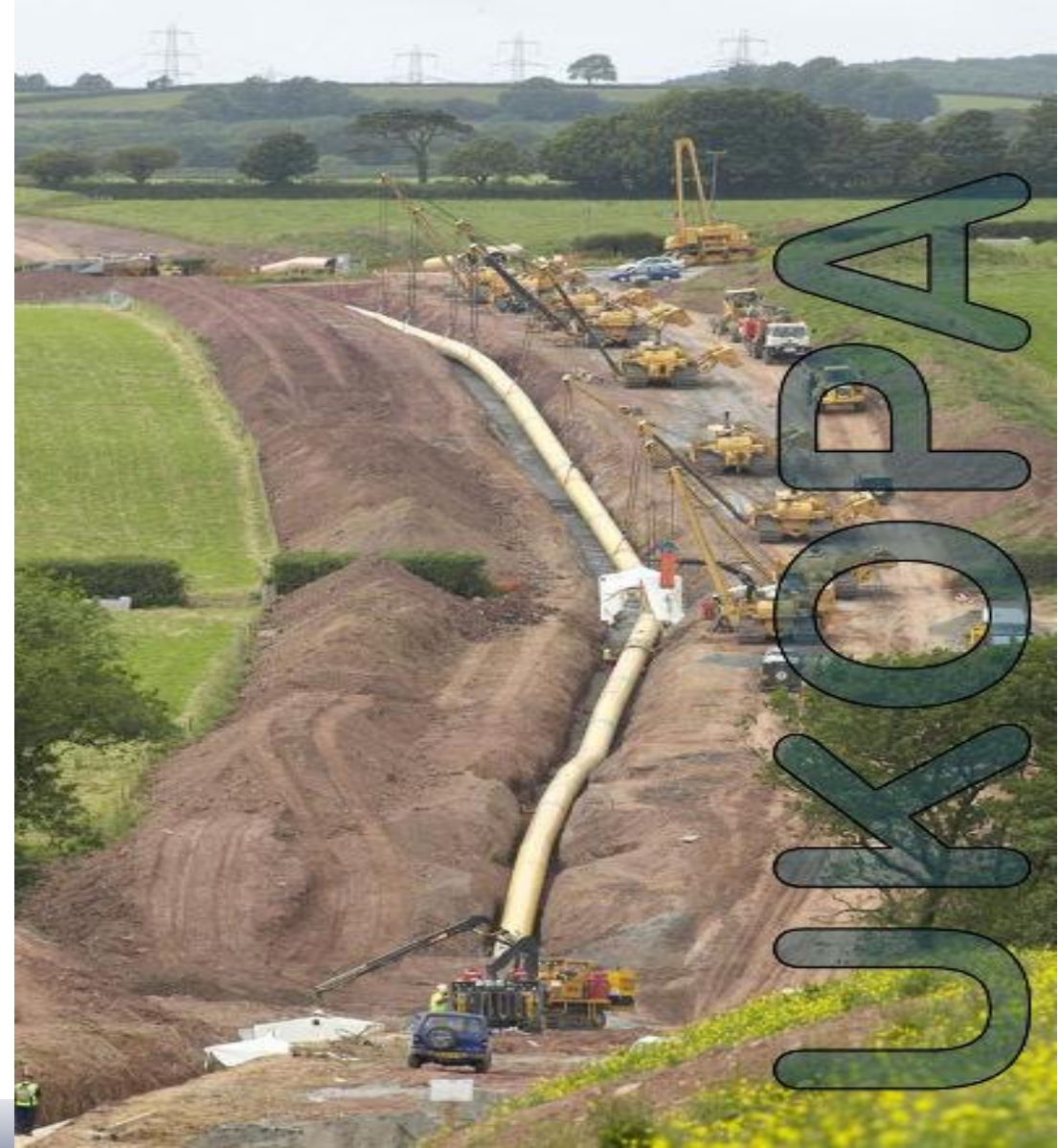


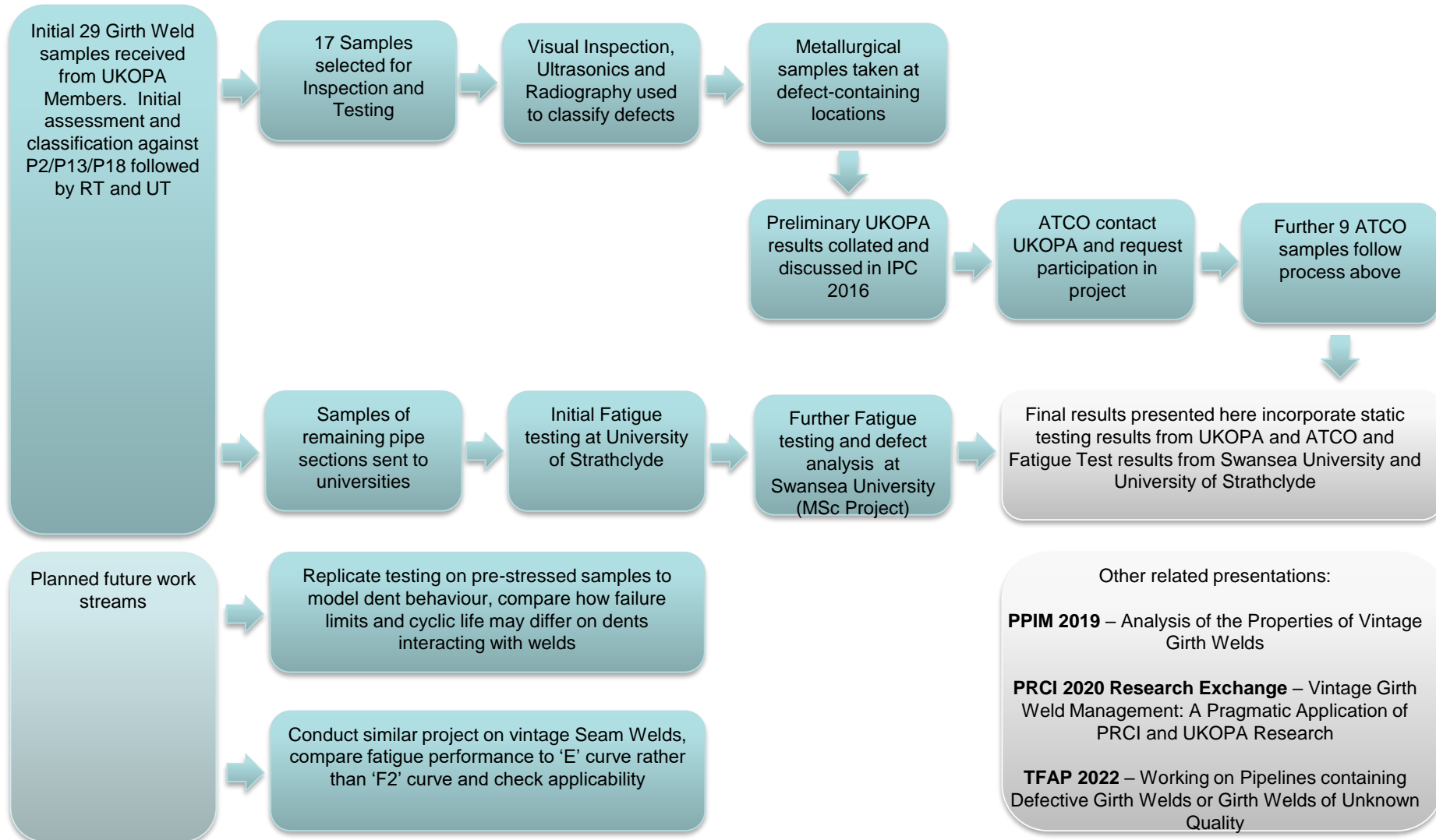
Mechanical and fatigue properties of Pre-1972 Girth welds

