

IMPACT OF 80% SMYS OPERATION ON RESISTANCE TO THIRD PARTY MECHANICAL DAMAGE

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IMMEDIATE FAILURE (PUNCTURE) FROM A BACKHOE TOOTH HITTING A PIPELINE



DELAYED FAILURE FROM PRIOR LONG SCRAPE BY DIGGING EQUIPMENT



HOW MANY PIPELINE INCIDENTS RESULT FROM MECHANICAL DAMAGE?

	Total number of reportable incidents from all causes 1985 through 2003	Number of immediate incidents from mechanical damage	Number of delayed incidents from mechanical damage	Ratio of immediate to delayed
300,000 miles of natural gas transmission and gathering pipelines	1583	440 (28% of total)	49 (4% of total)	9 to 1
160,000 miles of liquid petroleum pipelines	3366	724 (21% of total)	153 (5% of total)	5 to 1

RESISTANCE TO MECHANICAL DAMAGE IS A DESIRABLE PIPELINE ATTRIBUTE

- Resistance to immediate failure avoids largest category of third-party damage failures
- Long-term tolerance to damage affords opportunity to find by ILI avoiding delayed failure

RESISTANCE TO IMMEDIATE PUNCTURE

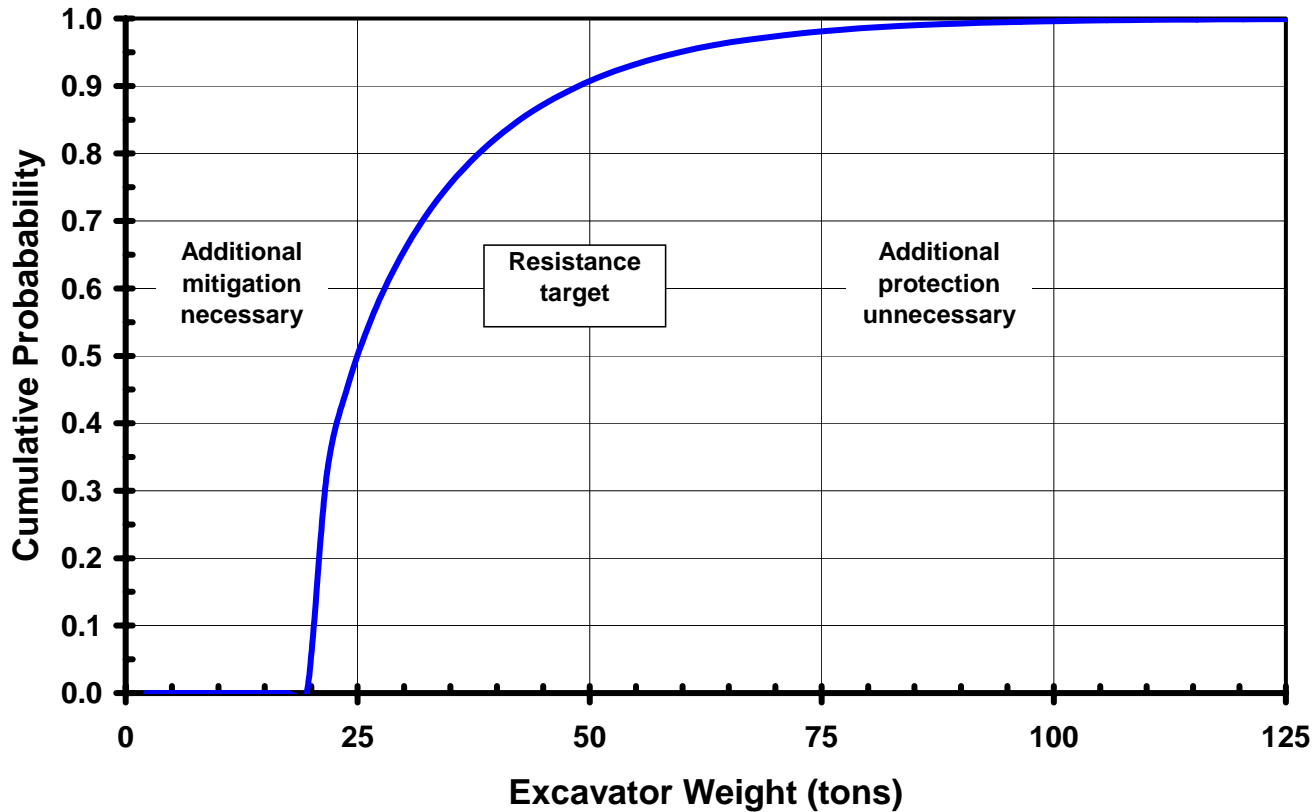
- Puncture resistance increases with:
 - Increasing wall thickness
 - Increasing material strength
- With sufficient wall thickness, puncture resistance becomes so high that the pipeline cannot be punctured by the majority of the digging equipment in use

RESISTANCE TO IMMEDIATE PUNCTURE

- In other words, with sufficient wall thickness, resistance to puncturing becomes “maximal”.
- With maximal resistance, no additional mitigating measures are needed to offset the effect of an increase in operating stress level.

