Noise Considerations for the Design, Specification, and Installation of Roller Conveyor Systems

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CONVEYOR PRODUCT SECTION
Material Handling Industry
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Table of Contents

Introduction .............................................................................................................. Page 3
Fundamentals of Sound .......................................................................................... Page 3
Sound Measurement ............................................................................................... Page 6
Noise Control Options ............................................................................................ Page 8
  • Conveyor Design and Installation Issues ......................................................... Page 9
  • Operating Environment and Other End-User Considerations ....................... Page 10
Summary .................................................................................................................. Page 12
References ............................................................................................................... Page 12

Purpose

These Noise Considerations for the Design, Specification, and Installation of Roller Conveyor Systems have been developed by the member companies of the Conveyor Product Section of the Material Handling Industry to offer guidance to those considering noise in the design, specification, and installation of roller conveyor systems.

Noise Considerations for the design, specification, and installation of roller conveyor systems was made possible because of the direct contribution of many member companies of the Conveyor Product Section of Material Handling Industry. However, a very special recognition is due to Rod Reason, Virginia Tech University and a member of College-Industry Council on Material Handling Education (CIC-MHE), who prepared numerous drafts and conducted the research necessary to produce this document.

Disclaimer

These considerations are advisory only. They have been promulgated by the member companies of the Conveyor Product Section (CPS) of the Material Handling Industry with the sole intent of offering information for the design, specification, and installation of roller conveyor systems. Reference to these considerations in inquiries by the purchaser is permissible. The considerations are not intended to and do not in any way limit the prerogative of a manufacturer to design or produce roller conveyor systems. Whenever mandatory or other language used in the considerations seems to impose requirements, same is intended to be advisory only.

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Introduction

Noise can be defined as unwanted sound. Noise has an adverse impact on people and their performance in the workplace. As such, it is good business practice to minimize exposure to noise. However, in an industrial setting, there are generally many sources of noise. Each noise source contributes to the total level of noise which a person may be exposed. However, reduction in noise from one or more these sources may not significantly reduce the level of noise. Therefore, the total work environment (including the building structure) and all sources of noise must be considered as an integrated system when addressing noise reduction. Focusing on only one component of that system (e.g., the material handling system), may not yield the level of noise reduction desired.

These guidelines have been developed by the Conveyor Section of The Material Handling Industry to address noise reduction issues related to the design and installation of roller conveyor systems. As such, it addresses the impact of only one noise source (the material handling system) and its impact on the total work environment. However, many of the guidelines discussed are also more generally applicable to other noise sources (e.g., production equipment). These should help you develop specifications for the design and installation of roller conveyor systems which will help meet hearing safety standards for the total work environment.

Fundamentals of Sound

Sound is created by the vibrating motion of displaced molecules in an elastic medium. This medium can be air, wood, steel, or other materials. This vibration produces waves which radiate in all directions, much like ripples on a pond. As these waves travel through a medium, a small pressure change, above atmospheric pressure, is created. Our ear is able to sense this change, enabling us to hear. This change in pressure is known as sound pressure level. The sound pressure level is the measure of sound most commonly referred to when discussing industrial noise control. It is easily measured using simple hand-held devices. People are able to hear sound pressure levels between about $1 \times 10^3$ psi and 15 psi (or 1 atm). Since this represents 10 orders of magnitude change, logarithmic scales are used to measure sound pressure levels in decibels (dB).

Frequency is defined to be the rate at which molecules vibrate. A given noise source contains many different component frequencies. The sound pressure level may vary for different frequencies as shown in Figure 1.

![Sound Pressure Level Versus Frequency](image)

**Figure 1**: Sound Pressure Level Versus Frequency
The human ear is able to perceive a relatively narrow frequency range, from 30 to 17,000 Hz. When measuring sound pressure level, it is convenient to express sound pressure level as a single number rather than as a function of frequency. The A-scale on common sound level meters uses a weighting scheme which closely follows the frequency response of the human ear. This enables sound pressure level to be expressed as a single measure denoted as dBA. The A-scale plays a prominent role in noise control.

