OPERATION AND MAINTENANCE OF NUCLEAR POWER PLANTS

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ASME Codes and Standards

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Foreword

This document was developed and is maintained by the ASME Committee on Operation and Maintenance (O&M Committee) of Nuclear Power Plants. The O&M Committee develops, revises, and maintains codes, standards, and guides applicable to the safe and reliable operation and maintenance of nuclear power plants. The Committee operates under procedures accredited by the American National Standards Institute as meeting the criteria of consensus procedures for American National Standards.
New Section:

ISTA-3170  Inservice Examination and Test Frequency Grace

Section IST specifies component test frequencies based either on elapsed time periods (e.g., quarterly, 2 yr, etc.) or the occurrence of plant conditions or events (e.g., cold shutdown, refueling outage, upon detection of a sample failure, following maintenance, etc.).

(a) Components whose test frequencies are based on elapsed time periods shall be tested at the frequencies specified in Section IST with a specified time period between tests as shown in Table ISTA-3170-1. The specified time period between tests may be reduced or extended as follows:

(1) For periods specified as fewer than 2 yr, the period may be extended by up to 25% for any given test.
(2) For periods specified as greater than or equal to 2 yr, the period may be extended by up to 6 months for any given test.
(3) All periods specified may be reduced at the discretion of the Owner (i.e., there is no minimum period requirement).

Period extension is to facilitate test scheduling and considers plant operating conditions that may not be suitable for performance of the required testing (e.g., performance of the test would cause an unacceptable increase in the plant risk profile due to transient conditions or other ongoing surveillance, test, or maintenance activities). Period extensions are not intended to be used repeatedly merely as an operational convenience to extend test intervals beyond those specified.

Period extensions may also be applied to accelerated test frequencies (e.g., pumps in alert range) and other fewer than 2-yr test frequencies not specified in Table ISTA-3170-1.

Period extensions may not be applied to the test frequency requirements specified in Subsection ISTD, Preservice and Inservice Examination and Testing of Dynamic Restraints (Snubbers) in Light-Water Reactor Nuclear Power Plants, as Subsection ISTD contains its own rules for period extensions.

(b) Components whose test frequencies are based on the occurrence of plant conditions or events may not have their period between tests extended except as allowed by Section IST.
<table>
<thead>
<tr>
<th>Frequency</th>
<th>Specified Time Between Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quarterly (or every 3 months)</td>
<td>92 days</td>
</tr>
<tr>
<td>Semiannually (or every 6 months)</td>
<td>184 days</td>
</tr>
<tr>
<td>Annually (or every year)</td>
<td>366 days</td>
</tr>
<tr>
<td>$x$ years</td>
<td>$x$ calendar years where $x$ is a whole number of years $\geq 2$</td>
</tr>
</tbody>
</table>
Part 3
Vibration Testing of Piping Systems

1 SCOPE
This Part establishes vibration testing requirements for certain piping systems in light-water reactor (LWR) power plants. This Part is applicable to preservice and initial startup testing, and plant post modification testing (e.g., power uprate and steam generator replacement). This Part may be used to assess vibration levels of applicable piping system during plant operation. This Part establishes test methods, test intervals, parameters to be measured and evaluated, acceptance criteria, corrective actions, and records requirements.

