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STUDY OF PIPELINES THAT RUPTURED AT HOOP STRESS <30% SMYS

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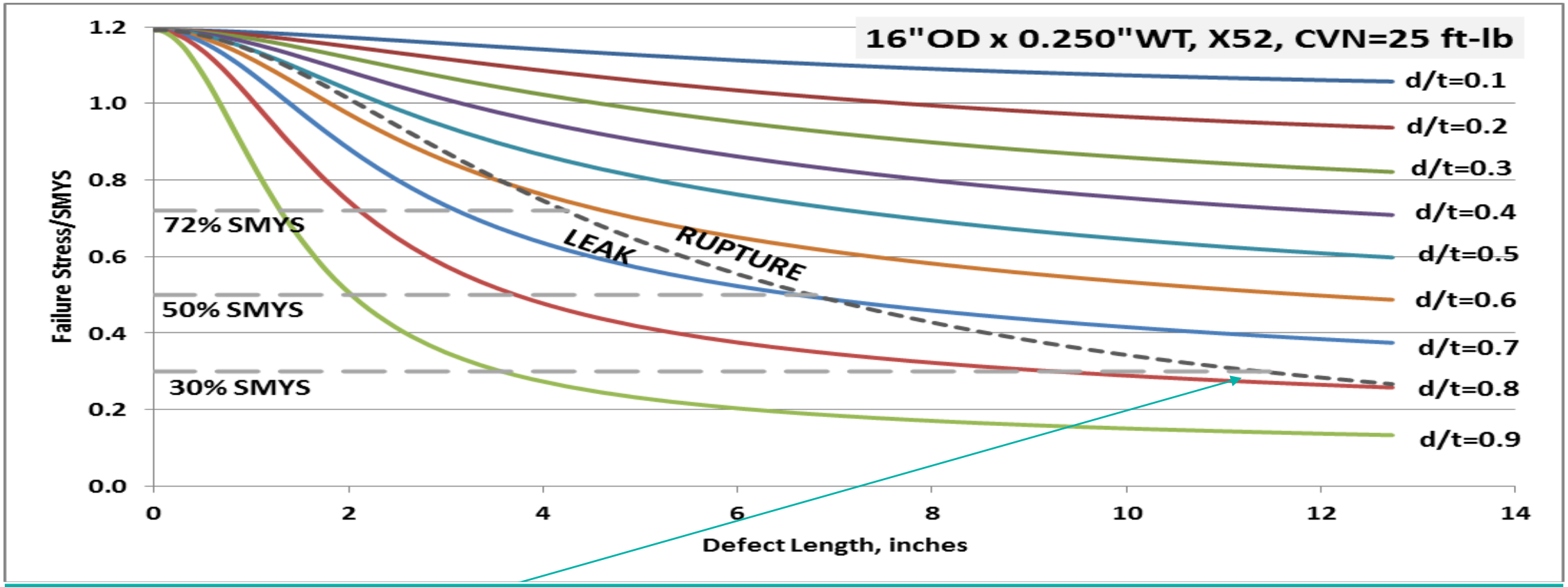
BACKGROUND

