

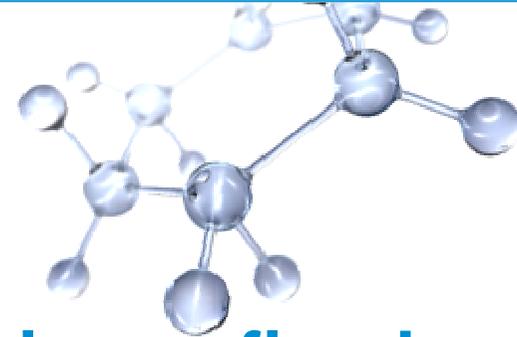
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Pipeline Integrity

Pipeline & Distribution Europe

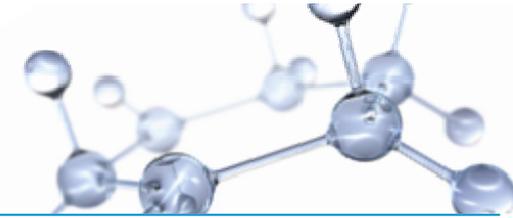
CASE STUDY: Failure of a dent in a refined products Pipeline



Wilson Santamaria
Esso Petroleum Company.
UKOPA Technical seminar
Eakring, UK – 9th June 2009

This presentation includes forward-looking statements. Actual future conditions (including economic conditions, energy demand, and energy supply) could differ materially due to changes in technology, the development of new supply sources, political events, demographic changes, and other factors discussed herein (and in Item 1 of ExxonMobil's latest report on Form 10-K). This material is not to be reproduced without the permission of Exxon Mobil Corporation.

Pipeline Data & Background



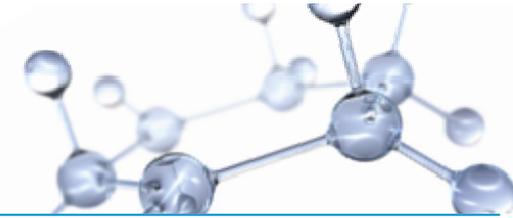
Product:	Refined products
Length:	228.5 km
Construction:	1973
MAOP:	77 barg
Hydrotest (1973):	96 barg
Diameter (D):	16-inch
Wall thickness (t):	mainly 6.35 mm
D/t:	>60
Pipe:	ERW, X52