2 DEFINITIONS
These definitions are provided to ensure a uniform understanding of selected terms used in this Part.

ASME B31: ASME Code for Pressure Piping.
Design Specification: the document provided by the Owner, as required by NCA-3250 or NA-3250 of the ASME BPV Code, Section III, for the component/system, which contains requirements to provide a complete basis for the construction of the component/system.
design verification: the process of reviewing, confirming, or substantiating a design by one or more methods to provide assurance that the design meets the specified design input.
duplicate: a system built on the basis of a previously used and proven design for which test results are available.
hot shimming: the process of adjusting support and restraint clearances in the hot condition.
initial start-up testing: test activity performed during or following initial fuel loading, but prior to commercial operation. These activities include fuel loading, precritical tests, initial criticality tests, low power tests, and power ascension tests.
maintenance/repair/replacement: actions taken to prevent or correct deficiencies in the system operation.
normal operating conditions: the service conditions the system would experience when performing its intended function.
operational testing: test activities performed subsequent to initial start-up testing (e.g., testing performed during commercial operation of the plant).
Owner: the organization legally responsible for constructing and/or operating a nuclear facility including, but not limited to, one who has applied for or who has been granted a construction permit or operating license by the regulatory authority having lawful jurisdiction.
peripheral equipment: device(s) used in the setup, checkout, or on-site calibration of other VMS devices.
physical units: the engineering units that quantitatively represent the measured variable (e.g., if the measured variable is displacement, the physical units can be inches, mils, feet, or meters).
preoperational testing: test activities performed prior to initial fuel loading.
processing equipment: device(s) used for further handling, reformating, or manipulation of the transducer output to reduce it to manageable or intelligible information.
prototype: system built on the basis of an original design for which there are no previous system test results available.
quality assurance: all those planned and systematic actions necessary to provide adequate confidence that an item or facility will perform satisfactorily in service.
record drawing set: the set of drawings that defines the system's layout and support configuration at the time the system is placed in service for testing.
recording and display equipment: recording equipment devices are used for storing signals in a form capable of subsequent reproduction. Display equipment devices are used to obtain a visual representation of a signal (conditioned and/or processed transducer output).
shell-wall vibration: radial vibration of a pipe wall, which typically occurs at high frequencies, characterized by axial and circumferential lobate mode shapes and natural frequencies.
signal conditioner: device(s) used to modify or reformat the transducer output to make it intelligible to or compatible with processing equipment.
steady-state vibrations: repetitive vibrations that occur for relatively long periods of time during normal plant operation.
system: an assembly of piping subassemblies and components whose limits and functions are defined in its Design Specification.
**Fig. 1 Typical Components of a Vibration Monitoring System (VMS)**

Transducer  
Signal conditioner  
Processing equipment  
Peripheral equipment  
Display or recording devices

**system interconnections**: all cables, wires, or mechanical linkages used between the devices comprising the VMS.

**system specification**: that document that uniquely describes the VMS. The system specification shall contain the information specified in para. 7.2.

**test conditions**: the conditions experienced by the system when undergoing tests.

**test hold points**: events in the test program usually associated with system operating conditions for which test information is to be collected (e.g., with the reactor at X% power and with the system at full flow).

**test specification**: the document(s) prepared by the Owner or his assignee that meet(s) the requirements set forth in section 3 of this Part.

**transducer**: a device that converts shock or vibratory motion into an optical, mechanical, or, typically, an electrical signal that is proportional to a parameter of the experienced motion.

**transient vibrations**: vibrations that occur during relatively short periods of time and result in less than $10^6$ stress cycles. Examples of transient sources of vibration are pump actuation and pump switching, rapid valve opening or closing, and safety relief valve operation.

**vibration monitoring system (VMS)**: the system composed of all instrumentation or test equipment used to measure and record the vibration data. It is assumed to have as input the monitored variable (i.e., displacement velocity and acceleration) at the measurement location. The system output is a signal analogous to the measured variable and readily convertible to appropriate physical units. A typical VMS is shown in Fig. 1.

The Owner shall determine the portions of piping systems to be tested and shall classify these systems into the vibration monitoring groups defined below. The minimum general requirements for the classification by groups are provided in para. 3.1; however, the Owner may place a system into a more stringent vibration monitoring group (VMG).

Vibration conditions are classified into steady-state and transient vibration categories. A system may be classified into one vibration monitoring group for steady-state vibrations and into another group for transient vibrations. The testing requirements, acceptance criteria, and recommendations for corrective action associated with these categories are provided below. The vibration testing and assessment of vibration levels may be conducted during preoperational and initial start-up testing or during plant operation in accordance with the requirements of the test specification.

For preoperational, initial start-up, and operational testing, a test specification shall be prepared that will include, as a minimum, the following items:

(a) test objectives  
(b) systems to be tested (including boundaries)  
(c) pretest requirements or conditions  
(d) governing documents and drawings  
(e) precautions  
(f) quality control and assurance (including required documentation and sign-offs)  
(g) acceptance criteria  
(h) test conditions and hold points  
(i) measurements to be made and acceptable limits (including visual observations)  
(j) instrumentation to be used (including instrument specifications)  
(k) data handling and storage  
(l) system restoration

The test specifications shall be written in a manner to ensure that the objectives of the tests are satisfied and that results obtained are accurate or conservative. Prior to testing, an inspection of components and supports shall be made to verify correct installation according to the record drawing set, specifications, and appropriate codes.
When test results are to be correlated to specific analysis, test conditions and measurements should be sufficiently specified to ensure that the parameters and assumptions used in the analysis are not violated. The correlation between test and analysis should confirm the validity of the analysis and should indicate that the analytical results are conservative. If the test results indicate that the analysis is not adequate or when the measured data from the test indicates that the actual forcing function is not conservatively covered by the forcing functions used in the analysis, the analysis should be reconciled.

