UKOPA

United Kingdom Onshore Pipeline Operators' Association

Good Practice Guide

Management of Pipework Vibration

UKOPA/GPG/030 Edition 2

January 2026

GUIDANCE ISSUED BY UKOPA:

The guidance in this document represents what is considered by UKOPA to represent current UK pipeline industry good practice within the defined scope of the document. All requirements should be considered guidance and should not be considered obligatory against the judgement of the Pipeline Owner/Operator. Where new and better techniques are developed and proved, they should be adopted without waiting for modifications to the guidance in this document

Comments, questions, and enquiries about this publication should be directed to:

UK Onshore Pipeline Operators' Association
Ripley Road
Ambergate
Derbyshire
DE56 2FZ

E-mail: secretary@ukopa.co.uk

Website: www.ukopa.co.uk

Revision and change control history

Planned revision: 2031

Edition	Date	No. of pages	Summary of changes
1	20/03/2020	15	Issued for use
2	24/01/2026	17	Includes editorial review, incorporation of member feedback, and updates to referenced standards

CONTENTS

1 INTRODUCTION

This guidance aims to provide background knowledge on the cause and effects of vibration in above ground piping and associated equipment, including good design practices and methods to identify, measure, and monitor vibration. Mitigation and remedial actions to prevent failure through vibration are introduced, as well as specialist predictive techniques.

1.1 Background

There have historically been a number of vibration-related fatigue failures of pipework at Above Ground Installations (AGIs). The following list outlines some of the incidents experienced:

- **Failures at threaded connections -** Threaded connections are a potential site for initiating a fatigue crack, due to the local stress concentration factor at the root of the thread, with the stress distribution being highest at the first engaged thread as it enters the valve body or flange. Fatigue cracks can initiate at this location if the fatigue loading is high enough.

- **Failures at welds -** The toe of a fillet weld is a potential site for fatigue failures due to the local stress concentrations and the presence of microscopic imperfections such as slag inclusions. These factors promote crack initiation at the weld toe. Under conditions of sufficiently high cyclic loading, particularly from vibration, the fatigue life is typically governed by the propagation phase of these cracks rather than by the initiation phase.

- **Failures at compression fittings -** Fatigue failures have also occurred on impulse pipework at compression fittings, with the failure originating from where the ferrule of the compression fitting is located on the pipe.

1.2 Scope

This good practice guide provides guidance on identification and management of pipework vibration on AGIs. Guidance is based on the Energy Institute document 'Guidelines for the Avoidance of Vibration Induced Fatigue Failure in Process Pipework' [1], relevant standards [2, 3, 4] and operator internal documents.

1.3 Application

The guidance in this document is applicable to high pressure AGIs.

Within this document:

Shall: indicates a mandatory requirement.

Should: indicates good practice and is the preferred option.

2 CAUSES OF VIBRATION

The main causes of vibration related problems are:

2.1 Flow Induced Turbulence

Flow induced turbulence can be severe if the flow velocities are high, the flow path is tortuous or major flow discontinuities occur in the system (typical examples are partially closed valves, short radius or mitred bends, tees or reducers).

2.2 Mechanical Excitation

Mechanical excitation can occur in systems containing reciprocating or positive displacement compressors and pumps. The dynamic forces generated by such equipment can induce vibration in connected pipework and common support structures. This may affect pipework which shares supports with the vibrating system, even if it is not directly part of the excitation source. The transfer of these dynamic forces can result in excitation of nearby pipework, with vibration issues typically occurring close to the source of mechanical excitation.

2.3 Pulsation

Excitation of acoustic natural frequencies can amplify low level pressure pulsations in a system, resulting in high amplitude pressure pulsations and excessive shaking forces. The most serious vibration problems occur when the frequency of excitation coincides with both the acoustic and structural natural frequency (i.e. a resonant condition).

High frequency acoustic energy can be of particular concern as it tends to affect safety related (e.g. relief and blowdown) systems, in addition to which the time to failure is short (typically a few minutes or hours) due to the high frequency response.

Gas systems, at relatively high flow velocities, can exhibit a form of tonal excitation which is generated when flow past the end of a dead leg branch generates an instability at the mouth of the branch connection.