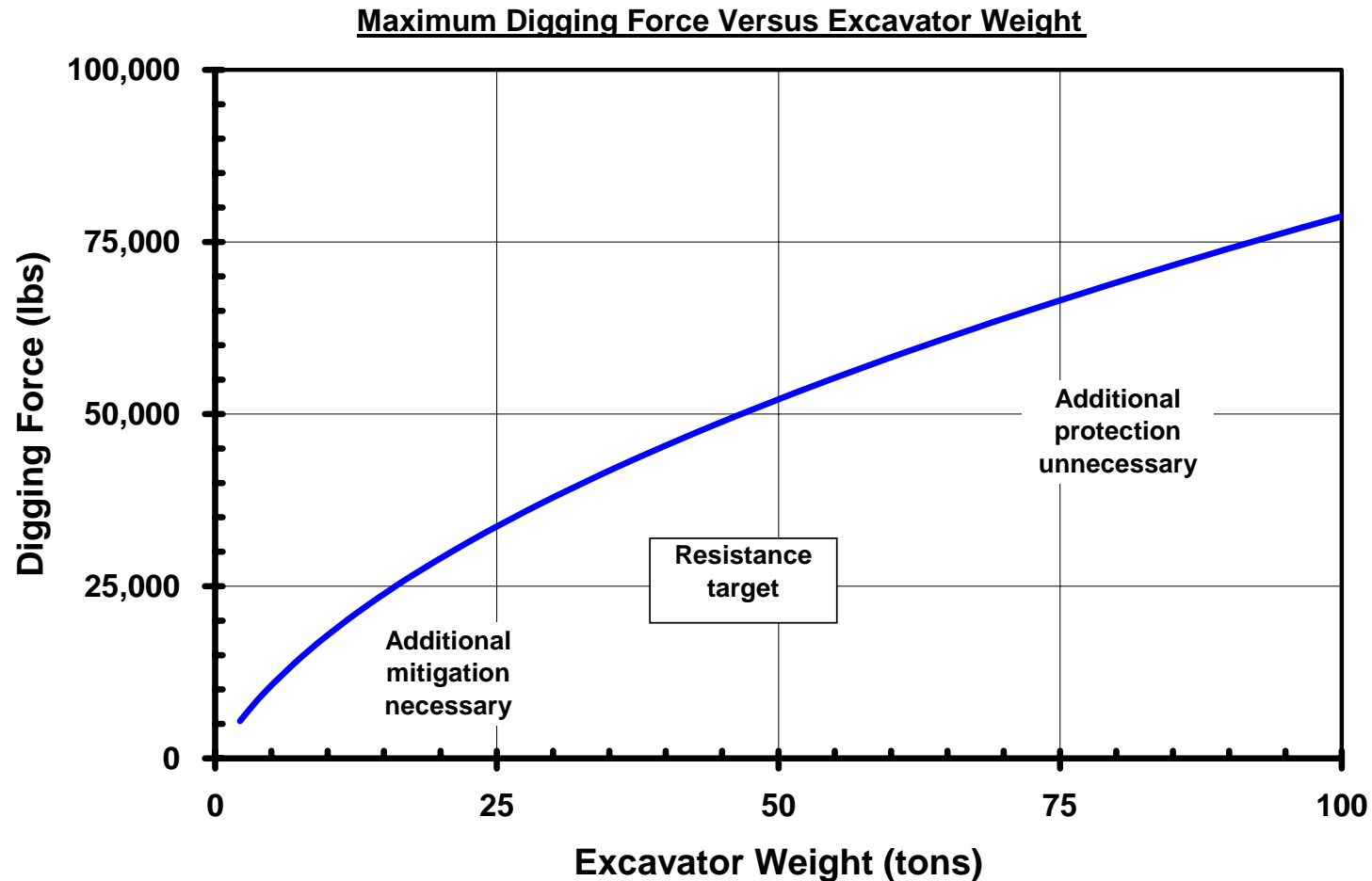
Immediate penetration resistance

Cumulative Probability Versus Excavator Weight



