Cost of Compliance Challenges with Materials Verification

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Integrity Solutions
Overview

- Regulatory Background
- Material Testing
- Records Review
Regulatory Background: Timeline

- **2010**
  - September - NTSB findings from the San Bruno pipeline failure
- **2011**
  - January - PHMSA Advisory Bulletin (I): “Traceable, Verifiable, Complete”
- **2012**
  - May – PHMSA Advisory Bulletin (II): Annual reporting
Regulatory Background: Timeline

- **2013**
  - July – Integrity Verification Process workshop and flowchart I
  - September – Integrity Verification Process flowchart II

- **2016**
  - April – NPRM for CFR 192
    - Includes, “Reliable, Traceable, Verifiable, and Complete” requirement,
    - Includes gap filling measures for areas with missing records
NPRM
Material Verification Requirements

- “Traceable, Verifiable, and Complete” (TVC) records are required in ~21 places (and App.A)
  - Determining pressure reductions
  - Calculating remaining strength
  - Design pressure and pressure test
  - Jurisdictional requirements
  - Threat identification
NPRM
Requirements to Address Records Gaps

- 192.607 Verification of Pipeline Material
  - Material documentation plan

- 192.624 Maximum Allowable Operating Pressure Verification
  - 6 methods

- Related and interdependent, but not the same
NPRM 192.607: “Material Documentation Plan”

- **Material Documentation Plan**
  - To address records gaps following the TVC records review
  - Must be implemented within 180-days (after rule)
  - Excavation requirements:

<table>
<thead>
<tr>
<th>Number of Excavations with Inconsistency Between Test Results and Existing Expectations Based on All Available Information for each Population</th>
<th>Minimum Number of Total Required Excavations for Population. The lesser of:</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>150 (or pipeline mileage)</td>
</tr>
<tr>
<td>1</td>
<td>225 (or pipeline mileage times 1.5)</td>
</tr>
<tr>
<td>2</td>
<td>300 (or pipeline mileage times 2)</td>
</tr>
<tr>
<td>&gt;2</td>
<td>350 or pipeline mileage times 2.3</td>
</tr>
</tbody>
</table>
NPRM 192.624: “MAOP verification”

- **MAOP Verification**
  - To address areas with records gaps with respect to setting operating pressure

- **6 Methods**
  - These don’t appear to waive the need for material records for threat determination, etc.

- **50% within 8 years**
- **100% within 15 years**
Controlling Cost

- 150-350 digs!
  - ...or 1 to 2.3 per mile
  - Saves money with respect to older rules (e.g. 1 out of 10 joints)

- Exhaust all options for TVC records

- Comments submitted about the number of digs
Cost Challenges

- Measurements required at “each excavation”
  - Diameter
  - Wall thickness
  - Yield Strength
  - Ultimate Tensile Strength
  - Toughness
  - Chemistry
  - Seam type

- Newer Technologies to perform in-the-ditch measurements

- Will this cause us to perform fewer exploratory excavations?
## Material Testing:
What can we determine / How can we do it?

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Indicates</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seam Type</td>
<td>Vulnerability to failure/threats, Seam factor</td>
<td>Visual, ILI, Supplemented by NDT and metallography for some types</td>
</tr>
<tr>
<td>Composition</td>
<td>Weldability, susceptibility to selective seam corrosion, toughness (?)</td>
<td>OES (portable spectroscopy), Lab analysis of steel filings</td>
</tr>
<tr>
<td>Tensile properties</td>
<td>Pressure capacity, input to fatigue calculations</td>
<td>Portable hardness testers, Instrumented indentation, ILI</td>
</tr>
<tr>
<td>Toughness</td>
<td>Planar flaw tolerance</td>
<td>Instrumented indentation? Hardness + microstructure + composition?</td>
</tr>
</tbody>
</table>
So....How Do We Measure Actual Properties?

