

Errata Sheet for AMCA Standard 300-05
Reverberant Room Method for Sound Testing of Fans

August 28, 2007

The corrections listed in this errata sheet shall apply to all printings of AMCA Standard 300-05.

Page(s)	Erratum
29-33	Annex E. Duct end reflection correction: remove this entire annex and replace with Annex E: Duct End Reflection Correction found in the following pages of this errata

Annex E. Duct End Reflection Correction (Normative)

E.1 General

Conditions at the end of a test duct will prevent some of the sound energy from being transmitted into the test room. Therefore, the sound power measured in the room will be less than the true sound power in a duct. Unless an anechoic termination is used, correction factors must be added to the fan sound pressure measured in the test room in order to account for the reduction caused by end reflection.

The prediction of the duct end reflection is difficult. Theoretical solutions exist only for round ducts with highly idealized end conditions and are based on the assumption that the frequency is low enough that only plane waves exist (which implies that $ka < \pi$). Actual fan test setups rarely, if ever, conform to the conditions under which the theoretical solutions are valid. Using the methods suggested in this Annex will result in predicted values that are reasonably close to the actual values. Nonetheless, the test setup should be selected to minimize the potential error by using components that most closely reproduce the theoretical conditions.

For open ducts, theoretical solutions exist for two cases: a thin-walled round duct terminating in an infinite space [*On the Radiation of Sound from an Unflanged Circular Pipe*, Levine, H., and Schwinger, J. – *Physical Review*, Vol. 72, No. 4, February 15, 1948] and a round duct terminating in an infinite wall [*Fundamentals of Acoustics, 3rd Edition*, Kinsler, Frey, Coppens and Sanders, Wiley, New York, 1982, Equations 9.13 and 9.14]. Most test setups incorporate terminations that use a flanged duct terminating in a large space, which would make the solution provided by Levine & Schwinger more appropriate.

E.2 End reflection curves

In the event that circumstances require a setup indicating the presence of a duct end correction there are two cases to be considered. The two cases are considered separately below.

E.2.1 Open ducts in a large space. To determine the end reflection values, it is necessary to first calculate the reflection coefficient R , which gives the fraction of the energy reflected back into the duct. **Levine and Schwinger** reduced the exact solutions to manageable forms, one for $ka < 1$ and one for $ka > 1$.

Where:

$$\begin{aligned}k &= \omega/c = 2\pi/\lambda \\a &= D/2 \\ \omega &= 2\pi f\end{aligned}$$

And:

k is the wave number
 ω is the angular frequency, rad/s
 c is the speed of sound, m/s (ft/s)
 λ is the wavelength, m (ft)
 D is the duct diameter, m (ft)
 f is the frequency, Hz

For rectangular ducts, use the equivalent round duct diameter:

$$D = \sqrt{4wh/\pi}$$

Where w and h are the rectangular duct's width and height.

The two equations are:

For $ka < 1$

$$|R| = \exp\left[\frac{-(ka)^2}{2}\right] \left[1 + \frac{(ka)^4}{6} \left(\log_e \left(\frac{1}{1.7810 \times ka} \right) + \frac{19}{12} \right) \right] \quad \text{Eq. E.1}$$

And:

For $ka > 1$.

$$|R| = \sqrt{\pi ka} \exp(-ka) \left[1 + \frac{3}{32} \frac{1}{(ka)^2} \right] \quad \text{Eq. E.2}$$

Note: \log_e indicates a natural logarithm and \log_{10} indicates a base 10 logarithm

The ratio between the transmitted sound and the reflected sound is $\alpha = 1 - |R|^2$ and thus the end correction (in dB) is $E = 10 \log_{10} \alpha$. These equations shall be used to calculate E as a function of ka ($0.5kD$). The resulting curve is shown for illustrative purposes in Figure E.1. Values are presented up to $ka = 4$, even though the equations are strictly limited to $ka < 3.832$.