Presenter: Tim Rudd (Valero)

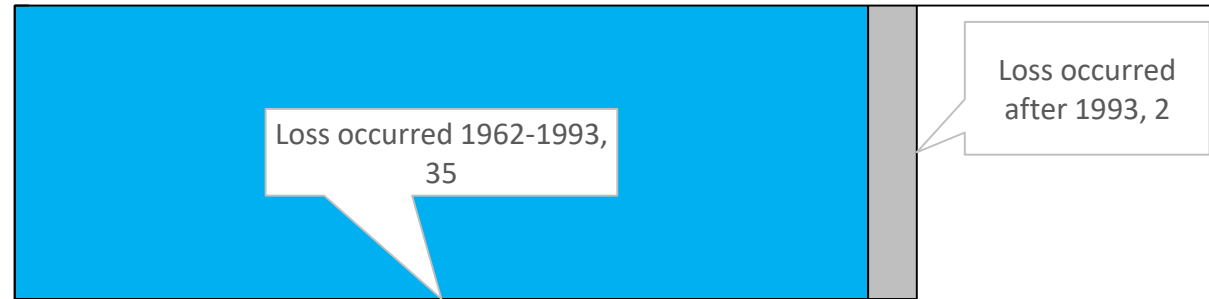
Co-Authors: A. Cosham, K. McDermott, K. Jensen, J. Haswell, T. Rudd



- Workmanship acceptance criteria and QA/QC requirements for pipeline girth welds (GW's) have evolved over time.
 - Prior to 1972 no requirement for 100% NDE on pipelines (before P2 standard)
 - Earlier lines frequently build to API standard (1104 and successors)
- UKOPA Weld Quality Project was initiated to demonstrate that although the overall quality of Vintage (Pre-1972) GW's might not meet modern acceptance levels, they are not an inherent risk to pipeline integrity.
 - P/18 standard assumed vintage welds were of poor quality unless known otherwise
- GW's from pipeline assets constructed prior to 1972 within the UK and Canada have been analysed
 - These historical welds contained a wide variety of welding defects that would not be acceptable according to modern pipeline welding standards
 - Analysis of the results indicated that the GW's were fit-for-service.
- Fatigue tests on samples showed that their fatigue performance can be predicted by the class F2 curve in BS 7608.
- The conclusion drawn is that vintage GW's are not an inherent integrity risk, and are not of inherently poor quality

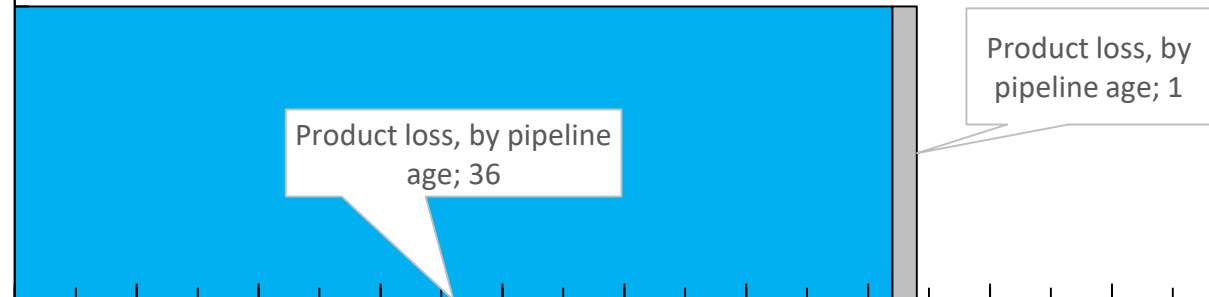


Product loss, by year



The two product loss incidents, both in 2013, were described as a “leak on pipeline branch vent point coming above-ground” and “on butt weld adjacent to previous leak” so are not true GW failures

