Lab-Testing Capabilities to Determine Integrity for Repurposing

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Introduction

Engineering Mechanics Corporation of Columbus – Emc^2

- Small business research engineering consulting
- Analytical and testing
- Energy industry – oil & gas, nuclear
- Government & commercial

Today's presentation:

- Repurposing of older line pipe for CO2 (pre 1990s)
- Consideration for newer high strength steel

Example of Line Repurposing for CO_2

Condition:

- 16”OD by 0.25”wt X52 pipeline consisting of pre and post 1970 vintage line pipes
- Originally used for liquid service
- Primarily below ground with several above ground valves
- Changed hands multiple times with sparse material documentation
- ILI runs has been performed

Challenge:

- Operator want to convert the line for gaseous CO_2 service
- Segments of lines with different vintage and unknown pipes
- Short turnaround: dig time, assessment, and decision making

Consideration

Axial crack propagation, which could be:

- Ductile crack propagation
- Brittle crack propagation

Determination of ductile and brittle fracture

- Environment:
  - Minimum below ground temperature -> 55F
  - Minimum above ground temperature -> 40F
- Material:
  - Charpy transition temperature
  - DWTT transition temperature

Additional tests: tensile and chemical analysis as screening tool to ensure that pipes are truly what they are

Charpy Shear Area Transition Temperature (SATT)

Pre 1970 pipes

- Wide temperature 85%SATT spread (70F range)
- Upper shelf plateau at more than 100F

Unknown pipes

- Narrower 85%SATT temperature spread (20F range) with about the same average temperature of the pre 1970 pipe materials
- Upper shelf plateau at 75F

Drop Weight Tear Test (DWTT) and Brittle Fracture Arrest

Use equivalent full size Charpy plateau energy to DWTT relationship

DWTT SA requirement for brittle fracture arrest is lower than 85%

Using an updated brittle fracture arrest analysis procedure from Maxey, Eiber, and Kiefner's AGA NG-18 work

(IPC2014-33514 "BRITTLE FRACTURE ARREST IN HIGH CHARPY ENERGY STEELS COMPARISONS WITH SOME EXISTING DATA")

Outcome

The unknown pipes pass the brittle fracture arrest criteria at colder above ground temperature.

The Pre 1970 pipes statistically pass the brittle fracture arrest criteria at the warmer below ground but not the above ground temperature.

Operator can elect to perform full scale test(s) at condition to validate the analysis and small-scale tests.

All materials passes the ductile fracture control.

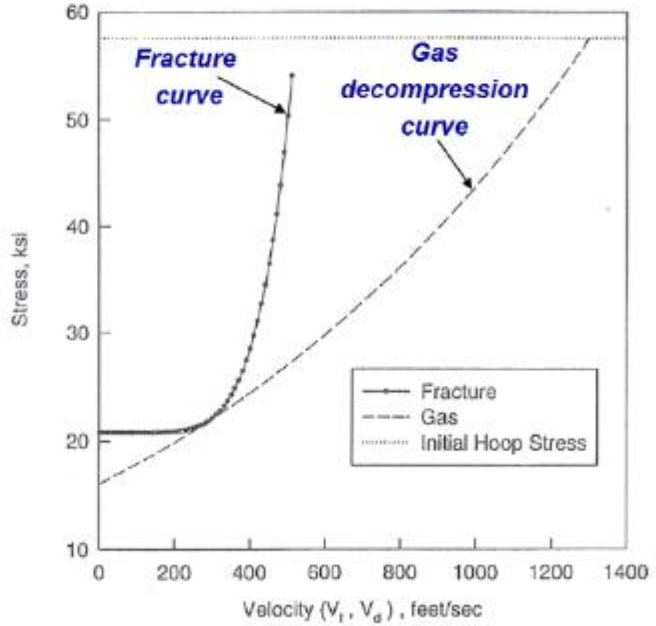
Ductile Fracture Control – Battelle Two Curve (BTC) Method

