Fan Testing – Not All Fans Are Created Equal

Introduction

Fans, like electric motors, have followed a casing standardisation to allow for interoperability between various manufacturers. This is documented in the AMCA 99-0098-76 R20 and DIN 323-1 R20 standards.

Dimensions such as the nominal impellor diameter, the outlet size, the distance to the centre of the shaft etc. are covered by these standards. With these limitations, developments to improve both the aerodynamic and acoustic performance of the fans have been focussed on the design of the impellor, the inlet cones, and the casing cut-offs.

Also, with engineers demanding better data, fan manufactures started testing to higher classes of tolerance to make their data more predictable. As well, the advent of requirements for various green building codes and climate change energy savings has focussed manufacturers to supply ever more efficient and quieter fans into the market. These developments have occurred in both standard housed fans and more recently plenum fans.

Performance Standards

The current applicable standards for fan performance are:

Fan Aerodynamic Performance	BS EN ISO 5801:2008, BS 848-1:2007, DIN24163 & AMCA 210
Fan Acoustic Performance	DIN 46635 Part 38 &9, ISO 5136, BS ISO 13347-4:2004, BS 848-2.4:2004 & ANSI/AMCA 330.

Acoustic Performance

In order to allow engineers to correctly compare sound data, twelve standard measurement positions are used. The most common for centrifugal fans are:

Lw1	Total Sound Power Level free inlet and outlet condition.
Lw2	Total Breakout Sound Power Level outside the duct.
Lw3	Total Sound Power Level inside the inlet duct.
Lw4	Total Sound Power Level inside the outlet duct.
Lw5	Total Sound Power Level at the inlet.
Lw6 *	Total Sound Power Level at the fan outlet in a free discharge condition.
Lw6d	Total Sound Power Level outside the termination of the outlet duct.
Lw7	Inlet Total Sound Power Level, with ducted outlet.
Lw8	Total Sound Power Level at the fan in a free discharge condition.

* For plenum wheels: Sound Power Level at the wheel outlet

Typical reported values are as follows:

DWDI Housed Fans	Lw4, Lw7, & Lw6d
SWSI Housed Fans	Lw3, Lw4, Lw7, & Lw6d
SWSI Plenum Fans	Lw3, Lw5, & Lw6

Within these test methods however, not all data is presented equally. Data may be to different accuracy classes or even interpreted as the wrong type.

For sound, the three most common factors to take into account when comparing data are:

1. The accuracy class to DIN 24166.
2. The inclusion or exclusion of tonal noise caused by blade-passing increment.
3. Whether the manufacturer/supplier has reported the correct measurement position e.g. presenting Lw6 figures as Lw4 or interpreting Lw3 & Lw5 data as equivalent.

1. The Accuracy Class to DIN 24166

The DIN 24166 standard defines the "accuracy" that the published data must have, and this must be reported with the data.

From DIN 24166 Table 1: Limit Deviation *t* for Accuracy Class

Parameter	Limit deviation *t* for accuracy class				Notes
	0	1	2	3	
Volume flow rate, V	±1%	±2.5%	±5 %	±10 %	
Pressure increase, Δp	±1%	±2.5%	±5 %	±10 %	
Power, P	+2%	+3%	+8%	+16%	Negative deviations are permissible
Efficiency, η	-1%	-2%	-5%	-	Positive deviations are permissible
A-weighted Sound Power Level, LwA	+3dB	+3dB	+4dB	+6dB	Negative deviations are permissible

As can be seen above, presenting data with a lower accuracy class allows for a significant discrepancy between published and actual data.

2. Tonal Noise

Some fan suppliers remove the tonal noise component from their results. This tonal component can be as high as 10dB between 125Hz and 250Hz, leading to significantly lower overall noise levels. This situation may be difficult to determine however, as it is often hidden in the small print.

The tonal noise component is determined by the number of blades of the impellor and the number of times that it passes the cut off or an obstruction. The intensity depends on the fan type and design, and the frequency at which it occurs depends upon the number of blades and speed.