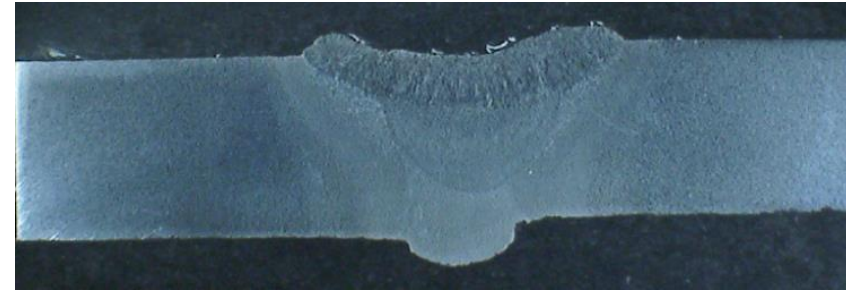
Product loss, by pipeline age



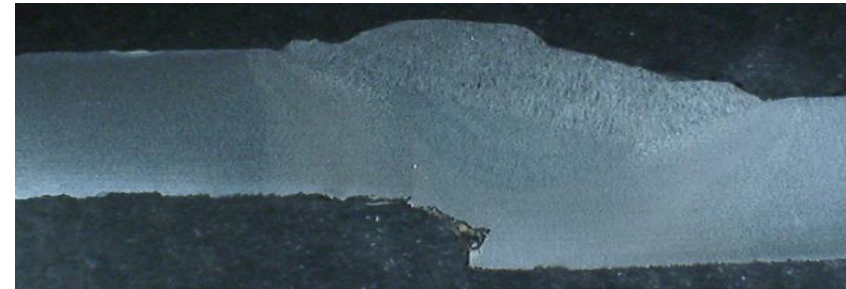
0 5 10 15 20 25 30 35 40 45 50
number of product loss incidents

- 36 Weld samples examined in this project – 26 contained defects of varying severity
 - Majority minor/non-injurious
- All welds had survived hydrotest
- None of these welds had failed in-service

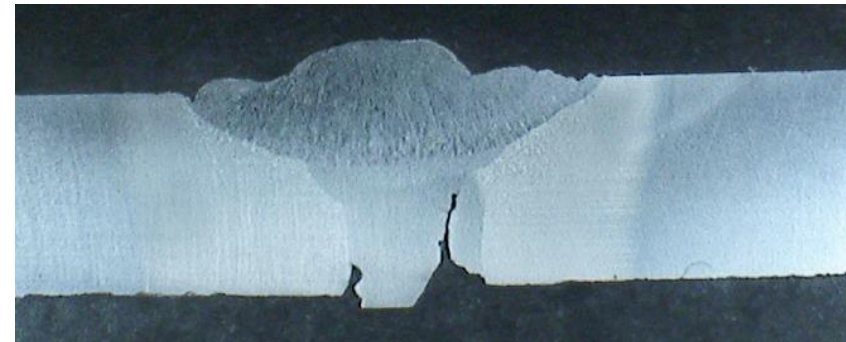
Type of Defect	Number of Occurrences
Crack	1 (3%)
IP/LF	7 (18%)
Slag	4 (11%)
Por.	6 (16%)
Burn through	2 (5%)
Undercut	10 (26%)
Concavity	4 (11%)
Hi/Lo	Very common
Defect Free	4 (11%)



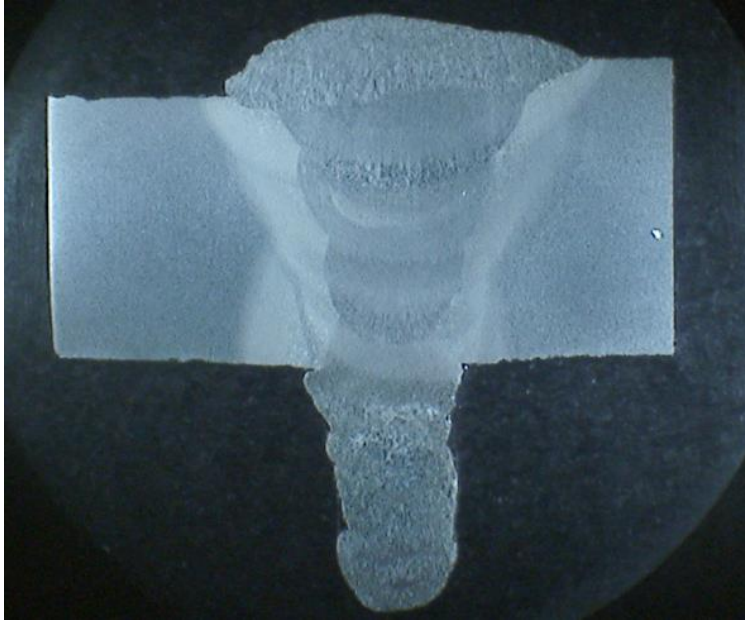
Excess Penetration, Concavity, minor misalignment



