threshold

WS-1919: The effects of duct size and aspect ratio on flow noise in elbows

Brandon Cudequest

ASHRAE TC 5.2
15 June 2021

THRESHOLD ACOUSTICS

141 West Jackson Boulevard
Suite 2080
Chicago, Illinois 60604

P 312.386.1400
F 312.386.1414
www.thresholdacoustics.com

threshold

Predictive Algorithm

4.2 ELBOWS FITTED WITH TURNING VANES

The 1/1 octave band sound power levels associated with the noise generated by elbows fitted with turning vanes can be predicted if the total pressure drop across the blades is known or can be estimated (36,44). The method that is presented applies to any elbow that has an angle between 60° and 120°. The 1/1 octave band sound power levels generated by elbows with turning vanes are given by

$$L_W(f_o) = K_T + 10 \log_{10} \left[\frac{f_o}{63}\right] + 50 \log_{10} [U_c] + 10 \log_{10} [S] + 10 \log_{10} [CD] + 10 \log_{10} [n] \quad (4.7)$$

where f_o is the 1/1 octave band center frequency (Hz), U_c is the flow velocity (ft/sec) in the constricted part of the flow field between the blades determined from Equation (4.10), S is the cross–sectional area (ft²) of the duct, CD is the cord length (in.) of a typical vane, n is the number of turning vanes, and K_T is the characteristic spectrum (Figure 4.3). In addition to the above parameters, it is also necessary to know the duct height, DH (ft), normal to the turning vane length. The regenerated sound power levels associated with elbows with turning vanes are obtained as follows:

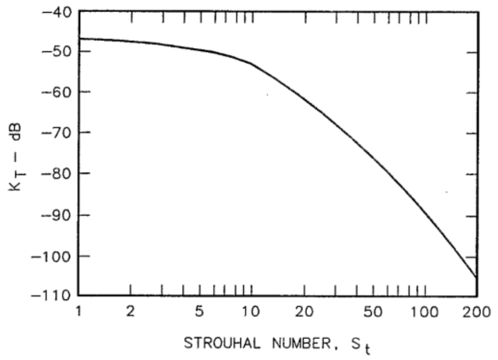


Figure 4.3 Characteristic Spectrum, K_T, for Elbows Fitted with Turning Vanes

Algorithms for HVAC Acoustics, Douglas Reynolds (1991)

Table Look-Up

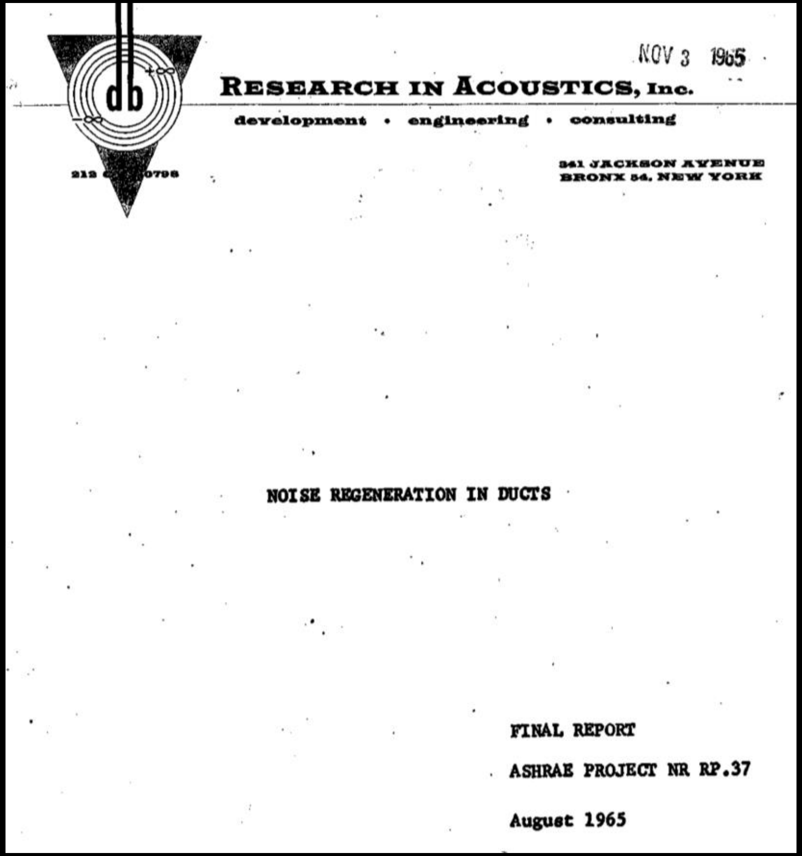
Table 8 Maximum Recommended Duct Airflow Velocities to Achieve Specified Acoustic Design Criteria

