Vibration-Induced Fatigue – A Risk-Based Approach

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energy API

ASSET INTEGRITY THROUGH CORROSION MANAGEMENT, INSPECTION AND ENGINEERING TECHNOLOGY

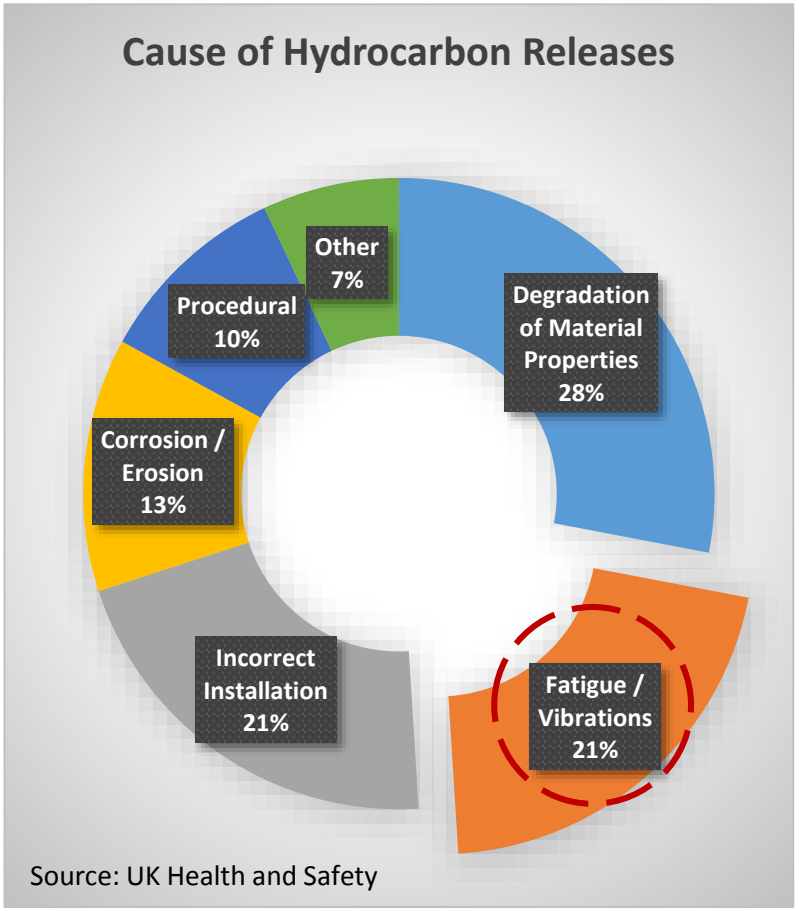
Presentation Overview

1. Introduction
2. Common Vibration Issues
3. Sources of Vibration
4. The Industry Gap
5. Case Studies
6. Best Practices
7. A Risk-Based Approach
8. Summary

Introduction

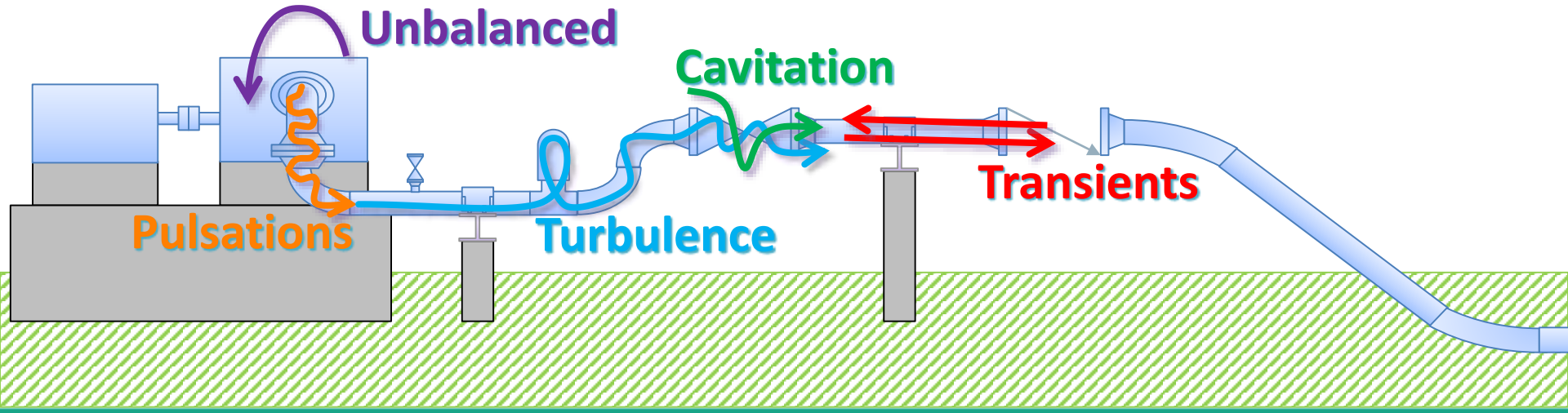
- What is vibration-induced fatigue (API 571)?
- What causes it?
- How does it affect integrity?
  - Shaking mainline
  - Small-bore connections
  - Loosening of bolts and cracking of supports
- How can you prevent it?