E.2.2 Open ducts terminated in a large wall. For the case of a round duct terminated at a large wall, the end correction can be determined using Equations 9.13 and 9.14 from **Kinsler, Frey, Coppens and Sanders** with the impedance

calculated using Equations 5.1, 5.2 and 5.3 from **Beranek**. It should be noted that there is no transition at the wall-duct interface. The equations to be used to calculate E as a function of ka are given below.

$$Z_M = \pi a^2 \rho c \left[1 - \frac{J_1(2ka)}{ka} \right] + j \frac{\pi \rho c}{2k^2} K_1(2ka) \quad \text{Eq. E.3}$$

$$J_1(2ka) = \frac{(2ka)}{2} - \frac{(2ka)^3}{2^2 \times 4} + \frac{(2ka)^5}{2^2 \times 4^2 \times 6} - \frac{(2ka)^7}{2^2 \times 4^2 \times 6^2 \times 8} \dots \quad \text{Eq. E.4}$$

$$K_1(2ka) = \frac{2}{\pi} \left(\frac{(2ka)^3}{3} - \frac{(2ka)^5}{3^2 \times 5} + \frac{(2ka)^7}{3^2 \times 5^2 \times 7} \dots \right) \quad \text{Eq. E.5}$$

$$R = \frac{B}{A} = \frac{(Z_M / (\pi a^2 \rho c)) - 1}{(Z_M / (\pi a^2 \rho c)) + 1} \quad \text{Eq. E.6}$$

$$\alpha = 1 - |R|^2 \quad \text{Eq. E.7}$$

$$E = |10 \log_{10} \alpha| \quad \text{Eq. E.8}$$

Note: \log_{10} indicates a base 10 logarithm

The series for K_1 and the Bessel function J_1 converge rapidly (at least for values of $ka < 3.6$), so the computation of E vs. ka is straightforward. The resulting curve for illustrative purposes is shown in Figure B.2. As before, values are shown up to $ka = 4$, but for $ka > 3.6$, the value of α is defined to be 1.

Table E.1 - End Corrections for Ducts Terminating in a Large Space

<i>ka</i>	<i>E</i>
0.14	17.20
0.15	16.62
0.16	16.08
0.17	15.57
0.18	15.09
0.19	14.64
0.20	14.22
0.25	12.39
0.30	10.94
0.35	9.74
0.40	8.73
0.45	7.88
0.50	7.14
0.55	6.49

<i>ka</i>	<i>E</i>
0.60	5.92
0.65	5.42
0.70	4.97
0.75	4.56
0.80	4.20
0.85	3.86
0.90	3.56
0.95	3.28
1.0	3.02/3.09
1.1	2.55
1.2	2.13
1.3	1.79
1.4	1.51

<i>ka</i>	<i>E</i>
1.5	1.28
1.6	1.08
1.7	.92
1.8	.78
1.9	.66
2.0	.56
2.1	.47
2.2	.40
2.3	.34
2.4	.29
2.5	.24
2.6	.21
2.7	.17

<i>ka</i>	<i>E</i>
2.8	.15
2.9	.12
3.0	.10
3.1	.09
3.2	.07
3.3	.06
3.4	.05
3.5	.04
3.6	.04
3.7	.03
3.8	.03
3.9	.02
4.0	.02

