Material and Construction Issues Concerning Pipelines at Elevated Stresses

Presentation to OPS Public Meeting

March 21, 2006

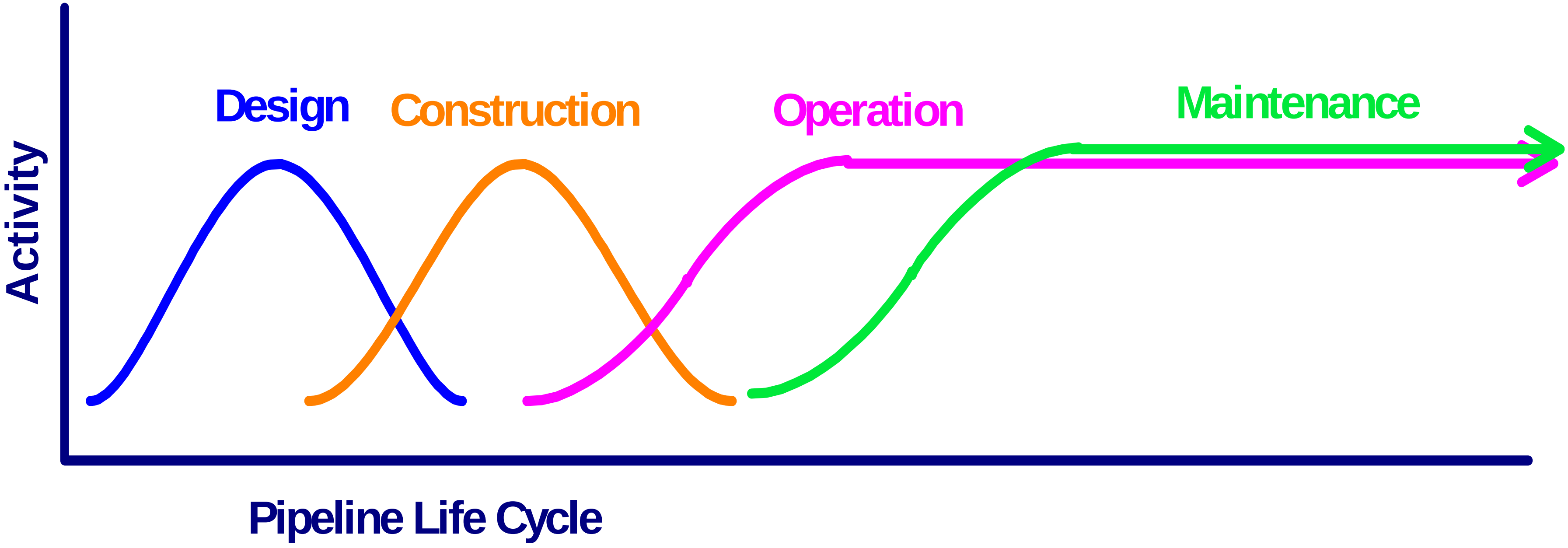
Kiefner & Associates incorporated

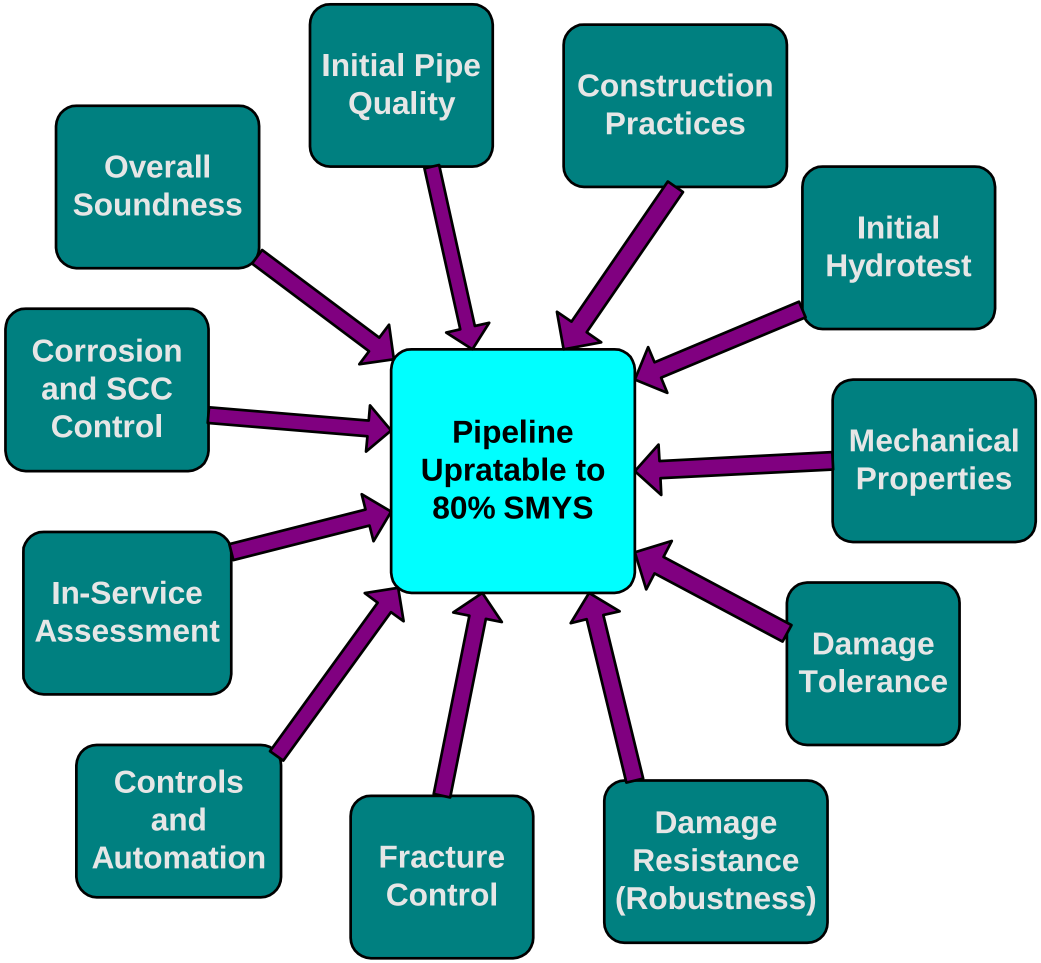
Material & Construction Factors

- Two case studies, APL & MNE
- Multi-tiered framework
- Some specific criteria

• Pipeline integrity accrues from sound choices made in each phase of a pipeline's life cycle

• Choices made in Design or Construction affect the limits of Operation, or dictate the intensity of activities in Maintenance phases.