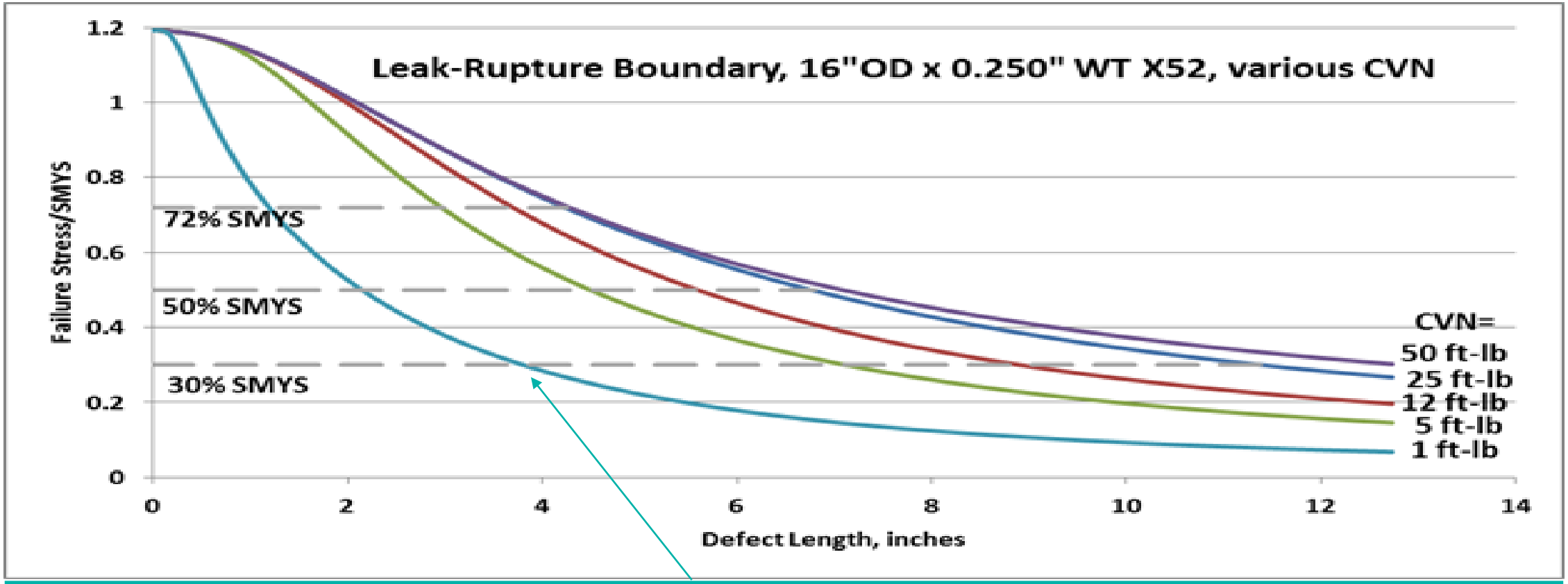
- Conventional wisdom holds that pipe operating at hoop stress < 30% SMYS will only fail as a leak
- This is a reliable assumption – except when it isn't
- Several low stress ruptures noticed in between 2007 & 2013
- Review of PHMSA reportable incident database and Kiefner failure investigation database confirmed others
- PHMSA data missed root-cause trend to be discussed in this presentation

HOW IS THIS POSSIBLE?



Pipe having normal toughness and operating at low stress would require a defect to be very deep and very long in order for a rupture to occur.

HOW IS THIS POSSIBLE?