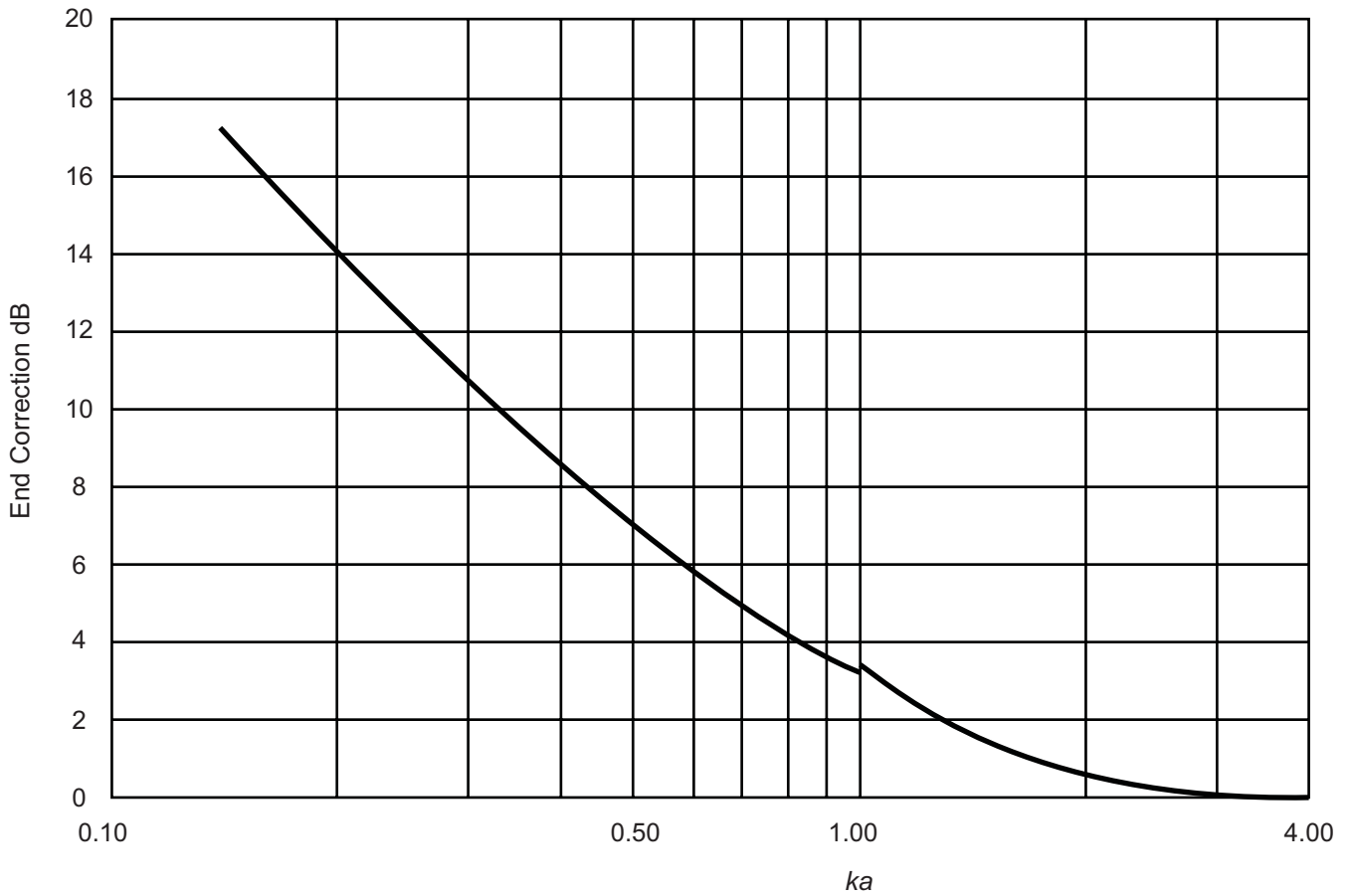


Figure E.1 - End Correction for Open Ducts in Large Space

Table E.2 - End Corrections for Ducts Terminating in a Wall

<i>ka</i>	<i>E</i>
0.14	14.22
0.15	13.65
0.16	13.11
0.17	12.61
0.18	12.14
0.19	11.70
0.20	11.29
0.25	9.52
0.30	8.13
0.35	7.01
0.40	6.09
0.45	5.33
0.50	4.69
0.55	4.14

<i>ka</i>	<i>E</i>
0.60	3.68
0.65	3.28
0.70	2.93
0.75	2.63
0.80	2.37
0.85	2.14
0.90	1.93
0.95	1.75
1.0	1.59
1.1	1.32
1.2	1.11
1.3	0.93
1.4	0.79

<i>ka</i>	<i>E</i>
1.5	0.67
1.6	0.57
1.7	0.48
1.8	0.41
1.9	0.35
2.0	0.29
2.1	0.25
2.2	0.21
2.3	0.17
2.4	0.14
2.5	0.12
2.6	0.09
2.7	0.07