- Metallography
- Chemical Analysis - example, OES or lab analysis of filings
- ILI - example: Rosen RoMat
- Instrumented Indentation – example: T.D. Williamson PMI process
- Hardness Testing – example: ASME CRTD Vol. 91 and CRTD Vol. 57
In-situ Metallography

- ERW seam bondline vs. base metal images from in-situ metallography
Chemical Analysis

- **Why?**
  - Calculate carbon equivalent for selection of in-service welding procedures
  - Composition influences toughness and strength

- **How?**
  - Remove steel filings for lab analysis
  - In-situ OES (*NOT XRF!*). Argon flushed probe preferred
  - Don’t forget to remove decarburization first
Chemical Analysis of Steel Filings

- Steel cleaned to shiny metal
- Collection trough w/ duct tape
Field Portable Hardness Testing

- **Why?**
  - Estimate of pipe yield strength and tensile strength
  - Evaluation of ERW seam heat treatment
  - Evaluation of welds subject to hydrogen embrittlement
  - Assessment of “hard spots”

- **How?**
  - Leeb ball rebound, UCI, Telebrineller, others
  - Refer to ASME CRTD Vol. 57 and Vol. 91

- **Limitations?** (Test method dependent)
  - Thickness, Age, grade, diameter (if used to estimate YS)
  - Vibration, Temperature
  - Magnetism, Proximity to open pipe ends
Various Field Portable Hardness Test Devices Exist

- Telebrineller
- UCI
- Leeb Ball Rebound
Boundary Conditions per ASME CRTD Vol. 91

- API 5L Grade X52 and lower pipe
- Manufactured before 1980
- Nominal Pipe Size $\geq$ 4 inches (102 mm)
- Diameter/thickness ratios $\geq$ 20
Hardness Testing for Yield Strength Estimates is Not New; See Examples Below

1. Burgoon, D.A. Chang, O.C., et.al., ASME CRTD-Vol.91 "Determining the Yield Strength of In-service Pipe" ASME Gas Pipeline Safety Research Committee, 1999


Key Steps in the Process

- Preassessment of the pipeline segment
- Qualify the procedures
- Qualify the technicians
- Make the measurements
- Adjust the data from randomly selected joints to estimate the lower bound hardness of the entire segment
- Determine the lower bound YS for the pipeline segment based on estimated lower bound hardness
YS from Hardness per ASME CRTD Vol. 57
Massachusetts Materials Technology
HSD Tester

Material Signature (Wake Profile)

Hardness = \frac{P}{2\pi a_r^2}

Pile-up Ratio = \frac{h_p}{h_r}

![Diagram showing hardness and pile-up ratio calculations](image)

![Image of HSD Tester](image)

Graph showing hardness and pile-up ratio over length:

- Base Metal
- HAZ
- Weld

Length (mm)

Hardness (GPa)

Pile-Up Ratio
Rosen RoMat ILI
**NPRM Non-Destructive Testing Requirements**

- The NPRM indicates PHMSA acceptance of methods that meet the stated accuracy requirements.

- **Accuracy Required** *(NPRM page 460)*
  - For strength: Accurate within 10% of the actual value with 95% confidence
  - For composition:
    - within 25% of actual value at 85% confidence for carbon,
    - Within 20% of actual value at 90% confidence for Mn, Cr, Mo, V
  - Property values must conservatively account for measurement inaccuracy and uncertainty based upon destructive testing (unity charts)
Records Review: What are companies doing?

1. Discriminate pertinent from non-pertinent records
2. Establish a reliability index for captured data
3. Make permanent and structured electronic records
4. Verify or re-establish MAOP. Identify/Close gaps
5. Build from a traceable, auditable, and GIS compatible framework

- TRACEABLE, VERIFIABLE, RELIABLE, and COMPLETE
Industry best practice: 5-step verification process

1. DISCRIMINATE PERTINENT FROM NON-PERTINENT RECORDS

*Document search, collection and tabulation*

- Team of *Verification Specialists/Researchers* led by pipeline engineer(s)
- Identify all records that relate (or may relate) to MAOP/MOP
  - Construction
  - Hydrostatic tests
  - Purchasing (material properties for original construction, modifications, replacements, re-routes)
  - Mill tests
- Where? Follow the records (remote, centralized)
  (Must be conducive to Step #3, Digital Capture)
Industry best practice: 5-step verification process

1 DISCRIMINATE PERTINENT FROM NON-PERTINENT RECORDS

*Document search, collection and tabulation*

- Identify and Use Legacy Document Systems
  - Regional Project Tracking Systems
  - Work Order Numbers
  - Project Numbers
  - Assessment Numbers
  - Test Numbers
  - Acquired Assets
Industry best practice: 5-step verification process

