# Low Frequency Noise from Vibrating Screens

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**ABSTRACT**
Vibrating screens are commonly used to separate and classify material across a variety of processing industries. The operation of the screens can be a source of noise (unwanted sound) within communities and environments near to processing plants and industrial premises. The emissions can include prominent low frequency sound which has the potential to impact public health and wellbeing. The nature of potential impacts associated with low frequency noise can be contentious, particularly where the low frequency sound is not always audible (often referred to as infrasound). Decisions to rectify low frequency noise problems require a detailed understanding of the mechanisms which generate the low frequency sound during the operation of the vibrating screens. This paper considers vibrating screens as sources of low frequency noise and discusses techniques to diagnose and quantify the low frequency sound emissions.

## 1 INTRODUCTION

Vibrating screens are widely used for classifying materials. The material processed by vibrating screens is referred to as “feed” and in a continuous process, feed enters the screen on one side and is then conveyed to the discharge chute by a combination of vibration and gravity. The vibratory motion is usually generated by large unbalance motors mounted on the screen itself. Vibrating screens typically operate in the 12 Hertz (Hz) to 18 Hz range at vibration velocity amplitudes of a few hundreds of millimetres per second.

In order to accommodate the necessary motion amplitudes of vibrating screens, they require a resilient connection to the supporting structure; usually springs (coils, rubber, or air) are used at this interface. Particles and fluids that can pass through the screen panel are collected in an underpan, which is located below the screen and supported on the structure, not the vibrating screen itself. Multiple factors influence the operational settings of a vibrating screen: size, texture and shape of granules, density of the material, moisture content and the size distribution (Sullivan, 2013).

Vibrating screens are often housed in buildings with a roof and are otherwise open to the elements. The construction of the roof and facades (if present) are often similar and usually consist of corrugated sheet metal screwed to purlins, which span horizontally between columns and rafters. The roof and facade structures are not usually constructed to assist in the control of noise and vibration emissions. The main components of a generic vibrating screen within a processing plant are presented in Figure 1.

A vibrating screen, due to its nature of operation, can be a major source of sound and vibration within the processing plant. While some 99% of the A-weighted overall sound level comes from the 100 Hz to 10 kHz frequency range and originates from sources such as the feed, the drive mechanism and water spray (Lowe et al., 2010; Yantek et al, 2005), significant energy is present at low frequencies.

Low frequency sound is understood to mean sound in the frequency range from about 10 Hz to 200 Hz. The low frequency range includes infrasound, which is defined by ISO 7196 as sound whose frequency spectrum lies mainly in the band from 1 Hz to 20 Hz. Human hearing is generally capable of detecting sound in the 20 Hz to 20 kHz range, however infrasound (less than 20 Hz) can be perceptible if the levels are high enough (Leventhall, 2006).

The sound emissions from vibrating screens, either individually or combined, can be a source of low frequency noise within the environment. Relative to mid and high frequency noise, low frequency noise attenuates less with distance and through barriers and has therefore the potential for far-reaching perceptible impacts. In addition, the presence of beating of low frequency tones could further fuel annoyance or disturbance reactions.

Beating is a periodic change in amplitude, and, in the case of processing plants, this can occur where two or more screens are running at slightly different frequencies.

This paper considers vibrating screens as sources of low frequency sound and techniques to diagnose and quantify the source of the low frequency noise are discussed.