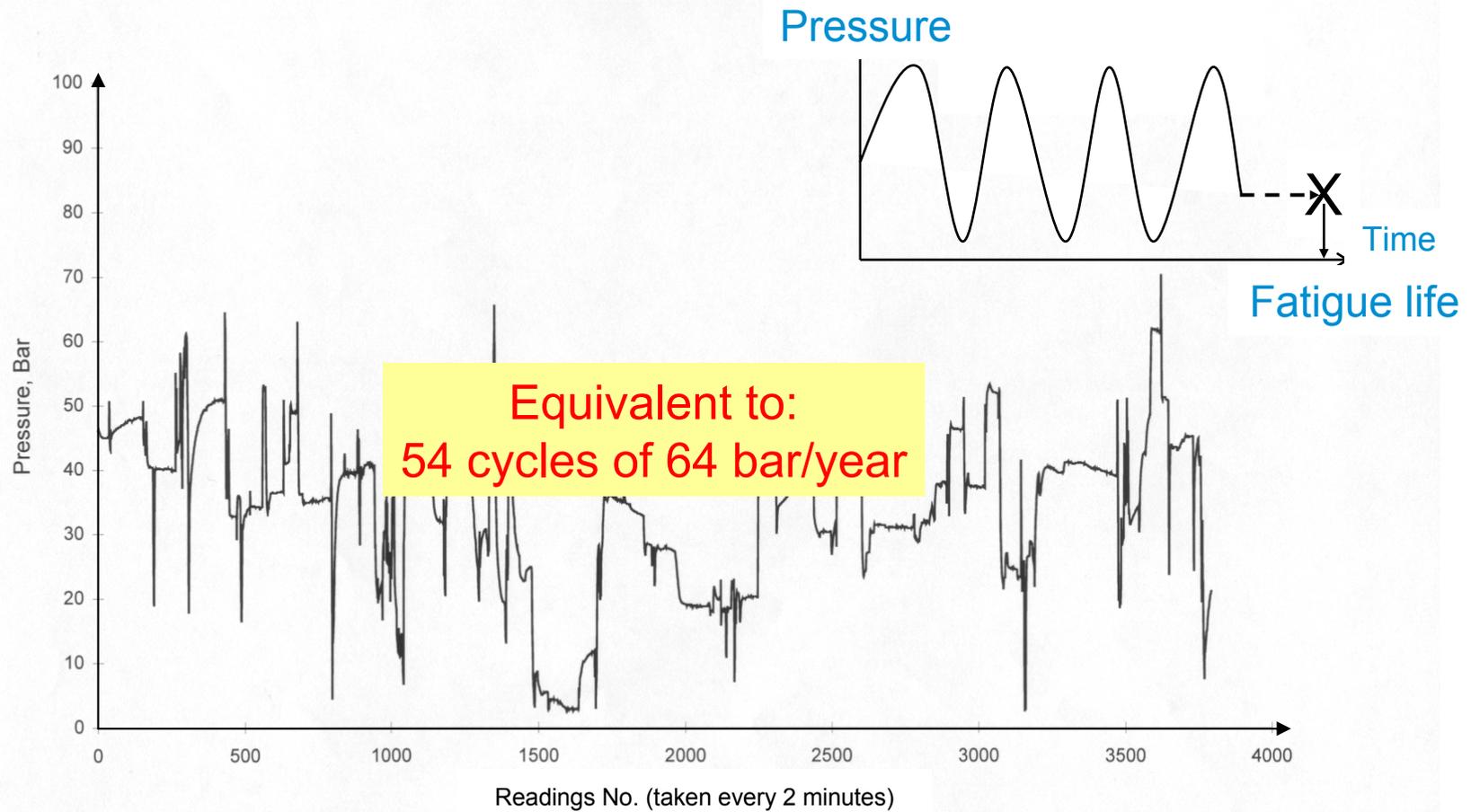
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Pipeline Data & Background

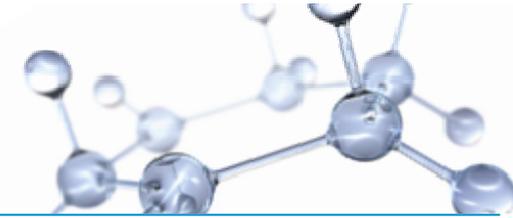


Pipeline Pressure Cycling



Typical Pressure Variations

Pipeline Data & Background



Pipeline Inspections Prior to Failure

- Latest In line inspections reported many dents in the pipeline, mainly at the bottom of the pipeline, indicating dents created by rocks
- ‘Rock’ dents are usually associated with construction, and hence would have been in this line since 1973, i.e. 31 years at time of failure.

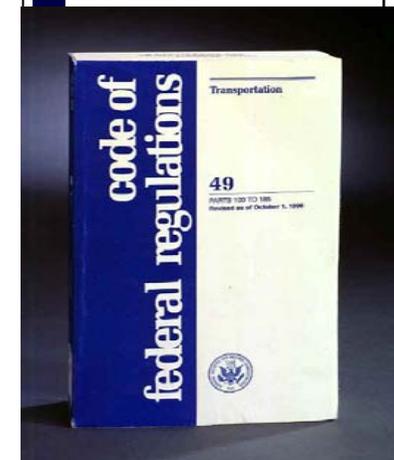
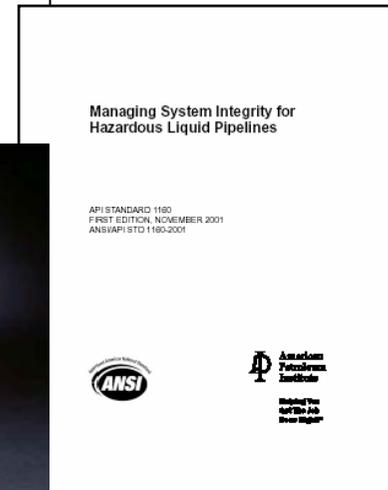
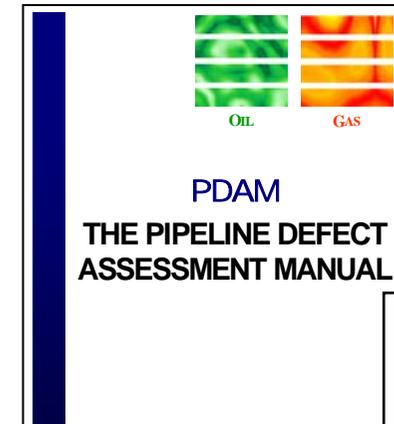
Smart pig	Dents reported	Dent Depth (% pipe diameter, OD)
‘MFL’	128	
‘TFI’	227	
‘Caliper’	122	Most <2% OD, Largest = 5.2% OD