The vibration monitoring requirements and acceptance criteria are defined in para. 3.2. If the test data exceeds the value specified in the hold point section of the test specification, two options are available: further testing or evaluation to a more rigorous method or corrective action taken, as described in section 8.

Cognizant engineering personnel shall participate in the development of test specification requirements, selection of instrumentation, establishment of acceptance criteria, review, evaluation, and approval of test results.

Selection of the locations of measuring devices and the type of measurements to be made shall be based on piping stress analysis, response of a similar system, or experience gained through testing of the subject system and shall reflect any unique operational characteristics of the system being tested. Evaluation of the test data shall consider characteristics of the measuring devices used.

3.1 Classification

Piping system vibrations are classified into two categories, steady-state and transient, as defined in section 2. Within each applicable category, the piping system shall be classified into one of the three vibration monitoring groups according to the criteria presented in paras. 3.1.1 and 3.1.2.

Piping systems that are inaccessible for visual observation or measurement using portable devices, as a result of adverse environmental effects during the conditions listed in the test specification, shall be classified into either VMG 1 or VMG 2.

In addition to the requirements presented in paras. 3.1.1 and 3.1.2, the safety or the power generation function, or both, of the system should also be considered when classifying the system into the vibration monitoring groups.

3.1.1 Steady-State Vibration

3.1.1.1 Vibration Monitoring Group 1. The monitoring program required for systems evaluated in this group typically involves sophisticated monitoring devices and extensive data collection to accurately determine vibratory pipe stresses or other specified component limitations.

Determination of mode shapes, modal response magnitudes, and total system response is possible using these evaluation techniques. When accurate measurement of the system response characteristics is required, the techniques and devices implied by the requirements for this vibration monitoring group shall be employed.

All portions of piping systems that experience steady-state vibrations and meet one of the following requirements shall be classified in VMG 1 and shall meet the acceptance criteria specified in para. 3.2.1:

(a) piping systems that exhibit a response not characterized by simple piping modes (e.g., piping shell-wall vibrations, as defined in section 2)

(b) piping systems for which the methods of VMG 2 and VMG 3 are not applicable based on limitations given in sections 4 and 5

3.1.1.2 Vibration Monitoring Group 2. The methods and devices employed in the evaluation of VMG 2 provide a means of measuring and assessing the piping vibration at a given location.

All portions of piping systems that meet one of the following requirements shall be classified in VMG 2 and shall meet the acceptance criteria specified in para. 3.2.2:

(a) all piping systems that may exhibit significant vibration response based on past experience with similar systems or similar system operating conditions

(b) piping systems for which the method of VMG 3 is not applicable

3.1.1.3 Vibration Monitoring Group 3. The visual method employed in the evaluation of VMG 3 is most fundamental and provides the most simplified means for determining whether any significant vibrations exist in the system. Evaluation of vibration levels using this method is based on experience and judgment and provides an acceptable basis for assessment. If firm quantitative assessments are required, the methods in VMG 1 or VMG 2 should be employed.

All portions of piping systems that meet one of the following requirements shall be classified in VMG 3 and shall meet the acceptance criteria specified in para. 3.2.3:

(a) systems falling in VMG 1 or VMG 2 classifications, for which measurements or prior test data are available on prototype or duplicate systems and for which the minimum unacceptable vibrations are observable

(b) portions of ASME Classes 1, 2, 3, and ASME B31 piping systems that are not expected to exhibit significant vibrational response based on past experience with similar systems or system operating conditions

3.1.2 Transient Vibration. Table 1 presents some examples of transient conditions to which systems may be subjected.

3.1.2.1 Vibration Monitoring Group 1. Portions of piping systems that experience transient vibrations and meet the following requirements shall be classified in
Using \( N_v \), the maximum alternating stress intensity \( S_{alt} \) shall be limited to \( S_a \) where
\[
S_a = \text{allowable alternating peak stress value from ASME BPV Code, Section III, Fig. I-9.1, I-9.2.1, or I-9.2.2.}
\]
For transient vibrations that were not previously analyzed and for which it is not appropriate to evaluate the load separately, a new fatigue analysis may be required in accordance with Section III of the ASME BPV Code.