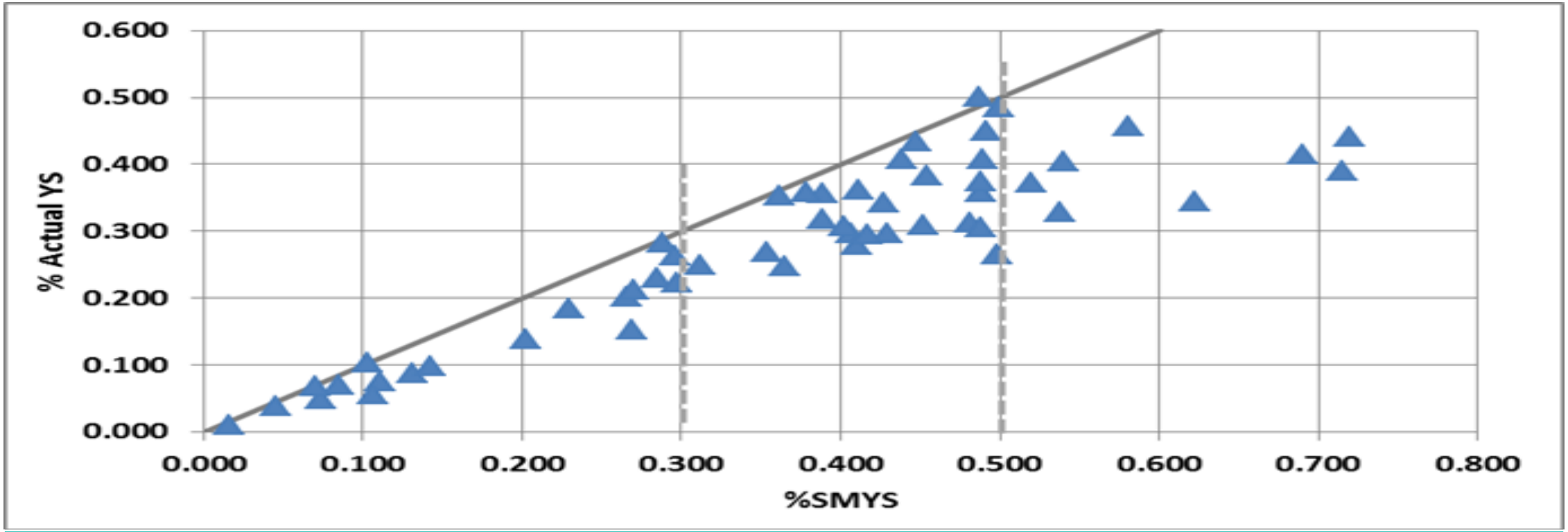


But if toughness is extremely low, a rupture could occur with a much shorter and shallower defect. Extremely low toughness can occur in some LF-ERW seams.

DATA REVIEW

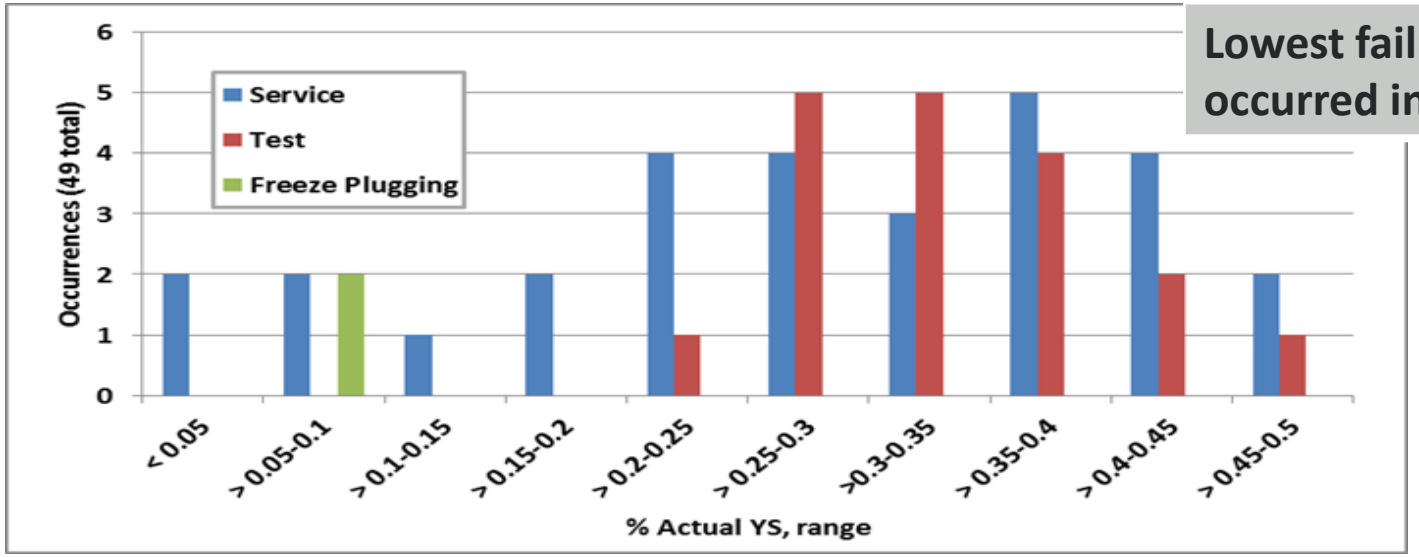
- 49 pressure-controlled ruptures identified at hoop stresses below 50% YS
  - 14 occurred between 20% and 30% YS
  - 9 occurred below 20% YS
  - 6 occurred below 10% YS
  - 2 of those were freeze plugging operations leaving 4 actual in-service ruptures below 10% YS
- 7 external-load-controlled “ruptures” (involving complete separations of pipe)
  - 5 occurred below 20% YS
  - 2 occurred below 10% YS (plus 1 at 10.3%)