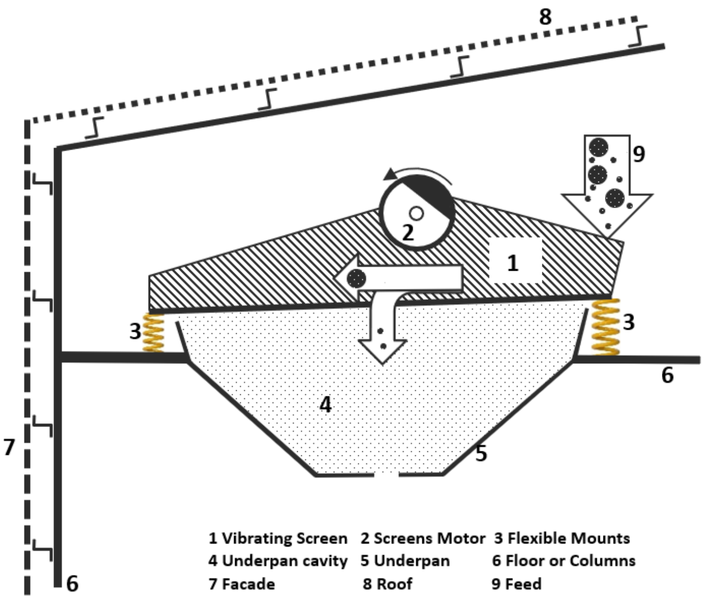


Figure 1: Basic schematic identifying parts.

## 2 MECHANISM FOR LOW FREQUENCY SOUND EMISSIONS

The underlying dominant low frequency sound mechanism is not always evident. On a basic level, the relative importance of the airborne path versus the structure-borne path needs to be understood. In a dominant airborne path, the positive and negative pressure waves either side of the screen's deck, akin to loudspeakers, are the direct source of the low frequency sound. In a dominant structure-borne scenario, the vibratory forces are transferred via the screen's springs into the structure. The dynamic forces transferred via the springs excite the structure, specifically the roof and the facades (if present) and these elements, in turn, reradiate low frequency sound.

An illustration of the typical airborne and structure-borne mechanisms for low frequency sound is provided in Figure 2.

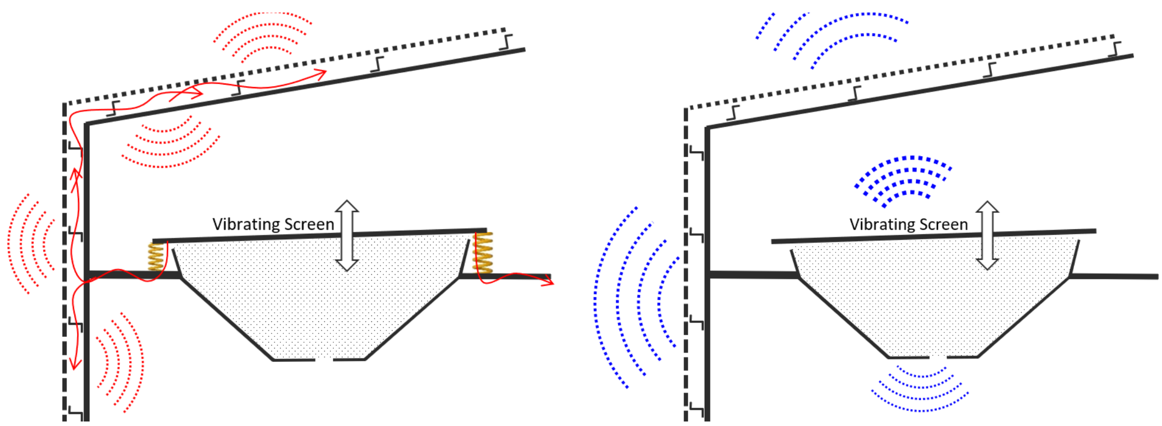


Figure 2: Low frequency sound mechanisms (left: structure-borne, right: airborne).

Often complex measurement programs are required to distinguish the airborne and structure-borne paths. “Back of envelope” approximations will often provide ambiguous conclusions. Consider the sound power of a vibrating plate (Equation (1), adapted from Crocker, 2007).

$$W_{rad} = \rho_0 c_0 S\langle v^2\rangle\sigma \tag{1}$$

where, $\rho_0 c_0$ is the acoustic impedance, $S$ is the surface area, $v$ the surface averaged mean velocity of the screen and $\sigma$ is its radiation efficiency.