Thermowells or other probes which extend into the flow stream (e.g. chemical injection quills or flow measurement probes) can be susceptible to resonant excitation caused by vortex shedding.

2.4 High Frequency Acoustic Excitation

Severe sources of vibration energy associated with the process conditions or the geometry of the flow path. At a gas AGI the dominant source is likely to be the pressure drop occurring at each regulator.

2.5 Surge

Surge (or water hammer) is a pressure wave caused by kinetic energy of a fluid in motion when it is forced to stop or change direction abruptly. High transient forces can be generated by the rapid change in fluid momentum caused by situations such as the sudden opening or closing of a valve (e.g. fast opening of a relief valve) or changing flow direction to one with no through route (e.g. dead-heading the flow - when a pump runs against a closed valve).

2.6 Cavitation

Cavitation can occur where a localised pressure drop occurs in liquid systems and is followed by a pressure recovery (e.g. at a control valve or restriction such as an orifice plate). If the pressure falls below the vapour pressure of the liquid, vapour bubbles will form. When the pressure recovers to greater than the vapour pressure, these bubbles collapse, releasing energy, causing noise, damage to mechanical components and vibration.

2.7 Flashing

If the pressure in a pipe falls below the vapour pressure of the fluid, the fluid can suddenly change from liquid to vapour, known as flashing. This results in large forces. Flashing typically occurs when there is localised pressure drop in the process fluid or when two fluid types mix.

2.8 Vulnerable Geometry

Small bore attachments can experience vibration problems when there is a cantilevered pipe with a large mass on the end (e.g. flanges or valves), a long unsupported piping run or poorly/incorrectly constrained section. Vulnerable pipework connections such as fillet welds and sockolet fittings are also susceptible.

3 VIBRATION CONSEQUENCES

Vibration can result in loss of containment through two processes:

3.1 Fatigue

Vibration results in dynamic stresses. If these are above a critical level, they can initiate and/or propagate a fatigue crack. Cracking can result in through thickness failure and loss of containment if not remediated. An example of a fatigue crack induced in regulator pipework is shown in Figure 1.

Figure 1: Vibration induced fatigue crack on regulator pipework

Welded joints associated with main lines and small-bore connections are the most sensitive to fatigue. Failure typically occurs at the connection of the small-bore connection and the main line pipe but can occur at other weld locations.

3.2 Fretting

Fretting occurs when two surfaces are in contact and subject to cyclic relative motion. This can result in loss of wall thickness of one of both surfaces and ultimately loss of containment. An example of vibration induced fretting on impulse pipework is shown in Figure 2.

Figure 2: Vibration induced fretting on impulse pipework

4 DESIGN GOOD PRACTICE

This guidance focuses on in-service installations; however the following are notes to consider at the design stage.

The preferred method of mitigating vibration related issues is to consider vibration during the design and commissioning stage. There is design guidance in IGEM/TD/13 Appendix 5 [4] and Energy Institute document 'Guidelines for the Avoidance of Vibration Induced Fatigue Failure in Process Pipework' [1].

4.1 Temperature Monitoring

Vibration of any thermowells due to vortex shedding can be a threat to both the thermowell and the instrument connection and should be assessed using the methods in ASME PTC 19.3 TW [5]. If the thermowell is required for operational reasons but is considered to be at risk of vortex shedding, it should be replaced with a surface mounted temperature probe, unless temperature response time is critical. For those cases which still require a thermowell, one-piece forged, flanged thermowells should be used, together with weldoflange type instrument connections.

4.2 Noise

Where noise does not pose a threat to pipework integrity but remains above acceptable levels, mitigation measures such as acoustic cladding or lagging of pipework and valves may be implemented to reduce noise emissions. However, these must be carefully managed to prevent corrosion under insulation (CUI).

Where engineering controls cannot reduce noise exposure below acceptable limits, hearing protection must be provided in accordance with relevant occupational health legislation [6].

5 VIBRATION IDENTIFICATION

Where indicators of high vibration and/or pipework problems potentially caused by vibration are observed, then further investigation should be undertaken as described below.

5.1 Overview

Visual inspection should be undertaken at various operating conditions. It is recommended that operational staff are interviewed regarding their experience of when vibration has occurred and under what conditions. The process and operating conditions under which the vibration and/or noise occurs should be noted, for example operating pressures and temperatures, the operating regime of nearby equipment, and flow rates.