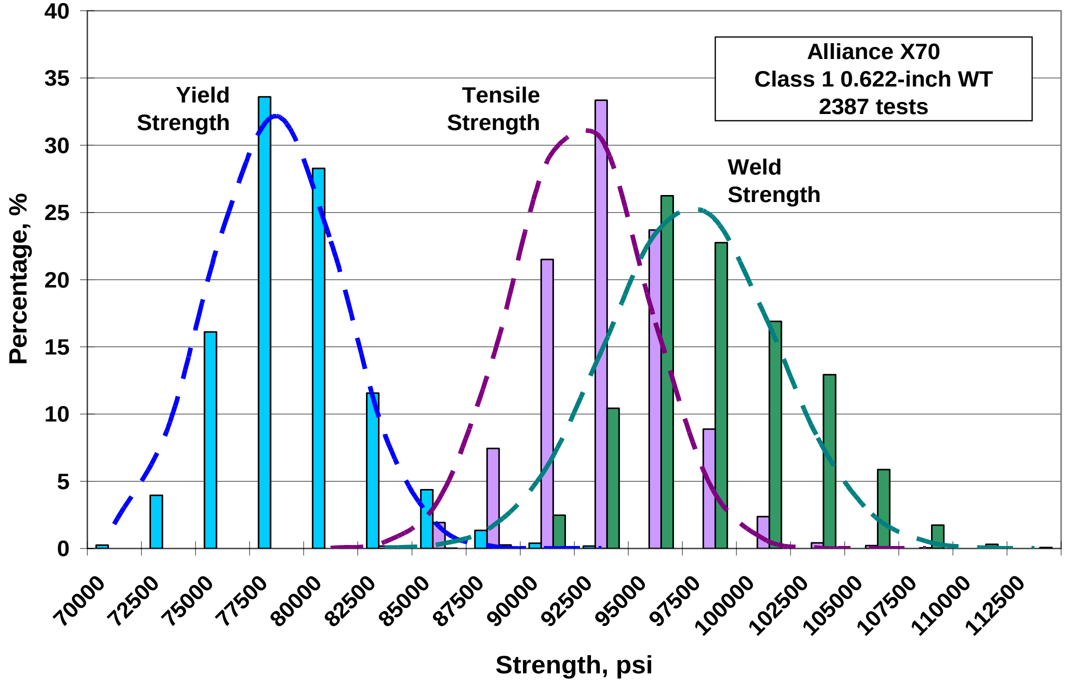
Elements of pipeline integrity to consider in uprate evaluation:

- **Are pipeline's liabilities adequately accounted for?**
- **Is there increased commitment to maintaining integrity through life cycle, commensurate with increased stress?**
- **Is overall risk reduced and managed over time?**
- **Is it business as usual but at higher stresses?**

MNE & APL Initial pipe quality

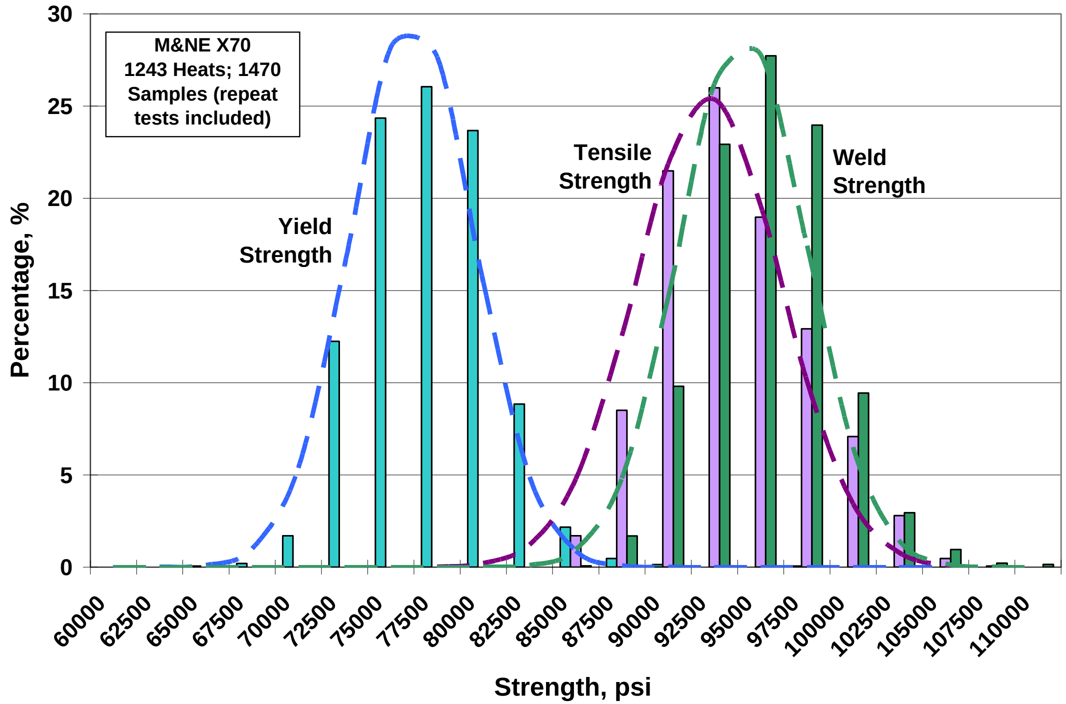
- Microalloyed fine-grained plate
- X70 PSL 2 or better
- Controls on chemistry
- Controls on properties
- Extensive testing
- Traceability
- Comprehensive pipe seam and body NDE