The product $S\langle v^2\rangle$ for a screen can be of similar magnitude to that of a building’s facade and roof, which vibrate at much lower vibration velocities than the screen but have a much greater radiating surface than the screen deck. Accordingly, for similar radiation efficiencies, the sound power of the screens and that of the building envelope will be similar; a result which does not readily allow for identifying the primary sound generating mechanism. Applying Eq. (1), the theoretical sound powers of screens at their nominal runspeeds are often in the range of 130 dB to 150 decibels (dB).

In-situ measurement programs, if planned carefully, can assist greatly in determining the dominant source mechanism at a particular site. Key questions worth considering are:

- Screen identification: which vibrating screens are the primary source of the low frequency noise?
- The effects of feed: if sound pressure levels change as feed material is introduced to the system, which elements exhibit an associated change in vibration levels?
- Spatial characteristics of the pressure field: what is the sound pressure level above a screen deck and below the underpan? How does sound pressure vary with distance from a screen?
- Ask how efficiently the facade or roof would actually radiate noise. What is the relationship between facade/roof vibration velocity and sound pressure level, particularly their phase relationship?
- The measurement of sound to isolate the contribution of the individual screens in the outdoor environment: how can low frequency sound be reliably measured to support the identification of the source emissions?

## 3 SCREEN IDENTIFICATION

The process to classify materials usually requires a sequence of individual screens to progressively isolate specific materials based on their size. Individual vibrating screens have unique sound pressure signatures associated with the specific runspeeds of each unit.

The sound contribution from individual screens can be determined from the overall sound emissions through narrow band analysis by applying a Fast Fourier Transformation (FFT) of the measured sound pressure. An FFT will highlight the operational frequencies of the dominant screens. Similarly, FFTs of a screen’s oscillatory mechanical motion can be used for identifying a screen’s characteristic frequency. Once the frequency spectrum of each screen is identified, the contribution of the individual screens to the overall level of low frequency sound can be better appreciated.

Figure 3 presents the FFT of a pressure signal recorded remotely from a processing plant in which several screens were operated. The abscissa is truncated to coincide with the 16 Hz one-third octave band frequency bandwidth. In this example, the combined sound pressure from the vibrating screens contributed to prominent low frequency noise at the 16 Hz octave band, with corresponding peaks at the 31.5 Hz second harmonic and 50 Hz third harmonic.