(b) For ASME Classes 2 and 3 piping, the stresses shall be evaluated in accordance with the requirements of subpara. 3.2.1.2(b). Alternatively, the appropriate ASME code shall be used to evaluate the stresses for transient vibration.

3.2.2 Vibration Monitoring Group 2

3.2.2.1 The vibration response of Group 2 systems shall be measured using one or more of the vibration monitoring devices specified in section 5.

3.2.2.2 For steady-state vibration, the piping vibratory responses of VMG 2 piping shall be evaluated in accordance with the allowable deflection or velocity limits given in section 5. These limits are based on meeting the stress requirements of para. 3.2.1. If adequate quantitative data cannot be obtained or unacceptable vibration response is indicated by the methods and devices listed in section 5, the methods and devices of section 6 may be used.

3.2.2.3 For transient vibration, the criteria of para. 3.2.2.2 for steady-state vibration may be used as a screening tool but may be overly conservative. If these limits are exceeded, the criteria of para. 5.2.3 or the criteria of para. 3.2.1.3 shall be employed.

3.2.3 Vibration Monitoring Group 3

3.2.3.1 The vibration response of Group 3 systems shall be determined by the methods and devices listed in section 4.

3.2.3.2 If an acceptable level of steady-state or transient vibration is noted, no further measurement or evaluation is required. The observer shall be responsible for assessing whether the observed vibration level is acceptable. The basis for determining whether the vibration level is acceptable shall be consistent with the limits specified in para. 3.2.1.

3.2.3.3 If the level of vibration is too small to be perceived and the possibility of damage is judged to be minimal, the system is acceptable.

The judgment as to acceptability can be made only by the evaluation of all the following facts as to their effects on the piping stress:

(a) vibration magnitude and location
(b) proximity to “sensitive equipment”
(c) branch connection behavior
Deflection limits are given in terms of a characteristic span length, outside pipe diameter, and a configuration coefficient. The characteristic span length and the configuration coefficient are established by subdividing the piping system into a series of characteristic spans as described in para. 5.1.1.6.

The configuration coefficient, \( R \), and the nominal vibration deflection, \( \delta_\text{n} \), values are based on an allowable stress of 10,000 psi with stress indices equal to unity. The allowable deflection limit, \( \delta_\text{allow} \), is shown in para. 5.1.1.5.1.

Where the user demonstrates analytically or by experience that the VMG 2 methods are inherently conservative by at least a factor of 1.3, \( K \) may be taken as 1.0. The allowable deflection limit is then compared to the measured value for piping vibration qualification.

5.1.1.5.1 Determination of Allowable Deflection Limit. Nominal vibration deflection value

\[
\delta_\text{n} = (S_{\text{el}} \times \delta_{\text{n}})(C_2 K_2 \times \delta_{\text{n}})
\]

Allowable vibration deflection limit

\[
\delta_\text{allow} = (S_{\text{el}} \times \delta_{\text{n}})/(C_2 K_2 \times \sigma_1 \times \sigma_2)
\]

where

\( D_\text{o} \) = the outside diameter of the piping, the units of \( D_\text{o} \) and \( L \) are the same (e.g., both in feet or both in meters)
$K = \text{the configuration coefficient determined based on a nominal stress} (\delta_n) \text{ of } 10,000 \text{ psi (68.95 MPa)}$

$L = \text{the characteristic span of the vibrating piping segment}$

$\delta_{allow} = \text{the allowable zero to peak vibration deflection limit based on the endurance limit} (S_{el}/\alpha) \text{ of the piping material and the applicable peak stress indices} (C_2K_2)$

$\delta_n = \text{a nominal zero to peak vibration deflection value based on a nominal stress} (\sigma_n) \text{ of } 10,000 \text{ psi (68.95 MPa) and with no consideration of peak stress indices}$

Paragraph 3.2.1.2 defines $S_{el}$, $C_2$, and $K_2$.

5.1.1.6 Characteristic Span Models. It is recommended that the measured deflection data be examined to assist in determining the appropriate characteristic span used to obtain the allowable deflection limit.

