Selection guide for vibration studies – small bore connections assessment and specification

Evaluation of vibration induced fatigue failure on SBCs for new projects (design) or existing piping systems

Vibration induced failures on small bore connections (SBCs) are the most common integrity issues for compressor and pumping systems. A failed piping connection is a high impact problem, and has safety, environmental, and operational consequences.

Wood Machinery Analysis offers a range of services to manage this integrity/reliability risk, and has conducted hundreds of successful projects. Appendix 1 contains a summary of the service options, and Appendix 2 contains the specifications/features. For application or support, please contact info.vdn@woodplc.com or call us at +1-403-245-5666.

Available Services for SBC

1. For **new installations (or revamps)**, there are three levels of service – depending on the risk profile of the unit and customer.

Service	New (revamped) compressor or pump packages		
	Description	**Summary**	**Remaining risks**
SBC-D1	Design SBC Review	Basic approach: review available drawings and provide "best practice" recommendations. No field measurements.	**Medium:** Many remaining risks since resonance is possible (and no field verification/testing).
SBC-D2	Standard SBC Design Assessment	Design evaluation of proposed SBC, with recommended changes. Shop and field testing to verify vibration levels are acceptable.	**Low:** Common risks are significantly addressed. A small amount of residual risk remains.
SBC-D3	Comprehensive SBC Integrity Assurance	Wood is directly involved in SBC design to ensure a conservative system that avoids resonances at key frequencies. Shop and field testing to address steady state and transient situations.	**Minimal:** Maximum assurance for the designed operating system.

2. For **existing sites**, there are two service levels.

Service	Existing facilities (in operation)		
	Description	**Summary**	**Remaining risks**
SBC-F1	Standard SBC Field Assessment	Ideal for evaluating SBC integrity and the associated piping system on the machine system. Includes impact testing for MNFs, vibration screening, speed sweep, and detailed Finite Element Analysis (FEA) (if required) to resolve problem locations.	**Low:** For standard service, there are practical limits to testing all locations. Not all operating conditions checked. Plant piping (off-skid) SBCs not evaluated.
SBC-F2	Comprehensive SBC Integrity Audit	For critical applications where more stringent testing is required. Includes transient and steady state testing, fatigue analysis, and assess pipe strain. Can include station piping (away from the rotating/reciprocating machine).	**Minimal:** Common risks are significantly addressed. A small amount of residual risk remains.

To mitigate this risk, **the owner (or its EC) must specify an SBC vibration study** when it orders a new rotating machine, or to request a field assessment on existing units. Refer to Appendix 1 for service specifications and options.

Appendix 1: Service overview and features

Evaluation of vibration induced fatigue failure on SBC

This Appendix outlines the SBC service for new units (design stage), or for assessing vibration on existing facilities. Wood's services are based on over 40 years of field-testing experience and research in SBC and piping fatigue failure. The scope also includes requirements per Energy Institute Standards, GMRC guidelines, API, and other vibration standards.

Refer to Appendix 2 for description of each service (specification), and an overview of the remaining integrity risks.

Service Overview

	Service name	Engineering			Shop		Field measurements (baseline)					Report
		Engineering Review	Risk Assessment Approach	Detailed Engineering Evaluation	Inspection, Best Practices	Impact Testing (MNFs)	SBC Vibration Survey (including MNFs)	SBC Off-Skid Survey	Mainline Vibration Survey (including pulsations)	Transient Vibration Testing and Fatigue Analysis	Assess Pipe Strain at Key Locations	Conclusions, Recommendations
New unit (design stage)	SBC-D1 (Design Review)	✓										✓
	SBC-D2 (Standard Assessment)	✓	✓		✓	✓	✓	✪	✪			✓
	SBC-D3 (Ultra Assurance)	✓	✓	✓	✓	✓	✓	✪	✓	✓	✓	✓
Existing unit	SBC-F1 (Standard Field Assessment)	✓		✓	N/A	N/A	✓		✪			✓
	SBC-F2 (Comprehensive Integrity Audit)	✓		✓	N/A	N/A	✓	✓	✓	✓	✓	✓

✓ included

✪ optional

Appendix 2: Specifications for each service

Evaluation of vibration induced fatigue failure on SBC

This appendix can be used to specify the required service and option (refer to Appendix 1 for summary). The description also summarizes the remaining integrity risks.