Line Pipe Strength Properties



<u>Alliance X70</u>

100% exceedance of specified minimum



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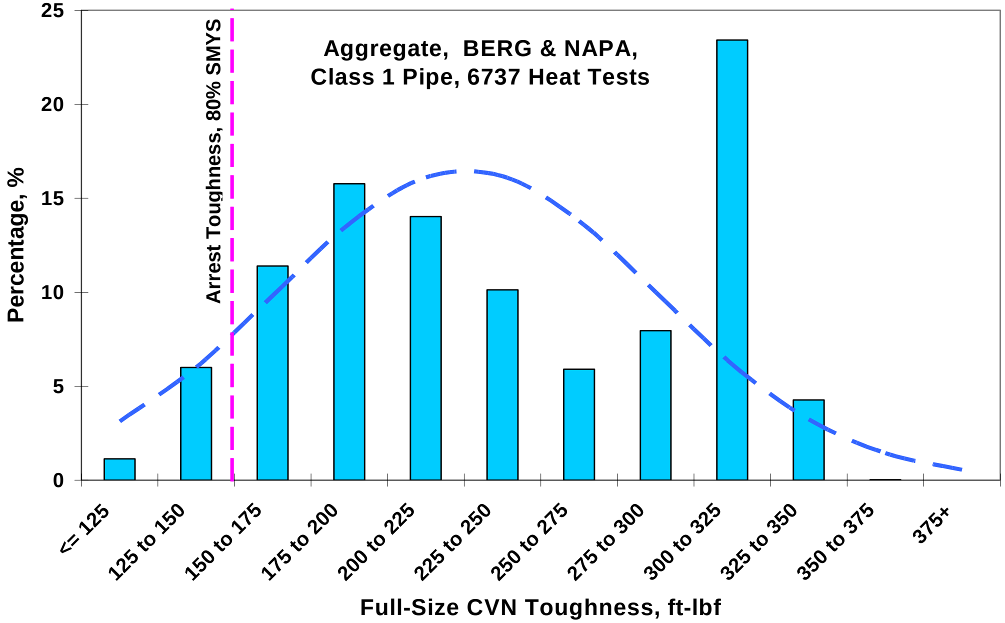
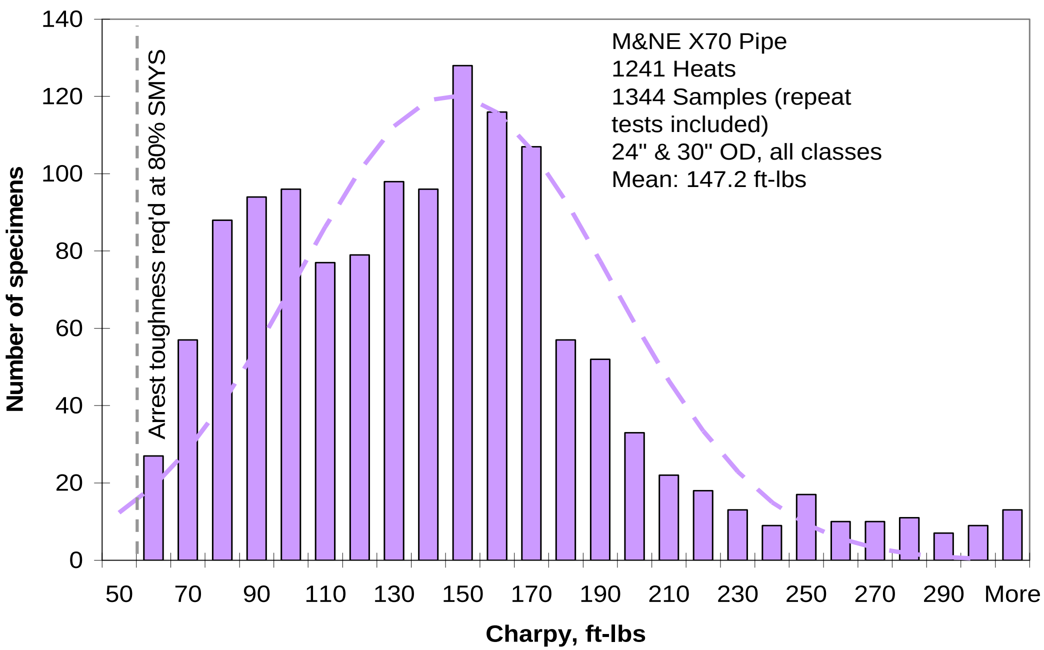
Line Pipe Toughness Properties