Characteristic spans are broadly classified into two categories by the piping restraints. A single-end restraint with one end free forms the first category, and restraint of both ends of a characteristic span forms the second category. The categories are then subdivided into combinations of a single span and two spans joined by a 90-deg elbow. Deflections are measured in the plane of the elbow and out of the plane of the elbow as shown in Fig. 2. The rotational constraint at restraint points is assumed to be fixed for a conservative computation of the allowable deflection limit. An outline of the basic characteristic spans is given below. For any configuration not covered below, a conservative K factor may be established by the user, provided equivalent conservatism is maintained.

(a) Single-end restraint, cantilever

(1) Cantilever single span (Fig. 4)

(2) Cantilever span, elbow, span

(-a) Deflection in plane of elbow, end span free (Fig. 5)

(-b) Deflection in plane of elbow, guided end span (Fig. 6)

(b) Restrains at both ends

(1) Single span

(-a) Single span (Fig. 3)

(-b) Single span with elbow restraint [special case of subpara. (b)(1)(-a) or limit case of subpara. (b)(2)]

(2) Span, elbow, span

(-a) Maximum deflection measured out of plane of elbow between restraint point and elbow of long span; ratio of short span to long span is less than 0.5 (Fig. 7 with configuration coefficient K from Fig. 9)

(-b) Maximum deflection measured out of plane of elbow at intersection of long span and elbow; ratio of short span to long span is between 0.5 and 1.0 (Fig. 8 with configuration coefficient K from Fig. 9)

5.1.2 Velocity Method

5.1.2.1 General Requirements. The method requires consecutive measurements of velocity at various points on the piping system to locate the point that is exhibiting the maximum vibratory velocity. Once this point is located, a final measurement of the maximum velocity can be read. The instrument should be capable of indicating a trace of the actual velocity-time signal from which the maximum velocity can be read. The readout may be achieved by readout devices such as a cathode-ray tube or a paper chart recorder. Alternatively, the instrument could have a holding circuit that would result in a meter reading of the maximum velocity.

5.1.2.2 Instrumentation. The instrument used should be portable and capable of making a number of consecutive velocity measurements at various points on the piping. The instrument should be capable of indicating a trace of the actual velocity-time signal from which the maximum velocity can be read. The readout of the signal should be of sufficient duration to ensure a high probability that the maximum velocity has in fact been obtained for that point in that direction.

5.1.2.4 Allowable Peak Velocity. The expression for allowable velocity is

$$V_{allow} = \frac{C_1C_4\beta(S_{el})}{C_3C_5K_2}$$

where

$V_{allow} = \text{allowable velocity, in./sec (mm/s)}$

$\beta = 3.64 \times 10^{-3}$ to obtain $V_{allow}$ in in./sec when $S_{el}$ is in units of psi

$= 1.34$ to obtain $V_{allow}$ in mm/s when $S_{el}$ is in units of MPa

$S_{el}, C_2, K_2, and \alpha$ are defined in para. 3.2.1.2. The secondary stress index $C_2$ and the local stress index $K_2$ are associated with the point of maximum stress and not necessarily with the point of maximum velocity.

This velocity criterion is consistent with the deflection criterion for a fixed end beam at resonance in the first mode.
**Part 3, Nonmandatory Appendix D**

**Velocity Criterion**

This Nonmandatory Appendix describes a method for establishing a velocity criterion for screening piping systems. Using these procedures, piping systems requiring further analysis can be determined. This Nonmandatory Appendix is to be used in conjunction with Part 3, para. 5.1.2.4.

**D-1 VELOCITY CRITERION**

The expression for allowable peak velocity from Part 3, para. 5.1.2.4 is

\[ V_{\text{allow}} = \frac{C_1 C_3 \beta S_{\text{el}}}{C_5 C_2 K_2} \]

where

- \( C_1 \) = correction factor that compensates for the effect of concentrated weights. If concentrated weight is less than 17 times the weight of the span for straight beams, L-bends, U-bends, and Z-bends, a conservative value of 0.15 can be used for screening purposes.
- \( C_2 K_2 \) = stress indices as defined in the ASME Code; \( C_2 K_2 \leq 4 \) for most piping systems.
- \( C_3 \) = correction factor accounting for pipe contents and insulation; for contents and insulation equal to the weight of the pipe, the value would be 1.414; in most cases it is less than 1.5.
- \( C_4 \) = correction factor for end conditions different from fixed ends and for configurations different from straight spans
  - 1.33 for cantilever and simply supported beam
  - 0.74 for equal leg Z-bend
  - 0.83 for equal leg U-bend
  - 0.7 as conservative value for screening purposes
- \( C_5 \) = correction factor that is used when measured frequency differs from the first natural frequency of the piping span; for frequency ratios less than 1.0, the value is 1.0.