<i>ka</i>	<i>E</i>
2.8	0.06
2.9	0.04
3.0	0.03
3.1	0.03
3.2	0.02
3.3	0.01
3.4	0.01
3.5	0.01
3.6	0.01
3.7	0
3.8	0
3.9	0
4.0	0

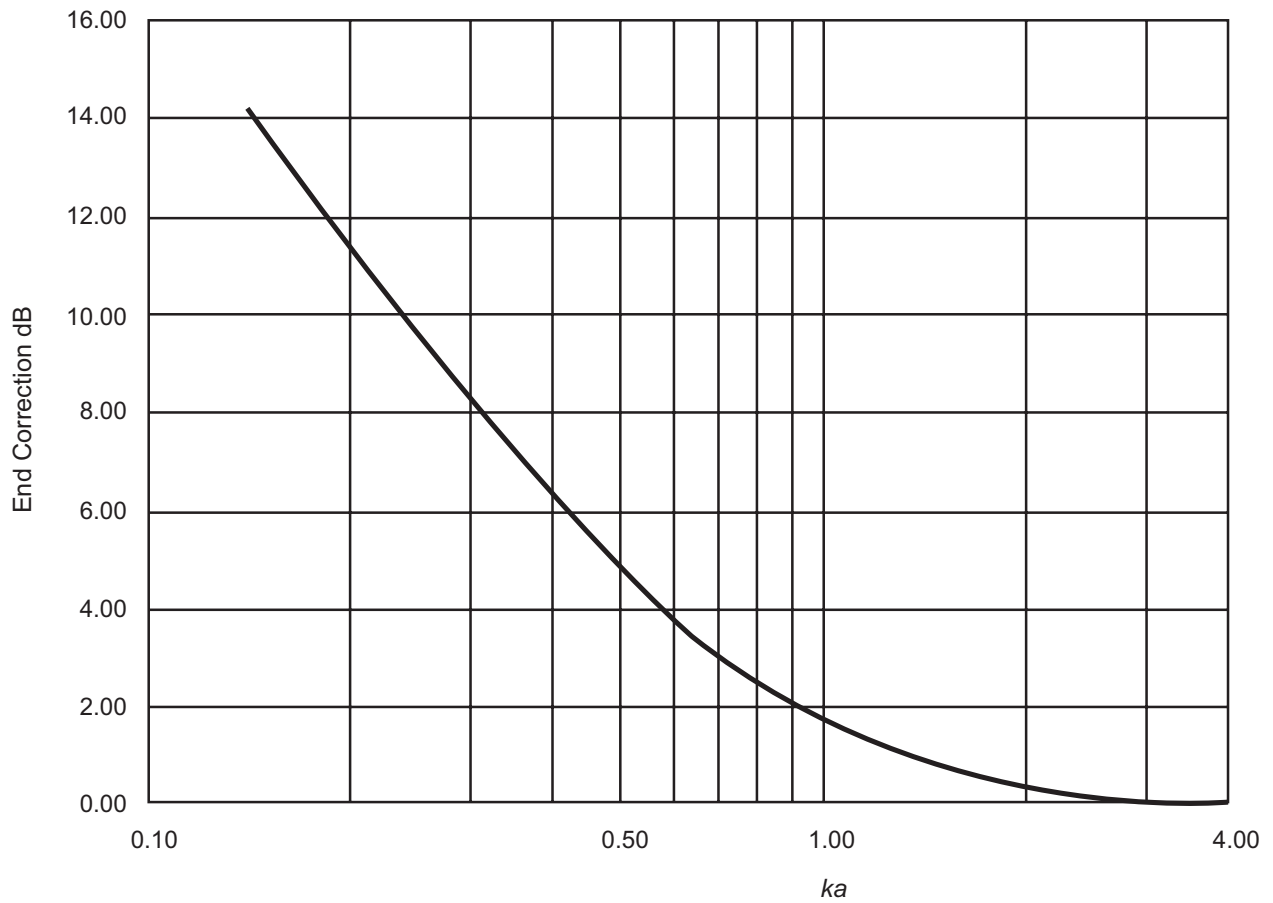


Figure E.2 - End Correction for Open Ducts Terminated in a Large Wall