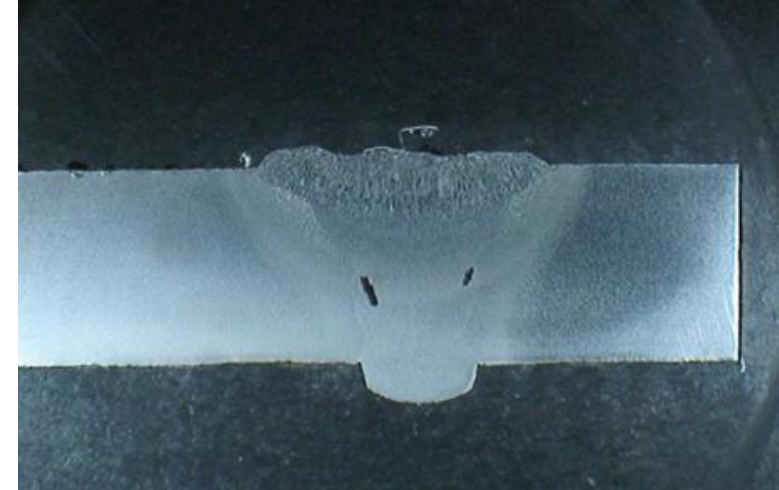
Misalignment



Lack of Fusion, incomplete Penetration

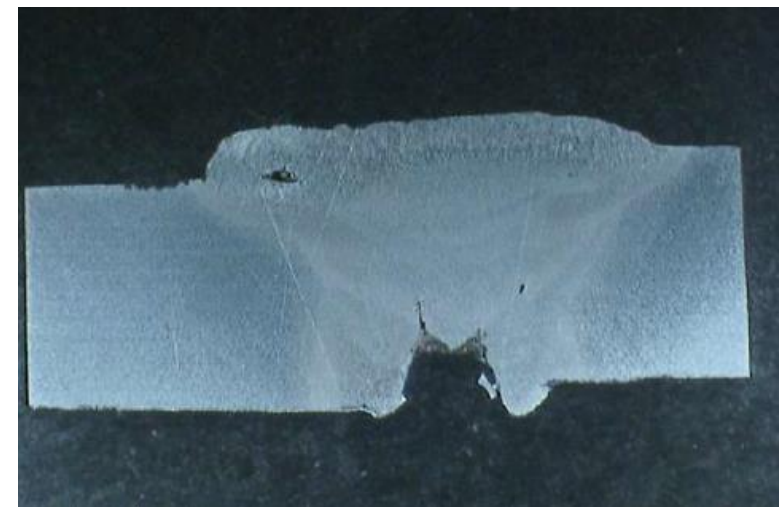


Excess Penetration



Excess Penetration, Oxide Inclusions/Porosity

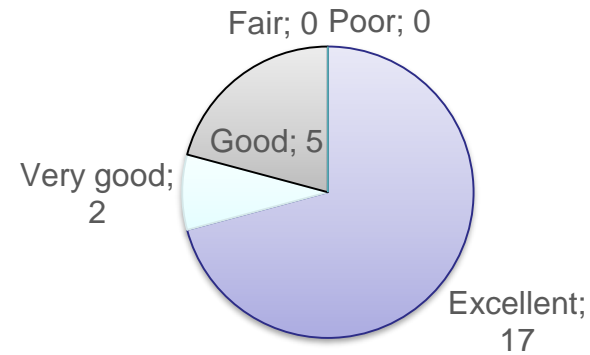
- Despite sharp stress-raisers no signs of fatigue cracking observed on static samples
 - UKOPA samples taken primarily from liquid lines, so subject to higher cyclic loading
- Microscopy found no significant differences between microstructures of vintage Girth Welds and modern equivalent



Porosity, Lack of Penetration, Lack of Fusion

Weld Property	Compared to	Why it matters
Chemistry	Established CE Ranges	Weldability
Tensile Strength	Weld overmatch, materials spec	Tensile strain capacity
Hardness (HV)	Limitations in modern codes of construction	Propensity for cracking, brittle failure
Impact Toughness	Pipe body, materials spec	Ductile behavior, weld spec

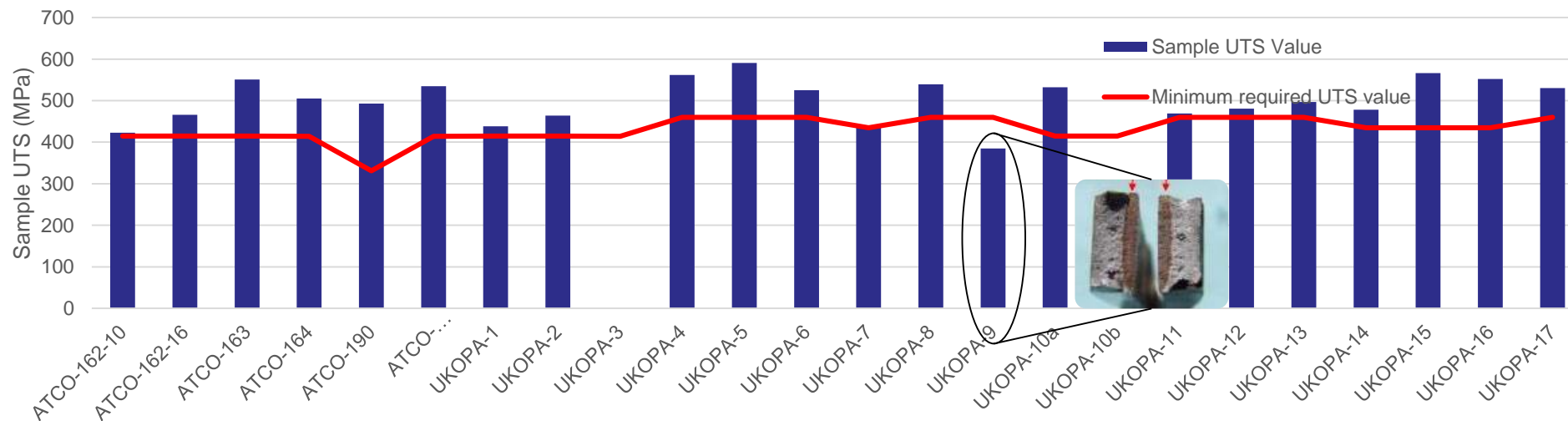
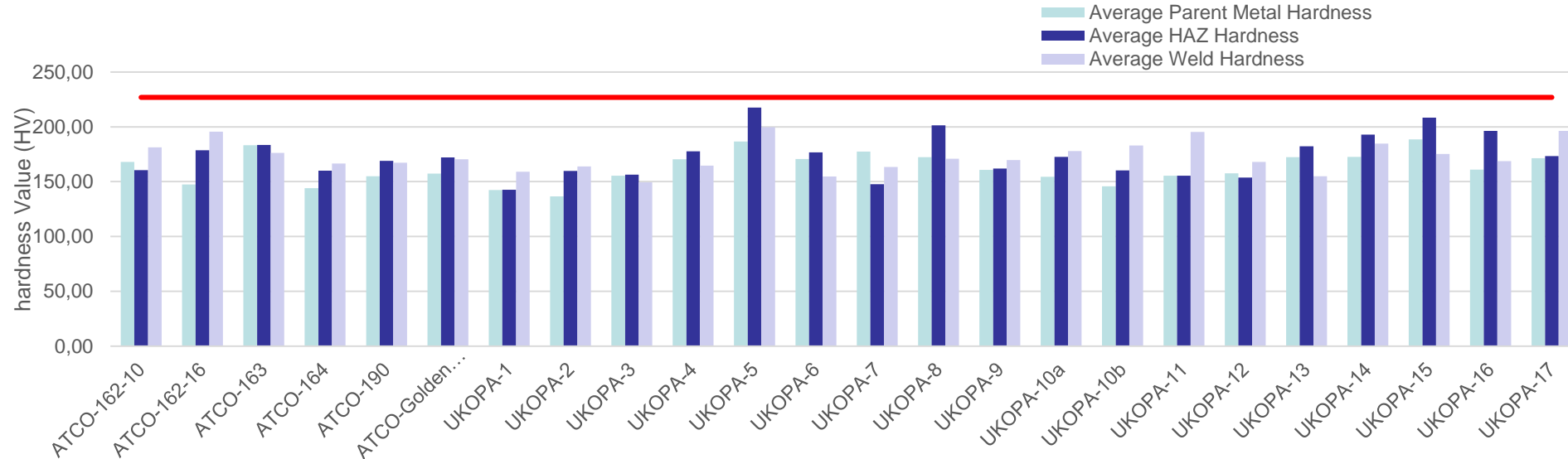
$$CE_{IIW} = C + \frac{Mn + Si}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$