<u>Alliance X70</u>

93% arrest toughness at uprated pressure

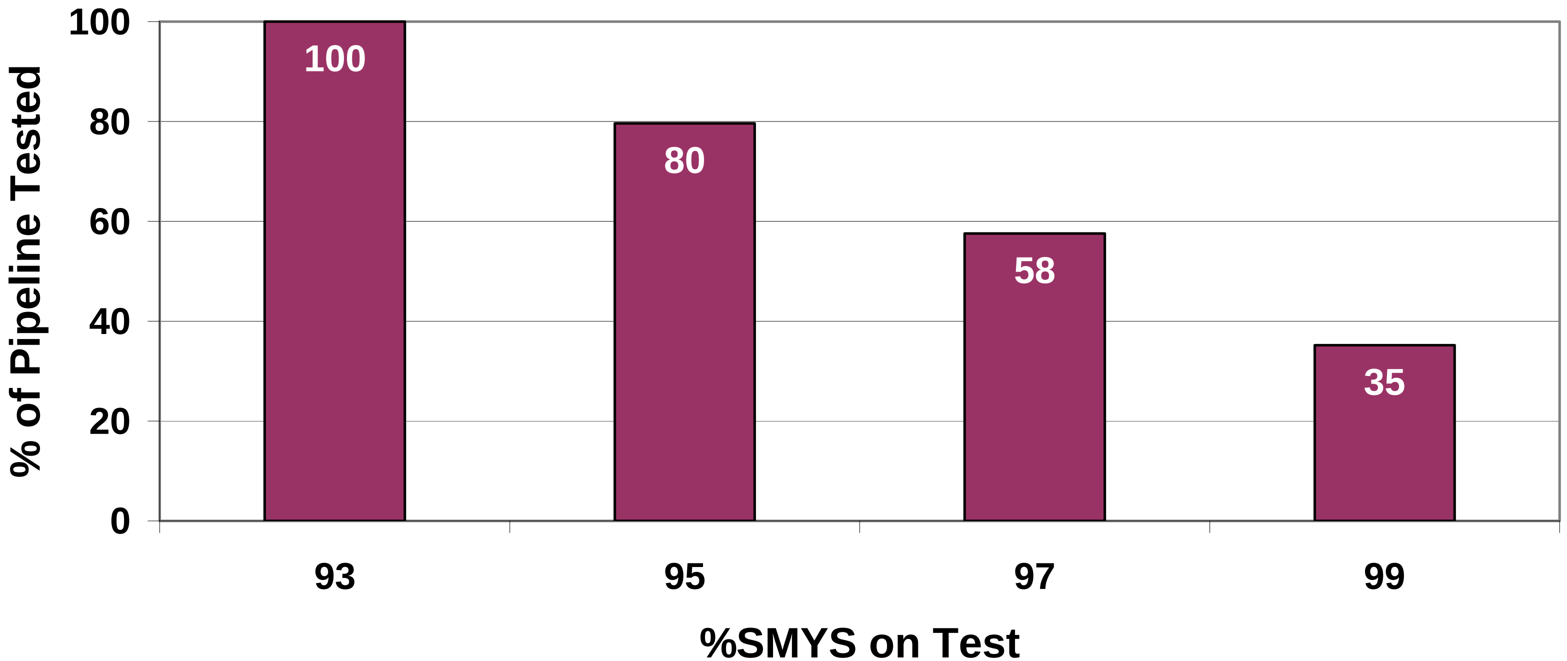


<u>Maritimes & NE X70</u>

100% arrest toughness at uprated pressure

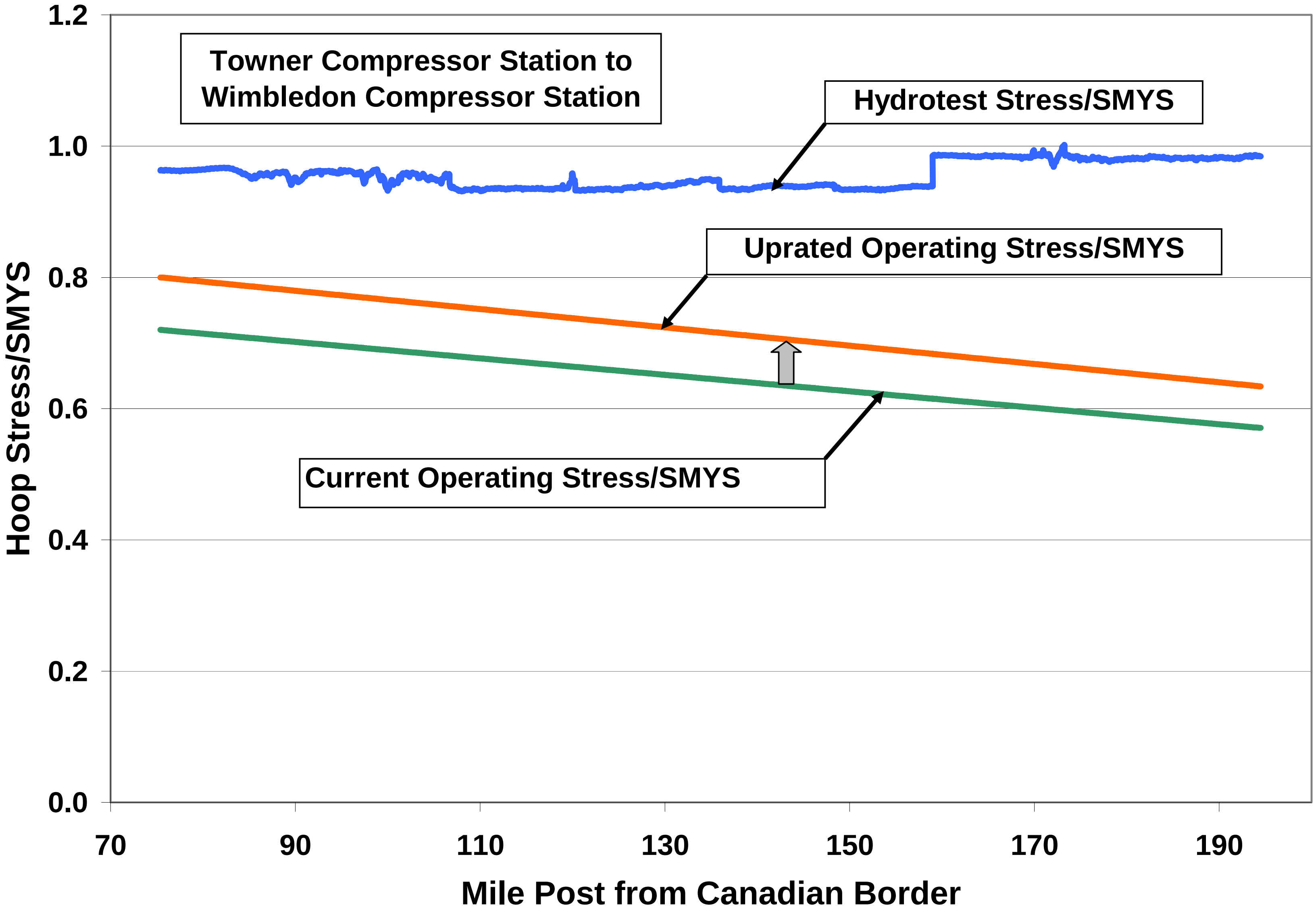
Case Study:

- Conventional wisdom requires 1.25 x MAOP hydrotest, but APL *not* tested to 100% SMYS min
- Study undertaken to determine effectiveness of the tests by determining actual