Absence of high noise and/or vibration levels during visual inspection should not be assumed to indicate a low risk of vibration-induced fatigue.

If fatigue cracking is identified in the vicinity of small-bore connection welds on a main pipe, either during routine inspection or through reports from site technical staff, or if fretting wear has resulted in pipe wall thickness loss, urgent action is required. The following should be used as guidance for visual inspections in order to identify whether pipework might be at risk of experiencing excessively high levels of vibration.

Indicators of high vibration being present on the pipework:

- Main pipework, branch connections, or impulse pipework exhibit excessive vibration when touched (e.g. uncomfortable to touch).
- Audible or visible rattling of attached or nearby instrument panels or enclosures.
- Evidence of fretting wear (loss of wall thickness) on pipework in contact with another component (e.g. thermal/acoustic cladding, other pipework, supports, branch connection).
- Basic Process Control System (BPCS) vibration or condition monitoring systems and associated alarms or trips.

Areas where pipework issues may be due to high vibration levels:

- Main pipework support incorrectly aligned (e.g. gap between pipe and support) or missing supports.
- Long unsupported sections or small-bore pipework.
- Small bore pipework systems with significant cantilevered mass (e.g. valve).
- Excessive corrosion of threaded section of fittings.
- Insufficient clearance between pipework and another component (e.g. thermal/acoustic cladding, other pipework, supports, branch connection).
- Damaged or broken supports.

5.2 High Vibration/Noise

Three practical indicators of vibration frequency are:

1. Visible vibration of pipework suggests low frequency vibration (typically up to 10 Hz).
2. Vibration felt by touch is indicative of low to medium frequency vibration (approximately 10 – 100 Hz).
3. Pipework exhibiting audible noise is indicative of high frequency vibration (typically greater than 100 Hz).

Elevated vibration or noise should be quantified using an appropriate measurement survey.

5.3 Fretting Damage

Typical locations to investigate for fretting damage include:

- U-bolt pipe clamps.
- Resting supports.
- Loose or damaged insulation cladding.
- Pipe contact.
- Pipework in contact with other equipment (e.g. cable trays, handrails, fittings).
- Temporary supports.

If fretting is identified, components should be separated, and the damage quantified and assessed.

5.4 Small Bore Connections

There are various considerations to determine the susceptibility of a small-bore connection to fatigue damage [1]. These include:

- **Type of fitting -** the following list of fittings ranks their resistance to vibration, from most to least resistant:
    - Short contoured body.
    - Contoured body / welded tee / forged reducing tee.
    - Weldolet / threadolet, fully back welded / screwed, fully back welded.
    - Threadolet / screwed.
    - Threadolet, partially back welded / screwed, partially back welded.
    - Set-on / set-in / set-through.

- **Length of fitting** - the greater the distance from the connection to any unsupported mass, the more susceptible the fitting to vibration induced fatigue.

- **Mass loading** - the greater the mass on a connection, the greater the stress and the more susceptible the fitting to fatigue.

- **Fitting diameter** - the smaller the diameter, the more susceptible the fitting to fatigue damage.

- **Parent pipe wall thickness -** the thinner the wall, the less the structural support, and the more susceptible the fitting to fatigue.

- **Location of connection on parent pipe -** the closer a small-bore connection is to an anchor location on the parent pipe, the less susceptible the fitting to fatigue. Conversely if a connection is located at a mid-span or close to a discrete energy source (e.g. valve, orifice plate), the more susceptible the fitting to fatigue.

5.5 Pipe Supports

Features to consider regarding supports are:

- Damaged or missing supports.

- Temporary supports (e.g. rope, wooden supports).

- Supports that are not adequately stiff relative to supported pipe.

- Incorrectly placed supports (e.g. at a point of zero vibration amplitude).

5.6 Bracing of Small-Bore Connections

The following are considerations which can result in fatigue issues even when a connection has been braced:

- Unsuitable bracing (e.g. wood blocks, rope, cable ties).

- Brace not supporting free mass on the connection end.

- Brace only supporting the first weld.

- Bracing in only one plane.

- Connection not braced back to parent pipe (e.g. neighbouring structure or adjacent pipe).

- Use of welded gusset plates on pipework without reinforcing plates (notably for thin-walled pipes).