Pipeline Data & Background



Guidance on Dents in Pipelines

- Dents are acceptable if dent is in lower portion of pipe (04:00 to 08:00), and depth is $\leq 6\%$ pipe diameter (OD) (e.g. ASME B31.4: 2006 and API 1160)
 - Largest dent in this line was measured at 5.2% OD
- USA regulations (195.452) also give this 6% limit, but emphasise that dent must be free of other defects such as cracks
- 'PDAM' gives a depth limit of 10% OD (Constrained), but this is for 'static' loads, not for 'cyclic' loads.
 - PDAM gives a fatigue calculation for cyclic loads



Pipeline Data & Background



Fatigue Assessment on Dents

- Consultant hired to use latest inspection results to determine the safety of the dents under 'static' and 'fatigue' loadings
 - *'It is recommended that: 38 dents are investigated and repaired following a priority listing based on dent size and location'*

Priority Listing				
Dent No.	Type	Dent Depth (%D)	Fatigue life (yrs)	'Priority'
1 to 3	Dent + weld or metal loss or top of line	0.2 to 2.2	'immediate'	1
4		0.7	8.2	2
5 to 9		Not listed		2
10		2	10.1	3
11	Dent	5.2	1.3	4
↓	↓	↓	↓	↓
38	Dent	2	13.5	4

Failure Data



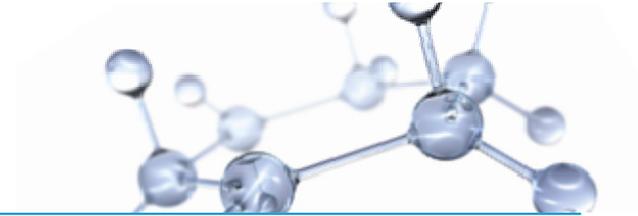
Failure Timeline

- Member of public reports hydrocarbon smell at pipeline road crossing.
- Pipeline shut-down, after visit by operator staff to site.
- Emergency procedures put into action.
- ‘temporary’ repair using epoxy-filled shell was installed.
- Pipeline Operation restarted.
- Failed section and temporary repair replaced with new pre-tested line pipe and line restarted.