test pressure at each pipe joint based on pipeline elevations
- Inertial ILI data gave elevations of 118,532 joints
- Good agreement in total elevation differential on all 44 test sections (average agreement = 4.2 ft = 2 psig = 0.08% test pressure)
- Determined actual average test stress = 97.6% SMYS



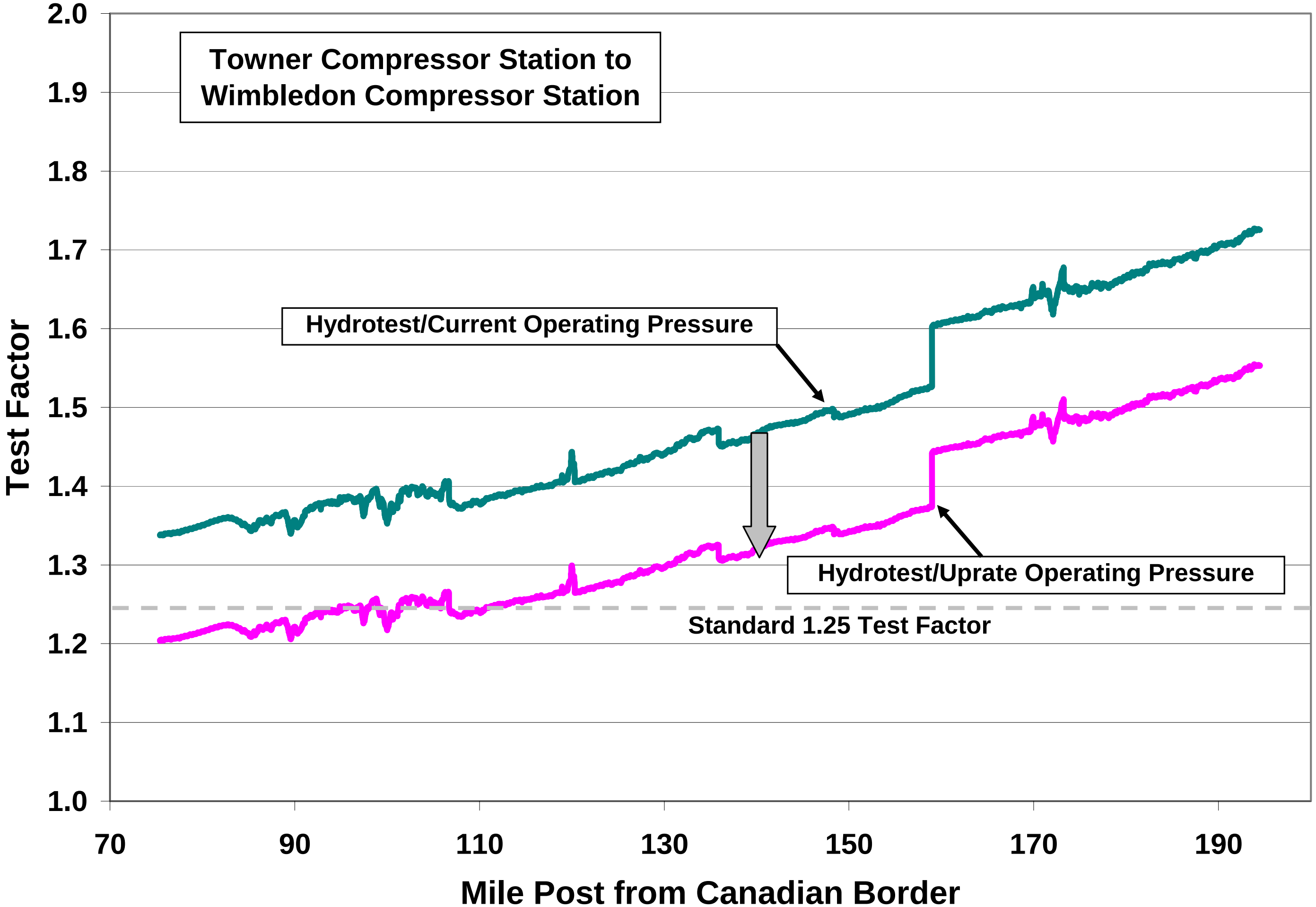
Alliance pipeline hydraulic gradient between stations

