SUBSIDENCE ENGINEERING METHODOLOGY CAN BE OF BENEFIT
- WITH BETTER UNDERSTANDING OF THE PROBLEM, THE BETTER THE HANDLING OF THE PROBLEM
QUESTIONS?

Thank You!