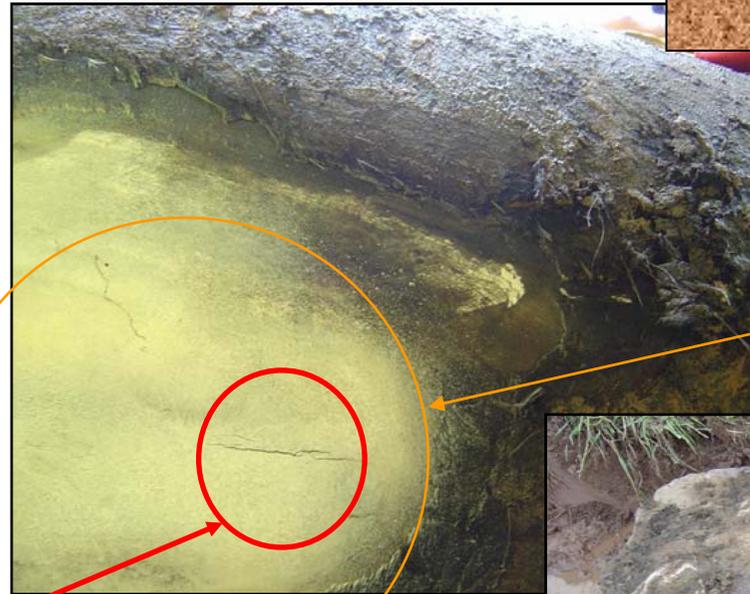
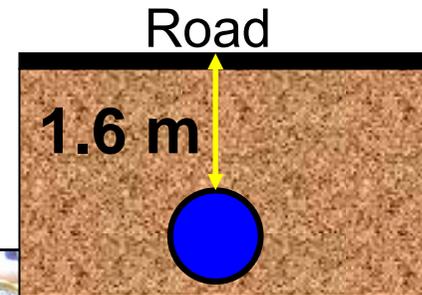
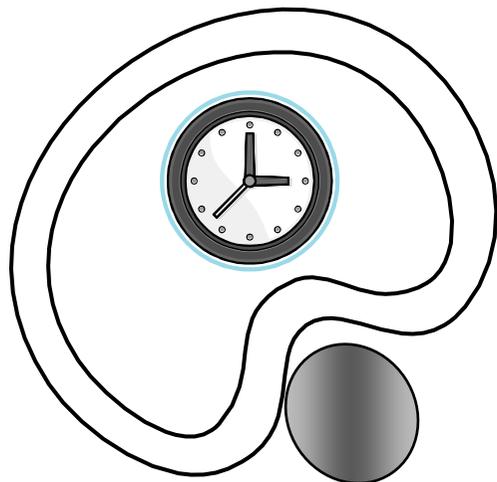
Epoxy-filled repair

Failure Data



Failure

- Failure was a leak through a crack in a dent
- Depth of cover = 1.6 m below a minor road
- Dent at 04:30, resting on large rock



Dent

Crack

Rock

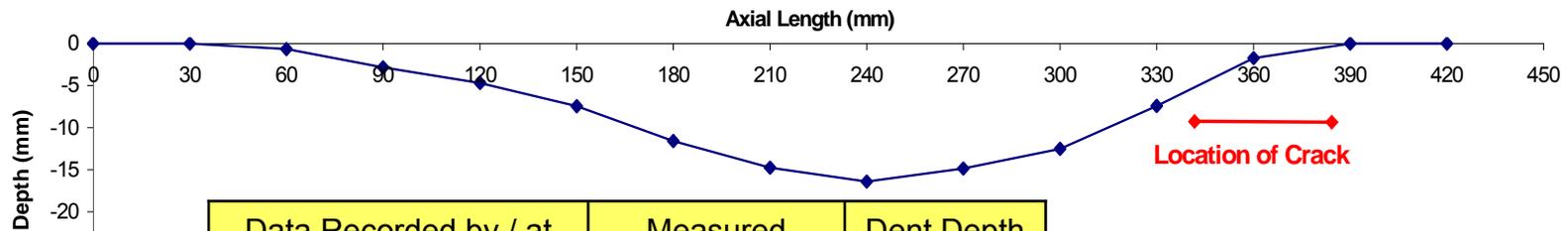


Failure Data

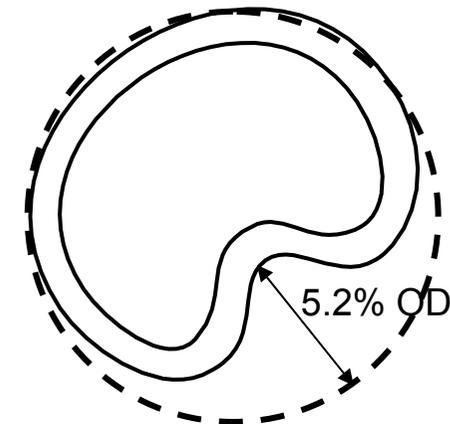
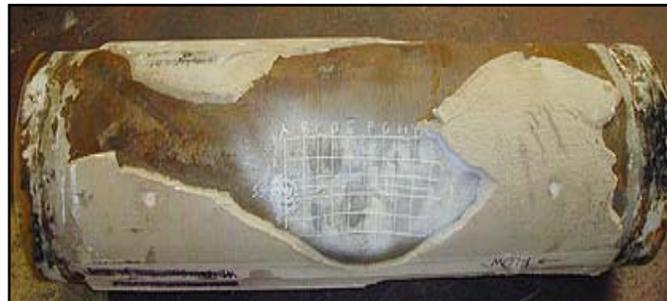


