PREDICTING EXHAUST SOUND POWER LEVELS OF GENERAL PURPOSE BOILERS

Robert D. Stevens[1] and William J. Gastmeier[2]
HGC Engineering, 2000 Argentia Road, Plaza 1, Suite 203, Mississauga, Ontario L5N 1P7

1 Introduction

Presented herein is a new prediction equation derived empirically from sound power measurements of various boiler exhausts, conducted by the authors between 2003 and 2015, with thermal ratings ranging from about 500 kW to 50 MW. The prediction applies to general purpose boilers, for comfort heating or industrial processes; large-scale power generating boilers and those with induced draft fans or special resonant, "pulse" combustors are not considered here. The new equation agrees well with the measured data, suggesting that it is a suitable estimate when measured data are unavailable.

2 Existing Method from Reference Texts

There are standard reference texts available [1, 2], which purport to provide prediction equations to estimate the sound level for boilers, with thermal ratings in the range of 40 to 1500 kW:

$$L_W = 95 + 4\cdot\log(bhp), \quad (1)$$

where L_W is the un-weighted "overall" sound power level in decibels, *bhp* is the thermal rating, in "boiler horsepower" (equivalent to 0.746 times the thermal rating in kW), and "overall" refers to the single-number, spectrally-summed sound power level. To obtain the component sound power levels in octave bands, and the overall A-weighted sound power level, the texts offer a set of adjustment factors, which are to be subtracted from the overall unweighted sound power level, as listed in Table 1, below.

Table 1: Published Octave Band Adjustments to be Subtracted from the Overall Unweighted Level [1, 2]

Frequency [Hz]	Adjustment Factor	Frequency [Hz]	Adjustment Factor
31	6	1k	15
63	6	2k	18
125	7	4k	21
250	9	8k	24
500	12	Overall, A	9

Reference [3] provides similar results, in tabulated form, rather than an equation, and only in terms of overall A-weighted spectral sum sound levels.

In using the predicted sound levels from these three reference texts over time, the authors have noticed that the results generally differed significantly from measured sound power levels of actual boiler exhausts. Toward investigating this apparent discrepancy, the authors have compiled their available measurement results for various boilers gathered between 2003 and 2015, and compared those to the predictions from Equation 1. The measured sound power levels were obtained using sound intensity instrumentation, generally following the methods of ISO Standard 9614-2 [4]. That comparison is shown graphically in Figure 1.

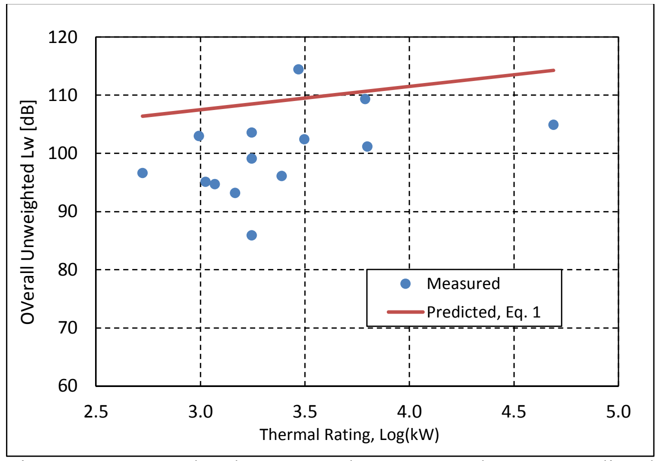

Figure 1: Measured Exhaust Sound Power Level versus Predicted Using Equation 1

The predictions tend to overestimate the sound levels, relative to measured results. The discrepancy between the predictions and measurements ranges in magnitude from 2 to 22 dB. If we define an ensemble-average discrepancy as the logarithmic mean of the magnitude of difference in decibels between the measurements and prediction, the average discrepancy in overall unweighted sound power levels is 14 dB. The average discrepancy on an octave-band basis (comparing the results obtained using the adjustment factors in Table 1 relative to measured values) is 39 dB.

None of references [1] through [3] contains any primary research in regard to predicting the sound from boilers, but instead, each cites earlier works. References [1] and [2] cite a seminal but difficult-to-obtain 1978 publication [5] from the Edison Institute, authored by Bolt Beranek and Newman ("BBN"). Reference [3] cites a 1981 publication by BBN [6]. Both of the BBN texts present the results of original work in deriving an empirical prediction from measured data.

What is apparent explicitly from [5 and 6] is that the prediction is not intended for the sound power emitted from the boiler exhaust outlet, but from the housing of the boiler. References [1] through [3] are unclear in this regard. In fact, reference [3] specifically purports to be a guide for estimating outdoor sound levels in the far field from mechanical equipment. Since general purpose boilers are typically located indoors, such that the exhaust outlet is the only source of sound to the outdoors, it is not surprising that references [1] through [3] could be misinterpreted to apply to the exhaust sound levels. There is a clear need for an equation to predict the sound power level of boiler exhausts.