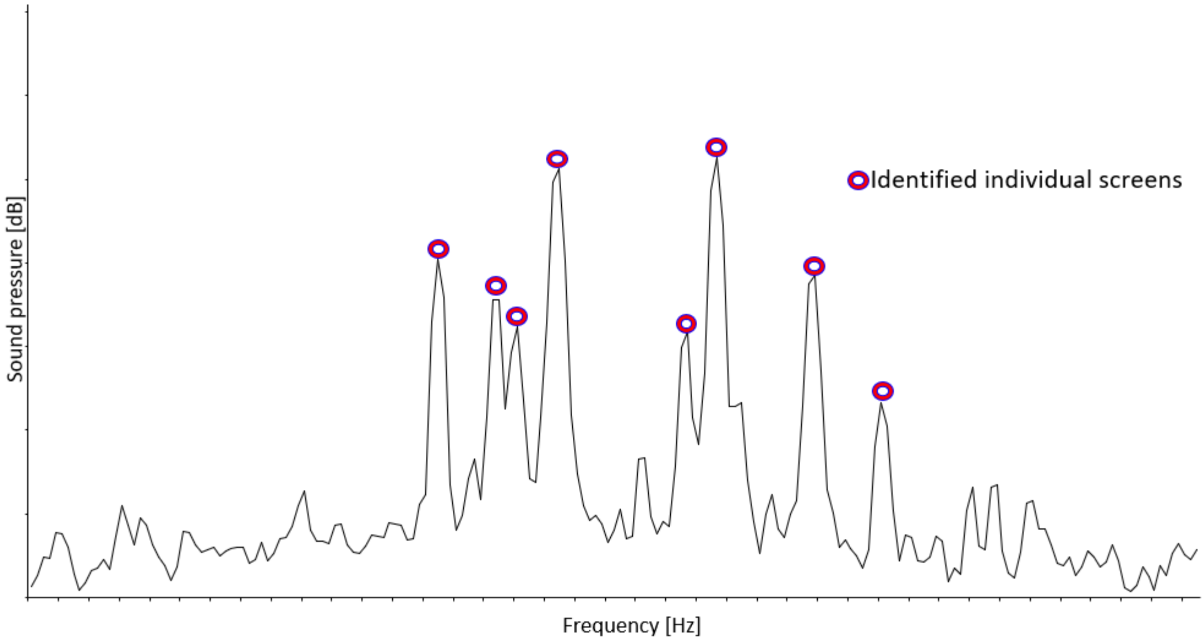


Figure 3: Identification of the runspeed of individual vibrating screens by narrowband FFT analysis.

## 4 THE EFFECTS OF FEED

The sound pressure and vibration emissions within a processing plant and the external environment can vary depending whether individual screens are running with and without feed. The half hour time segments of the out-of-plane vibration of a facade panel and the linear pressure measured inside a processing plant are shown in Figure 4. The sound pressure was measured at approximately 2 metres (m) from the facade vibration measurement point.

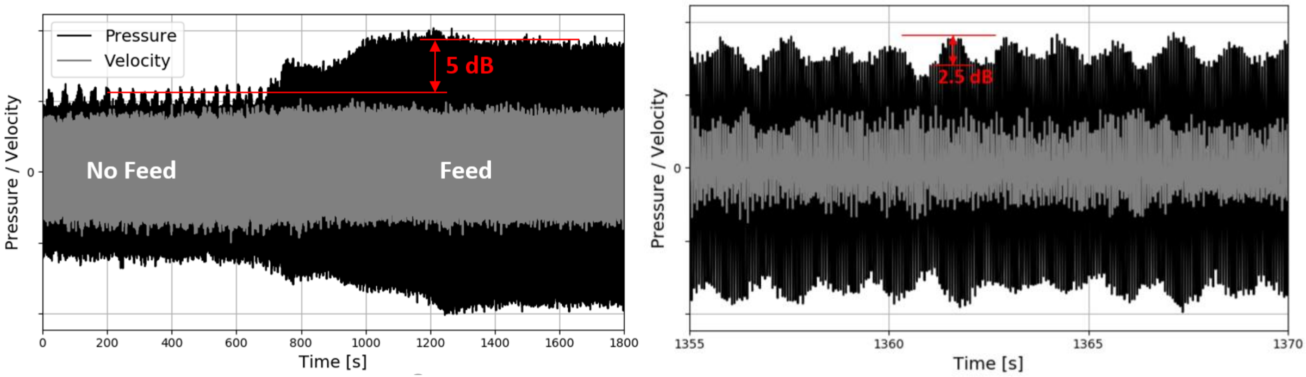


Figure 4: Processing plant sound pressure (black) and facade vibration velocities (grey).

The plotted data captures the period when the plant changed from not processing material (operated without feed) to full capacity. This process lasted from approx. 700 seconds to 1,000 seconds. In this particular case, the presence of material feed increased the overall pressure by approximately 5 dB while almost no increase of the facade's vibration velocities occurred.

The screen vibration levels (not shown in Figure 4) actually reduced somewhat due to the feed's mass and some added damping. The Authors attribute the increase in sound pressure level to changes in the screens' radiation efficiencies since the feed forms an almost continuous carpet of watery material covering the perforated (and often plastic) surface of the screens.

The right hand side in Figure 4 shows in detail a short time segment with feed on the vibrating screen. A modest amplitude variation of 2.5 dB at an approximate 1.5 second period is evident. Amplitude variations due to beat cycles in excess of 20 dB are not uncommon and have been observed by the Authors.

For the time trace presented on the left hand side of Figure 4, narrowband FFTs were calculated which revealed that the increases in the frequency domain were quite characteristic with the increase being 5 dB at the the nominal runspeed and increases of 15 dB at its second harmonic. Measurements of sound pressure remotely from the plant reciprocated this effect.

