Sound Power Levels And Directivity Patterns Of Refrigerated Transport Trailers

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1 Introduction

Refrigerated transport trailers are part of the daily operation of many food processing facilities, distribution centers, grocery stores and some pharmaceutical facilities. Refrigeration units mounted on the front of the trailers are used to maintain the trailer temperature. An example of a refrigeration unit mounted on a transport trailer is pictured on the left-hand side of Figure 1.

The type of refrigeration unit described in this paper is autonomous, typically comprised of a diesel engine, a compressor, a condenser and an evaporator. The most common manufacturers, Carrier and Thermo King, each have several models. They are generally constructed with one or more fresh air intakes at the front or side. Heat rejection and combustion exhaust are emitted from the top. Each of these primary sound emission locations is shown in Figure 2. This paper treats the unit as a single source rather than separating each of the emission points.

One of the challenges with including this type of equipment in facility noise models is that the specific model and manufacturer of refrigeration units can vary on a day-to-day basis. Manufacturer data can also be difficult to obtain or is unavailable. The trailers at the facility often are operated by a shipping or logistics company instead of the facility owner. In such cases the benefits of any specific model of refrigeration unit (e.g. low noise package) cannot be reliably used in predictive modelling.

Detailed sound power data for this type of equipment are also infrequently available. Generic or average sound power information is of value in these circumstances. This paper presents a summary of measured sound power levels and directivity patterns for refrigerated transport trailers based on measurements conducted by RWDI between 2003 and 2016.

2 Method

The sound power levels presented in Table 1 have been calculated from sound pressure level measurements of sixteen distinct refrigeration units collected between 2003 and 2016. In each case the unit was operating without a truck connected to the trailer, while the trailer is parked at a loading dock or in a parking lot. Situations where a refrigeration unit was close to other sources were not included in this analysis. The surface of the ground in all cases was considered to be hard and reflective. The sound from the front of the unit has the highest overall level and has been used to develop the average sound power level.

The source directivity in the horizontal plane was quantified at facilities where sufficient space was available. Sound pressure levels were collected at multiple angles from the refrigeration unit. For documenting directivity, we are defining zero degrees as straight out from the refrigeration unit (e.g. directly in-front of the refrigeration unit), and ninety degrees as perpendicular to the direction of travel of the transport trailer.

Figure 1: Example of a refrigerated transport trailer

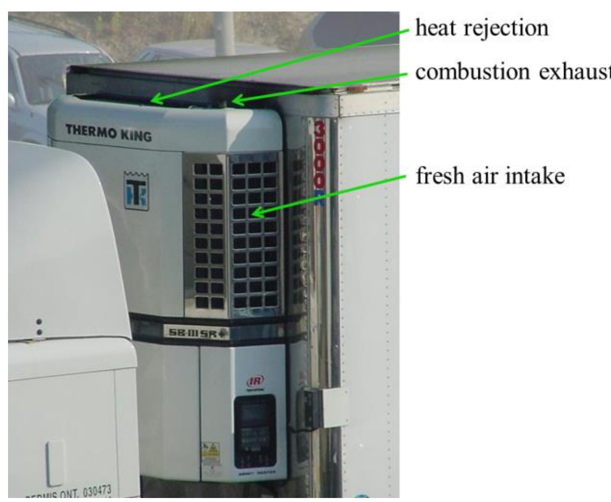

Figure 2: Primary sound emission locations

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Table 1: Average sound power level and standard deviation

	Frequency (Hz)								
	31.5	63	125	250	500	1000	2000	4000	8000
Average	97	111	105	102	97	96	94	89	83
Standard Deviation	3.7	4.5	5.5	5.5	5.0	5.5	5.1	5.4	6.1

3 Results

3.1 Octave band sound power levels

The average sound power level from in-front of the refrigeration units is 102 dBA, with a standard deviation of 4.7 dB. Variation in manufacturer, model and operation setting contributed to a range from 93 dBA to 109 dBA. The average linear octave band sound power levels from in-front of the refrigeration units and standard deviations are shown in Table 1. The octave band sound power level data are presented in Figure 3.