Examples of Vibration Problems



Vibration Excitation Mechanisms

- Machinery excitation
- Pressure pulsation
- Turbulence
- Flashing/cavitation
- Transients (water hammer)
- Rotating stall
- Dead-leg pulsation
- Acoustic-induced



The Industry Gap

What?

- Vibration is not properly managed in mechanical integrity programs
- Reoccurring failures
- Reactive approach

Why?

- Most integrity professionals lack tools/experience to address vibration
- Reliant on operator surveillance
- Focused on corrosion

Solution

Integrate vibration into your mechanical integrity program

Case Study #1 – Plunger Pump

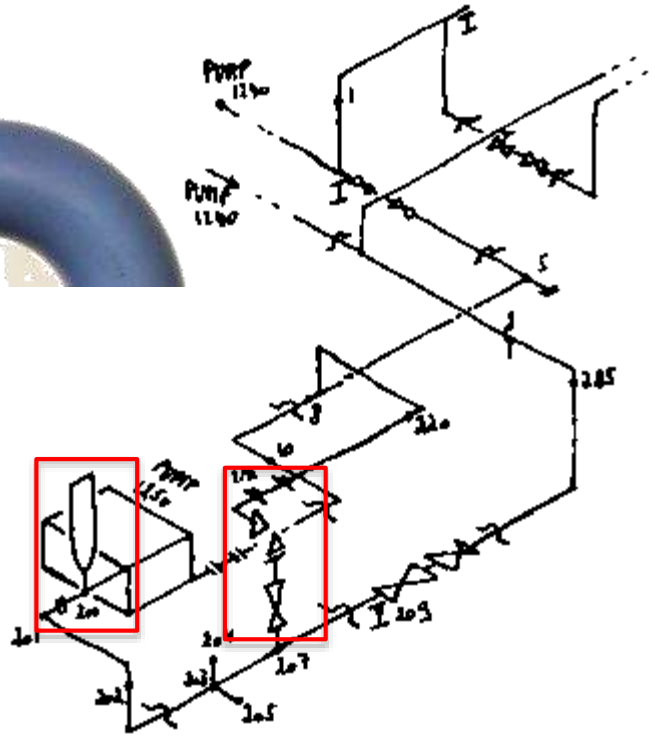
Description:

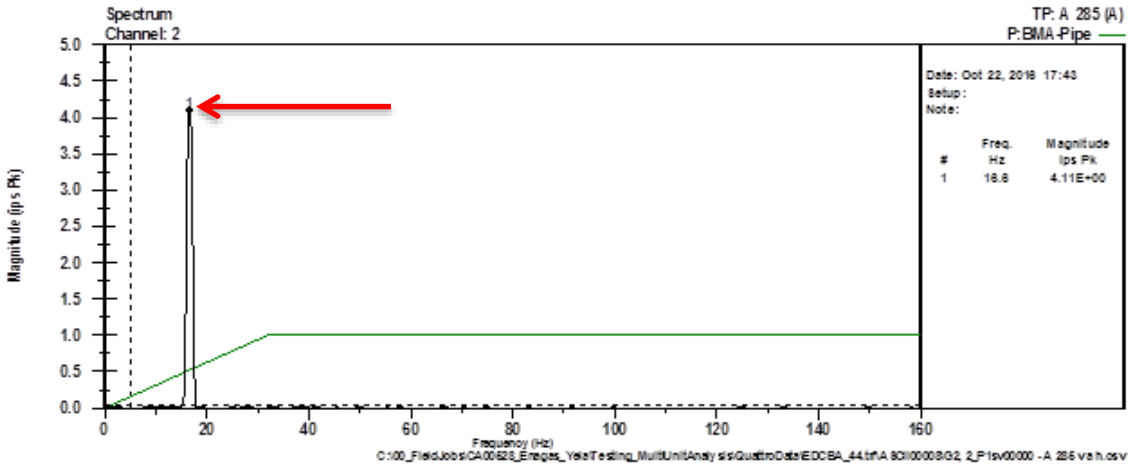
- Quintuplex Plunger Pumps @ 297 HP
- Liquid Propane
- Speed Range 200-400 RPM
- 6 months in operation
- Very high piping vibrations!

Case Study #1 – Plunger Pump

Field Visit:

- High vibrations measured
- PSV resonant
- Dampener resonant

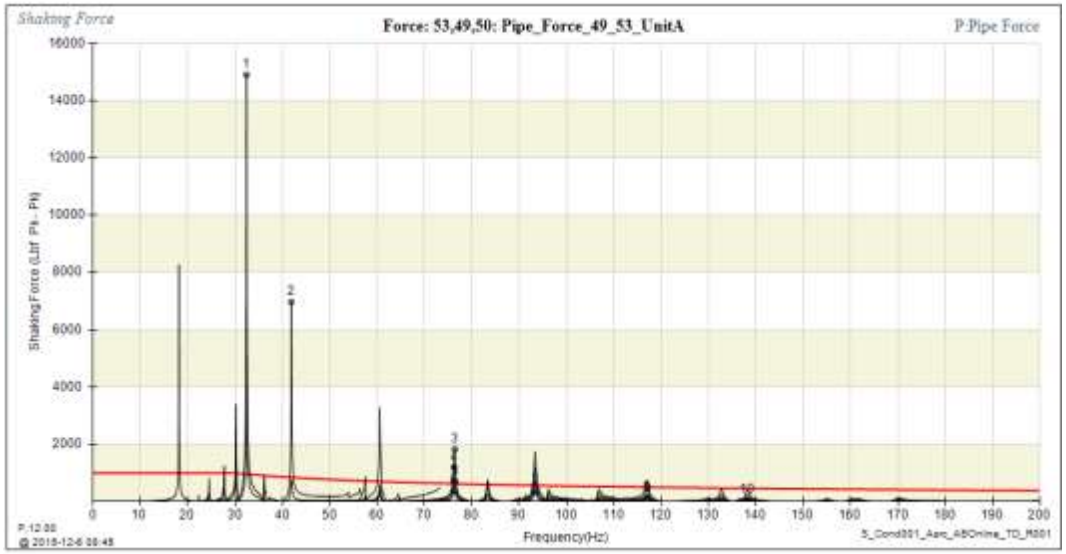


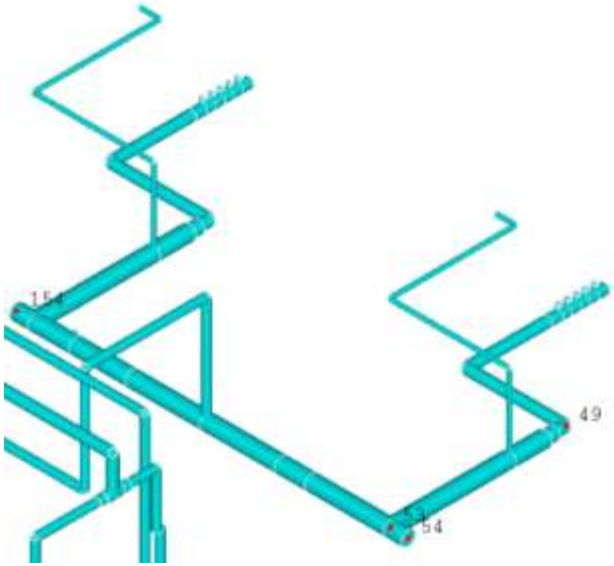


Case Study #1 – Plunger Pump

Vibration analysis (API 674):

- System modelled using proprietary software
- Very high shaking forces predicted
- Due to pressure pulsations





Case Study #1 – Plunger Pump

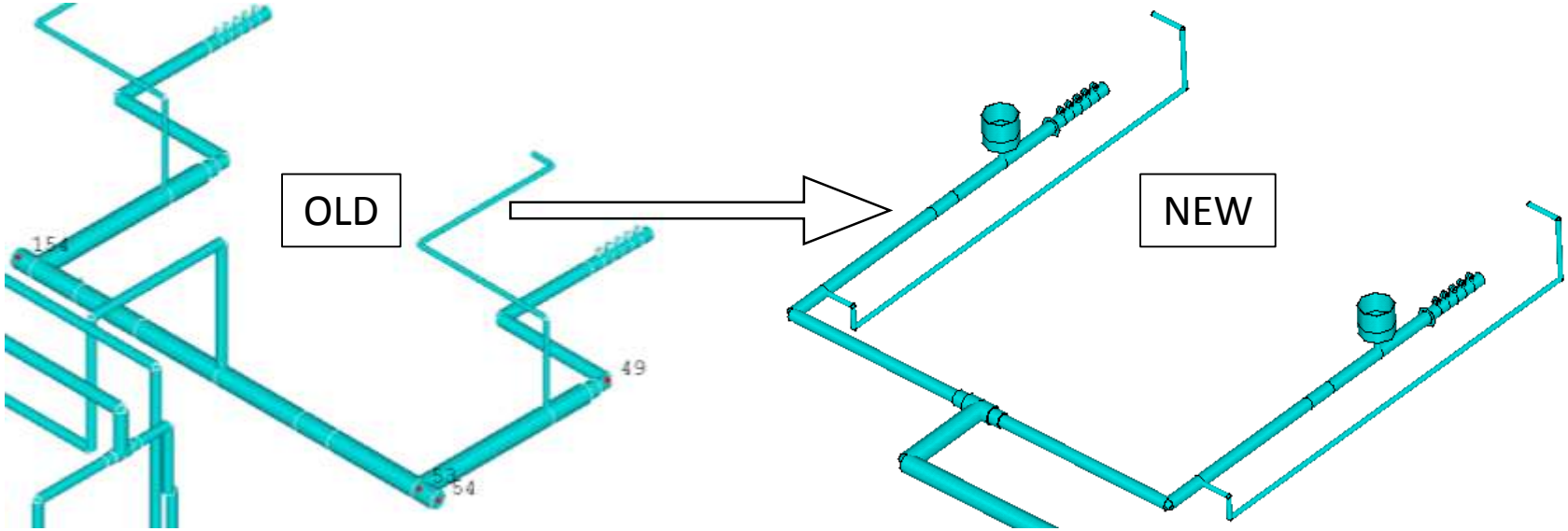
Field follow-up:

- NDT locations determined from highest predicted forces
- Significant cracking found
- Units shutdown

Case Study #1 – Plunger Pump

Outcome:

- Owner had to replace significant amounts of piping
- Downtime, however, **<u>hydrocarbon release avoided!</u>**