Main Duct Location	Design RC(N)	Maximum Airflow Velocity, fpm: Rectangular Duct	Maximum Airflow Velocity, fpm: Circular Duct
In shaft or above drywall ceiling	45	3500	5000
	35	2500	3500
	25	1700	2500
Above suspended acoustic ceiling	45	2500	4500
	35	1750	3000
	25	1200	2000
Duct located within occupied space	45	2000	3900
	35	1450	2600
	25	950	1700

Notes:
1. Branch ducts should have airflow velocities of about 80% of values listed.
2. Velocities in final runouts to outlets should be 50% of values or less.
3. Elbows and other fittings can increase airflow noise substantially, depending on type. Thus, duct airflow velocities should be reduced accordingly.

Chapter 49, ASHRAE Applications Handbook (2019)

State of the Art


NOV 3 1965

RESEARCH IN ACOUSTICS, Inc.

development · engineering · consulting

212 [illegible] 0798

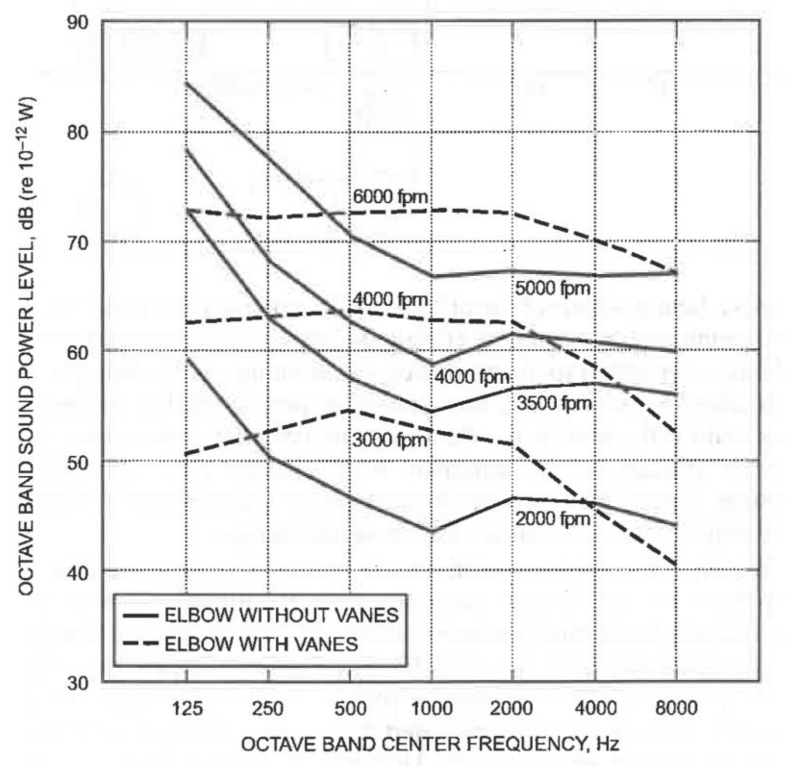
341 JACKSON AVENUE
BRONX 54, NEW YORK

NOISE REGENERATION IN DUCTS

FINAL REPORT

ASHRAE PROJECT NR RP.37

August 1965



Note: Comparison of octave band sound power levels produced by airflow through 8 × 8 in. rectangular elbow with and without 7 circular arc turning vanes.

Predictive Algorithm:

User inputs duct size, velocity, and type of fitting (with/without turning vanes) and you get octave band sound power