- Loose bolts on bolted clamps.

5.7 Instrument Tubing

Failure due to vibration of instrument tubing typically occurs at connections. As instrument tubing generally uses mechanical fittings and not welded connections, it can tolerate a greater degree of dynamic stress before fatigue cracking initiates. Instrument tubing should allow differential movement of the two connected components. There should be no direct, rigid connections between two fixed points, as this can transmit vibration and lead to fatigue failure.

6 VIBRATION MEASUREMENT TECHNIQUES

Vibration measurement techniques measure vibration acceleration, velocity, displacement, or dynamic strain as a function of time, which is then analysed to generate the frequency spectra of vibration stress. Specialist advice is required to achieve accurate vibration measurement and analysis in order to identify and calculate fatigue life [2] [3].

Note that applicable frequency ranges are instrument and installation dependent and should be confirmed against equipment specifications.

6.1 Vibration Velocity Measurement

Vibration velocity is the maximum speed reached during the vibration cycle. Vibration velocity measurements provide a simple method for screening a piping system for vibration problems. Measurements are obtained at a number of locations using accelerometers and data loggers. The advantage of this technique is the relative ease of obtaining measurements. The disadvantage is that the data cannot be used to directly derive an estimate of fatigue life. Typically applicable up to 100 Hz.

6.2 Direct Dynamic Strain Measurement

Direct dynamic strain is measured using either permanent or portable strain gauges. The measurements provide a comprehensive assessment of the likelihood of fatigue failure, as it enables dynamic stress to be calculated. The main disadvantages are that specialist equipment is required and the location of the strain gauges is critical to deriving a representative stress. Typically applicable up to several hundred Hz.

6.3 Vibration Fast Fourier Transform (FFT) Measurement

The Fast Fourier Transform (FFT) converts vibration measurements (acceleration, velocity, or displacement) from the time domain into the frequency domain, allowing identification of dominant system excitation frequencies. These measured excitation frequencies can then be compared with natural frequencies predicted by modal analysis (e.g. via Finite Element Analysis) or determined experimentally. This comparison helps identify potential resonances and excessive vibration amplitudes that could contribute to fatigue damage, informing the design of modifications to mitigate vibration risks. Typically effective up to several kHz.

6.4 Motion Amplification

In addition to measurement of vibration amplitude and frequency, motion amplification uses video processing and specialised software to detect and visualise motion that is not visible to the human eye. This non-invasive technique amplifies subtle movement, enabling visualisation and qualitative assessment of vibration behaviour. Typically applicable up to 100 - 150 Hz.

7 REMEDIAL AND MITIGATION MEASURES

Where there is a pipework vibration problem, the severity of the problem will determine the timescale for implementation of the mitigating actions required.

To reduce the risk to an acceptable level, different options may be considered dependent on the vibration source. These can be grouped into those that modify the excitation mechanism and those modifying the response mechanism. If practicable, the excitation mechanism should be addressed to reduce or remove the excitation energy and vibration response.

In cases of multiple excitation mechanisms, the remedial action should address all excitation mechanisms.

Remedial options could include the following:

- Tightening up clearance on supports. This produces a similar effect to adding supports, stiffening the pipework and altering the natural frequency. If an existing support permits pipework to move it can be the cause of excessive vibration. By tightening the clearance on supports the pipework natural frequency is increased, normally resulting in reduced vibration (typically the levels of energy fall with increased frequency). This is not always possible as thermal expansion may be accounted for in the support.

- Avoid metal-to-metal contact. The two surfaces should be separated to remove the risk of fretting. If contact is necessary (e.g. a pipe support) then a wear resistant or compliant material should be used between the surfaces

- Stiffening the system via additional or modifying supports. This will increase the natural frequency resulting in reduced levels of vibration. Consider changing the type and orientation of supports to increase stiffness, specifically in the direction of principal vibration. Consider adequate support at sources of turbulence (e.g. valves, mitred bends) to reduce coupling between turbulent energy generated by the source and the piping. Care needs to be exercised in the placing of supports to ensure they work as intended without introducing new dynamic issues. Placement should be based on direct measurement data and/or vibration modelling.

- Checking the alignment of pipework sections to identify whether misalignment is causing stress and vibration issues.