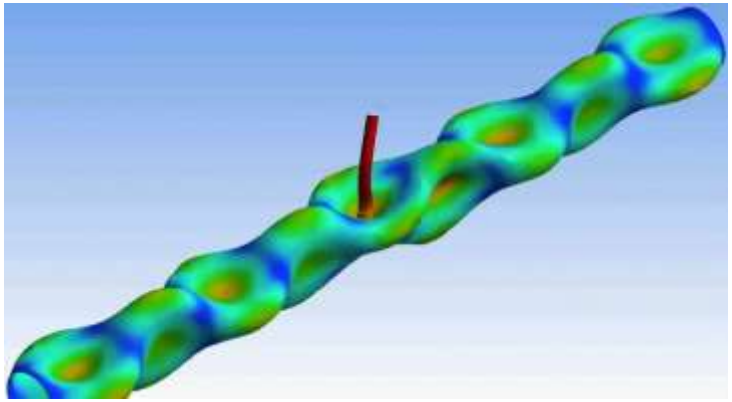


Vibration analysis integrates with integrity management

Case Study #2 – Acoustic-Induced Fatigue

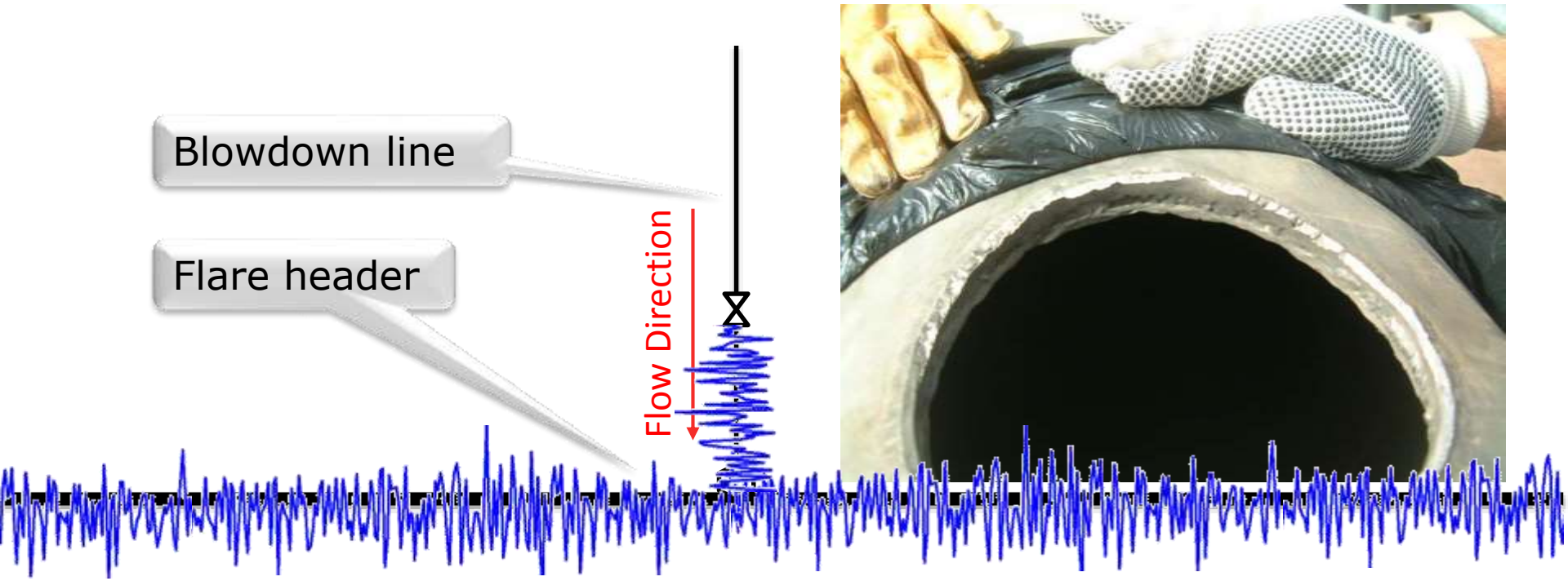
Description:

- At pressure letdown (eg, control valve, blowdown, PSVs)
- Flare systems (API 521)
- Not visible, but frequently audible
- Short time to failure
- Failures at branches, supports, etc



Case Study #2 – Acoustic-Induced Fatigue

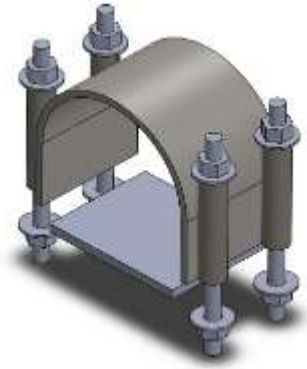
- Catastrophic failure
- 6” blowdown line to 16” flare header
- Desktop screening would have flagged the connection as a concern

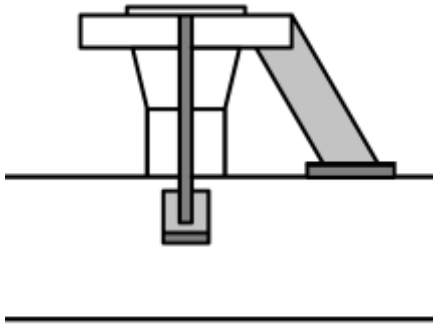


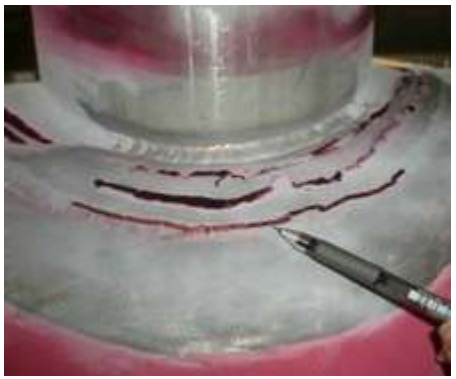
Case Study #2 – Acoustic-Induced Fatigue