DATA REVIEW



- Pipe is generally overstrength – we categorize by operation at %SMYS out of convenience, but material behaves in accordance with actual YS
- Ruptures at 50% SMYS were typically 30%-50% actual YS
- Ruptures at 30% SMYS were typically 20%-30% actual YS

DATA REVIEW

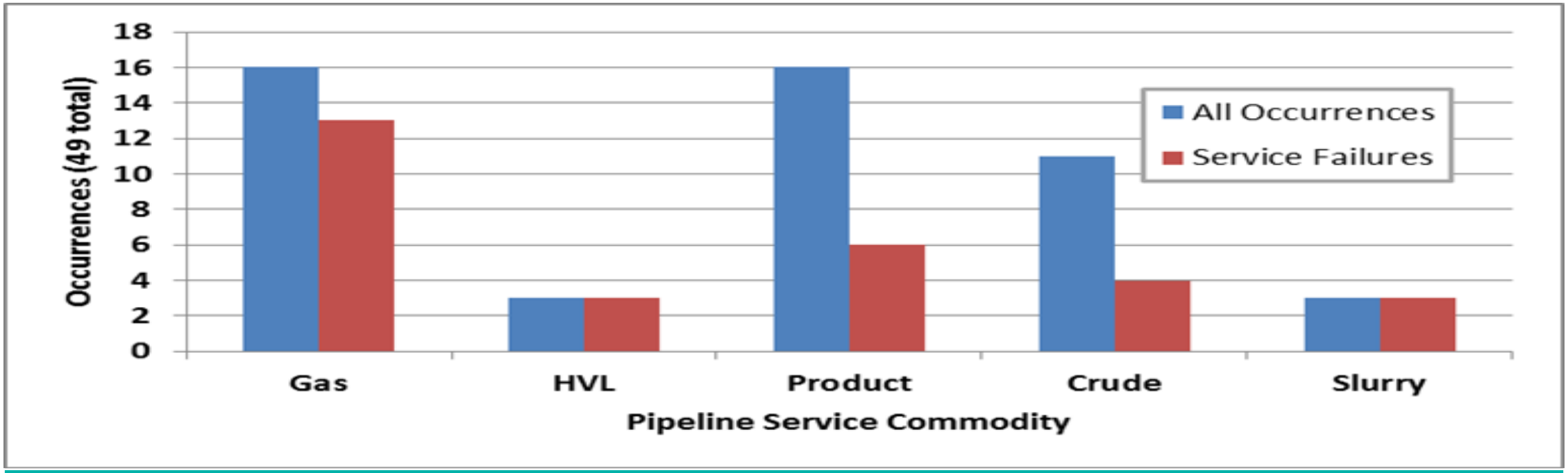


Lowest failures occurred in service

Stress level	All*	Service	Testing
<50% YS	47	29	18
<30% YS	21	15	6
< 20% YS	7	7	0
<10% YS	4	4	0