- Conduct a surge analysis to determine the magnitude of any surge and identify appropriate mitigation measures.

- Quantify surge hazards and the effect of mitigating measures such as the use of surge alleviators, anti-surge valves (e.g. pressure control valves), changing system timings (in controlled shutdowns only), and/or other process controls to avoid dead-heading scenarios.

- Changing span length or support types to avoid resonant conditions.

- Changing the diameter, wall thickness, or pipework layout to change the response.

- Changes in components (e.g. valves, bend/tee radius) to reduce turbulence.

- A change in operation (e.g. velocity, pressure, flow path) to avoid resonance, or flow induced pulsations.

- Removal, redesign or bracing (permanent or temporary) of small-bore connections.

- Design modifications. If the vibration source is due to flow induced turbulence, reducing the fluid velocity will reduce the excitation energy and therefore the response of the pipework. Decreases in fluid velocity can be achieved by increasing the diameter of the main pipe, running a second parallel pipe, or changing the operating conditions. Consider flow smoothing and/or changing the valve type.

- More regular checking or non-destructive testing. This increases the likelihood of identifying vibration and related fatigue cracking.

- Viscous dampers. Stiffening of the system is not always appropriate. Vibration dampers can be an effective vibration mitigation as they allow relatively large movement whilst providing damping. Note these are ineffective at frequencies over 30 Hz or for narrow band excitation.

- Shock arrestor / absorber / snubber. Thermal growth requirements may limit additional support. Shock arrestors allow low velocity movement but provide resistance for sudden movements caused by forced vibration. Shock arrestors lock in position at certain level so can result in high applied loads during slugging.

- Composite wraps. Composite wraps can beneficially stiffen a main line, but the increased weight could negate the benefit. Composite wraps also increase damping levels which may reduce the vibration response. Currently there is a lack of knowledge on the effects of high-cycle fatigue resistance of composite wraps.

- Increased wall thickness. This will result in a lower dynamic stress level for a given level of excitation. For a given outer diameter, an increased wall thickness will decrease the inner diameter which increases the fluid velocity and with it the turbulent excitation. The realised benefits outweigh this negative effect.

Management of Change - Any modifications should be assessed to understand the implications of the proposed changes. Design documentation should be updated to reflect any changes made, with drawings and asset records updated as appropriate.

Where sections have been identified as being at high risk, a check should also be undertaken for similar pipework locations on the same or other sites that may therefore also be at risk. Mitigation across all similar sections should avoid the problem being repeated elsewhere.

8 SPECIALIST PREDICTIVE TECHNIQUES

Table 1 identifies applicable predictive techniques for various excitation and response mechanisms:

Excitation Mechanism	Structure Finite Element Analysis	Acoustic Finite Element Analysis	Computational Fluid Dynamics (CFD)	Pulsation Analysis	Surge Analysis	Valve Sizing Calculations
Flow induced turbulence	✓		✓			
Mechanical excitation	✓					
Pulsation: Reciprocating/positive displacement pumps and compressors	✓	✓		✓		
Pulsation: Rotating stall	✓	✓		✓		
Pulsation: Flow induced excitation	✓	✓		✓		
High frequency acoustic excitation	✓					
Surge/momentum changes due to valve operation	✓				✓	✓
Cavitation and flashing	✓		✓			✓

Table 1: Applicable predictive techniques for common excitation and response mechanisms

9 REFERENCES

[1] Energy Institute, “Guidelines for the Avoidance of Vibration Induced Fatigue Failure in Process Pipework,” Second Edition, London, 2008.

[2] British Standards Institution, “Guide to methods for assessing the acceptability of flaws in metallic structures,” BS 7910:2019, London, 2019.

[3] British Standards Institution, “Guide to fatigue design and assessment of steel products,” BS 7608:2014+A1:2015, London, 2015.

[4] Institution of Gas Engineers and Managers, “Pressure regulating pipeline installations exceeding 7 bar,” IGEM/TD/13 Edition 3, Kegworth, 2023.

[5] American Society of Mechanical Engineers, “ASME PTC 19.3 TW - 2016 Thermowells,” New York, 2016.

[6] Health and Safety Executive, “The Control of Noise at Work Regulations,” Statutory Instrument 2005 No. 1643, London, 2005.