1 rstevens@hgcengineering.com
2 bgastmeier@hgcengineering.com

3 A New Empirical Prediction

As is common for many types of mechanical equipment, a general trend was evident in the authors' measured data between the logarithm of the power rating (thermal input, in this case) and acoustic power output. A linear regression of this relationship yielded equation 2, below.

$$L_W = 81 + 5.6 \cdot \log(kW), \quad (2)$$

Figure 2, shows a plot of the measured sound power level versus the logarithm of the thermal input for the fourteen boilers in the data set, along with the predicted sound power level, using Equation 2.

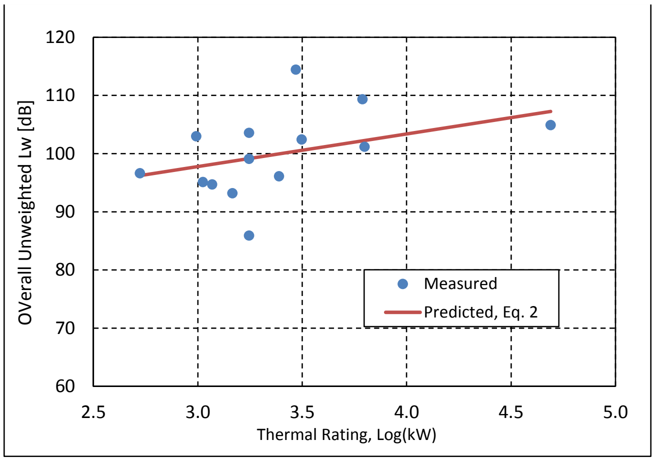

Figure 2: Measured Exhaust Sound Power Level versus Predicted Using Equation 2

The average error between the predicted and measured overall unweighted sound power levels shown in Figure 2 is 7 dB. This average error, while not negligible, certainly represents better correlation than would be achieved using the (albeit inapplicable) Equation 1, with an average error of 14 dB.

Having derived an equation to estimate the overall sound power level of a boiler knowing its thermal rating, it is further possible to derive a spectrum of adjustment factors, to apportion the overall level into its component octave band levels, and the corresponding A-weighted overall level, as was done in [5 and 6]. The results are presented in Table 2. Figure 3 shows the octave band levels used to derive the weightings in Table 2.

Table 2: Octave Band Adjustments for Boiler Exhausts Derived from Measured Data of 14 Boilers

Frequency [Hz]	Adjustment Factor	Frequency [Hz]	Adjustment Factor
31	4	1k	29
63	5	2k	37
125	8	4k	40
250	10	8k	54
500	22	Overall, A	16

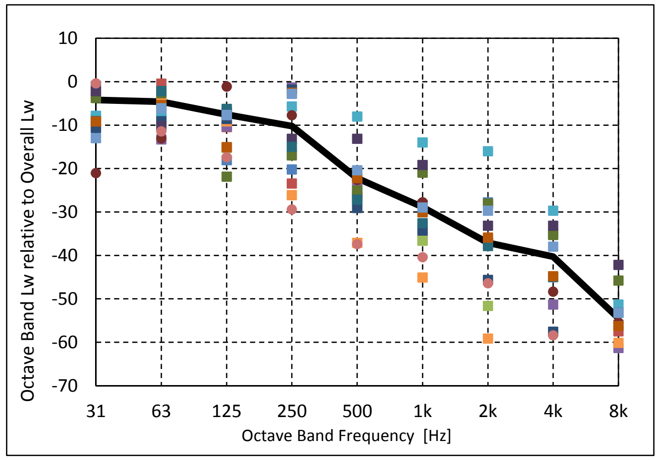

Figure 3: Octave Band Adjustments, Measured and Best-Fit Values

Using Equation 2 and the adjustments in Table 2, the predicted octave band sound levels exhibit an average error of just 11 dB, which is considerably better correlation than would be achieved using the (albeit inapplicable) Equation 1 and Table 1 (with average octave band error 39 dB).

Coincidentally, the data set of 14 boilers measured by the authors is almost the same size as the data set of 13 boilers in the seminal paper by BBN [5], although the current data set spans a slightly greater range of thermal power ratings: 500 kW to 50 MW here, versus 40 kW to 1.5 MW in [5].

4 Conclusion

Equation 2 and the weighting factors in Table 2, provide a reasonable estimate of sound levels from boiler exhausts, when measurements or manufacturer's data are not available.

Acknowledgments

The authors wish to thank W. Dale Stevens, Assistant Professor of Psychology at York University, Toronto, for assistance in obtaining reference [5] via inter-library loan.

References

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[5] Bolt Beranek and Newman Inc. *Electric Power Plant Environmental Noise Guide – 2nd Edition*. Edison Electric Institute. Washington, DC, 1st Ed. 1978, 2nd Ed., 1984.

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