## 5 SPATIAL CHARACTERISTICS OF THE PRESSURE FIELD

The spatial pressure fluctuations can provide valuable insights when considering the relative importance of airborne sound and structure-borne sound paths. The relative difference in sound pressure measured above a vibrating screen and below its underpan (refer to Figure 1) can be a useful indicator.

The Authors carried out a detailed sound pressure survey within an enclosed processing plant. For this specific plant, the sound pressures below the underpans were approximately 10 dB lower than the sound pressures above the corresponding screens. The underpans, which were found to vibrate typically ten times less than the screen deck, were a physical barrier and attenuated the sound pressure below the screens. The Authors judged this result to be consistent with a pressure field governed by a direct airborne sound path. A structure-borne path would be expected to exhibit a smaller pressure differential between the screen deck and below the underpan as the parts of the facade extending above and below the screens were found to vibrate at similar levels, thereby generating pressures of similar magnitude.

The study of the change of sound pressure with distance from a screen and the corresponding change of the facade/roof vibration levels can assist in determining the relative importance of the sound generating mechanisms. Where several screens are operational, beat cycles can greatly complicate the interpretation of results. Tests with only a single screen running at a time may provide better results, however, such tests require temporary plant shutdowns and would be unlikely to capture the effects of feed.

## 6 FACADE/ROOF MODE SHAPES AND PHASE RELATIONSHIPS

Operational Deflection Shapes (ODS) of the facade/roof (or part thereof) can assist in judging how effectively the external building surfaces of a processing plant may radiate sound at certain frequencies. Where the ODS show the facade/roof to be vibrating uniformly over large areas, sound may be radiated effectively and the structure-borne path may be dominant.

The simultaneous measurement of sound pressure near the facade/roof and measurement of vibration of the facade/roof determines the phase relationship between the facade/roof vibration and the near-field pressure. Orbit plots of near-field sound pressure versus facade vibration measured by the Authors in a processing plant where the airborne path was determined to be dominant are provided in Figure 5.

The four subplots correspond to four different measurement locations at the building facade at comparable locations (i.e. halfway between columns and purlins). If the facade was generating the near-field pressure, then a similar phase relationship between the structural vibration and pressure would be observed consistently within the plant. However, this is not the case as different phase relationships (i.e. differently oriented orbits) were observed at the measurement points. The absence of a globally consistent phase relationship between pressure and vibration was one indicator that the airborne path was dominant.

In other words, for structure-borne vibration to have been the dominant source of sound, the vibration measured at the facade would be both linear to the measured pressure and changes in the vibration levels would generally lead to fluctuations in sound pressure.