New unit/facility design
SBC-D1: SBC Design Review This review and shop test provides a basic level of assurance. **Note:** There are remaining vibration risks that can create integrity failures. This basic review **does not** include detailed design of SBC, or a visit to the installed site to conduct a baseline vibration survey. The review requires general arrangement (GA) and piping and instrumentation drawings (P&IDs), isometric drawings, and bill of materials including weights) during the design phase. Machinery packager to provide advanced notice to Wood to coordinate shop testing. For more integrity assurance, we recommend SBC-D2 service. Scope: • **Design Phase:** Review GA and P&ID drawings and provide recommendations for SBC location/orientation. These are general design recommendations • **Shop Inspection:** Inspect as-built SBC, best practice recommendation based on visual inspection (does not included detailed measurements) • **Field Testing: Not** included in this scope. This can be coordinated/purchased by owner at later date Remaining risks: Medium – SBC may be resonant at some operating conditions, such as: • Pipe strain due to fabrication, transportation or installation may be present • Vibrations measurements not conducted during operations
SBC-D2: Standard SBC Integrity Assessment This approach provides a very high level of assurance against SBC vibration related failures and includes more thorough design and testing. During the design phase Wood will evaluate SBC geometry, calculate MNFs, and compare results to industry guidelines. Wood will collect vibration measurements while the equipment is operating and recommend changes where needed. This service requires detailed drawings (GA, P&ID drawings, isometric drawings, and bill of materials including weights) during the design phase. Scope: SBC-D1 (above), plus the following additional features: 1. **Design Phase:** • Evaluate drawings and compare geometry to established standards

New unit/facility design
• Calculate MNFs • Recommend changes at locations with high risks • Using Wood's performance model, identify the worst case operating conditions (e.g. operating conditions having the highest dynamic forces (rod loads) and/or pressure pulsations) 2. **Shop Test:** Visual inspection and measure SBC MNFs, document geometries, compare MNF to predictions and guidelines. This allows time to make piping modifications before the unit is shipped to site. 3. **Field Vibration Survey (during operations):** • Survey all SBCs, including PSV piping, to screen vibration amplitudes • Identify areas exceeding guideline. Spectral data used to assess vibration frequencies. Pro-rate results based on test condition vs worst case condition (identified above) • For areas above guideline, measure relative vibration to obtain a more accurate vibration/stress risk assessment • Recommend modifications to reduce integrity risks. Verify recommendations using FEA. Report summarizes vibration baseline results Options: • Measure SBCs on the plant or station piping, away from the compressor/pump • Measure pulsation and vibration on main piping system **Note:** For contracting purposes, the service maybe separated into two components: • Packager scope (items 1 and 2) • Owner scope (item 3, field testing) Alternatively, the entire work could be contracted by owner. Remaining risks: Low – This service significantly reduces integrity risk, but does not totally eliminate all risks, such as: • Transient-related vibration • Pipe strain • Changes in operating conditions (outside original design)
SBC-D3: Comprehensive SBC Integrity Assurance For critical installations where maximum reliability/integrity is required, a more stringent design approach and testing is required. This design approach focuses on designing SBC with higher MNFs to avoid dynamic forces that could cause fatigue failure. Wood takes a direct role in SBC design, working closely with the owner and its design team.