- Most of the length of pipeline operates at less than MAOP

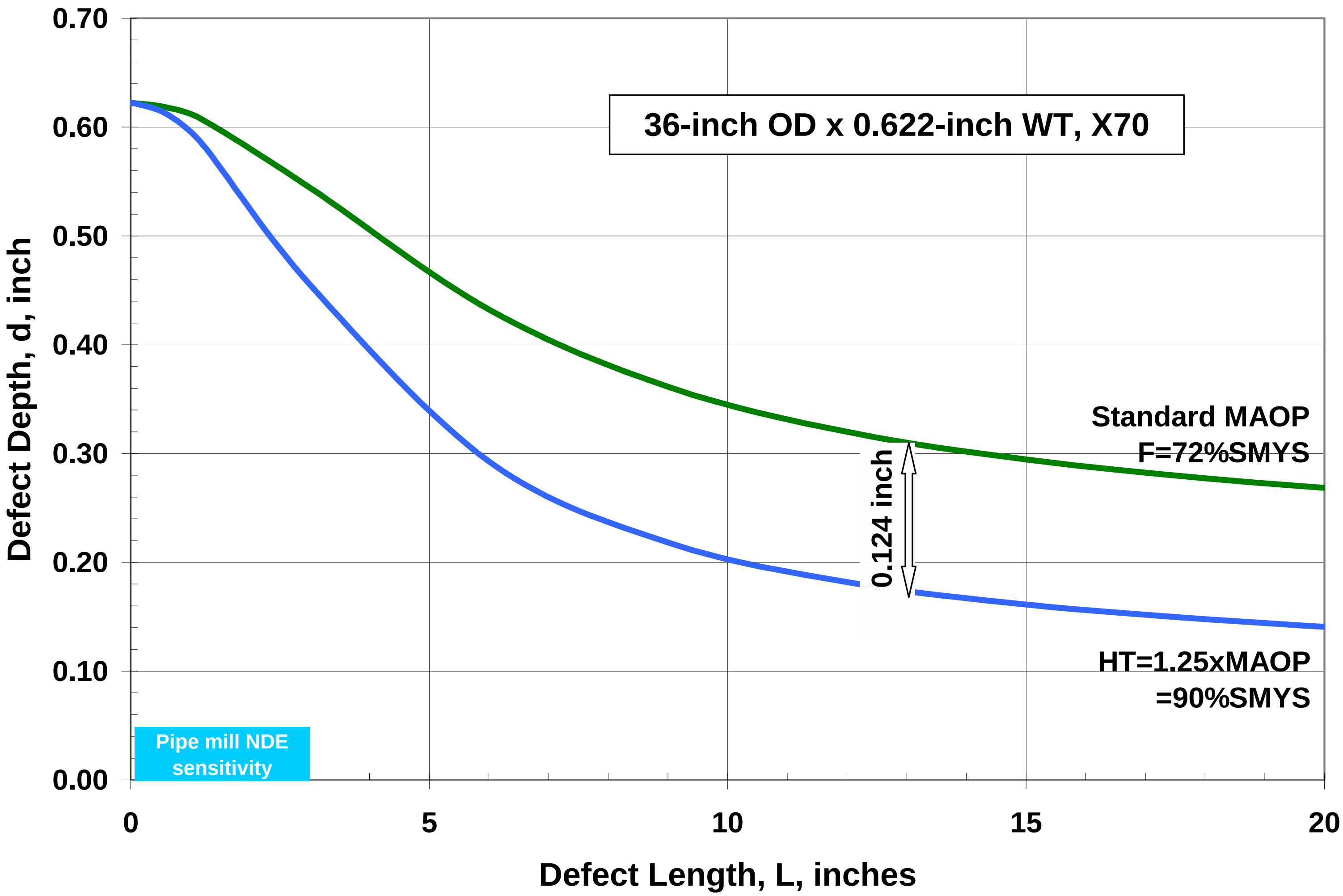


Effective test factor varies with elevation and distance from C/S discharge

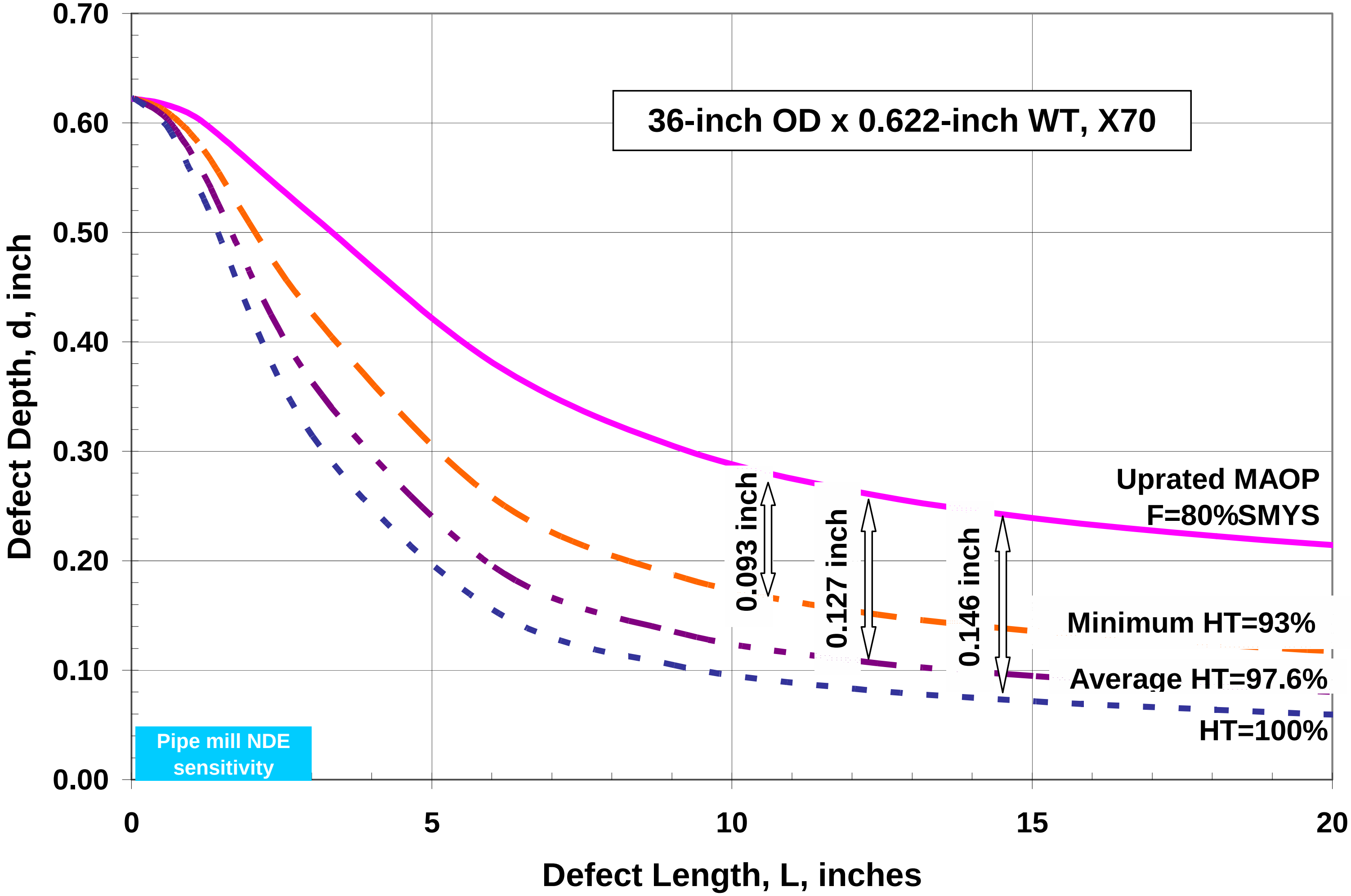
- Most of the length of pipeline operates with effective test factor greater than 1.25 after uprate
- Only 11.5% of pipe operates with effective TF<1.25