*Pressure-controlled ruptures, excluding freeze plugging incidents

DATA REVIEW

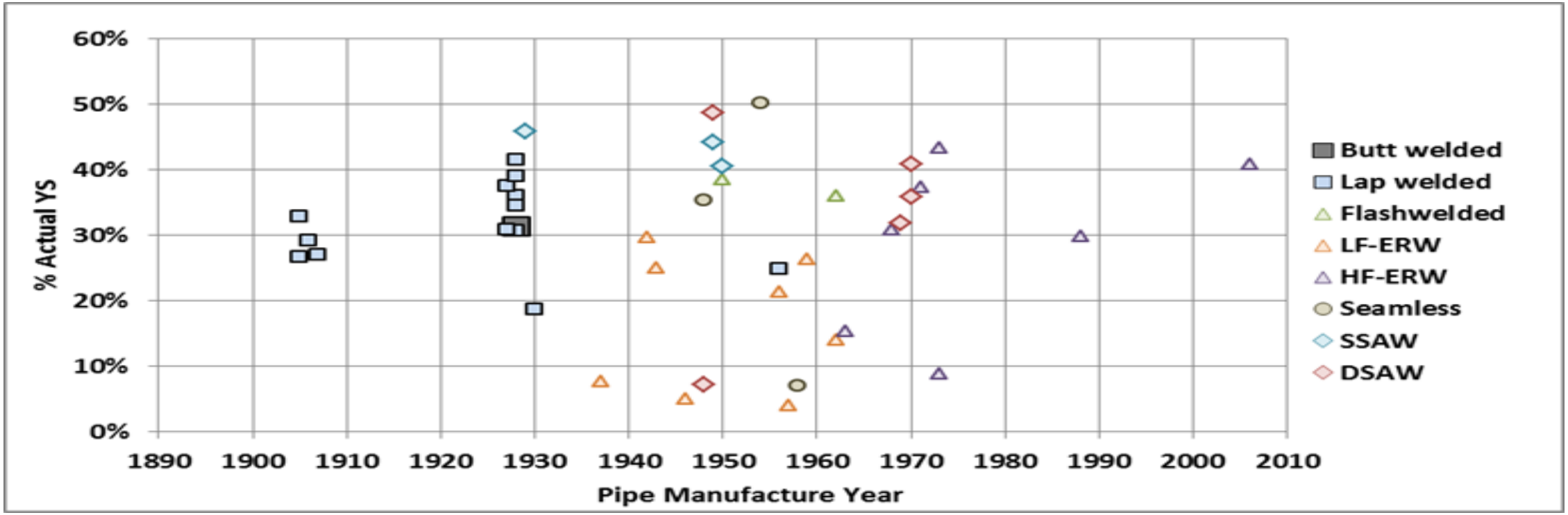


About the same number of low-stress service failures in gas and liquid pipelines.