Recommendations:

- Conduct screening of pressure-relief systems (API 521)
- Use forged tees instead of fabricated tees
- Change from welded to bolted supports
- Reinforce branch connections, where necessary
- Target NDT at high-risk branch connections







Small-Bore Connections

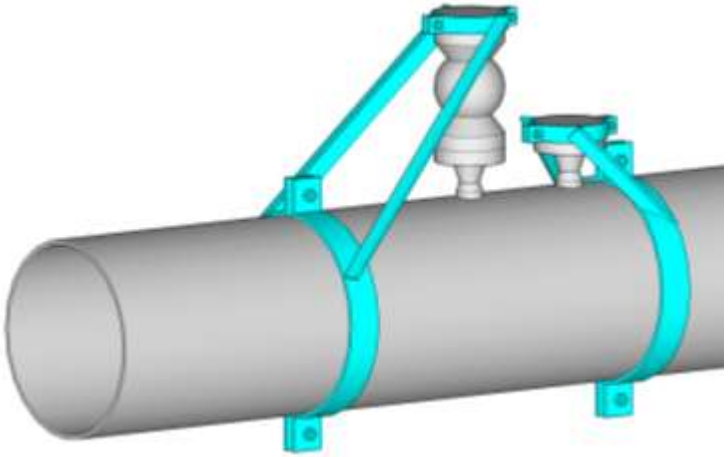
Description:

- Problematic in vibrating service
- Should be removed, moved, redesigned or braced

Small-Bore Connections

Recommendations:

1. Avoid redundant connections (or remove them)
2. Reduce length and mass
3. Brace back to the vessel or pipe (not to anything else!)
4. Use Schedule 160 pipe for nipples
5. Use monoflange valves, or similar



Best Practice Recommendations

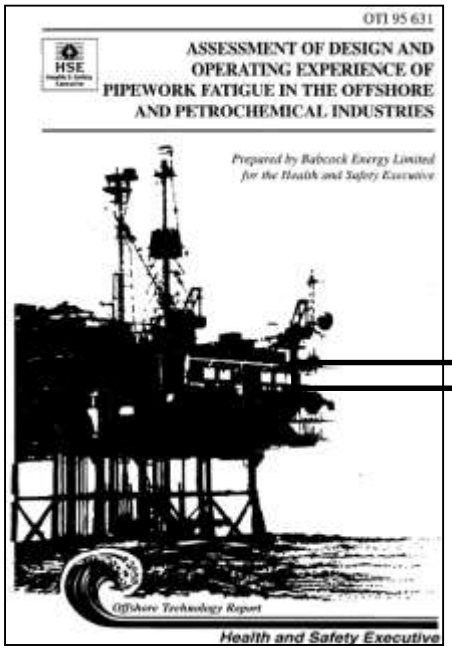
1. Conduct pulsation analysis for pumps > 25 hp
2. Conduct pulsation analysis for compressors > 75 hp/cyl.
3. Avoid elevated process piping and unsupported elbows
4. Ensure process piping supports are effective
5. Do not use U-bolts in vibrating service
6. Minimize or brace small-bore connections

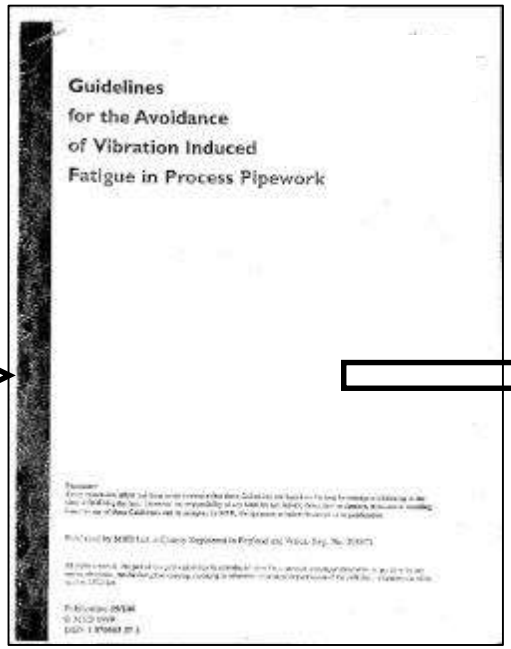
A Risk-Based Approach

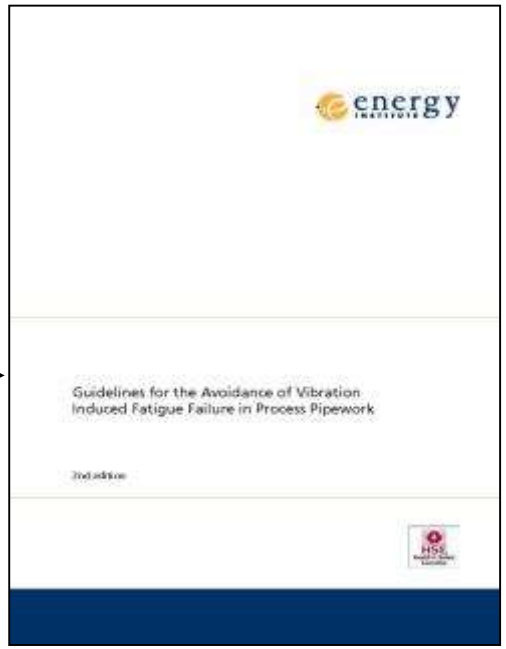
Background:

Regulators were concerned over number of fatigue failures

A JIP was formed including O&G majors and consultants





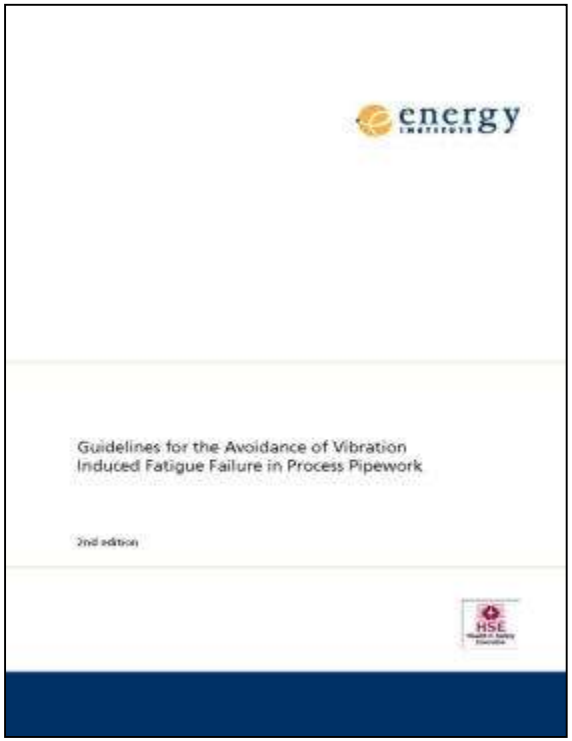


A Risk-Based Approach

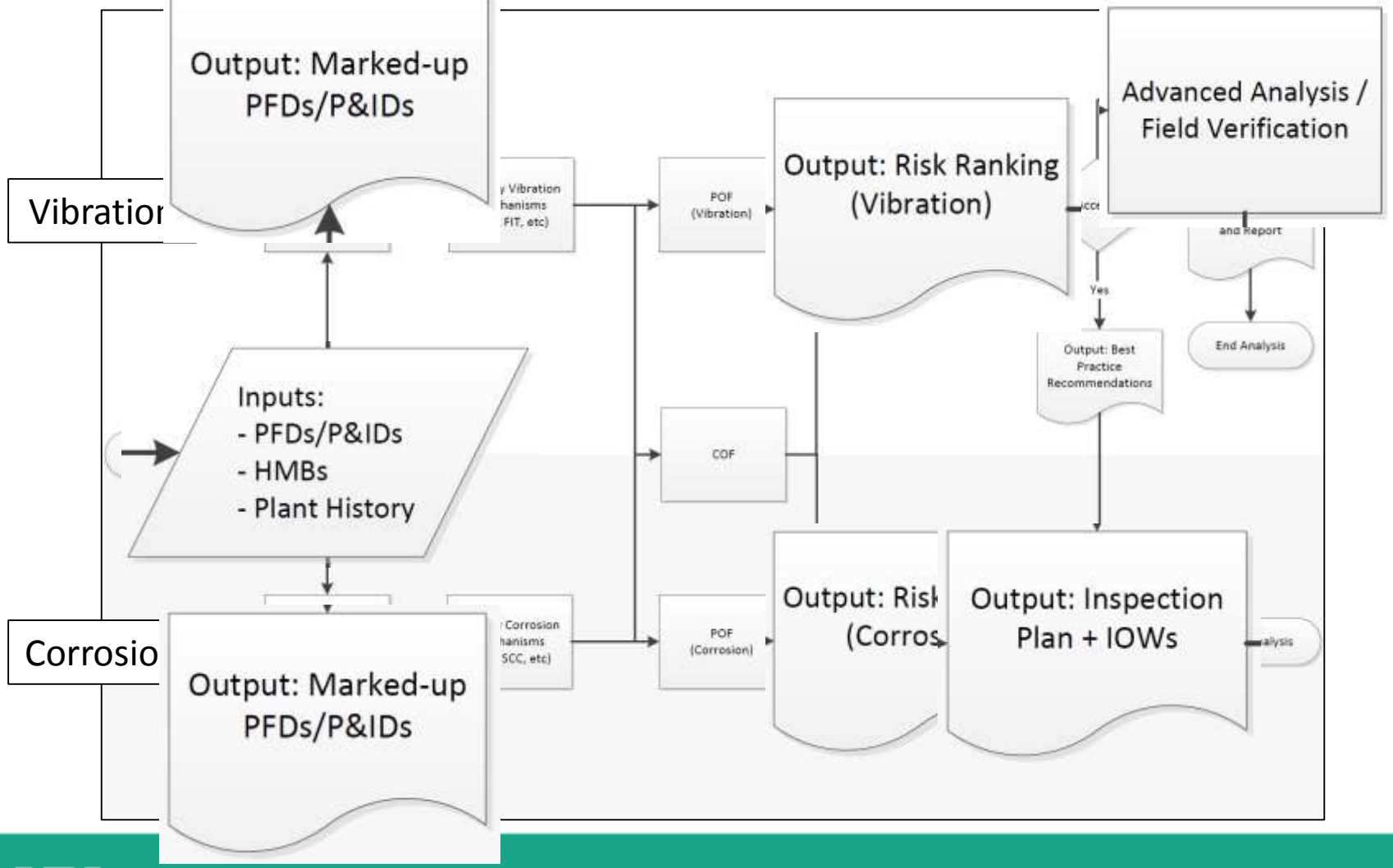
Energy Institute