Failure Details: Dent

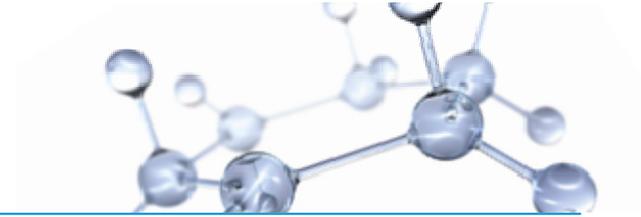
- Caliper pig reported dent had a depth of 5.2% of pipe diameter (OD). This was deepest dent in line.
- This dent was 11th on a 'Priority Listing'



Data Recorded by / at	Measured Depth (mm)	Dent Depth (%D)
Caliper Pig (at pressure)	21	5.2
site (no pressure)	16.4 - 18.5	4.0 - 4.5

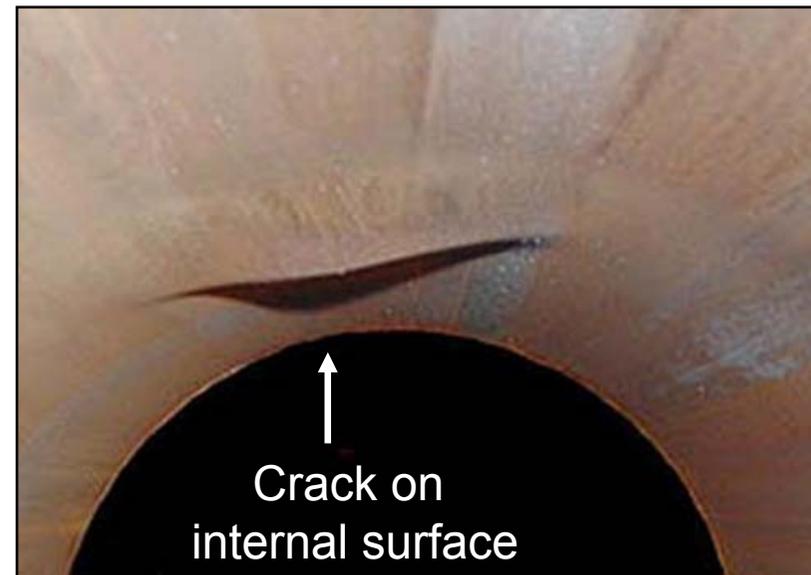
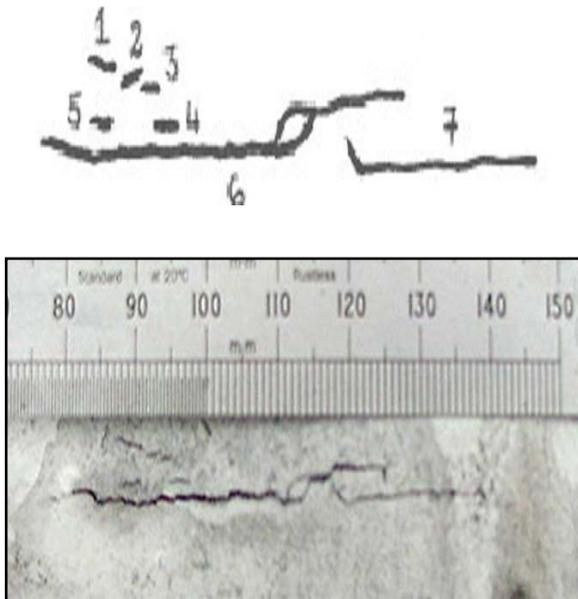


Failure Data



Failure Details: Crack

- 7 cracks on external surface
 - Longest crack was 45 mm
- Single crack on internal surface, coincident with 45 mm crack