Alliance critical flaw sizes, conventional requirements



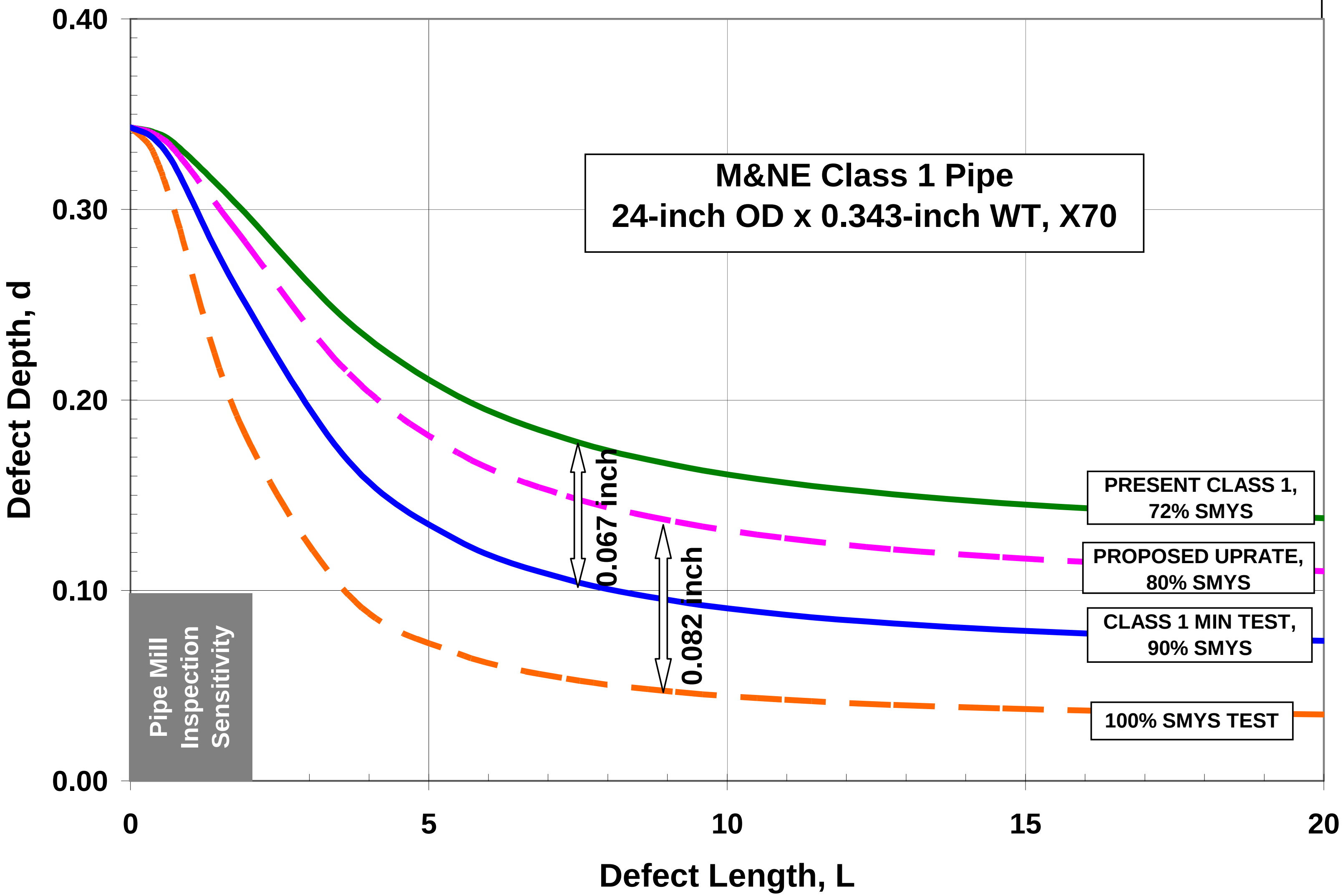
Alliance critical flaw sizes, as tested



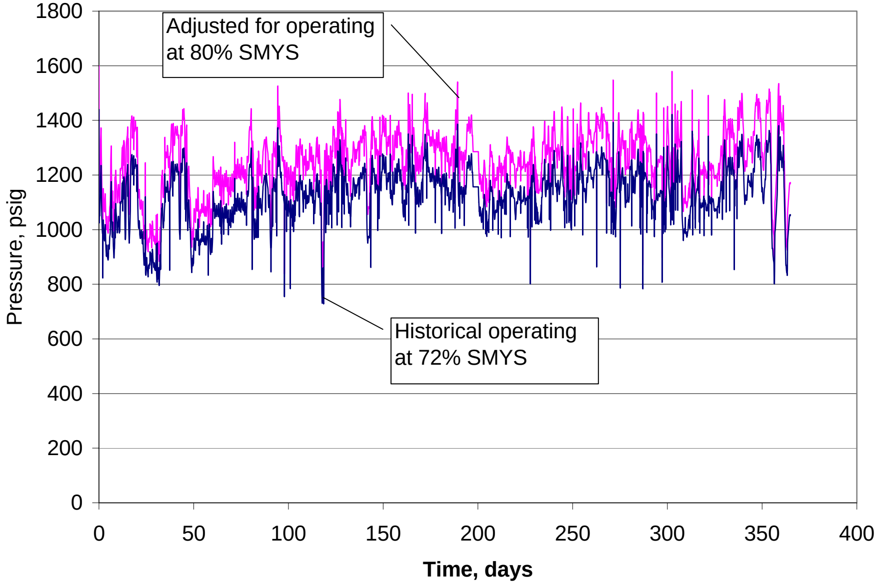
Critical Flaw Sizes

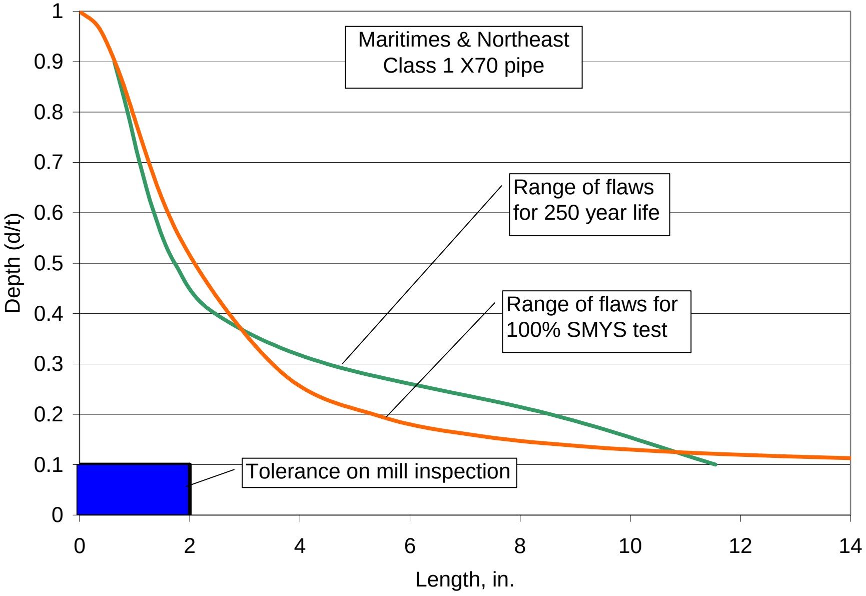
- Value of hydrotest lies in the margin in critical flaw size between test and operating pressures
- Margin in critical flaw size between test and operation for Alliance pipe as tested and uprated does not differ significantly from conventional requirements
- Higher hydrotest to 100% SMYS adds little incremental value *in this particular case* due to:
  - superior pipe properties
  - heavy wall thickness
  - mill inspection standards

M&NE Critical flaw sizes



M&NE fatigue life at 80% SMYS established by hydrotest





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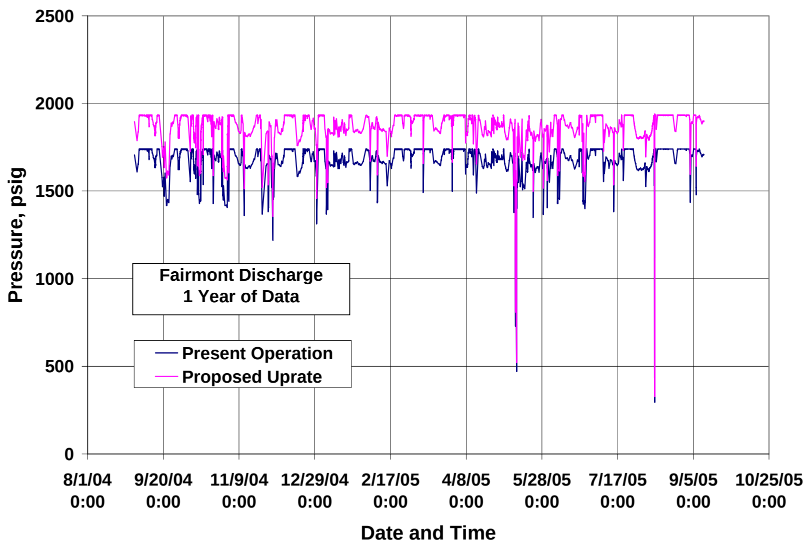