Guidelines for the Avoidance of Vibration-Induced Fatigue Failure in Process Pipework, 2nd Ed, 2008

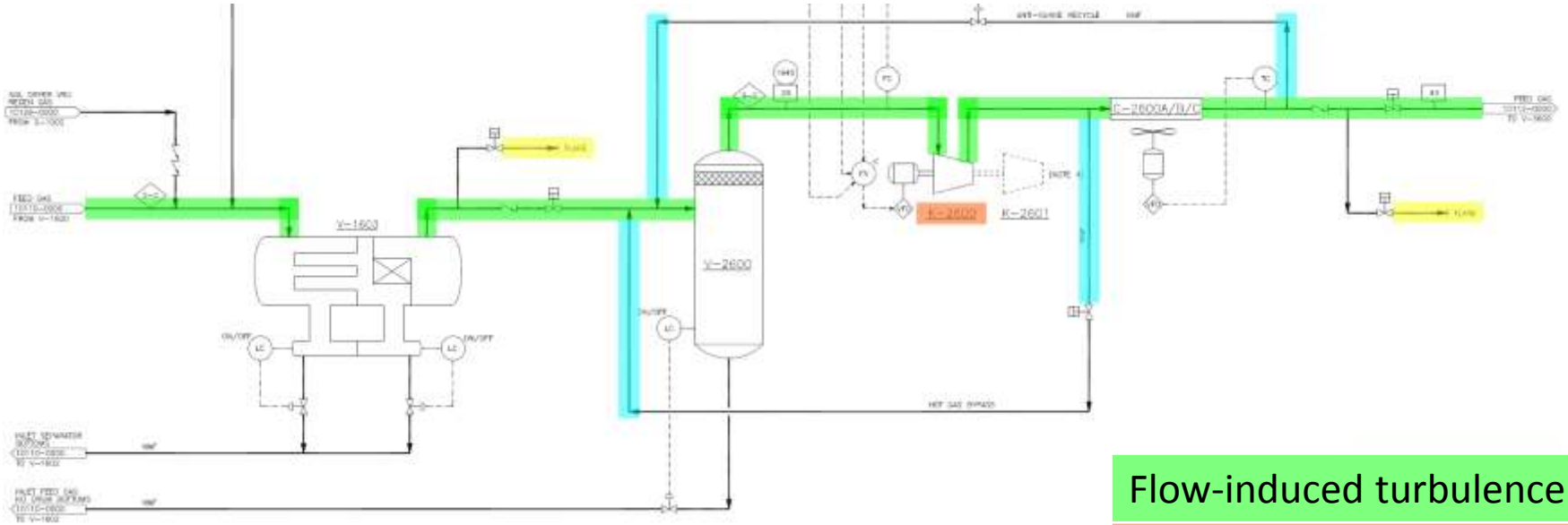
- A screening process for facilities
- A proactive, risk-based approach
- Qualitative and quantitative assessment leads to a "Likelihood of Failure" (LOF) value