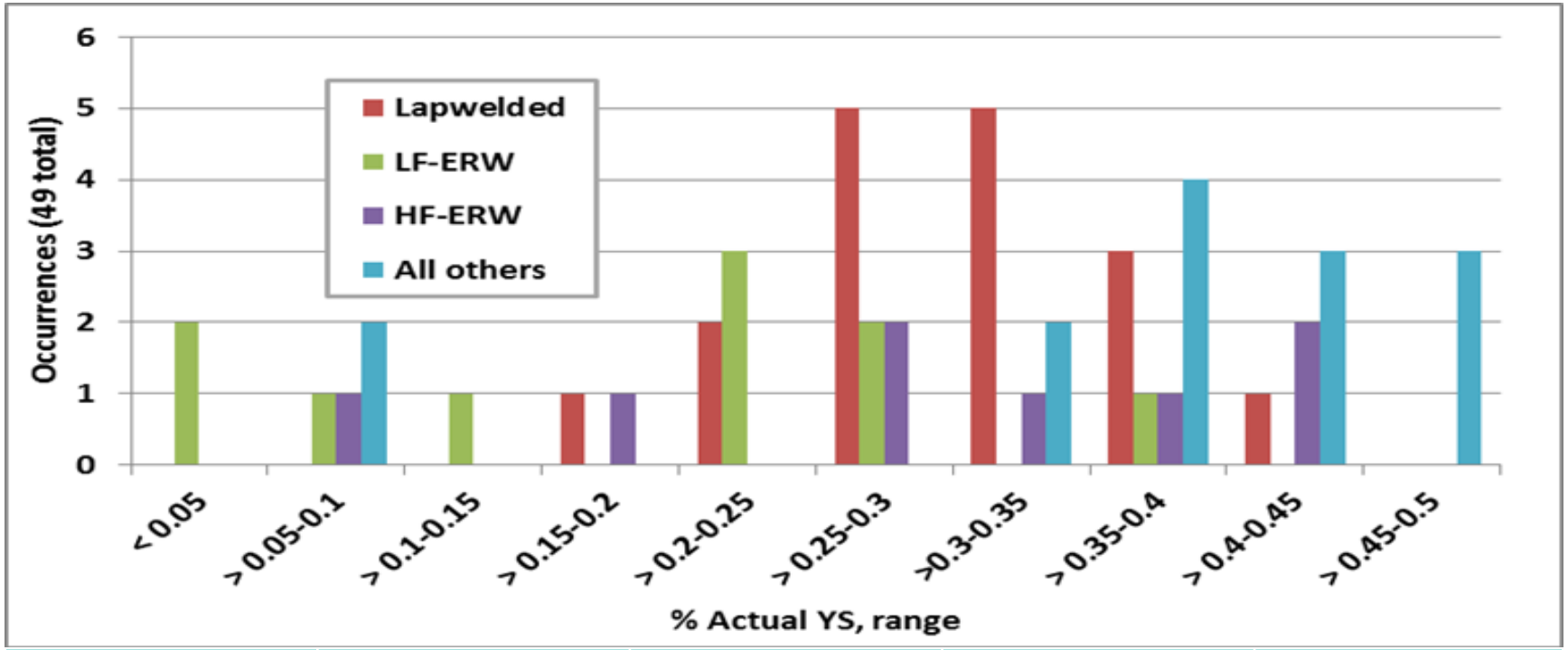
DATA REVIEW

- Pipe vintages ranged from 1905 to 2006
- Pipe grades ranged from Wrought Iron to X60
- Diameters ranged from NPS 6 to 24” OD
- Every seam type represented:
  - 1 butt welded
  - 17 lap welded
  - 3 seamless
  - 2 flash welded
  - 10 LF ERW
  - 8 HF ERW
  - 3 SSAW (2 SAW, 1 SMAW)
  - 5 DSAW

DATA REVIEW



- No distinct trend with respect to pipe vintage
- ERW dominated the lowest-stress occurrences



Pipe Type	< 50% YS	< 30% YS	< 20% YS	< 10% YS
LF-ERW	10	9	4	3
HF-ERW	8	3	2	1
Lap Welded	17	8	1	0
All others (a)	12	0	0	0

(a) Freeze plugging incidents omitted.

CAUSES OF SERVICE FAILURES AT LOW OR MODERATE STRESS LEVELS

- LF-ERW: selective corrosion of seam
- HF-ERW: internal selective corrosion, previously damaged pipe

- Lap welded: burnt metal or seam defects
- Others: previously damaged pipe, external corrosion, MIC, SCC, freeze plugging
- External loads (axial separations) can affect any pipe no matter how low hoop stress

COMMON FACTORS IN LOWEST STRESS SERVICE RUPTURES

- ERW pipe
- Selective seam corrosion (internal or external)
- Operating below 20% SMYS
- Toughness of pipe body was good
- Low toughness in LF-ERW pipe or large defect in HF-ERW pipe
- Threat assessment failed to account for the possibility of interacting threats
- Integrity assessment not selected to detect the condition

WHAT ARE INTERACTING THREATS?

- An integrity threat is something that ever has or ever could cause the pipe to fail
- Threats interact if they increase the likelihood of a failure when the threats occur simultaneously.
- Not all pipeline integrity threats interact, in fact most threats do not interact
- Analysis shows the two most common interacting threat pairs are
  - Select Seam Corrosion and ERW seams
  - External loads and low-quality girth welds

ENHANCED DEFINITION OF INTERACTING THREATS

- The lowest-stress ruptures appear to have occurred as a result of interacting threats. An enhanced definition of interacting threats could be:
    - Threats also interact if they (a) change the expected mode of failure from a leak to a rupture, or (b) change the occurrence of a rupture from a high stress level to a low stress level
- Implications for pipelines that operate at low or moderate stress levels

HOW HAVE WE MISSED THIS UNTIL NOW?

- Limited number of injuries, no fatalities (yet)
- Many occurrences not reportable at the time
- In some cases, poor correspondence between reported and actual cause
- No mechanism exists for detailed forensic reports to inform the pipeline operating community

WHAT CAN BE DONE?