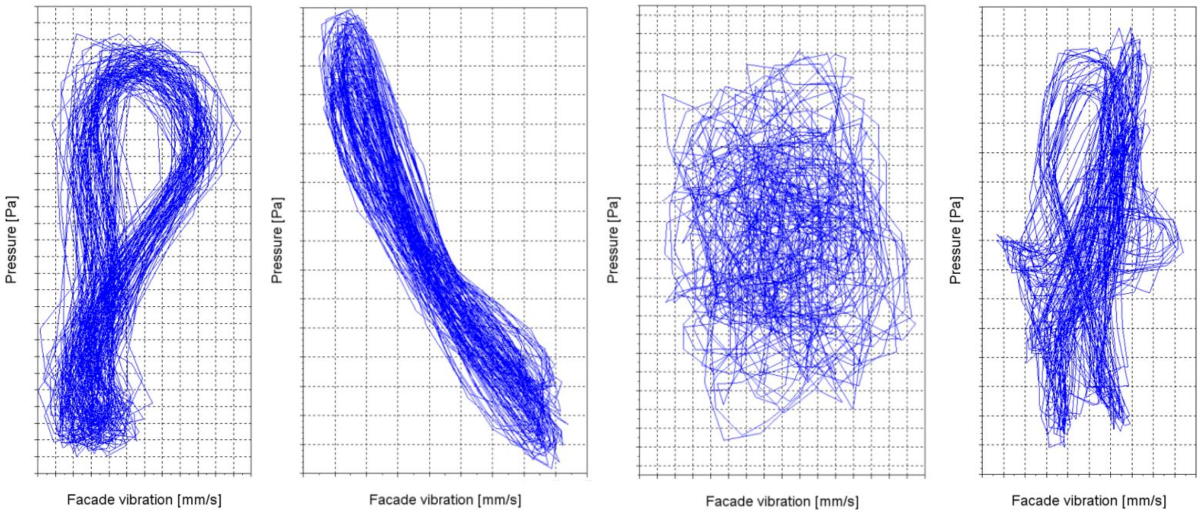


Figure 5: Example phase relationships between pressure and facade vibration measured in an airborne dominant environment.

## 7 MEASUREMENT OF LOW FREQUENCY SOUND

The measurement of low frequency sound to support the investigation of noise emissions from individual screens requires careful consideration of the source emissions and the measurement environment. In the experience of the Authors' the following are some of the aspects to consider when preparing surveys to measure low frequency sound from vibrating screens, particularly when investigating the effects of low frequency sound within a receiving environment:

- Microphones with low-frequency cut-offs well below the screens' runspeeds are required. The instrumentation must either have on-board FFT capability or be capable of saving audio recordings to allow for detailed post processing.
- Individual measurements at the source and the receiving environment should be of a sufficient duration to capture the operation of all screens including temporal amplitude fluctuations from beat cycles. A measurement duration of 120 seconds to 200 seconds can be sufficient.
- A scenario of all vibrating screens in operation should be considered to identify the presence of any modal effects.
- Measurements should include a complete cycle of operations allowing for operations with and without feed on all vibrating screens.
- When conducting measurements in the outdoor environment the operator must carefully observe any fluctuations in the one-third octave and narrow band frequencies of interest. Interference from extraneous sources can be a common challenge when quantifying low frequency sound and infrasound.
- The measurement of low frequency sound and infrasound can be highly sensitive to weather/meteorological conditions. A detailed understanding of the local wind speed, wind direction, air temperature, precipitation and relative humidity should be recorded (or obtained) for each measurement event. This is particularly important if conducting measurements over varying time periods.
- The measurement of sound outdoors is routinely undertaken where wind speeds are up to 5 metres per second (m/s). The practicalities of low frequency sound measurements usually mean calm/still conditions are unlikely to be achievable. For the measurement of low frequency sound and infrasound, the local wind speed conditions should ideally be less than 2 m/s (Evans et al., 2013).
- Avoid conditions where the prevailing wind direction would enhance the propagation of noise away from the point of measurement which could result in a potential under-quantification of the sound levels.
- Repeat the measurements. Adopt a survey that enables comparison of the various influencing factors. For example: the operation of the processing plant with and without feed, variations in low frequency sound surrounding the processing plant (directional sound) and changes to daily weather conditions.
- Consider the harmonics of the screen runspeeds. For example, vibrating screens operating at the 16 Hz one-third octave band can exhibit increased sound pressure at the 31.5 Hz one-third octave band (the second harmonic) and at the 50 Hz one-third octave band (the third harmonic).
- If measuring sound at low frequencies within a receiving room, the room modes associated with the lower frequencies of interest need to be understood. Within typical residential properties the room dimensions

are likely to be less than one wavelength of the sounds below 100 Hz. Further guidance on the measurement of low frequency sound within receiving rooms can, for example, be referenced from ISO 16283.

## 8 CONCLUSIONS

A careful and coordinated measurement program can effectively isolate the sound and vibration emissions that contribute to low frequency sound from vibrating screens. Narrowband FFT analysis of sound pressure levels measured within the processing plant and at the receiving environment are necessary to identify and rank the dominant sources of the low frequency sound. Detailed time domain measurement of the pressure and vibration at the vibrating screen and the surrounding infrastructure can support the determination of the relative importance of the airborne sound and structure-borne sound pathways. Without these detailed measurements there remains potential to readily misdiagnose the source of the low frequency sound and adopt ineffective, and costly, noise control strategies.

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