1 DISCRIMINATE PERTINENT FROM NON-PERTINENT RECORDS

Document search, collection and tabulation

- Identify Primary and Isolated Document Repositories
  - Filing Cabinets and Filing Rooms
  - Large Scale Document Storage Locations
  - Isolated locations like desks and closets will only be identified by word of mouth
Industry best practice: 5-step verification process

2 ESTABLISH A RELIABILITY INDEX FOR CAPTURED DATA

Document Precedence

- Unique to each operator
- Operator employees can help identify documents historically given more credence (accuracy, reliability, completeness)
- How and by whom was data obtained and what was its intended use?
- Reliability rating given to each document
- Critical for large scale review efficiencies
Industry best practice: 5-step verification process

MAKE PERMANENT AND STRUCTURED RECORDS

*Digital Capture*

- Electronic documents critical to future audits and records maintenance
- File-naming (metadata) structure put in place for referencing (for use in Step #5)
- Evaluate Enterprise Content Management (i.e. scanning and e-storage service) Providers
  - Quality work, efficient operations
  - Document quality at least as good as, if not better than the originals
  - Project specific mobile imaging hardware with dedicated team on site, or...
  - Specialized, high capacity equipment at home base
  - Formal chain of custody followed for all documents
  - Retrieval of needed docs ‘on the fly’ typically faster than in-house
Industry best practice: 5-step verification process

3 MAKE PERMANENT AND STRUCTURED RECORDS

Digital Capture

![Digital Capture Image]
Industry best practice: 5-step verification process

MAKE PERMANENT AND STRUCTURED RECORDS

Digital Capture
Industry best practice: 5-step verification process

**MAKE PERMANENT AND STRUCTURED RECORDS**

- Detailed Listing provides and Intermediate Cross-Reference to Link Source Records to Location Specific Pipeline Data

<table>
<thead>
<tr>
<th>Work Order</th>
<th>Type</th>
<th>Participant(s) ID</th>
<th>Page</th>
<th>Project Categories</th>
<th>Pipe Type</th>
<th>Diam (mm)</th>
<th>Schedule</th>
<th>Wall Thickness (mm)</th>
<th>Pressure</th>
<th>Size (nominal)</th>
<th>Chainage</th>
<th>Source Records</th>
<th>Location Specific Pipeline Data</th>
<th>Length (km)</th>
<th>Pressure Test Date</th>
<th>Leak Detection</th>
<th>Leak Mitigation</th>
<th>Leak Repair</th>
<th>Leak Recording</th>
<th>Leak Repair Date</th>
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IDENTIFY / RECONCILE GAPS

Verify or re-establish MAOP/MOP

- Database constructed that’s spatially aligned (to ILI footage, stationing, or Lat/Long).
- Gaps reconciled by SME’s, used only as needed
- MAOP Verification (NPRM)

Spatially aligned data eases identifying gaps
Industry best practice: 5-step verification process

BUILD FROM A TRACEABLE, AUDITABLE AND GIS COMPATIBLE FRAMEWORK

Risk-informed, Sustainable, Auditable Reference

- Integration to GIS
- On-going records management
- Management of change (MOC)
- Linear spatial alignment shows pipeline features as they appear on the pipeline
- Simplifies future audits
Meeting PHMSA’s requirement

- Process establishes:
  - Traceability
  - Verifiability

- Documentation Dictates
  - Completeness
  - Reliability
Creating Efficiencies

- Process staging
  - Scanning

- Tiered review
  - Robust quality control
  - Cost efficient

- Use engineers only when required

THINK
WORK SMARTER
NOT HARDER
Proven Success

- DNV GL’s best practices were presented before industry and PHMSA representatives at the International Pipeline Conference in Calgary (Track 13-1-1 U.S. Regulations 2012 and 2014)

- MAOP Verification process was used to satisfy CPUC following the San Bruno failure

- Using this process, DNV GL verified MAOP/MOP for liquid and gas operators across the United States

- DNV GL has performed multiple large and small projects (i.e. full-scale company wide reviews, and single pipeline reviews)

- One operator found hydrotest records for 50% of their Transmission system with an internal review, but 87% with DNV GL’s structured process.