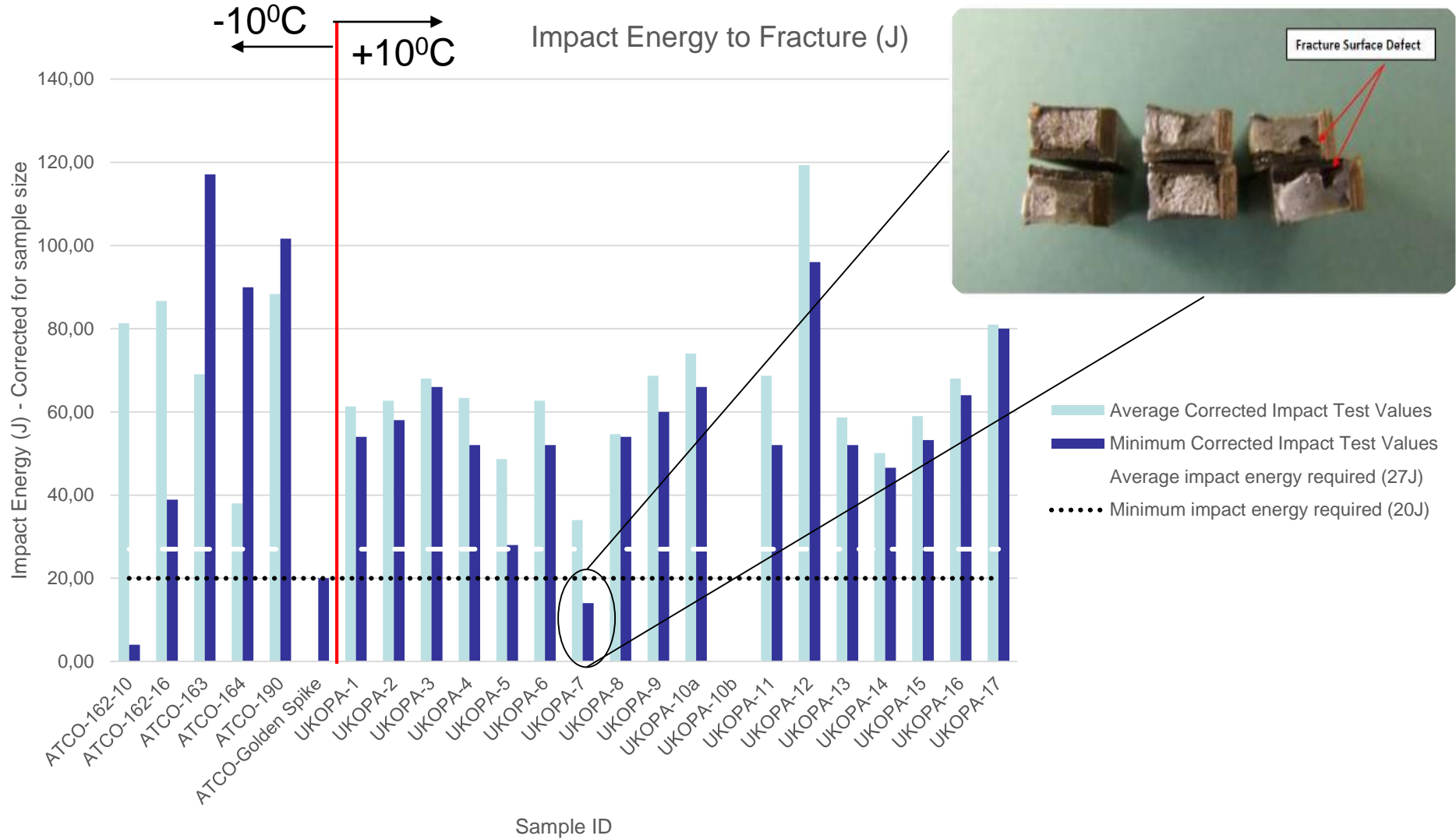
■ Excellent
 ■ Very good
 ■ Good
 ■ Fair
 ■ Poor