The BFI frequency is calculated by

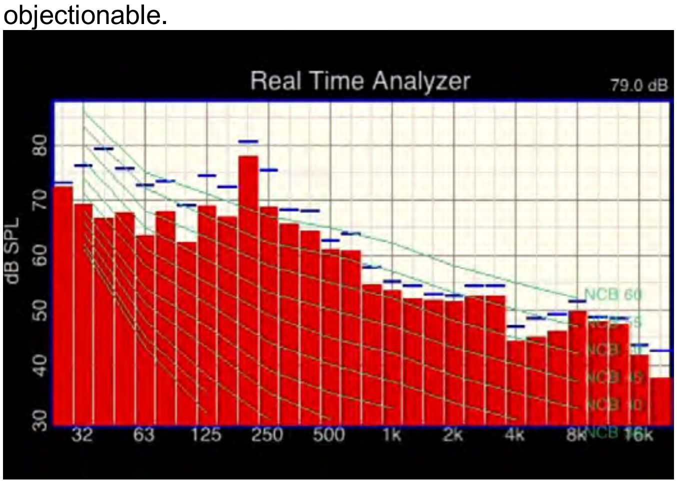
$$B_f = \frac{RPM}{60} x(Numberofblades)$$

On centrifugal fans, the following are approximate

Fan Type	1/1 Octave Band in which the BFI Typically Occurs	BFI in dB
Airfoil	250 Hz	3
Backward Curved	250 Hz	3 - 5
Forward Curved	500 Hz	2
Radial	125 Hz	8
Plenum Backward Curved	250 Hz	3 – 4
Plenum Backward Curved c/w Diffuser	250 Hz	5 – 10
Plenum Airfoil	250 Hz	3 – 4

The above data has been adapted from the ASHRAE Equipment Manual and ASHRAE Algorithms for Acoustics methodology for predicting these values with empirical data collected from various plenum fans.

In the example below, the 1/3 octave band at 225Hz is 9dB louder than the other adjacent bands; this is the impact of the tonal noise recorded from a competitor's unit in Auckland, and was highly objectionable.



3. Correct Data Reporting

Traditionally, fan manufacturers typically only gave the Lw6d and Lw7 fan sound levels, and for the discharge levels in particular, these were mistakenly interpreted by some AHU manufacturers as in-duct sound power levels. However these two levels have a free field end reflection component taken away from them.

The correction factor to convert free field values back to ducted is calculated from:

$$E_{oct} = 10\log_{10}\left[1 + \left(\frac{0.8 \cdot C}{f_{oct} \cdot L \cdot \sqrt{4\pi}}\right)^{1.88}\right]$$

F_{oct} is the centre frequency of each octave band
L is the largest outlet size in m
C is the speed of sound in m/s

For Housed fans, the following table gives the typical correction factors required to convert free field (Lw6) data to in-duct (Lw4) for the standard fan sizes.

Fan Size	Outlet Size	Correction Factor at Centre Frequency			
(diameter)	(mm square)	63 Hz	125 Hz	250 Hz	500 Hz
180	229	13.0	8.0	4.0	1.0
200	256	12.0	7.5	3.5	1.0
225	288	12.0	7.5	3.0	1.0
250	322	11.0	7.0	3.0	0.0
280	361	10.0	7.0	3.0	0.0
315	404	10.0	5.5	2.0	0.0
355	453	10.0	5.0	2.0	0.0
400	507	9.0	5.0	2.0	0.0
450	569	8.0	4.0	2.0	0.0
500	638	8.0	4.0	1.0	0.0
560	715	7.0	3.0	1.0	0.0
630	801	6.0	3.0	1.0	0.0
710	898	5.0	2.0	0.0	0.0
800	1007	5.0	2.0	0.0	0.0
900	1130	4.0	1.0	0.0	0.0
1000	1267	4.0	1.0	0.0	0.0
1120	1415	3.0	0.5	0.0	0.0
1250	1586	2.5	0.0	0.0	0.0

For Plenum fans, the following table gives the typical correction factors required to convert free field (Lw5) inlet data to inside the inlet duct (Lw3) data for the standard fan sizes.

Fan Size		Correction Factor at Centre Frequency			
(diameter)		63 Hz	125 Hz	250 Hz	500 Hz
180		17.0	11.0	7.0	3.0
200		16.0	11.0	6.0	2.0
225		15.0	10.0	5.0	2.0
250		14.0	9.0	5.0	2.0
280		13.0	8.0	4.0	1.0
315		12.0	7.0	3.0	1.0
355		12.0	7.0	3.0	1.0
400		11.0	6.0	2.0	1.0
450		10.0	5.0	2.0	1.0
500		9.0	5.0	2.0	1.0
560		8.0	4.0	1.0	0.0
630		7.0	3.0	1.0	0.0
710		7.0	3.0	1.0	0.0
800		6.0	2.0	1.0	0.0
900		5.0	2.0	1.0	0.0
1000		5.0	2.0	1.0	0.0
1120		4.0	1.0	0.0	0.0
1250		3.0	1.0	0.0	0.0
1400		3.0	1.0	0.0	0.0

As can be seen from the above tables, when evaluating different fan manufacturers data care must be taken to ensure that you are comparing equivalent data.