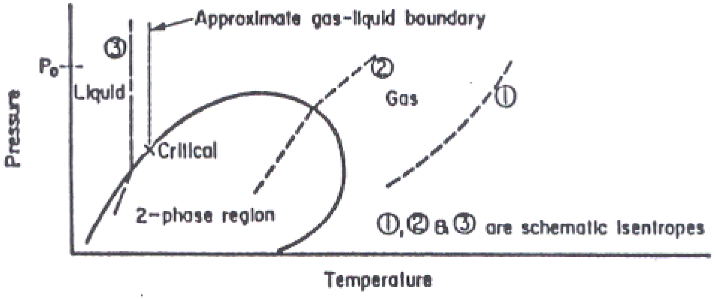
Developed by the late Mr. Bill Maxey

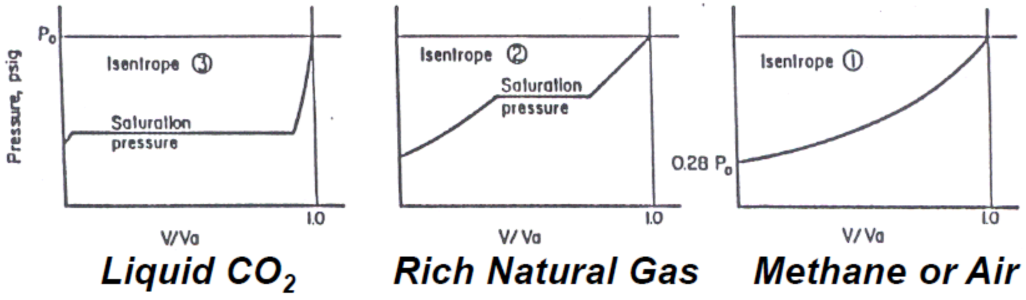
Consist of the “J” fracture or material resistance curve and the gas decompression (driving force) curve

Gas decompression equation of state of CO2 is sensitive to impurities

Material resistance curve need to be checked/updated with newer high strength steel







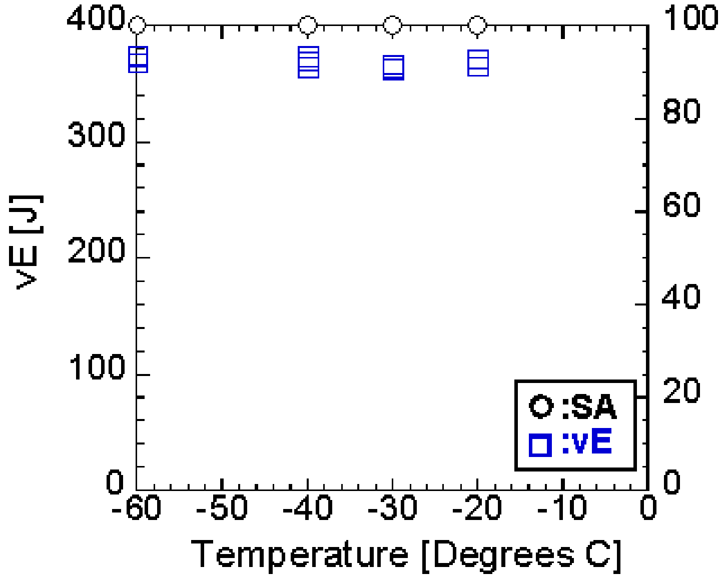
Newer High Strength Steel (CVE >200J)