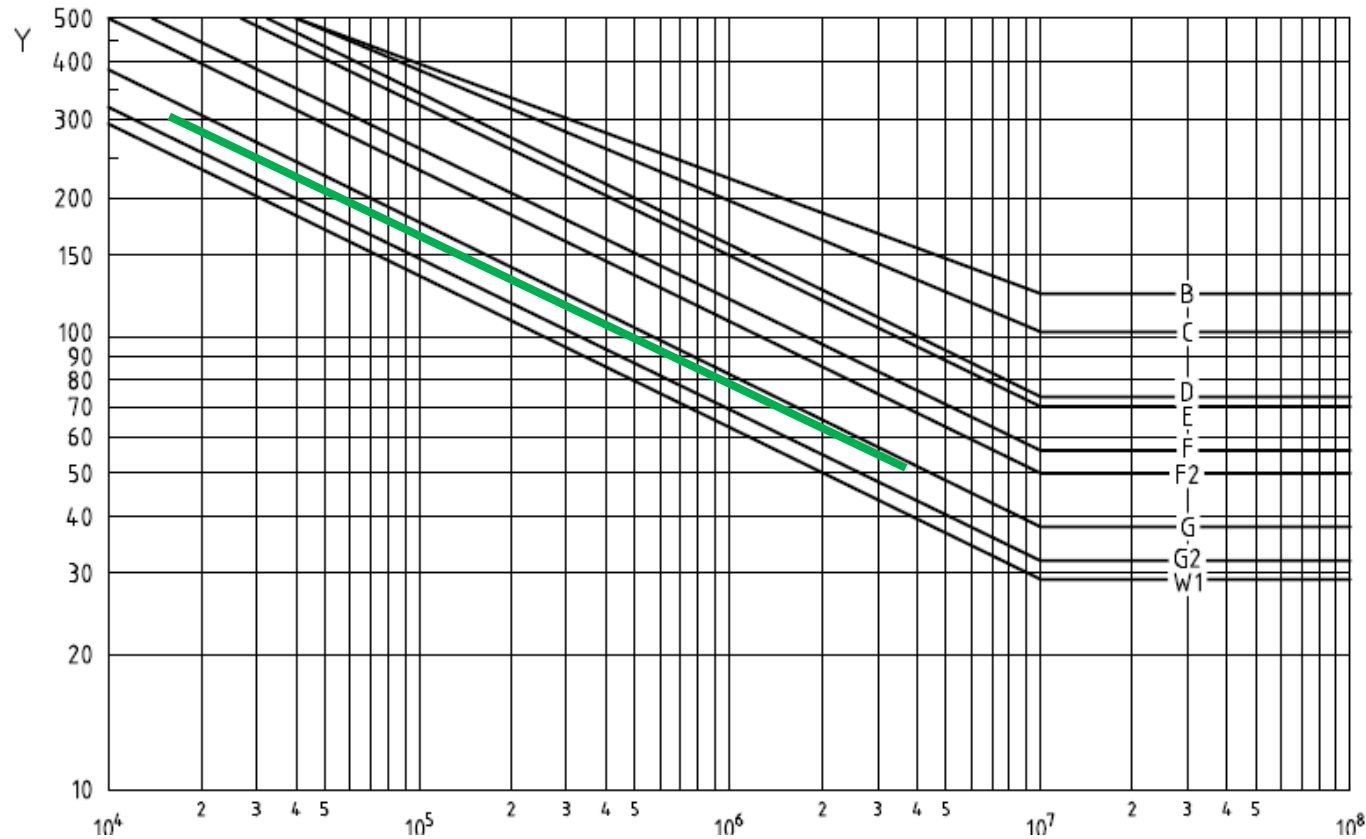
Carbon equivalent (CE)	Weldability
Up to 0.35	Excellent
0.36–0.40	Very good
0.41–0.45	Good
0.46–0.50	Fair
Over 0.50	Poor

UTS and Hardness



Charpy Impact (V-Notch)