Predictive - Parameters

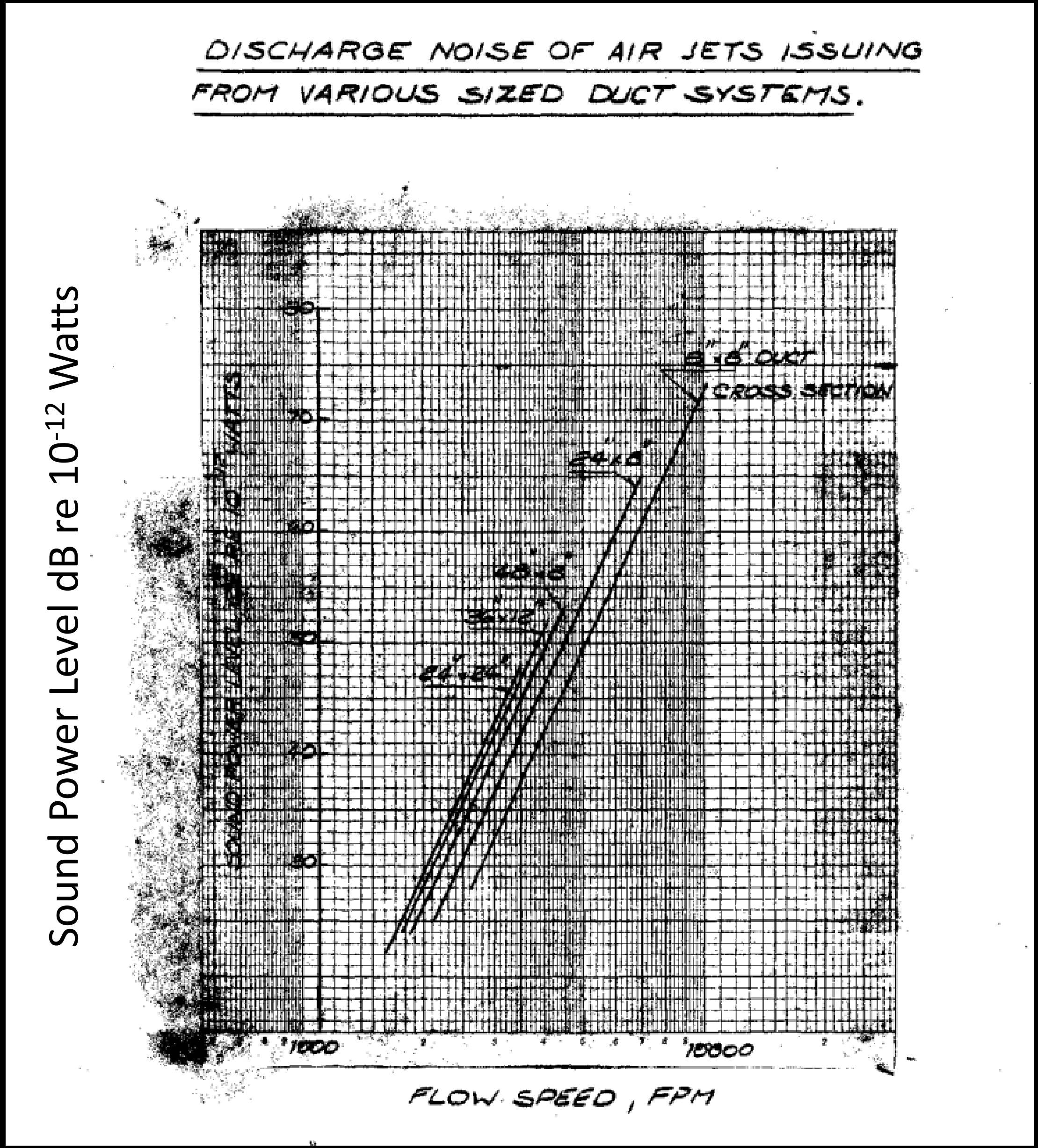
Element	Properties	NC	63	125	250	500	1000	2000	4000	dB(A)
◢ 32x32 Elbow, 10000cfm	Criteria: NC-65	37	59	53	46	39	30	21	11	42
◢ Radiated (10000cfm)	Criteria: NC-65	37	59	53	46	39	30	21	11	42
10000 cfm			0	0	0	0	0	0	0	
Rectangular Elbow Miter	32"x32" (0")		-1	-5	-8	-4	-3	-3	-3	
			59	53	46	39	30	21	11	
◢ 10x10 Elbow, 1000cfm	Criteria: NC-65	38	57	53	48	42	35	27	18	44
◢ Unassigned (1)	Criteria: NC-65	38	57	53	48	42	35	27	18	44
1000 cfm			0	0	0	0	0	0	0	
Rectangular Elbow Miter	10"x10" (0")		0	0	-1	-5	-8	-4	-3	
			57	53	48	42	35	27	18	

32x32in. Elbow @ 10000cfm = 1452 fpm
10x10in Elbow @ 1000cfm = 1440fpm

Area Effect: 10log(1024/100)= 10 dB

Yet, the smaller duct is louder

Are We Missing Something?