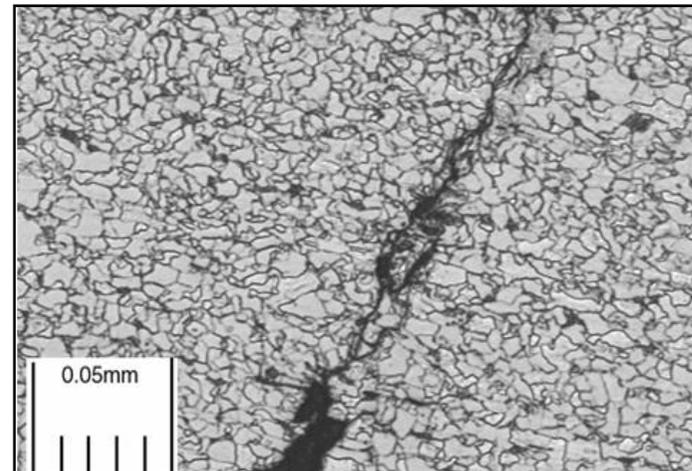


Failure Cause



Failure Location: Crack

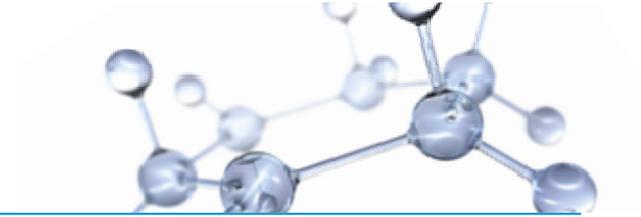
- Three separate initiation sites visible
- Fine beach-marking visible on surface
- No initial starter crack could be identified
- Crack was 'transgranular'
- 'SCC' and 'HIC' ruled out
- Hence, this is a fatigue crack



Crack was transgranular

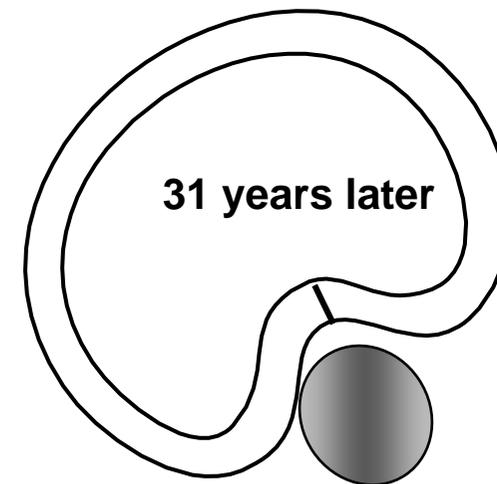
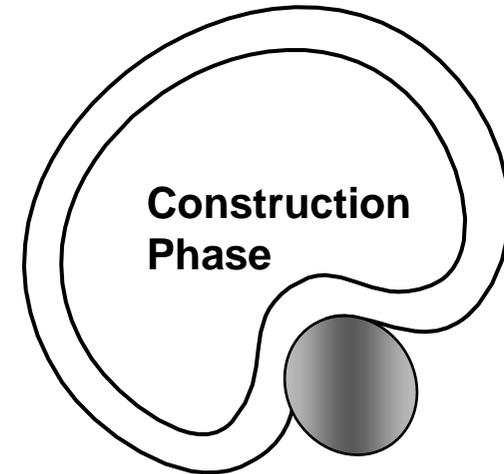
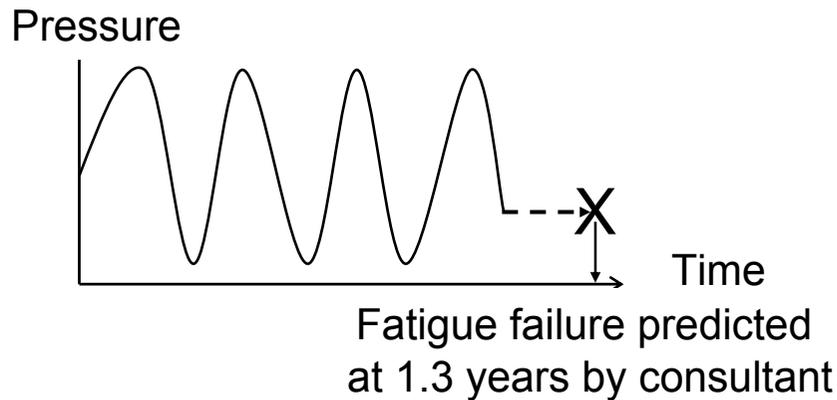