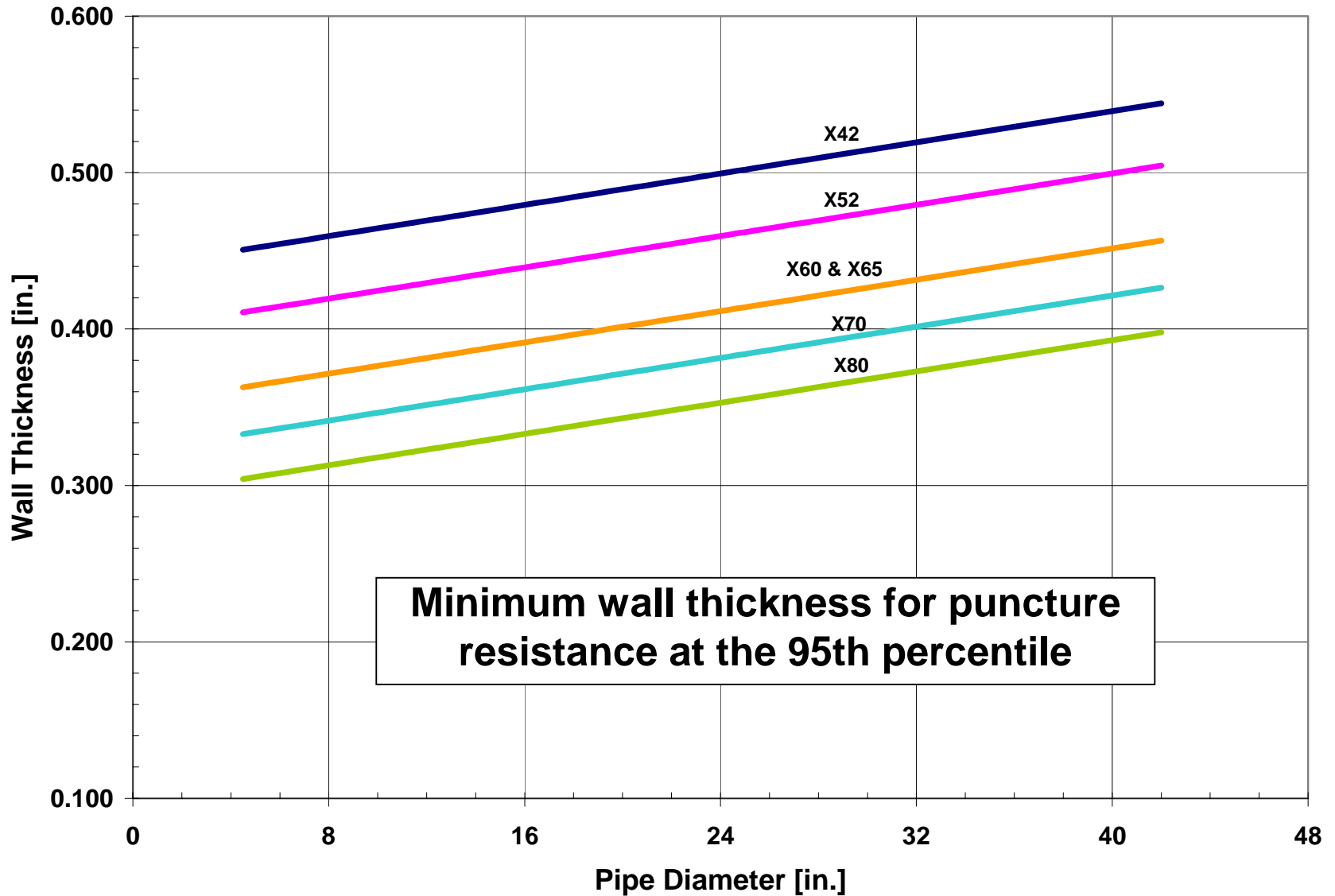
Desirable resistance between 75-95 percentile equipment, equivalent to 35-60 Tons. Below this requires added mitigation.