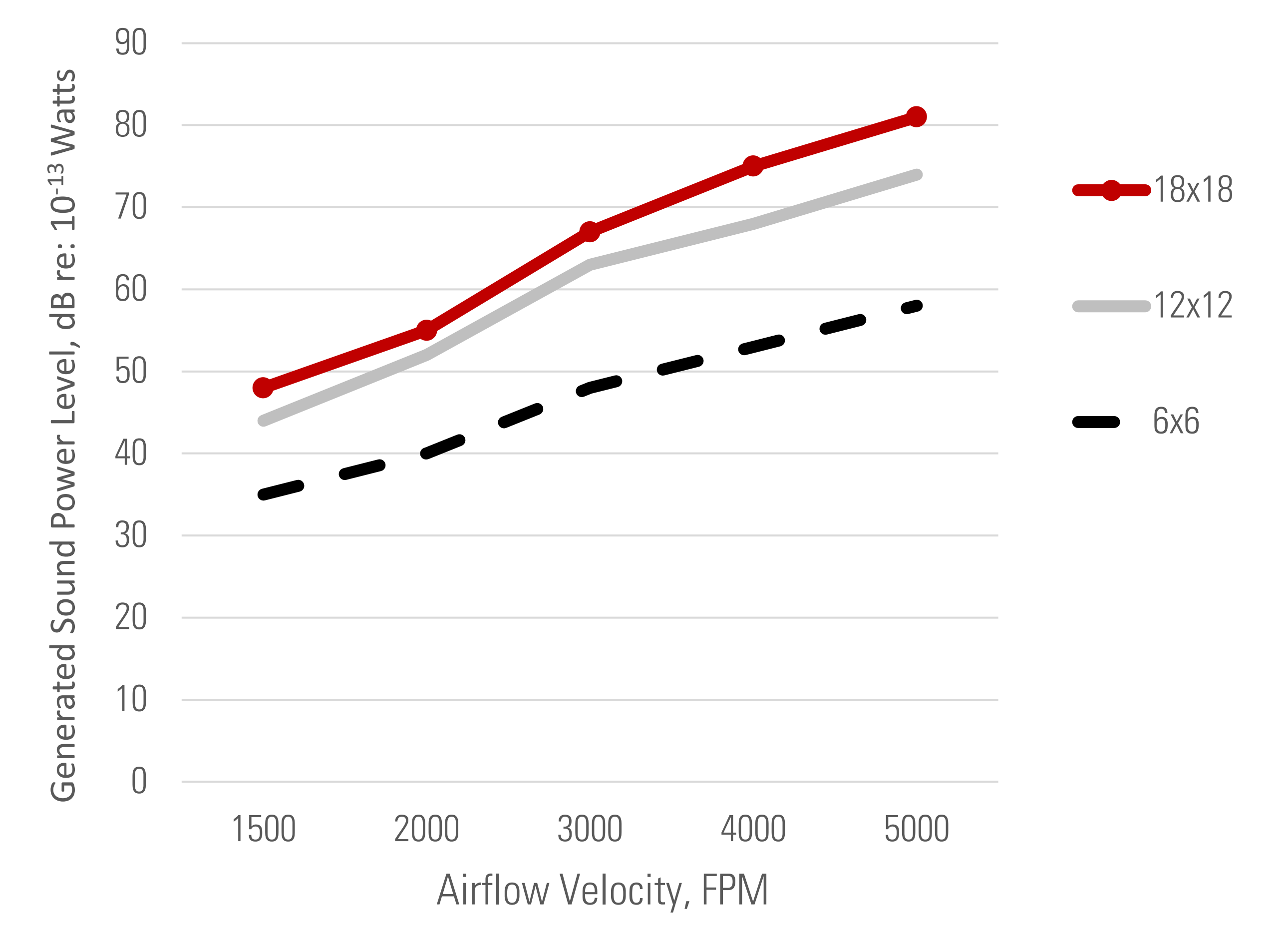


Taken from "Noise Regeneration in Ducts" ASHRAE Project RP.37 August 1965, Uno Ingard

Comparing 24x24, 36x12, 48x8, 24x8, and 8x8 Cross Sections as a Function of Flow Speeds (fpm)

Larger Ducts are Louder for a Given Velocity

Regenerated and Discharge Noise in Duct as a Function of Size?



Adapted from "Estimating Method for Predicting Noise Originating in Air Condition Systems on Naval Vessels (1964)"

F.B. Holgate, U.S. Naval Applied Science Laboratory

Pilot Study Referenced in 1961 Handbook

Sound Power Level Generated at 1000Hz Octave Band
Straight Ducts with No Lining, Dimensions are Inches

Regenerated Noise in Duct as a Function of Size?