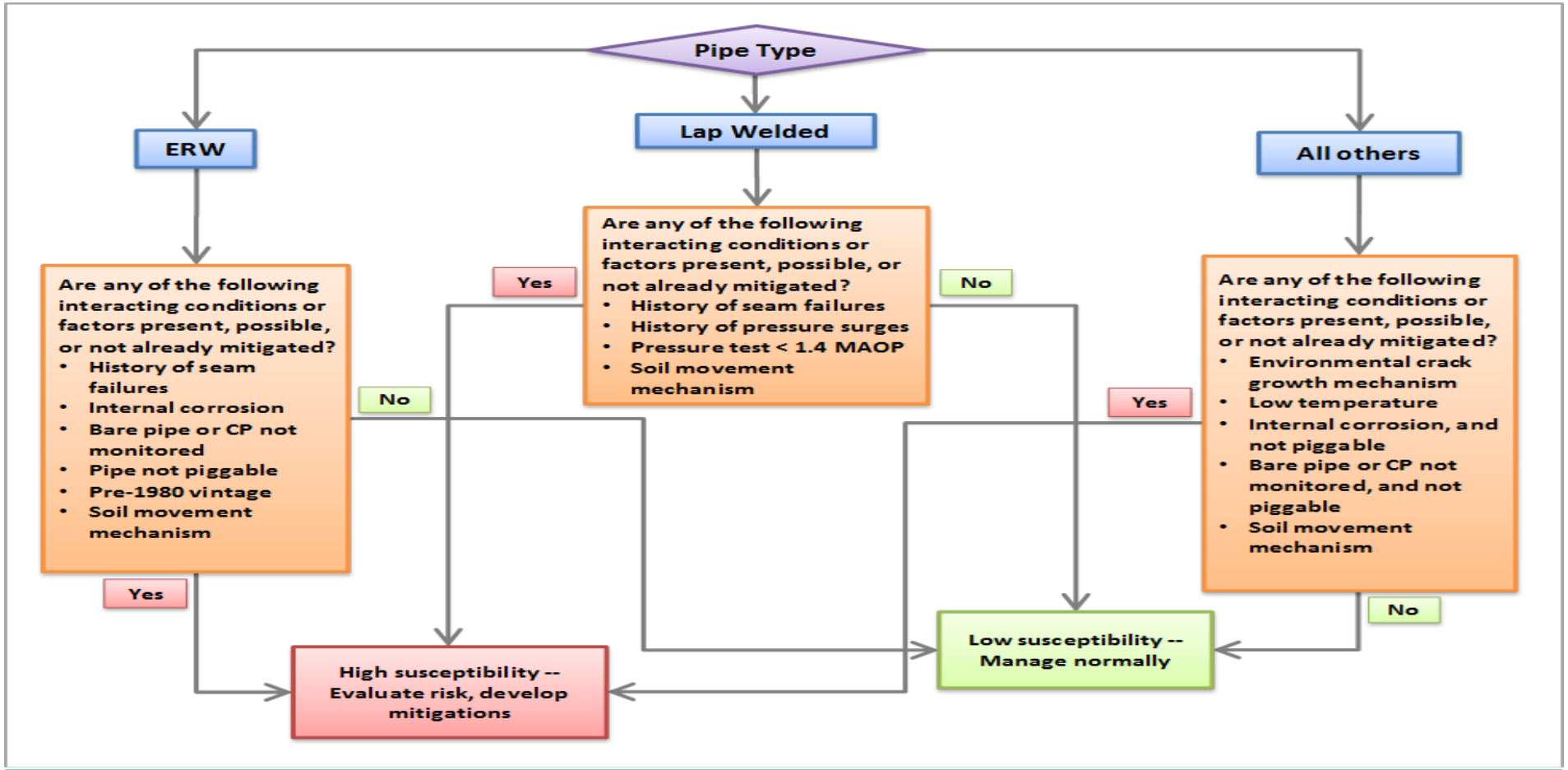
- PHMSA:
  - Improve QA in reported incident cause data
  - Improve flow of information from detailed forensic reports to the industry
- Benefits:
  - More accurate data
  - Improve industry's ability to identify causal factors and trends
  - Improve operator's integrity threat identification process and mitigation work

WHAT CAN BE DONE?

- ILI industry:
  - Continue to develop self-propelled internal inspection platforms
  - Continue to broaden the range of inspection technology available for such tools (EMAT, video)
- Benefits:
  - Improve operator’s ability to perform physical assessments
  - Assessment can be targeted to location and nature of integrity threat
  - Reduce uncertainty about pipe condition

WHAT CAN BE DONE?

- Operators:
  - Implement threat assessment process designed to evaluate interactions that affect failure mode or stress level, not just probability
- Benefits:
  - Enhanced integrity and reliability
  - Reduce unexpected events



Example template for a threat assessment process designed to evaluate interactions that affect failure mode and stress level, not just profitability.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Q & A

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