Immediate penetration resistance

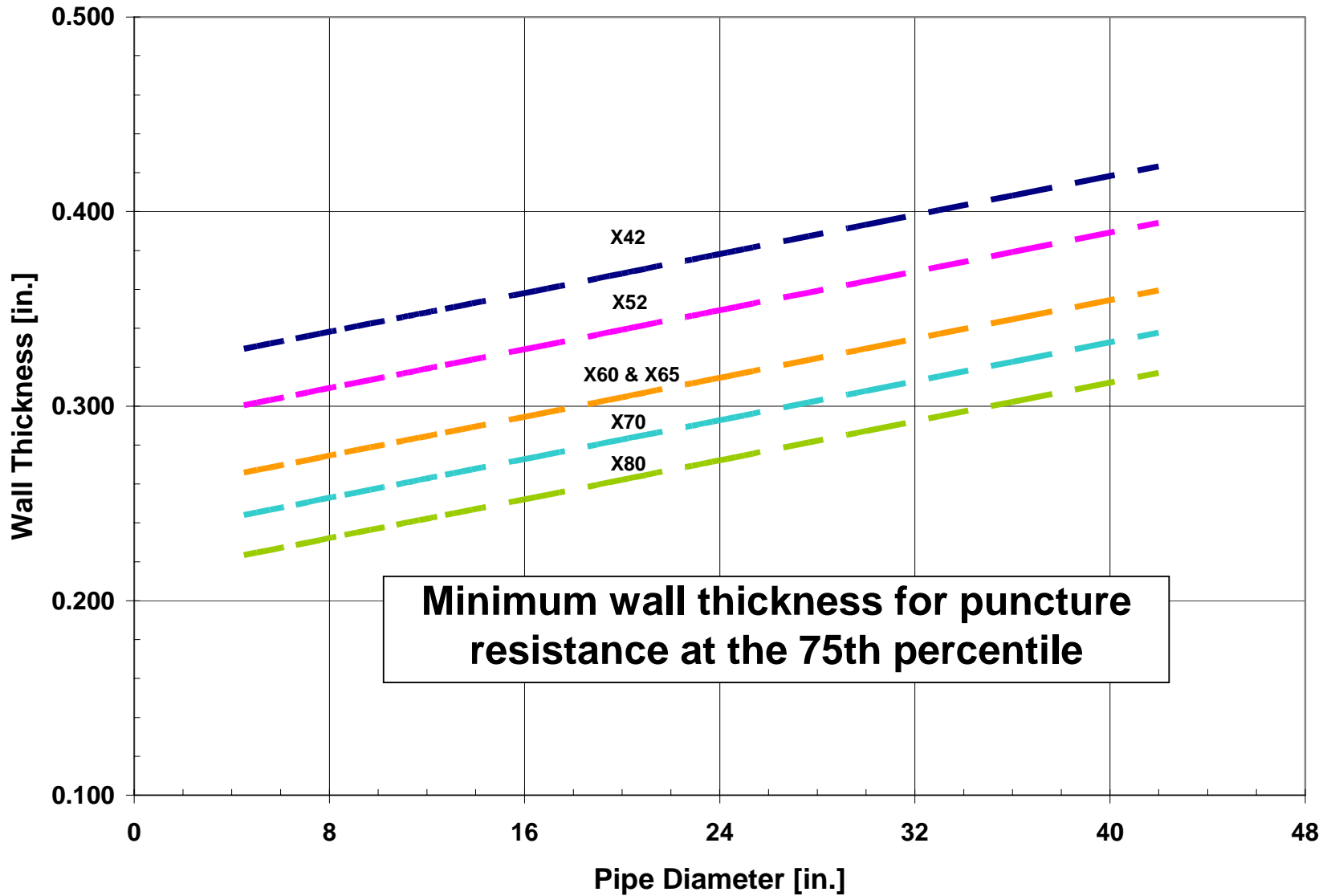


Target resistance corresponds to 40-60 kip penetration force.

Wall thickness target level of maximal penetration resistance.