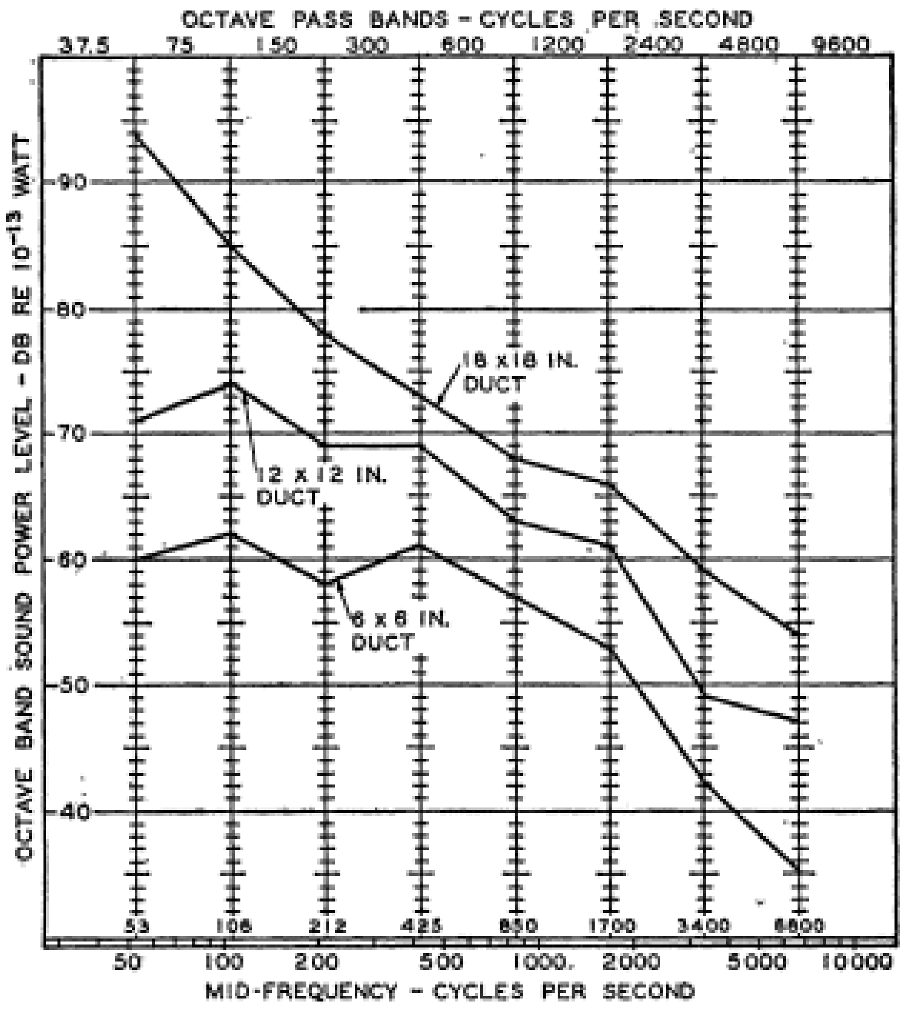
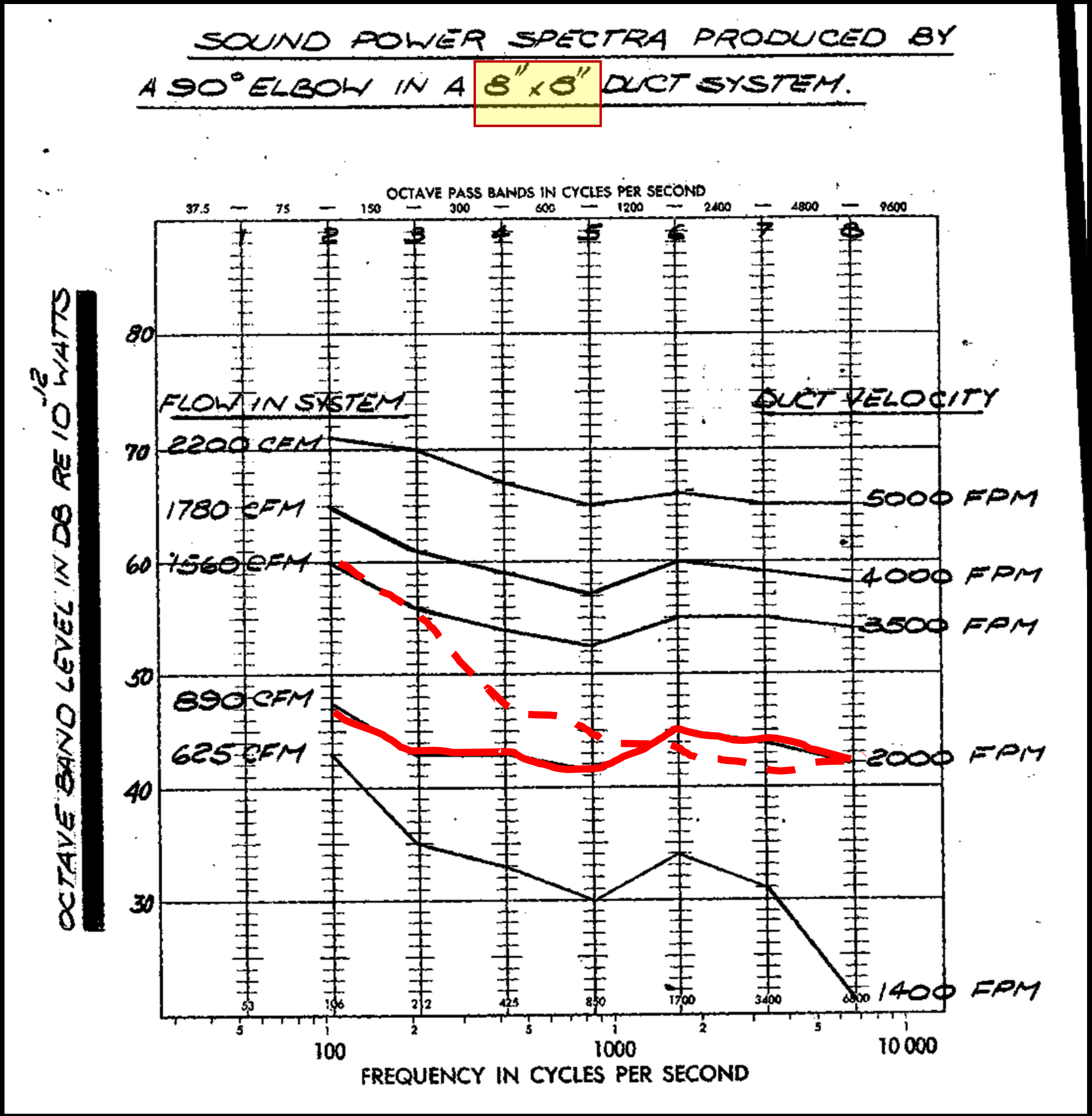