New unit/facility design
The service includes SBC-D2 (above), plus the following additional features: 1. **Design Phase:** • Wood takes a more active role in designing all SBCs in the system, working closely with the owner/EPC's to evaluate and recommend SBC alternatives. Using a range of design techniques, Wood's approach will ensure more conservative designs • The design will include FEA of SBCs to accurately predict MNF compared to predicted dynamic forces. Wood will calculate the allowable vibration for each SBC (for use in field testing and ongoing monitoring programs) 2. **Shop Test:** As per SBC-D2. 3. **Field Vibration Survey:** • Measure vibration on mainline and SBC. Measure pulsations on main piping system where required • Compare vibration to allowable stress limits (per FEA). Pro-rate to worst case operating condition and assess using FEA for more accurate prevention of fatigue failure (assuming compressor operates within initial operating envelope) • Assess pipe strain at key locations • Measure MNFs to confirm results and identify changes due to shipping, mounting, and installation • Measure vibration during transient conditions. Test transients during start-up, shutdown, and due to changes in speed and operating conditions. Measure the SBC response using multichannel data acquisition system. Assess transients versus fatigue life (SBC fatigue analysis) • Recommend changes where required. Test modifications using FEA • Detailed report documenting SBC characteristics and results. This information will be the baseline for future monitoring programs Option: measure SBCs on the plant or station piping, away from the compressor/pump. Remaining risks: Minimal – This service provides maximum assurance to the integrity of SBCs. One risk is that the compressor operates outside the original design envelope, or if changes are made to the system.

Existing units/facility (compressors, pumps, piping)

SBC-F1: Standard Field Assessment

This is the ideal approach to manage SBC integrity on existing compressors and pumps. SBCs on "off-skid" piping or on remaining facility piping are outlined in in SBC-F2:

1. **Planning** (prior to site visit):
    - Evaluate as-built drawings and photographs to established test points and work plan
    - Identify the range of operating conditions at site
    - Using Wood's compressor and pump performance models, identify the worst case operating conditions (e.g. operating conditions having the highest dynamic forces and/or pressure pulsations)
    - Prepare test plan and coordinate with customer's field/reliability team
2. **Field Vibration Survey (Baseline)** (during operations):
    - Survey SBCs at key locations, including PSV piping, to screen vibration amplitudes. Identify areas exceeding guideline. Spectral data used to assess vibration frequencies. Conduct speed sweep if required to measure vibration across operating speed range. Pro-rate results based on test condition vs worst case condition (identified above)
    - Conduct impact (bump) test to determine MNFs. Ideally this is done during short shut-down. Alternative method for collecting MNF may be applied if required
    - For larger systems, Wood's multi-channel data acquisition is used to capture transients for operations limited in the number of events that can be simulated. This provides more effective testing during speed sweeps or changing operating conditions
    - For areas above guideline, measure relative vibration to obtain more accurate vibration/stress predictions
    - Recommend modifications reduce integrity risks. Verify recommendations using FEA
    - Report summarizes vibration baseline results
3. **Options** (additional vibration or troubleshooting services):
    - Measure vibration at other agreed operating conditions
    - Measure vibration on main piping, vessels, skid, foundation, frame, etc. Measure pulsations where required
    - Perform operating deflected shape at key locations
    - Troubleshooting support for vibration related problems

Remaining risks: Low – This service significantly reduces integrity risk, but does totally eliminate all risks, such as:

- Transient related vibration
- Pipe strain

Existing units/facility (compressors, pumps, piping)
• Changes in operating conditions that create higher forces or different MNFs
SBC-F2: Comprehensive Integrity Audit For critical conditions where maximum reliability/integrity is required, a more stringent testing methodology is applied to evaluate vibrations at different operating conditions, or other locations in the facility. Scope can include transient events (stop, start, changing conditions). The service includes SBC-F1, plus the following additional features: • Assess pipe strain at key locations • Collect relative vibration data on headers, plant piping, etc (station or facility assessment) • Evaluate at key conditions • Strain gauge measurements as required • Measure vibration during transient conditions. Using multichannel data acquisition system, test transients during start-up, shutdown, and due to changes in speed and operating conditions. Assess transients versus fatigue life (SBC fatigue analysis) • Recommend changes where required. Test modifications using FEA • Detailed report documenting SBC characteristics and results. This information will be the baseline for future monitoring programs Remaining risks: This service provides maximum assurance to the integrity of SBCs. One risk is that compressor or pump operates outside the original design envelope, or if changes are made to the system.