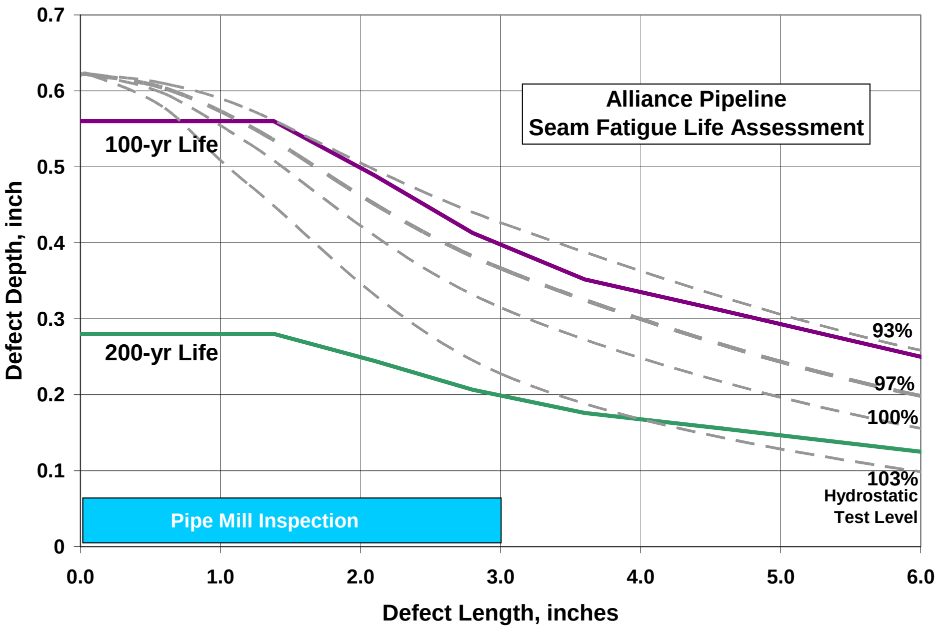

Initial hydrotest

- Test to 1.25 x MAOP = 100% SMYS is valuable – if it is the sole measure of installed quality
- Test < 100% SMYS may be adequate where:
  - Offset by other assurances of initial pipe integrity
  - Pipe is heavy-walled and high-toughness
  - Defect size margins equal or better than standard
  - Sufficient time to failure to find latent defects
  - Hydraulic gradient is significant

Waiver criteria may differ

New construction

- Best time to make it as good as possible
- Design and build intentionally for:
  - Fracture control
  - Robustness
  - Mitigation of threats
- May employ advanced concepts (e.g. plastic design, reliability theory)

Existing pipeline

- It is what it is
- Some attributes may be non-optimal:
  - HT < 100% SMYS
  - Fracture control
  - Coatings
- Long term plans must recognize and account for threats
- May require more intensive maintenance

Multi-tiered approach

- Tier 1 – Waiver probable.
- Tier 2 – Waiver possible.
- Tier 3 – Waiver requires substantial justification.
- Tier 4 – Unsuitable for waiver.

Multi-tiered approach

- Tier 1 – Waiver probable. Applies to modern pipelines with desirable attributes. Includes new projects designed for 80% SMYS from outset and existing contemporary high-quality pipelines

- Tier 2 – Waiver possible. Applies to sound pipelines with good records, important nonoptimal attributes adequately addressed

Multi-tiered approach

- Tier 3 – Waiver requires substantial justification. Applies to pipelines with known high-risk attributes where significant effort directed toward mitigation.

- Tier 4 – Unsuitable for waiver. Applies to pipelines with important high-risk factors, unfavorable attributes, or poor reliability.

Multi-tiered approach

- Tier 1 should be relatively straight-forward upon demonstration of sound engineering and planning.
- Tiers 2 and 3 require respectively greater amounts of effort by operator and intensive communication with OPS.

Initial pipe parameters – new projects

- X52+ mfd to PSL 2 or better
- Controls on chemistry and properties
- Traceability
- Mill pressure test (90% SMYS min)
- Comprehensive pipe seam and body NDE
- Robustness: heavy-wall low-D/t pipe resistant to external loadings, extends reassessment intervals

Construction practices – new projects

- Quality-oriented installation techniques
- Full NDE of girth welds
- High integrity coatings (e.g. FBE)
- No “liability” features (e.g. coatings that can disbond and shield CP, casings, uninspected welds in soil movement areas)
- Hydrotest to 100% SMYS (if possible)
- Baseline ILI within first 1-3 years

Other desirable attributes for new lines constructed for 80%

- 90%+ fracture arrest
- 100% SMYS hydrotest
- D/t<75
- CE<0.35
- Weld CTOD>0.010 inch
- 99% weld NDE
- Puncture > 60T excavator
- Hardened coating in bores and HDDs
- Concrete coat in rock, at crossings, in casings
- 4 ft depth of cover in tilled land
- Extra depth of cover in areas of expected future development
- Geometry ILI in first 6 months, metal loss in 1-2 yrs
- Linear anode in utility corridors and urbanized areas
- High integrity field joint coating
- 24 mils FBE downstream of compressor stations
- Strain criterion in soil movement areas

Existing lines, some possible attributes of Tier 1

Tier 1

- Post 1980 construction
- HT to 100% SMYS, or alternative assurances of quality and long-term reliability
- No history of seam quality concerns
- 80%+ fracture arrest (99% prob. of arrest < 5 joints)
- Puncture resistance against excavator 35T+
- D/t<100
- 99% weld NDE
- Nonshielding coating on pipe body *and* field joints
- Adequate depth of cover
- Stable geology, or plastic design for soil strain
- Safe operating record at 72% SMYS
- Has been ILI'd

Existing lines, some possible attributes of Tier 2

Tier 2

- Post 1970 construction
- HT to 90% SMYS
- 40%+ fracture arrest
- Thin wall, but protected against encroachment with slabs
- D/t<120
- Girth weld NDE <90% but no evidence of quality problems
- Nonshielding coating, some known corrosion
- Shrink sleeves, but with no evidence of disbonding
- Shallow cover, but risk assessment shows no threat
- Soil movement risk, but monitoring/mitigation plan
- Any prior failures due to pressure-insensitive cause
- Has been ILI’d

Existing lines, some possible attributes of Tier 3

Tier 3

- Post 1950 construction
- 10% girth weld NDE
- LF ERW or FW seams known to be reliable
- History of pressure cycle fatigue, mitigated by ILI or HT
- D/t>120
- 25-40% fracture control, or low toughness but crack arrestors or pipe replacement where needed
- PE tape coating, no history of SCC
- Other coating, isolated SCC
- Coating in deterioration
- Internal corrosion, but demonstrated under control
- Never operated at more than 60% SMYS
- No prior ILI but will be pigged

<u>Existing lines</u>, some possible attributes of Tier 4

<u>Tier4/Nonqualifying lines</u>

- Pre-1950 construction
- Mechanical joints, acetylene welds, or unknown GW NDE
- Lapwelded seams
- No fracture control
- ERW seams with history of reversals
- ERW seams with history of selective corrosion
- DSAW or ERW seams with history of fatigue
- Systemic experience of SCC
- Bare pipeline
- Sour gas
- Ongoing IC, CO_2 corrosion, H_2S related cracking
- Active geology, with failures
- Line not piggable

Summary

- Operating safely at 80% SMYS is certainly feasible for:
  - New pipelines so designed
  - Existing modern pipelines having appropriate attributes
  - Existing older pipelines where inherent vulnerabilities are addressed through rigorous assessment and mitigation practices
- Not all pipelines, new or old are suitable for elevated stress service
- Distinguishing criteria can be developed