\( S_{\text{el}} \) = see Part 3, para. 3.2.1.2

\( \alpha \) = see Part 3, para. 3.2.1.2

\( \beta \) = see Part 3, para. 5.1.2.4

**D-2 SCREENING VELOCITY CRITERION**

If conservative values of the correction factors are combined, a criterion can be derived that should indicate safe levels of vibration for any type of piping configuration. Using this criterion, piping systems can be checked and those with vibration velocity levels lower than the screening value would require no further analysis. Piping systems that have vibration velocity levels higher than the screening value do not necessarily have excessive stresses, but further analysis is necessary to establish their acceptability.

The following correction factors are considered to be conservative values and should be applicable to most piping configurations; however, the conservatism for extremely complex piping configurations cannot be attested.

\( C_1 = 0.15 \)
\( C_2 K_2 = 4 \)
\( C_3 = 1.5 \)
\( C_4 = 0.7 \)
\( C_5 = 1.0 \)

\( S_{\text{el}} = 7,690 \) psi (53 MPa)

\( V_{\text{allow}} = \) screening vibration velocity value

\( = \frac{(0.15)(0.7)(0.00364)(7,690)}{(1.5)(1.0)(4)} \)

\( = 0.5 \) in./sec (12.7 mm/s)

**D-3 USE OF SCREENING VIBRATION VELOCITY VALUE**

A screening vibration velocity value of 0.5 in./sec (12.7 mm/s) has been established that can be used in conjunction with Part 3, para. 5.1.2.4. Piping systems with peak velocities less than 0.5 in./sec (12.7 mm/s) are considered to be safe from a vibratory stress standpoint and require no further analysis. If vibrational velocities greater than 0.5 in./sec (12.7 mm/s) are measured, then further analyses are required to determine acceptability.

The first step to take if vibration velocities are greater than 0.5 in./sec (12.7 mm/s) is to determine more accurate values of the correction factors \( C_1, C_3, C_4, C_5 \), and the stress indices \( C_2 K_2 \) so that the applicable velocity criteria for the piping system in question can be established.
Piping beam vibration is the most commonly encountered response. This vibration results from excitation of piping structural modes that cause piping to vibrate similar to simple beams. This type of vibration is typically most predominant below 20 Hz although beam vibration with frequencies up to 100 Hz or more is possible. Eliminating or reducing the vibration excitation source is the most effective corrective action. Low-frequency beam vibration can also be adequately restrained through the addition of supports.

Experience has shown that the most effective use of restraints is obtained by supporting piping near bends and at all heavy masses and piping discontinuities. Vibrations of vents, drains, bypass, and instrument piping can be corrected by bracing the masses (valves, flanges, etc.) to the main pipe to eliminate relative vibrations.

Supports and structures used to restrain piping vibration must be capable of enduring the continuous vibration loadings that they are installed to restrain. This vibration can result in excessive wear and fatigue of components and supports not specifically designed for vibration. Therefore, items installed for this purpose must be able to withstand this vibration, or inspections and replacements of these items should be scheduled.

High-frequency piping vibration results in small displacement amplitudes, on the order of several mils or less, and is commonly prevalent throughout a large portion of a piping system. Therefore, the addition of supports is typically not an effective means of controlling high-frequency vibration. For example, the free play inherent in most supports would not restrain high-frequency vibration.

Piping shell-wall vibrations typically occur at high frequencies. For example, the lowest frequency shell mode of vibrations for a 24 in. Schedule 40 pipe is 190 Hz. Piping shell-wall vibration frequencies are proportional to the pipe-wall thickness and are inversely proportional to the pipe diameter. The most effective corrective action for shell-wall vibration is to eliminate the vibration excitation source. If the source cannot be adequately reduced, then the shell wall vibration frequency must be moved out of resonance, which could involve changing the pipe dimensions, such as using a heavier wall pipe. Circumferential stiffeners may also be used to increase the piping shell wall frequency. Constrained layer damping can be added to reduce the dynamic response and stress.