The human ear can barely detect a 3 dB difference in sound under controlled conditions. With everyday background noise present, a change of 5 dB requires careful listening. A change of 10-20 dB can be readily sensed. The sound pressure level generally depends upon how far you are from the noise source. The rate at which the sound pressure level decreases as a function of distance depends upon the impedance of the medium through which the sound is traveling. Impedance is the resistance of a fluid or material to the propagation of sound waves. The acoustical performance of absorbing materials and barrier materials depends upon this impedance.

Sound power measures the flow rate of acoustical energy from a sound source and is independent of any point in space or time. A sound source radiates power which results in sound pressure. Sound power is the cause and sound pressure is the effect or what we hear. Sound power and sound pressure are frequently confused. This is partly because they are both measured in decibels. The logarithmic decibel scale is also used to measure sound power because the range of values over which sound power (measured in watts) typically varies is extremely wide. However, sound power is analogous to the power rating of a light bulb. Experience indicates that a 100 watt light bulb is brighter (light intensity or illumination) than a 25 watt bulb at any given distance. Similarly, the sound pressure level created by a sound source of 100 watts (140 dB) is greater than that created by a 25 watt source at any given distance. Sound pressure level is a function of distance. Sound power is independent of distance.

The relationship between sound power and sound pressure level is given by the following equation:

\[ L_p = L_w - 20 \log_{10}(r) - 11 \]

where \( L_p \) = sound pressure level (dB)
\( L_w \) = sound power (dB)
\( r \) = distance from sound source (meters)

This equation is recognized as one of the most important equations in acoustics. As an illustration, consider a large chipping hammer with a sound power level of 120 dB. What is the sound pressure level at 15 meters from the source?

\[ L_p = 120 - 20 \log_{10}(15) - 11 \]
\[ L_p = 85.5 \text{ dB} \]

As reported earlier, sound pressure level can be easily measured using a sound level meter. However, sound power is not easily measured. Therefore, another useful equation expresses sound pressure level as a function of the distance from the noise source. Let \( L_{p,1} \) and \( L_{p,2} \) be the sound pressure levels at a distance \( r_1 \) and \( r_2 \), respectively, from the noise source. The resulting relationship between these sound pressure levels is:

\[ L_{p,2} = L_{p,1} - 20 \log_{10} \left( \frac{r_2}{r_1} \right) \]
Therefore, if the sound pressure level is 90 dB at 5 meters from the source, what is the sound pressure level at 10 meters from the source?

\[ L_{p,2} = 90 - 20 \log_{10}(10/5) \]
\[ L_{p,2} = 84 \text{ dB} \]

This illustrates an often quoted rule of thumb that states that the sound pressure level decreases by 6 dB when the distance from the noise source is doubled.

These equations assume that the sound waves emanating from a sound source are uniform, nondirectional, and freely propagating plane waves. Most sources do not radiate uniformly and therefore some caution should be exercised when using these equations to estimate sound pressure levels close to a source. However for larger distances they can be used with negligible error.

### Table 1: Sound power level of common sounds

<table>
<thead>
<tr>
<th>Common Sound</th>
<th>Sound Power Level (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbojet engine, 7000-lb thrust</td>
<td>160</td>
</tr>
<tr>
<td>4-propeller airliner</td>
<td>140</td>
</tr>
<tr>
<td>75-piece orchestra</td>
<td>130</td>
</tr>
<tr>
<td>Large chipping hammer</td>
<td>120</td>
</tr>
<tr>
<td>Auto horn</td>
<td>110</td>
</tr>
<tr>
<td>Radio hi-fi</td>
<td>100</td>
</tr>
<tr>
<td>Voice, shouting</td>
<td>90</td>
</tr>
<tr>
<td>Office</td>
<td>80</td>
</tr>
<tr>
<td>Voice, conversational</td>
<td>70</td>
</tr>
<tr>
<td>Whisper</td>
<td>50</td>
</tr>
</tbody>
</table>