3.2 Directivity

The sound from refrigeration units does not project uniformly in all directions. To present directivity consistently we have normalized the levels at angles other than zero degrees to the sound power at zero degrees for each unit. The directivity has been assumed to be symmetric along an axis along the length of the trailer, with the zero angle defined as the direction of normal trailer travel. An average directivity pattern is proposed in Table 2. The directivity for non-zero angles is based on a smaller sample set, but indicates a general trend.

Table 2: Average directivity pattern

Angle	63	125	250	500	1000	2000	4000	8000
0°	0	0	0	0	0	0	0	0
45°	-5.3	+2.7	+1.9	+1.1	+0.2	-1.0	-1.0	-1.1
90°	-7.5	-5.1	-3.1	-1.1	-2.6	-3.5	-3.9	-4.5
135°	-2.3	-4.7	-4.8	-2.8	-6.0	-8.2	-10.4	-11.2

4 Discussion

Sound from the refrigeration units show a large variation in level from one unit to another. However, the spectral shape is relatively consistent for all of the units measured at zero degrees. From Figure 3, it can be observed that for most of the units tested the 63 Hz band is dominant; however, this does not necessarily mean that the sound is tonal. As an internal combustion engine, the concentration of sound at 63 Hz covers a wider range of frequencies.

Some of the units show elevated levels at both the 63 Hz and 125 Hz octave bands. Factors influencing this characteristic and the overall sound level were not readily apparent. Information on factors such as the number of years the equipment had been in service, operating settings, and whether the manufacturer's low noise package was installed (if one was available) were not available for the units measured, but would be interesting to examine in future studies.

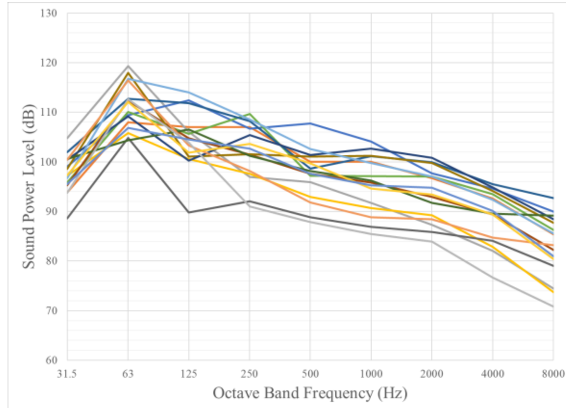

Figure 3: Trailer refrigeration unit sound power levels

As shown in Table 2, the sound levels generally decrease at angles away from zero degrees. The average directivity pattern should be primarily considered indicative of a trend. Additional data sets should be considered to develop a more definitive directivity pattern.

The adoption of standards and certification schemes for rating noise emissions of transportation refrigeration equipment, such as AHRI 1120 [1] in the United States, NFR 10-304 [2] in France, DIN 8958 [3] in Germany, and the PIEK certification scheme [4] (which originated in Holland and has been adopted in several other countries) are improving the availability of sound power data for new transport trailer refrigeration equipment. Nevertheless, documentation is still typically limited to only an overall A-weighted sound power level rating on most North American new product documentation.

5 Conclusion

Octave band sound power levels for sixteen different transport trailers' refrigeration units are developed into an average sound level spectrum. The spectrum is generic in that no differentiation between manufacturer, feature or operating condition is provided. The spectral shape is relatively consistent for all of the units tested at zero degrees, the typical direction of travel. At frequencies above 500 Hz, the sound levels show a pattern of becoming quieter with increasing angle.

References

[1] Air-Conditioning, Heating, and Refrigeration Institute. 2007 Standard for Acoustical Test Methods and Sound Power Rating Procedures for Transport Refrigeration Equipment. AHRI1120-2007.

[2] Association Francaise de Normalisation. Road Vehicles - Determination of Sound Power Level for Refrigeration Units Fitted to Thermal Goods Transport Vehicles. NFR 10-304:1994.

[3] Deutsches Institut für Normung. Testing of Cooling Equipment for Insulated Means of Transportation. DIN 8958:2011-08.

[4] PIEK-Keur. International. PIEK Certification Scheme Website. http://www.piek-international.com