Failure Cause

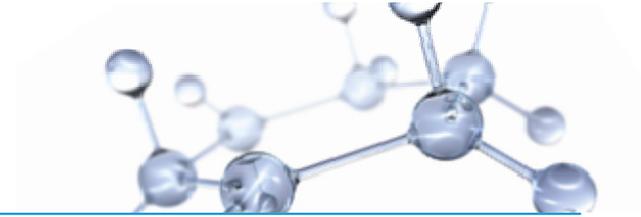


Likely Failure Cause

- Pipeline laid on rock during construction – dented.
- Rock may have been dislodged due to position (04:30), settlement, overburden load, and/or pipe product weight;
 - hence, rock could not ‘constrain’ any movement, and improve fatigue life.
- Pressure cycling created fatigue crack.
- Crack caused leak.

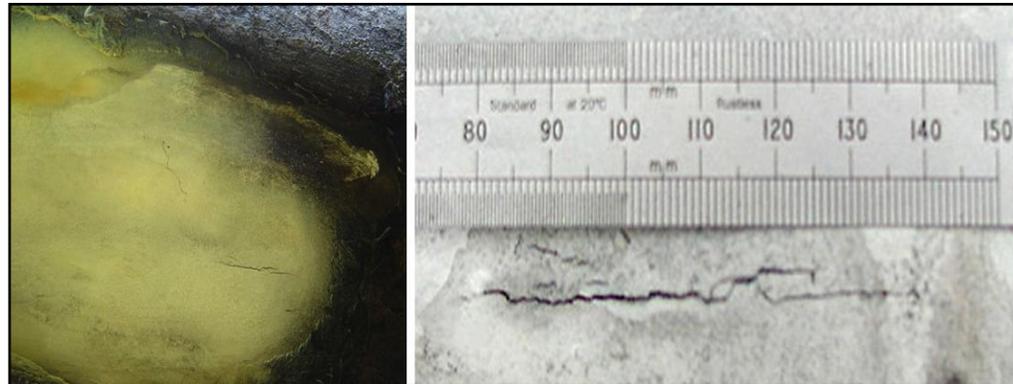


Summary

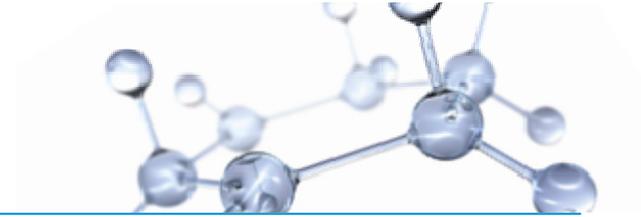


- Last set of Inspection consisted of MFL, TFI and Caliper: pipeline inspected for dents:
 - dent that failed was reported, and was deepest in line.
- Consultant's fatigue study on the line:
 - placed the dent that eventually failed at 11th on a 'priority' list.
 - listed fatigue life as 1.3 years.
- Repair programme commenced.
- Pipeline failed because a fatigue crack grew in this deepest dent:
 - the fatigue was caused by the pipeline's pressure cycling.

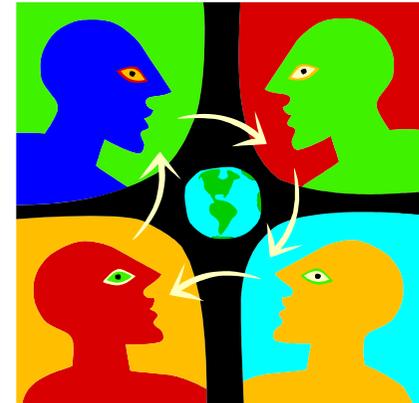
Fatigue crack grew from outside, indicating no rock restraint



Discussion



- 'Best practice' adopted (latest smart pigs :MFL, TFI and Caliper) and dent detected and sized:
 - but pipeline failed 7 months later...
- Hired consultant to advise on possible fatigue failures of Pipeline. Consultant listed failed dent as 11th 'priority'
 - but pipeline failed 5 months later...
- What could we have done better?
- Would other operators have followed same process and had a similar failure?
- Do we need general repair guidelines





Thanks for your attention.

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