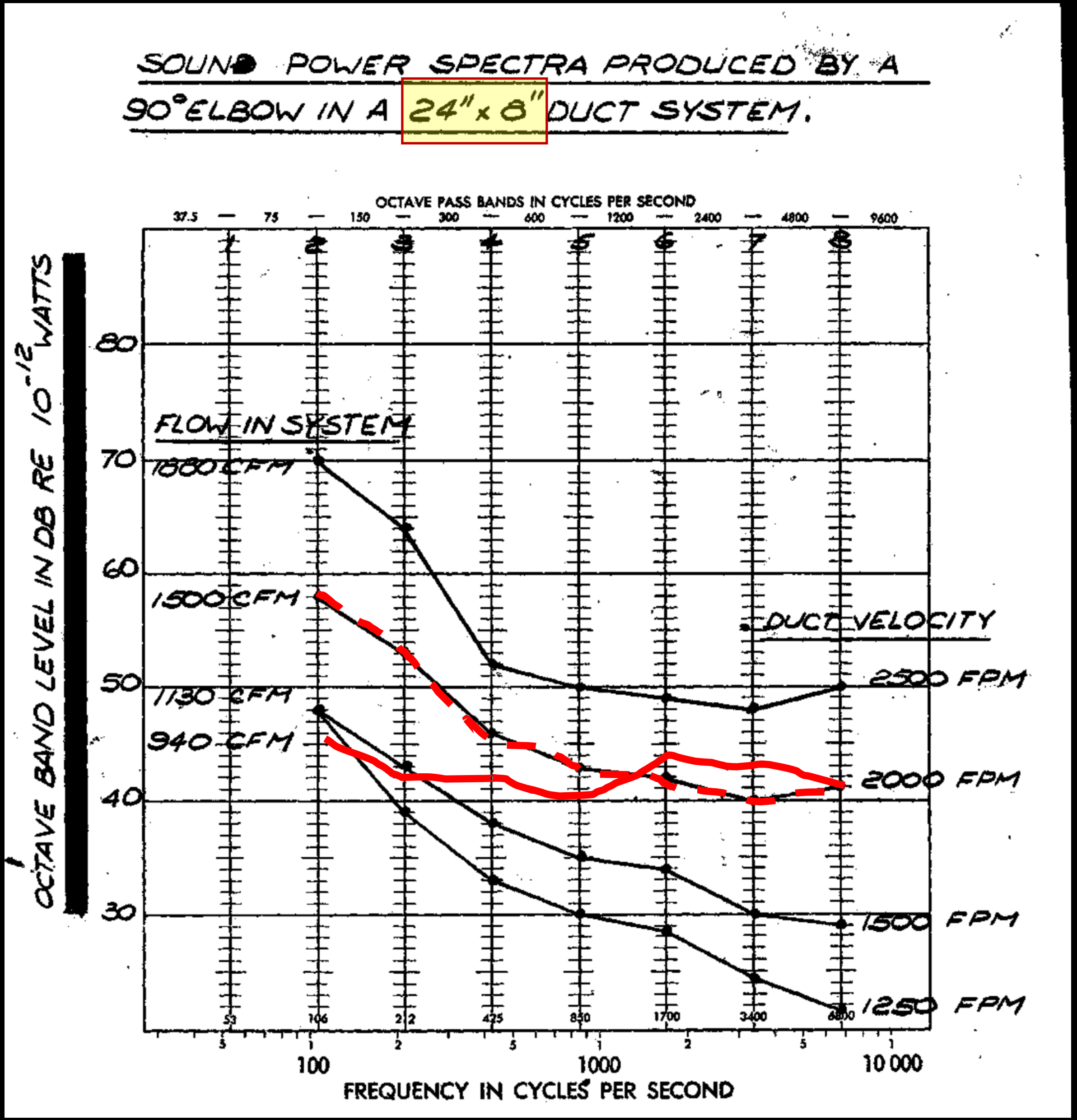