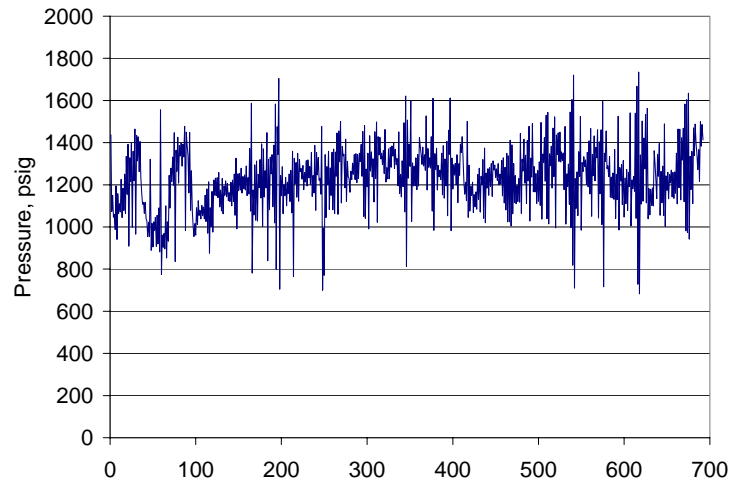
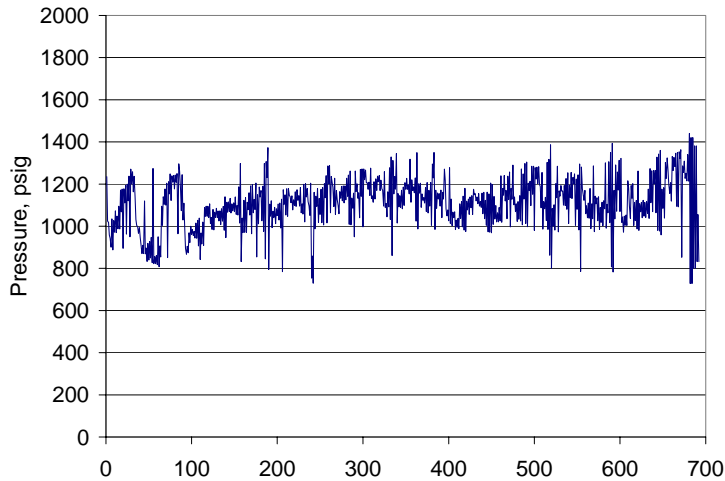


Minimum wall thickness target for no additional protective measure.

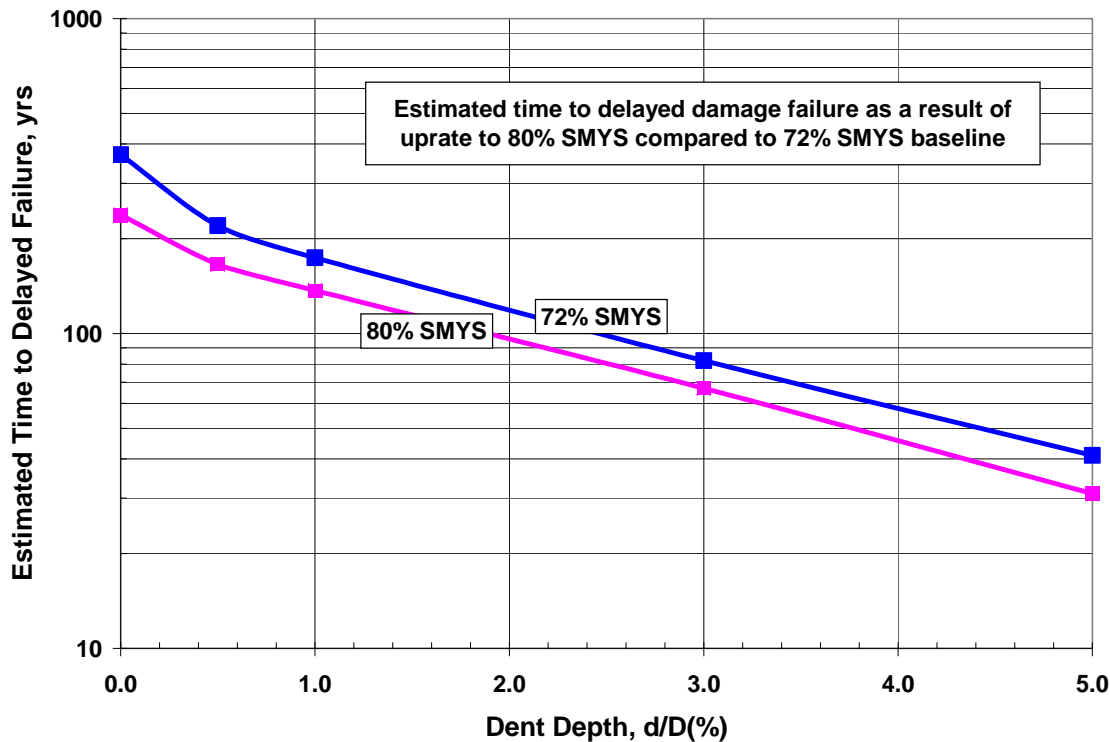


Resistance to delayed failure

- Long-term damage tolerance a function of
 - Ductility and toughness
 - Severity of pressure cycle spectrum
- Objective is to tolerate damage long enough to be able to find it by ILI at normal re-inspection intervals



Operating stress enhanced by dent



24" diam., 0.343" wall, X70 pipeline with 30% WT initial crack in dent with gouge