32 inch by 1 inch wall X65 TMCP

-40C target application

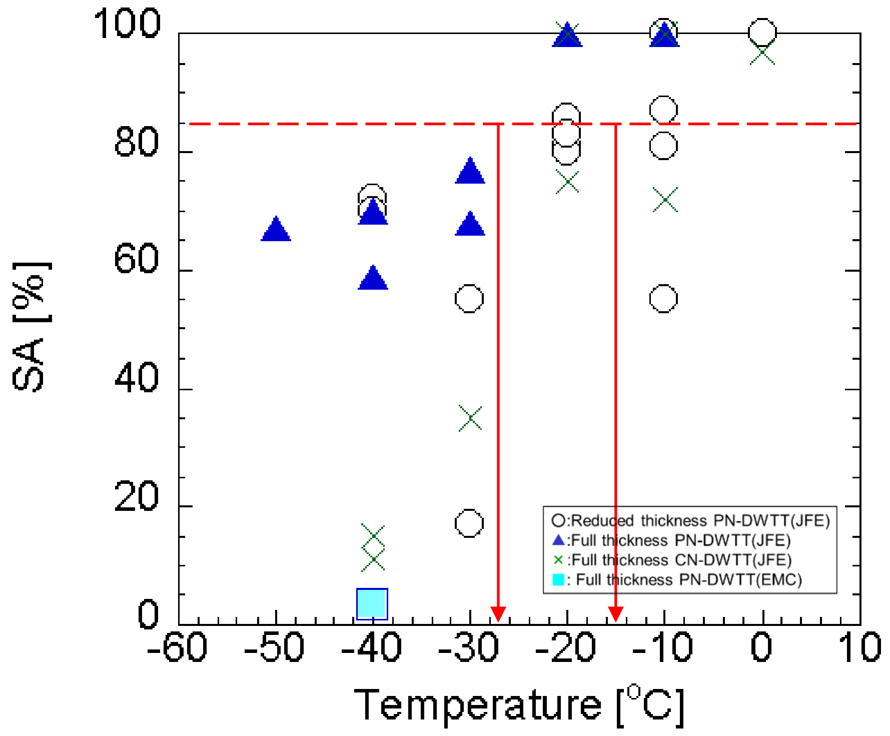
Charpy data shows ductile upper shelf behavior down to -60C

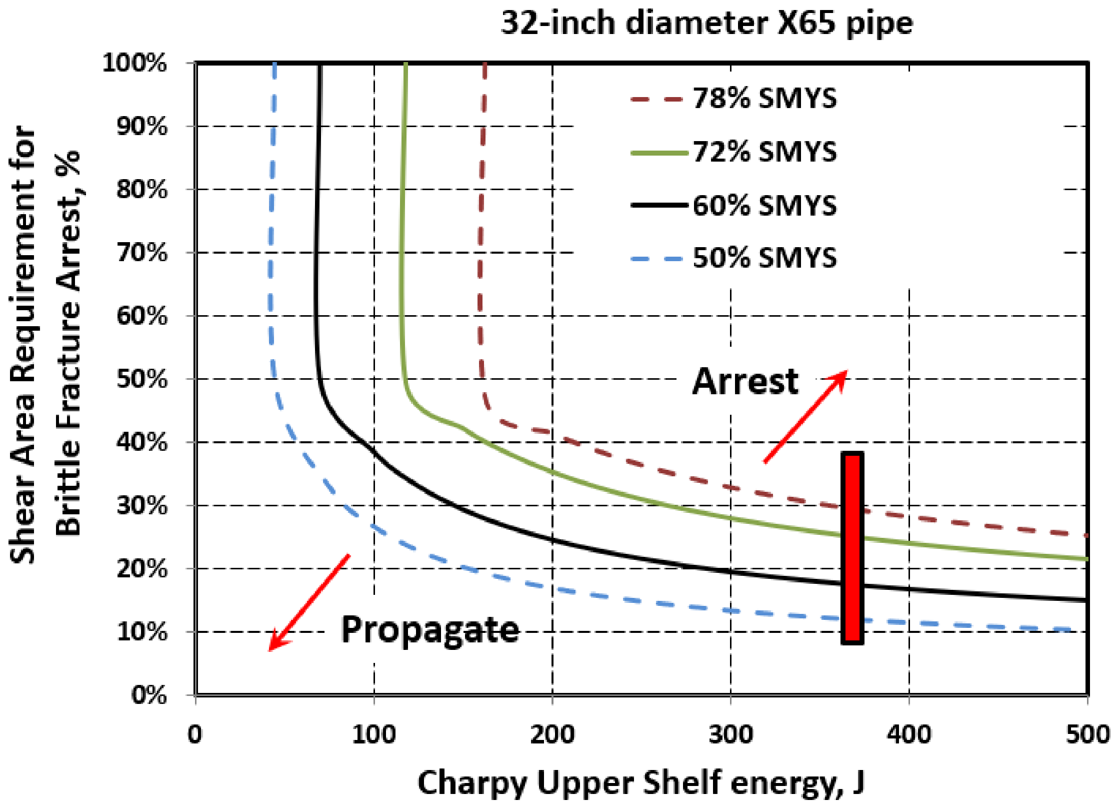
DWTT is questionable with Abnormal Fracture Appearance (AFA) and Fracture Behavior (AFB)