E-2 ADDITIONAL TESTING AND ANALYSIS

Root cause investigation may also involve more detailed analysis and/or testing. These steps can be taken to assist in determining the root cause of the vibration, or to reduce possible conservatism in the methods used to determine vibrational stresses. For example, vibration that exceeds the limits determined through the simplified evaluation techniques given in Part 3, section 5 may be demonstrated to be within acceptable limits when more detailed techniques are used. The methods of Part 3, section 5 were developed to be efficient methods of qualifying the majority of piping; however, conservative assumptions were made to simplify the criteria. Therefore, by either more detailed analysis and/or testing, higher vibrational displacements may be justified. More detailed analysis may, for example, include the methods described in Part 3, section 6 or finite element modeling of a particular structure or component. Detailed testing can involve the application of strain gages to determine with a higher degree of accuracy the actual peak stress levels in the piping. Strain gage testing may also be used, possibly in conjunction with test and analysis correlation, to reduce conservatism. A continuous monitoring data acquisition system may also be temporarily used to determine system vibrational response during plant operation.
E-1.3 Response of Supports
Supports and structures used to restrain piping vibration must be capable of enduring the continuous vibration loadings that they are installed to restrain. This vibration can result in excessive wear and fatigue of components and supports not specifically designed for vibration. Therefore, items installed for this purpose must be able to withstand this vibration, or inspections and replacements of these items should be scheduled.

On systems that experience significant vibration the design of the support systems should be reviewed to determine if they provide adequate restraint. The frequency of the supports and auxiliary steel may need to be increased above that of expected and/or anticipated piping vibration frequencies to avoid resonance with the piping vibration. Vibration of the supports and auxiliary steel could also potentially result in fatigue failure of the supports. In this case the support and auxiliary steel should accommodate the applicable design basis and vibrational loads and be designed to have a natural frequency above expected pipe vibration frequencies.

Vibration movements of piping can also potentially result in rubbing and wear of the pipe wall at some types of supports. A box support with a gap between the piping and support steel can potentially cause wearing of the pipe wall if the pipe vibrates and rubs against the support steel.
PART 3 (STANDARDS) ASME OM-2015

Part 3, Nonmandatory Appendix H
Guidance for Monitoring Piping Steady-State Vibration Per Vibration Monitoring Group 2

H-1 PURPOSE
The purpose of this Nonmandatory Appendix is to provide guidance for monitoring and qualifying, using the displacement acceptance criteria, steady-state piping vibrations per the requirements of Vibration Monitoring Group 2, VMG 2, of Part 3. This guidance is based on extensive experience associated with field walkdowns and testing.

H-2 ASSUMPTIONS
These criteria assume that the stresses resulting from the steady-state vibration of an entire piping system can be conservatively estimated by dividing the system into smaller piping spans with various end conditions and using simple beam analogies to determine the deflection limits. It is further assumed that the vibration between node points and/or adjacent, parallel, seismically rigid restraints is dominated by a single mode of vibration that can be conservatively approximated by the fundamental mode of a simple beam model.

The allowable stress amplitudes, \( S_a \), are in accordance with Part 3, section 3. These stress amplitudes are based on 80% of the alternating stress intensity at \( 10^6 \) cycles divided by a stress reduction factor of 1.3 for carbon steels, and the minimum alternating stress intensity at \( 10^{11} \) cycles for stainless steels. The values of alternating stress intensity are taken from Fig. I-9.1, I-9.2.1, or I-9.2.2 of the ASME BPV Code, Section III, Appendix I. Note that the assumptions stated in the ASME BPV Code for the use of these curves must be followed, including the following:

(a) The fatigue curves are not applicable at temperatures above 700°F for carbon steel and 800°F for stainless steel.

(b) The fatigue curves use a modulus of elasticity of \( 30 \times 10^6 \) psi for carbon steel and \( 28.3 \times 10^6 \) psi for stainless steel. Therefore, when an analysis is performed to determine vibration-induced stresses using a modulus of elasticity different than that used in the fatigue curves, the calculated stresses shall be adjusted as specified in ASME BPV Code, Section III, NB-3222.4.

H-3 IMPLEMENTATION
A sample steady-state vibration monitoring procedure is shown in Fig. H-1. The procedure begins with the least involved method of monitoring, and the monitoring methods and associated analyses become more extensive as the measured vibration exceeds the criteria of the various monitoring levels. The procedure requires further action for evaluating vibrations that exceed all levels of acceptance criteria. The procedure is discussed in paras. H-3.1 through H-3.2.4.