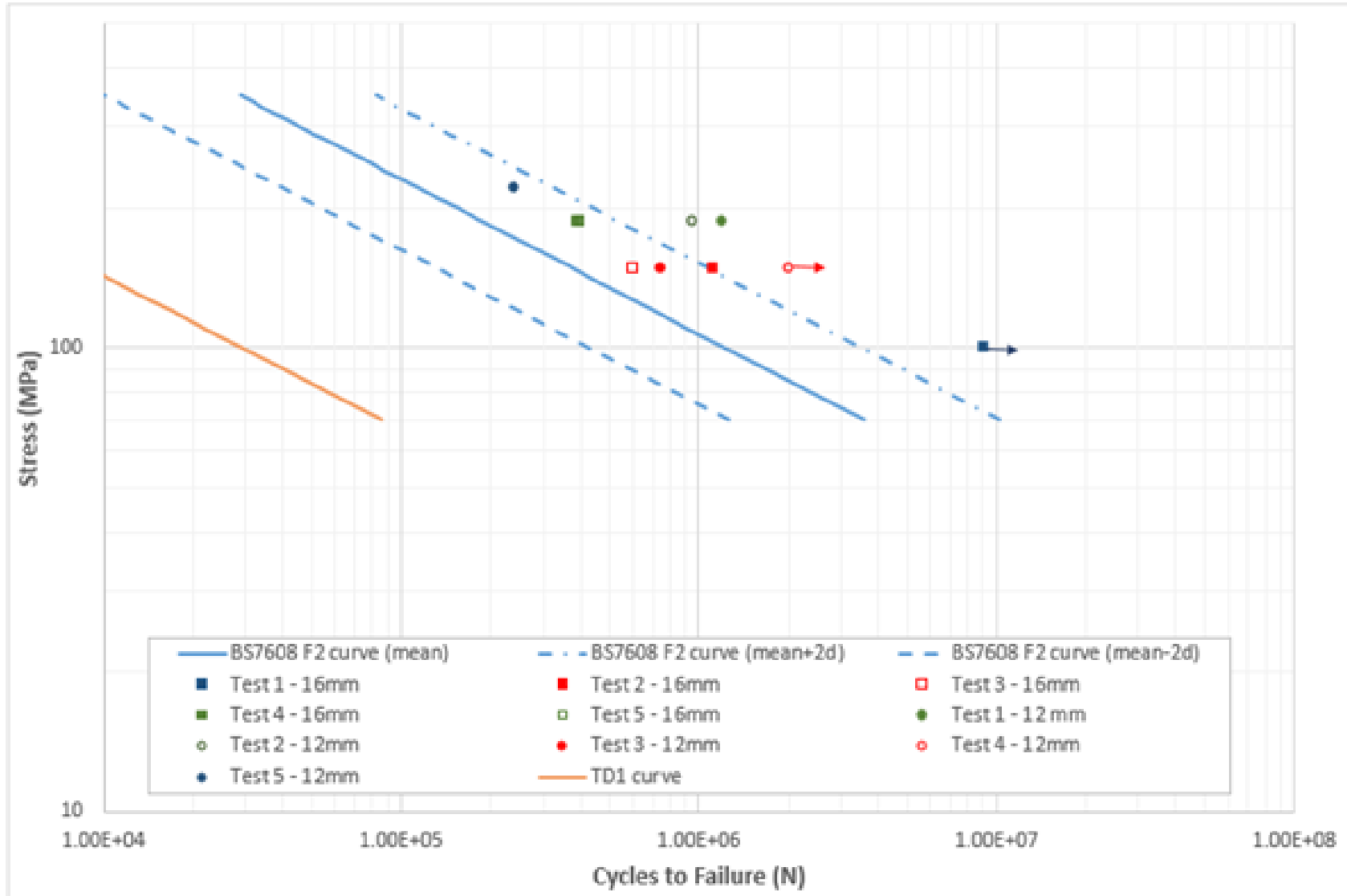




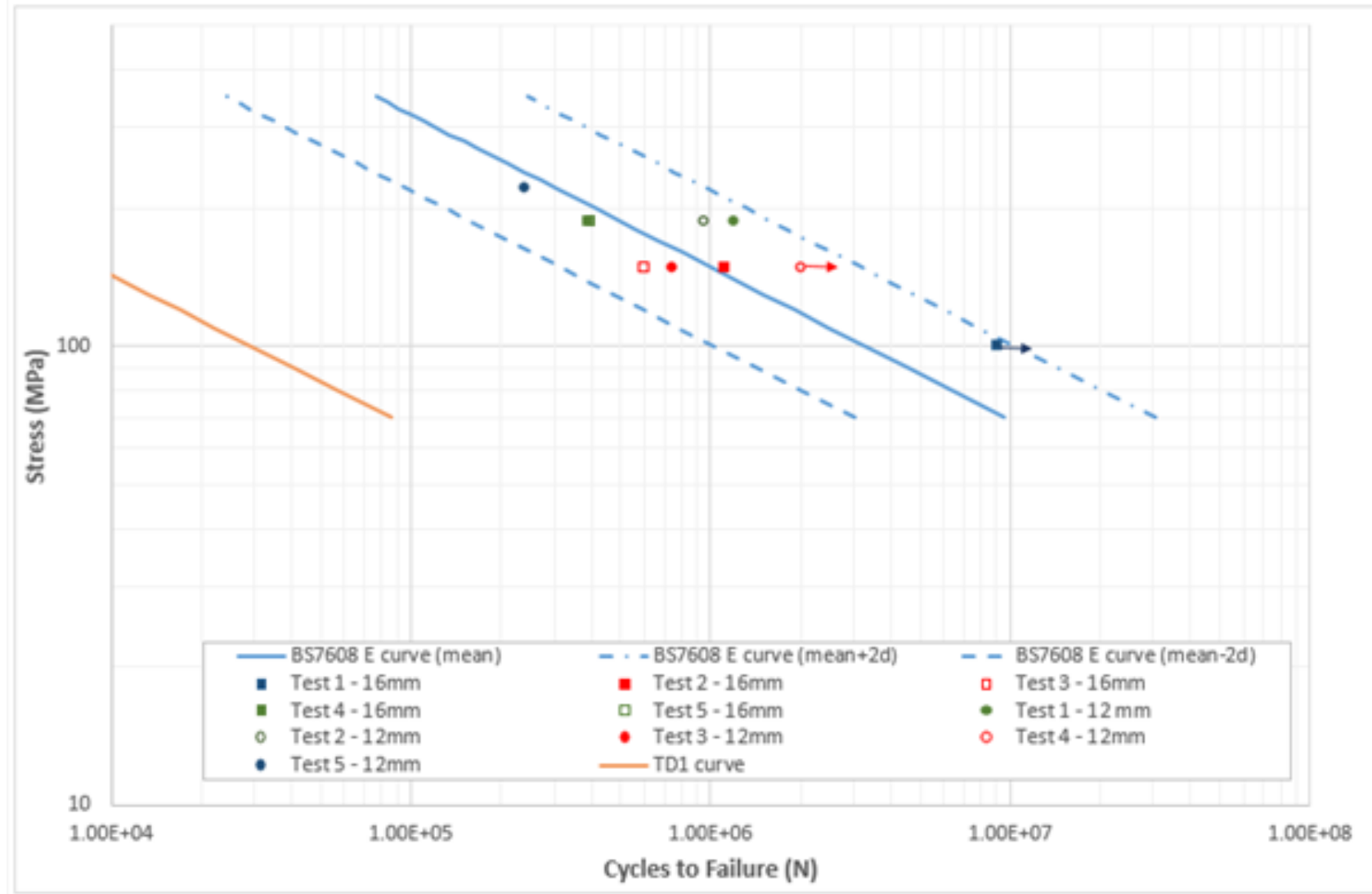
- Assessed against BS 7608 Fatigue Curves
 - 'E' curve for welds of known good quality (Strathclyde)
 - F2 curve for welds of un-known quality (Swansea)