Complementary Approaches



Marked-up PFDs/P&IDs



Flow-induced turbulence

Mechanical excitation

Dead-leg pulsation

Acoustic-induced vibration

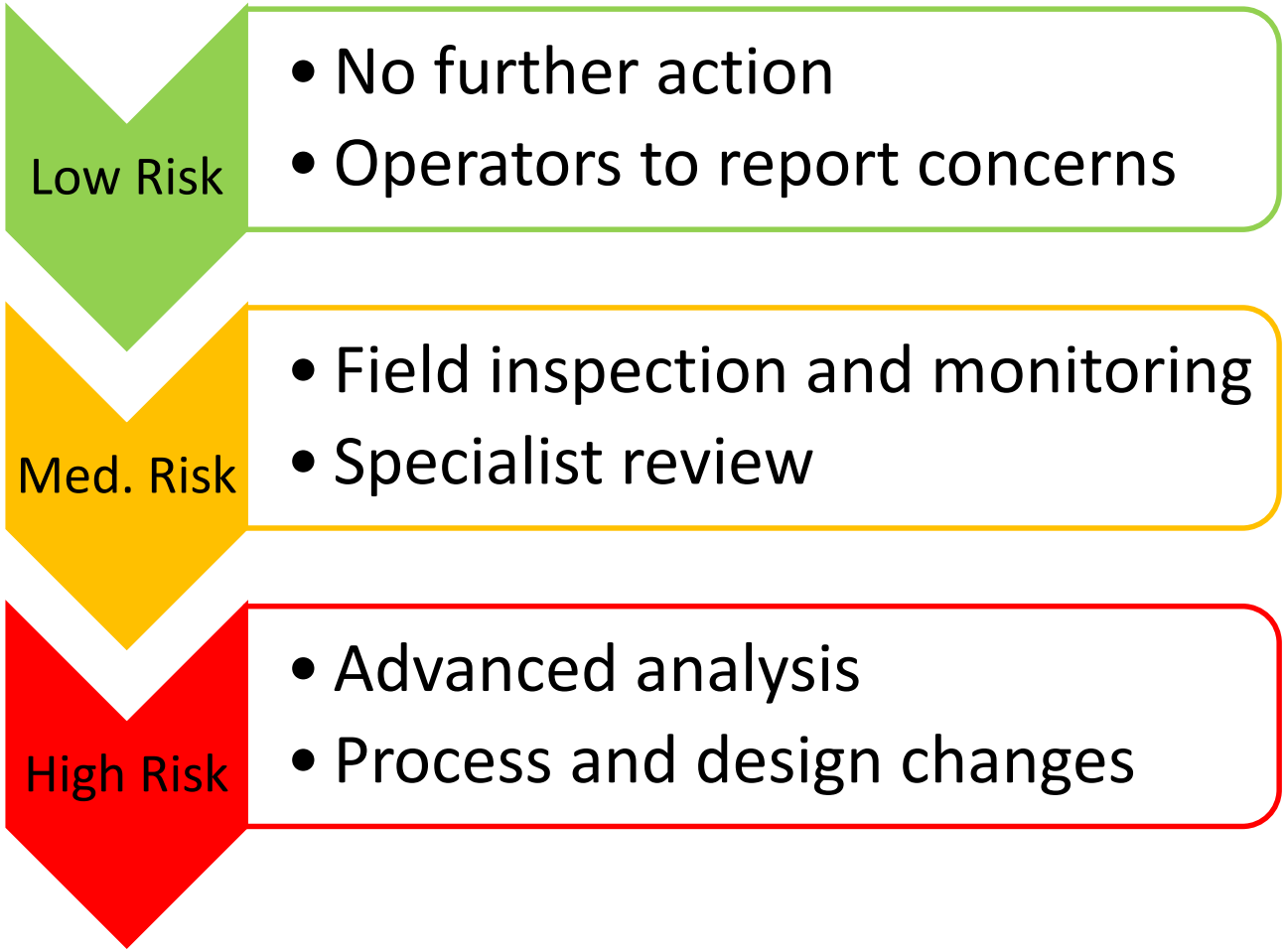
Qualitative Assessment

Modules / Qualitative Assessment	
(FIT) Flow induced turbulence (EI AVIFF Guidelines T2.2)	(fit)
Is the maximum value of kinetic energy (ρv^2) of the process fluid above 5000 kg/m s²?	Yes ▾
(SBC) Small bore connections (EI AVIFF Guidelines)	(sbc)
Is any of the main line LOF's ≥ 1?	Yes ▾
Mechanical Excitation (EI AVIFF Guidelines T2.3)	(mex)
Is there any rotating or reciproating machinery?	No ▾
Reciprocating items (EI AVIFF Guidelines T2.4)	(rec)
Are there any positive displacement pumps or compressors?	No ▾
Pressure drops & valves (EI AVIFF Guidelines T2.8 and T2.9)	(prd)
Are there any systems which exhibit flashing or cavitation, or are there any fast acting opening or closing valves?	Yes ▾
Thermowells	(thw)
Are there any intrusive elements in the process stream?	No ▾
Known vibration problem (EI AVIFF Guidelines - Specialist)	(vib)
Is there a history of pipework vibration issues on this system, or similar systems?	No ▾

Likelihood of Failure (LOF) Values

Record ID	P&ID	Line Reference	Description	Pipe Details	Stream	% of Stream	Qualitative Assessment (Modules)	Flow induced turbulence	Flow induced pulsation	Small bore connections
1	0428-MI20-90DP-3406	16-SW-N-40604 - 14" section, 16-SW-N-40606 - 14" section	System 1	14" 7000M WT:9.0 Glass Reinforced Epoxy	System 1 - Stream 1(liquid)	100	v = 6.2 m/s ρv² = 38594	0.97		
2	0428-MI20-90DP-3406	16-SW-N-40604/3P2-3	System 1	16" 7000M WT:10.3 Glass Reinforced Epoxy	System 1 - Stream 1(liquid)	100	v = 4.8 m/s ρv² = 22630	1.13		0.66
3	0428-MI20-90DP-3160	24-SW-N-40615/3PU	System 1	24" 7000M WT:15.4 Glass Reinforced Epoxy	System 1 - Stream 2(liquid)	100	v = 4.2 m/s ρv² = 17868	0.65		
4	0428-MI20-90DP-3435	24-SW-N-42601	System 2	24" 7000M WT:15.4 Glass Reinforced Epoxy	System 2 - Stream 1(liquid)	100	v = 2.2 m/s ρv² = 4881	0.18		

Modifications / Inspection Planning



Summary

1. Vibration is a **significant threat** to facility integrity
2. Vibration is **not managed effectively** in integrity programs
3. **Tools and experience exist** to assist integrity professionals
4. Vibration **screening is complementary** to integrity methods
5. **Field** vibration **measurement** is **effective** alongside NDT

A successful integrity program includes vibration!