H-3.1 Quantitative Evaluations

H-3.1.1 Determine Flow Modes to Be Monitored.
The first step in implementing the monitoring procedure is to align the piping system in the flow mode(s) that have been judged, based on a review of all the possible operating modes of the system, to result in the most severe vibrations. If the most severe mode(s) cannot be determined from a review of the operating modes, the system should be tested in several or all its operating modes. Generally, the most severe steady-state vibrations occur during maximum or minimum flow conditions.

H-3.1.2 Inspect the Piping.
Once the flow mode is established, the piping is inspected for perceivable vibration. Vibrations can be perceived not only by sight but also by touch and by hearing. Therefore, all senses should be alert when performing the walkdown, especially since lighting is usually not ideal and the piping may not be easily accessible.

H-3.1.3 Take Measurements.
Even if the vibration appears to be minimal, at least one vibration measurement should be taken to document system response and provide a baseline for future reference. Equipment that measures true peak-to-peak displacement is recommended for measuring piping vibration, since the displacement is proportional to the pipe mode shape and, therefore, is proportional to the vibrational stress.

Equipment that measures root mean square (rms) displacement indicates only an averaged stress. The rms measurement cannot be readily converted to peak-to-peak measurements, except for pure sinusoidal signals. Since piping vibration is often quasirandom, equipment that measures rms signals should not be used. The predominant frequency of the vibration is also important and should be documented for baseline purposes and for aiding in problem resolution.
The intent of the acceleration method is to provide screening acceleration limits as a supplement to the displacement limits discussed in Part 3, section 5 for small branch piping (pipe sizes ≤2 in.) with significant masses cantilevered from header piping or equipment. This method is intended to provide a conservative representation of the vibrational stresses in the branch connection between the small branch piping and the header.

These limits can be used to screen out configurations with acceptable vibration levels from those that may be unacceptable or may require more detailed evaluations to demonstrate the acceptability of the vibration. This method is intended to be a supplement to the displacement methods provided in Part 3, para. 5.1.1 when high accelerations are present.

Note that the limits resulting from this approach should be conservative, and exceeding these limits does not necessarily indicate that the allowable stresses of Part 3, section 3 have been exceeded (see also para. 4.2). The acceleration method is intended to be a supplement to the displacement methods provided in Part 3, para. 5.1.1 when high accelerations are present. These limits can be used to screen out configurations with acceptable vibration levels from those that may be unacceptable or may require more detailed evaluations to demonstrate the acceptability of the vibration. This method is intended to be a supplement to the displacement methods provided in Part 3, para. 5.1.1 when high accelerations are present.

CAUTION: Acceleration measurements often result in large overall values especially if high-frequency accelerations are present. It is important to note that these high-frequency accelerations likely will not affect the piping as assumed by the criteria provided herein. The acceleration limit is based on the assumption that the dynamic accelerations affect the piping equivalent to static accelerations. Using this assumption for the high-frequency accelerations (where high frequency can be taken as frequencies above the fundamental frequency of the small branch line) may result in overly conservative results.

Some piping configurations and operating conditions, for example, instrument lines branching off process piping, can be excited in higher-order modes (i.e., one or more node points exist between the branch connection and the measurement location). This type of vibration is indicated by large accelerations occurring along with small displacements at locations several feet from the branch connection. In addition, local effects can result in high accelerations that are transmitted through the shell and do not affect the global structural vibration mode of the small branch piping. The criterion presented in this Nonmandatory Appendix is not applicable for this type of vibration; however, if used, the acceleration limit should be conservative. In general, more detailed analyses are required to evaluate the vibration.

EXAMPLE APPLICATION: A peak stress index \((C_i K_i)\) equal to 4.2, which corresponds to a girth fillet weld is incorporated into the acceleration limit equation. The acceleration limit equation should be changed accordingly when other values of \(C_i K_i\) are applicable.

A \(\frac{3}{4}\) in. Schedule 80 cantilevered branch line is accelerated by a header pipe at a peak acceleration of 1.0g (zero to peak). The branch line contains a 15-lb valve that is 6 in. from the branch connection. It is determined that \(L_E = 6\) in. and \(W_T = 16.6\) lb (see Fig. 1-1 for determination of \(L_E\) and \(W_T\)). Determine if the measured acceleration falls within the simplified acceleration limit.

\[
\alpha_a = \frac{1.830z}{W_T L_E} = \frac{1.830 \times 0.0853}{16.6 \times 6} = 1.43g > 1.0g
\]

The vibration is acceptable.