Brittle Fracture Arrest Analysis

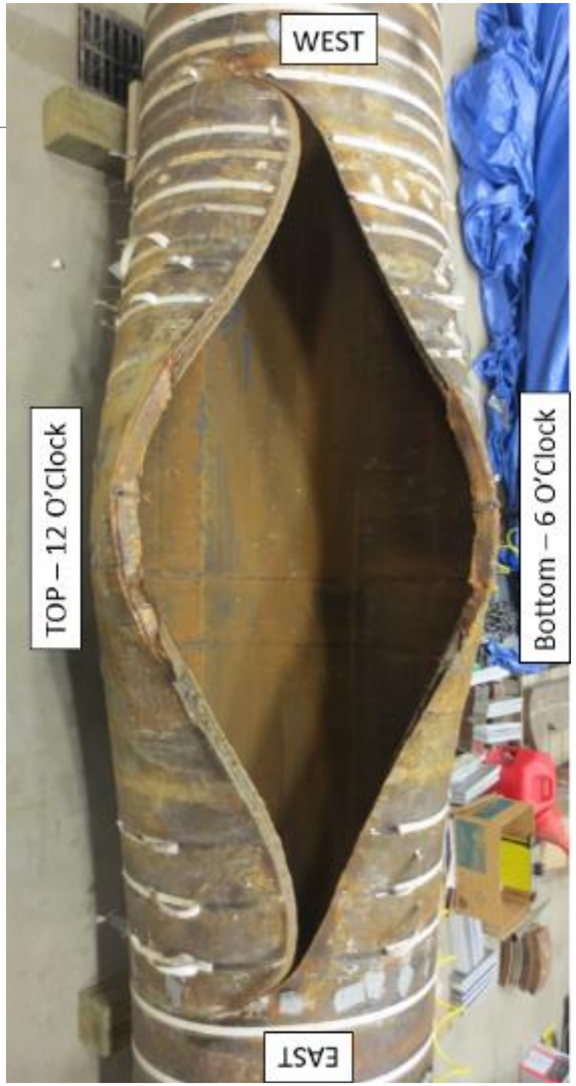
Full scale tests at -27C and -15C





West Jefferson (Partial Gas) Test at -27C

Warmer test at -15C



Outcome

Charpy transition temperature correlation to DWTT and full scale is off

DWTT, need understanding how to interpret the specimen shear area

Steady state behavior is IMPORTANT

- Development of brittle weld DWTT

Newer high strength steel (characterized as CVE upper shelf >200J) tends to show AFA/AFB and have steep transition temperature

IPC 2016-64317, *Modified West Jefferson Burst Test for Assessment of Brittle Fracture Arrest in Thick-Wall TMCP Line-Pipe Steel with High Charpy Energy*

IPC 2016-64569, *Determination of Brittle-to-Ductile Transition Temperatures of Large-Diameter TMCP Linepipe Steel with High Charpy Energy by Use of Modified West Jefferson Testing*

Available Test Specimens

Small-scale specimens: tensile, SENT, CT, SENB, CVN, DWTT

Full-scale capability: low, medium, and high energy

Creep, quasi-static, and dynamic (explosive) test rate

Cryogenic to high temperature test capabilities

Specialized testing for validation work

Key Takeaways

Lab testing goes hand-in-hand with analysis method and understanding of the application

New material might behave differently and therefore need for re-characterization or revision of test methods

There are information that might already been developed and therefore information sharing will be beneficial

Next Steps

Improvement on equation of state for CO_2 (and other)

- NIST Reference Fluid Thermodynamic and Transport Properties Database (REFPROP)
- Effect of impurities

Material resistance and behavior for newer high strength steel

- Understanding that DWTT is for brittle fracture crack arrest ability, not initiation
- Steady state fracture behavior

Assortment of Test Specimens