When there are multiple sound sources, \( L_{p,i} \), the resultant sound pressure level, \( L_{p,r} \), at a given distance can not be determined algebraically. Since the sound pressure level is measured using a logarithmic scale, the following equation is used to determine the combined effect.

\[ L_{p,r} = 10 \log \left( \sum_{i=1}^{n} 10^{L_{p,i}/10} \right) \text{ dB} \]

This equation yields two useful rules of thumb. When two equal sound sources are combined, the resulting sound pressure level will be only 3 dB higher. If two different sound sources are combined and the difference between the two levels being added is 10 dB, the combined sound pressure level will only be 0.5 dB higher than the higher of the two sources. These are illustrated in Figure 2.
Sound Measurement

The primary instrument used to measure sound pressure level in the field is the sound level meter (see Figure 3). The A scale should be used to integrate different sound frequencies into a single composite measure (dBA). For reliable and accurate sound level measurements, background noise should be reduced to a minimum. Measurements taken when the difference in level between total noise and background noise is 3 dB or less, should be avoided. In addition, sound can bounce or reflect from some surfaces. Severe measurement errors can and often do occur in industrial environments where reflective surfaces are present. This is especially true when these reflective surfaces are in close proximity to a noise source (e.g., a hard masonry wall close to a conveyor).

Figure 3: Typical sound level meter

The sound pressure level surrounding a source of noise will be a function of many factors. Therefore, the most realistic portrait of the noise a human operator will be exposed to can
be obtained from a noise contour map. A noise contour map provides a visual image of the sound field over an area as shown in Figure 4.

A noise contour map can be easily developed using the following 3-step process.

1. Using the A-scale and "slow" response settings on a sound level meter, walk around the sound source, maintaining a constant reading (e.g., 80 dBA). Record your path until it closes on itself, forming a loop, or until the path exits the area to be surveyed.

2. Trace the path followed on a plant layout or area map. This can most easily be done by a second person following the surveyor.

3. Repeat the process for as many contours as desired or needed. At a minimum, seven contours forming eight hearing hazard zones are recommended. These zones should be bounded by contours at 85, 90, 95, 100, 105, 110, and 115 dBA.

![Grid Locations On Plot Plan](image)

*Figure 4: Noise Contour Map*

Once noise contours have been defined, the risk to human operators can be established. The permissible levels of noise exposure specified by the U.S. Department of Labor in the Occupational Safety and Health Act are time-weighted average exposures. OSHA regulations become applicable when an operator’s exposure exceeds a time-weighted average level of 85 dBA for an 8-hour period. The permissible levels of exposure to occupational noise permitted by OSHA are shown in Table 2.

The portion of time an operator is projected to spend working in a given sound field can be estimated and the level of exposure calculated. For these calculations to be valid, the sound field must be defined based upon reasonable operating expectations. The amount of noise in the work environment depends upon more than the level of noise generated by the
conveyor itself. It also depends upon the speed at which the conveyor is operated, the nature and type of the unit load carrier used, the presence of other noise sources near the

**Table 2: Permissible Levels of Exposure to Occupational Noise**

<table>
<thead>
<tr>
<th>Sound Level (dBA)</th>
<th>Duration (Hrs. Per Day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>8</td>
</tr>
<tr>
<td>92</td>
<td>6</td>
</tr>
<tr>
<td>95</td>
<td>4</td>
</tr>
<tr>
<td>97</td>
<td>3</td>
</tr>
<tr>
<td>100</td>
<td>2</td>
</tr>
<tr>
<td>102</td>
<td>1.5</td>
</tr>
<tr>
<td>105</td>
<td>1</td>
</tr>
<tr>
<td>110</td>
<td>0.5</td>
</tr>
<tr>
<td>115</td>
<td>&lt; 0.25</td>
</tr>
</tbody>
</table>

operating area, the architectural design of the building housing the system, and other considerations. Ideally, the design specification should specify the operating environment in which the conveyor system must function. No one can accurately predict what the overall sound levels in a facility will be until after the system is up and operating in the intended configuration. However, there are several options for reducing the noise associated with these systems. These are discussed in the next section.