Fig. 17 . . . . Sound Power Generated by 30° to 90° Elbows with Turning Vanes in Various Size Ducts at a Duct Velocity of 2000 fpm

threshold

Regenerated Noise in Elbows, ASHRAE 1961





Aspect Ratio, From RP 37

	Element	Properties	NC	63	125	250	500	1000	2000	4000	dB(A)
▷	8x8 elbow, 2000fpm	Criteria: NC-65	51	66	63	58	53	47	40	32	55
▷	24x8 elbow, 2000fpm	Criteria: NC-65	52	68	64	59	53	46	38	30	55

The predictive algorithm fails to account for the difference in aspect ratio.
Should be +10dB at low frequencies)

Aspect Ratio, Predictive

Table 8 Maximum Recommended Duct Airflow Velocities to Achieve Specified Acoustic Design Criteria

Main Duct Location	Design RC(N)	Maximum Airflow Velocity, fpm: Rectangular Duct	Maximum Airflow Velocity, fpm: Circular Duct
In shaft or above drywall ceiling	45	3500	5000
	35	2500	3500
	25	1700	2500
Above suspended acoustic ceiling	45	2500	4500
	35	1750	3000
	25	1200	2000
Duct located within occupied space	45	2000	3900
	35	1450	2600
	25	950	1700

Notes:
1. Branch ducts should have airflow velocities of about 80% of values listed.
2. Velocities in final runouts to outlets should be 50% of values or less.
3. Elbows and other fittings can increase airflow noise substantially, depending on type. Thus, duct airflow velocities should be reduced accordingly.

Though the reasoning is sound, there's no link to a primary source.

Where did this come from?
(Appeared in 1995 Handbook, Often Attributed to Schaffer's 1993 book)