Plenum Fans

These are not new to the market, but have in the past been restricted to industrial applications in ovens etc. However, with the advent if newer designed impellers, these started to become more mainstream about 15 years ago.

The impellers have seen major developments within the last 4 years, with efficiencies now similar to DIDW housed fans but with major acoustic advantages.

For example let's look at a typical fan selection for an AHU at 6m³/sec at 1200Pa.

The DIDW selection ~ NTHZ 560R at 1601rpm (BFI at 293Hz & show at 250Hz)
Power at shaft 9.42kW
Power at motor 9.89kW = Power at shaft +5% belt lost (5 to 8% on a new belt)

The Plenum selection ~ NPA 710 at 1386 rpm (BFI at 231Hz & show at 250Hz)
Power at shaft 9.97kW

The sound data

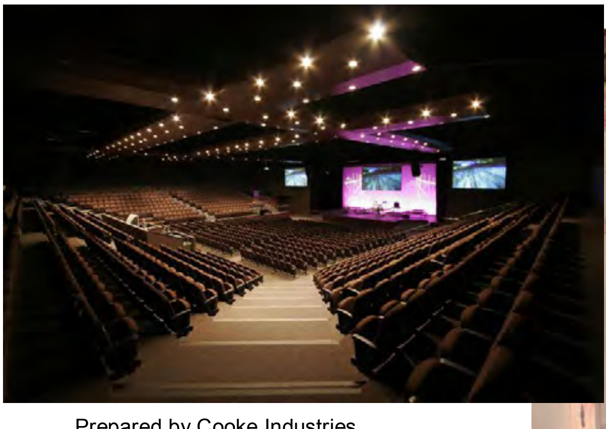
In Duct Sound Power Level	63Hz	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	8kHz
NTHZ 560	98	92	94 (BFI)	88	88	81	75	68
NPA 710	88	82	92 (BFI)	90	87	80	79	79

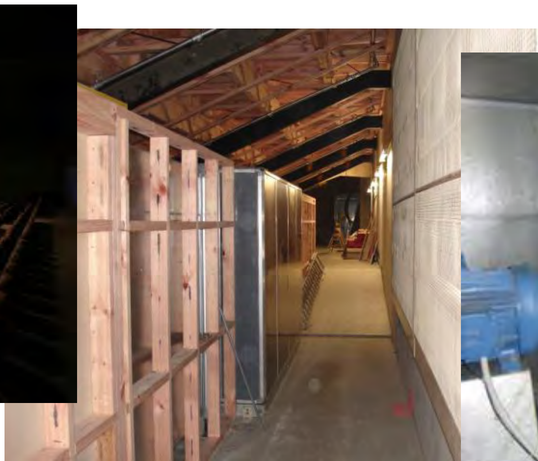
The NPA noise levels are in Lw6 and assumed to be the same as the LW4 induct level for the NTHZ 560 for this comparison. The Lw6 level does not take the plenum effect into account, which further reduces the sound power level.

From this the acoustic advantage from 63-125Hz can clearly be seen, with no real disadvantage with motor power. Additionally, acoustical lining of the fan discharge chambers (coplanar silencers) can provide further reduction in the sound power level entering the discharge duct.

The plenum fan also has the advantage of multiple axial or radial discharge options from the discharge plenum, and when used in a blow through application with downstream components, are more efficient than a standard housed fan when the additional pressure losses of the diffuser plate and free field discharge losses are taken into account.

Cooke Industries have tested the many different configurations to confirm fan selections and design. At City Impact Church, for example, acoustical engineers from Norman Disney Young consultants confirmed our acoustic calculations, taking sound measurements in the AHU inlet, fan discharge chamber, and auditorium as well as evaluating the casing breakout.





Fan Balancing

Fans are balanced to the ISO 1940/1 that has now been accepted as the AHRI Guide C for fan balancing.

The norm in Europe is supply fans to the ISO standard at 1.0, 2.5 or 6.3mm/s

The older American standard for fans called for balancing requirement of 0.16in./sec (approximately 4mm/s) as satisfactory and 0.1in./sec (approximately 2.5m/s) as good balancing. Some fans are balanced to 4mm/s to be equivalent of the 0.16in./sec, while still only complying with G6.3.

ISO 1940/1 Dynamic Balance Quality Grades

G16 ~ Drive shafts, engine components, engine crankshafts

G6.3 ~ Marine main turbine gears, fan & pump impellers, electric armatures

G2.5 ~ Gas and steam turbines, turbo compressors, computer memory drums

G1 ~ Grinding machine drives, small electric armatures, phonograph drives

G0.4 ~ Gyroscopes, Spindles, precision grinders