**Noise Control Options**

There are several options to be considered when seeking to reduce workplace noise. These include:

1. Do not make the noise.
2. Modify or substitute processes and components which generate less noise.
3. Use vibration isolation or damping.
4. Absorb acoustic energy.
5. Shield or enclose the noise source or the receiver.
6. Combine or integrate solutions.

Noise can be controlled at the source, anywhere along its transmission path, or at the receiver. The primary goal should always be to reduce noise at its source. Often the most effective noise reduction approaches involve simple design changes to reduce the noise generated.

A second approach involves modifying or substituting processes and components to reduce noise. For example, belts can be substituted for gears or free-fall conveying processes can be avoided. Cushioning impact points or substituting plastics for metal parts can be effective ways to isolate vibration or dampen sound. The use of acoustical materials to absorb sound within housings, enclosures, and buildings is another option frequently used. Alternatively, the noise source can be partially or fully enclosed. Properly done this can be very effective. However, if done incorrectly, it can be a complete failure or it may even amplify the noise from a source. Frequently, effective noise control requires a combination of these solution approaches.
There are many different types of powered roller conveyors frequently used in commerce and industry. The diversity of conveyor operating environments, conveyor designs, and installation options makes it impossible to specify a general solution to noise control problems. Noise control must be a partnership between the conveyor supplier and the end user. There are many different facets to the noise control problem. Some of these issues like conveyor design and installation can be addressed by the conveyor supplier. However, other issues like the operating environment and maintenance of unit load carriers are controlled by the end user. Working together in a partnership, noise control options can be identified and analyzed based upon user requirements. The following sections addresses the major concerns which must be addressed by this partnership.

**Conveyor Design and Installation Issues**

There are potentially many different approaches to noise control which can be developed. Different conveyor suppliers offer a range of conveyor designs. Different designs offer different challenges when it comes to noise control. What may be a noise control issue for one supplier may not be an issue for another supplier. Each conveyor design provides unique challenges and opportunities. For example, roller tube ringing is a common source of noise in conveyor systems. One cost effective approach to this problem utilizes lined or covered tubes. However, some line shaft conveyor suppliers have found that the drive belt on these designs has a dampening effect on this ringing sound and have found it unnecessary to use lined tubes. In addition, the type of unit load being conveyed may dampen this ringing. Therefore, to specify that lined or covered tubes be used may not provide a cost effective solution in all applications.

Recognizing that different conveyor designs offer different noise control opportunities, what problems commonly occur? A typical powered roller conveyor system consists of three major components as shown in Figure 5. These are the structural framework, the drive mechanism, and the conveyor rollers. In a complex conveyor system, there are typically a limited number of structural frameworks and drive mechanisms. However, there are hundreds or thousands of conveyor rollers in use. These rotating rollers can frequently be the major source of noise in many conveyor systems.

![Figure 5: Typical powered roller conveyor](image-url)

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9
Structural frames are generally fabricated of formed or structural steel with welded construction. These frames transmit the noise generated by the rotating components they support and the noise generated by the goods being conveyed. Isolation devices like dampening pads, non-metallic hangers, vibration absorbers, etc. help by absorbing noise at each support joint.