Max Velocity for Rectangular and Circular Ductwork

Max Velocity for Rectangular and Circular Ductwork

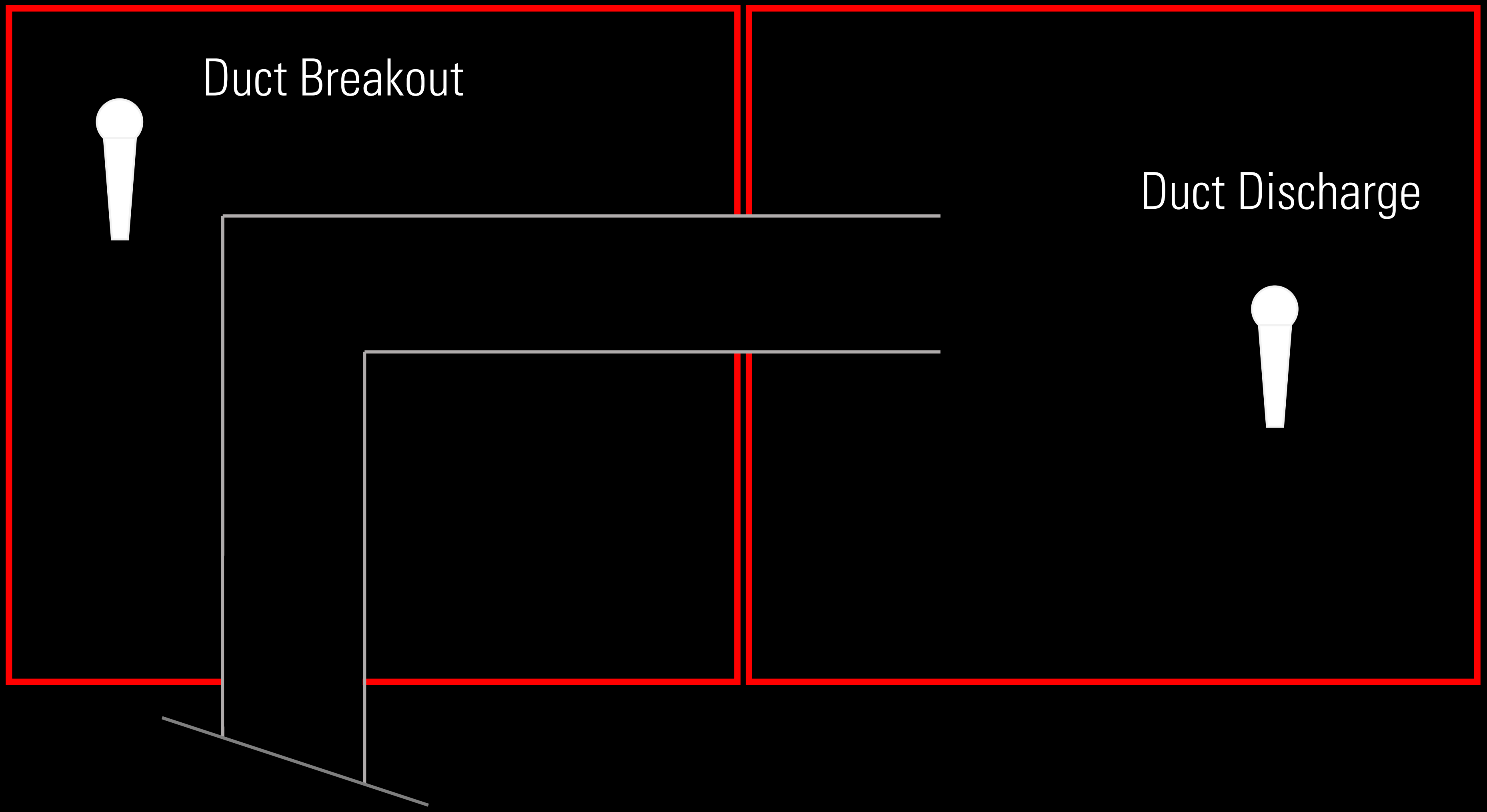
Table 8 Maximum Recommended Duct Airflow Velocities to Achieve Specified Acoustic Design Criteria

Main Duct Location	Design RC(N)	Maximum Airflow Velocity, fpm: Rectangular Duct	Maximum Airflow Velocity, fpm: Circular Duct
In shaft or above drywall ceiling	45	3500	5000
	35	2500	3500
	25	1700	2500
Above suspended acoustic ceiling	45	2500	4500
	35	1750	3000
	25	1200	2000
Duct located within occupied space	45	2000	3900
	35	1450	2600
	25	950	1700

Notes:
1. Branch ducts should have airflow velocities of about 80% of values listed.
2. Velocities in final runouts to outlets should be 50% of values or less.
3. Elbows and other fittings can increase airflow noise substantially, depending on type. Thus, duct airflow velocities should be reduced accordingly.

Does not detail assumptions re:size, aspect ratio, and duct gauge.

Does not provide guidelines for how much reduction is required at elbows



Proposed Test Set-Up

threshold

Duct Sizes:

1) 24x24
2) 36x12
3) 24x48
4) 48x48

Duct Fittings:

1) Mitered elbow, 90 degree (CR3-6)
2) Mitered Elbow with single wall turning vanes (CR3-10)
3) Mitered Elbow with double wall turning vanes (CR3-14)
4) Smooth radiused elbow, without vanes, 90 degrees (CR3-1)
5) Smooth radiused elbow with one splitter vane (CR3-3)
6) Smooth radiused elbow with two splitter vanes (CR3-4)

Speeds:

1) 1000fpm
2) 1500fpm
3) 2000fpm
4) 2500fpm

Proposed Test Set-Up

threshold

1) Full frequency data for duct break out and discharge

2) Pressure drop readings of each elbow geometry

3) Exit velocity profile

Data

threshold

1) New predictive algorithms

2) New tables with clear guidelines

Maximum Recommended Elbow Airflow Velocities to Achieve Acoustic Design Criteria					
	Design RC/NC	36x12 (3 SF)	24x24 (4 SF)	24x48 (8 SF)	48x48 (16 SF)
CR3-6	45				
	35				
	25				
CR3-10	45				
	35				
	25				
CR3-14 (etc.)	45				
	35				
	25				

Outcomes

threshold

WS-1919: The effects of duct size and aspect ratio on flow noise in elbows

Brandon Cudequest

ASHRAE TC 5.2
15 June 2021

THRESHOLD ACOUSTICS

141 West Jackson Boulevard
Suite 2080
Chicago, Illinois 60604

P 312.386.1400
F 312.386.1414
www.thresholdacoustics.com