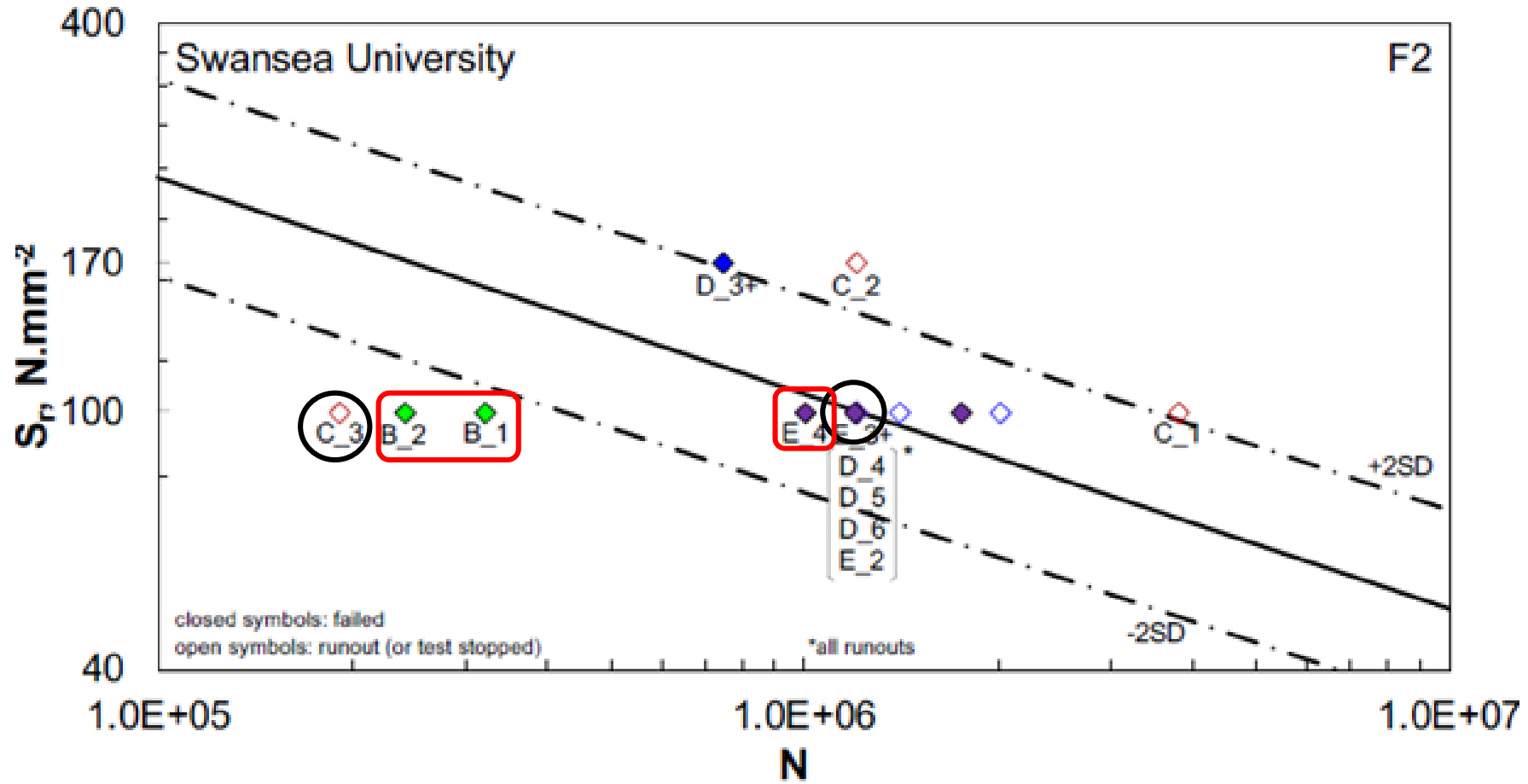


Welds without defects – Strathclyde (F2)



Welds without defects – Strathclyde (E)





 Fractured (had longitudinal cracks, IP, mis-alignment and undermatch in specimen)

 Test stopped due to rig issues

- All of the samples tested had acceptable mechanical properties, which indicated that the welds were relatively strong, tough and adequately ductile.
 - No evidence of in-service material degradation was seen, and no signs of fatigue or crack initiation were observed, despite the presence of weld defects which could act as stress concentrators.
 - Any poor results could be attributed to the presence of large defects in the small test pieces, so are not representative of the joint as a whole.
 - Microstructures seen were similar to those expected in a weld manufactured to current standards
- The results of the fatigue tests showed that the fatigue performance of specimens taken from pre-1972 pipe-weld samples would meet current fatigue S-N design criteria.
 - Test results obtained from these studies are conservative, as the specimens tested were taken from pipe-weld samples from pipelines which had been in operation for more than 40 years.
- The Swansea University study included fatigue samples containing defects, thereby confirming that the fatigue performance of welds containing defects typical of the welding standards applied to the fabrication of pre-1972 pipelines would typically be acceptable to current fatigue design criteria.
 - This research found that the BS 7608 F2 design curve could be used to model the fatigue behaviour of vintage samples containing defects.

- In the United Kingdom, not all pre-1972 girth welds were inspected during construction.
 - Historical welds may contain defects which do not meet current construction standards
- Static mechanical testing of these historical welds indicates mechanical properties are generally comparable with those welded to modern standards
 - The absence of inspection, not the quality of the welding, per se, is the differentiating factor.
- Samples from the UK and Canada behaved in a similar manner, suggesting that these observations are applicable in other countries where pipelines were constructed using similar codes and materials.
- The BS 7608 F2 curve is demonstrated to be applicable to vintage girth welds that contain significant welding defects.
- The data obtained does not support a hypothesis that pre-1972 welds are inherently of a poor quality, or have suffered a degradation in material properties over time. It is therefore concluded that historical welds constructed using similar materials to similar standards can be considered to be of good quality, unless there is inspection data to the contrary.

Questions/Comments?