The drive mechanism typically includes an electric motor and gearbox, and various bearings, belts, chains, sprockets, etc. The electric motors generally operate quietly if properly maintained. The gearbox connected to the motor can produce noise as torque is increased or speed reduced. Higher precision gearboxes effectively reduce noise. Also, high quality bearings should be used throughout the drive system. Vee belts or Polyvee belts produce less noise than chain drives. Finally, all powertrain hardware should be securely attached to rigid support structures to avoid vibration. Sound boxes lined with acoustically absorptive materials can be used to further isolate the drive from nearby operators.

Conveyor rollers can be a major source of the noise produced by high-speed conveyor systems. Most conveyor rollers are hollow metal tubes that resonate as conveyed materials move over them. In many high-speed roller conveyor systems, there is a constant “ringing” sound emanating from the roller tubes. This ringing can be reduced by using a plastic tube material or by covering or lining the tube with a sound absorbing material.

Shaft clatter can be another significant problem for rollers. While the manufactured roller is reasonably round, there is some ovality and some imbalance. These problems are accentuated at high speeds. As the roller rotates at high speeds, these problems cause the roller to bounce in its mount. Several techniques are available to prevent shaft noise. Threaded shafts with either male threads or tapped holes are popular in Europe. Alternatively, plastic or rubber inserts can be used to isolate the shaft from the frame.

Noise reductions can also be significant when precision bearings are used rather than stamped, commercial-grade, steel ball bearings. Precision bearings also offer longer life and lower maintenance than traditional bearings.

In summary, the opportunities for reduction of noise from the conveyor itself depend upon the conveyor design. Different suppliers utilize different designs requiring different approaches to noise reduction. The most cost effective approach varies from one application to the next. Therefore, it is important for the conveyor supplier and the end user to work in partnership to address these issues.

**Operating Environment and Other End-user Considerations**

The environment in which the conveyor system must operate can have a major impact on the amount of noise generated. Significant noise control can be obtained by controlling the reflected noise which accumulates in enclosed interior environments. This phenomenon, called reverberation, occurs when there is a lack of absorbing surfaces. The walls, floor and ceiling in industrial plants are typically acoustically hard and significant reverberation buildup is common. Acoustical bats or baffles can be suspended in rows or in “egg crate” type ceiling arrangements to absorb noise. However, little reduction is usually achieved within 10 feet of the source. In many factory areas, the noise sources are distributed over the entire floor area. As such, moving 10 feet from a noise source simply puts you in the noise field of another noise source. However, in areas remote to a noisy source, 20 ft. or more,
the addition of reverbrant treatment may reduce the reverberant noise buildup by 10 dB or more.

The unit load being conveyed can also impact noise levels. Unit load carriers (pallets, tote bins, etc.) should be adequately maintained to reduce noise and damage to rollers. The material used to construct the unit load carrier (wood, plastic, metal, etc.) can further contribute to the problem. Be sure to use materials that tend to dampen any noise generated by conveyance of the unit load. Also, loose parts being conveyed can generate noise as they vibrate or bounce around. These can be packed so as to minimize movement.

When considering noise control, what’s most important is the level of noise people will be exposed to during the performance of their jobs. The areas where people are expected to spend the majority of their work time need to be defined and sound pressure levels measured or estimated in these locations. If possible, jobs located in noisy areas may be redesigned to structure work differently and thus remove the operator from these areas. Noise reduction and the resulting quiet operating environment, will have a significant impact on employee performance, system throughput, and environmental conformity.

In summary, the operating environment, the unit load design, and the design of work to be performed by human operators are significant considerations in the management of noise. These issues are clearly the responsibility of the end user. However, in partnership with the conveyor supplier, cost effective solutions to these problems can be identified and evaluated.
Summary

It is good business practice to minimize operator exposure to noise. The total work environment and all sources of noise must be considered as an integrated system when addressing noise reduction. In addition to the conveyor itself, the building, the unit load carrier, the structure of work, other noise sources (e.g., production equipment), and reverberation must be considered. System design and installation specifications should focus on operator exposure to noise. Working together, the conveyor supplier and the end user can identify cost effective solutions to noise management.

References


