user **documentation**

nor**261**

reference **sound source**

CE

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Norsonic

On the Use of Reference Sound Sources

The noise level of a machine will depend not only on the actual amount of noise emitted from the machine, but also on the environment in which it is located.

It is therefore not enough to measure the A-weighted level when it comes to assessing the "noisiness" of the machine.

Note: We are here talking about how to characterise the machine as such. When it comes to assessing the impact the noise level may have on the operator, the noise level itself as measured there and then is the only thing that matters.

The fundamental indicator for the "noisiness" of the machine is the sound power level as this quantity is virtually independent of the environment.

There are several ways of determining the sound power level of a machine. The most prominent is sound intensity technique which allows direct measurements of sound power levels. Norsonic has been a supplier of sound intensity instrumentation for years – contact you local representative for details, or visit us on the world wide web (www.norsonic.com).

A less costly approach to sound power level determination lies in the use of indirect methods based on sound pressure levels and comparison with known, well-defined sources.

Traditional method

The traditional method for sound power determination based on sound level measurements uses the following relations:

$$20\log\frac{p}{p_0} = 10\log\frac{P}{P_0} + 10\log\left(\left(\frac{Q(\theta,\varphi)}{4\pi r^2}\right) + \frac{4}{R}\right)$$

in which:

$p_0 = 2\times10^{-5}$ Pa

$P_0 = 10^{-12}$ W

Q is the directivity factor for the sound source in the direction (θ,φ)

r is the distance from source to the measuring microphone

R is the room constant defined by $R = S\alpha/(1-\alpha)$

S is the total surface area of the room

α is the average absorption coefficient of the area S

The first term within the brackets in the above equation is the direct component of the sound field. This component obeys the inverse square law.

The second term is the contribution by the reverbeant field in the room which will be a function of the acoustic absorption coefficients of the surfaces, but also of the contents of the room (empty, filled up with absorptive materials etc.).

Using the traditional method is a cumbersome process. Therefore alternative methods have emerged – two of which shall be dealt with here.

Substitution method

The substitution method can be applied to situations where it is possible to turn off and move the machinery to be investigated. Else the juxtaposition method (see later) must be used.

The substitution method works as follows:

1. With the machinery operating, measure the A-weighted sound pressure level using a sound level meter.
2. Switch off the machinery.
3. Remove the machinery and replace it with the Reference Sound Source Nor-261.
4. Start the Nor-261.
5. Measure the sound pressure level.

The difference in decibels between the two readings will give the exact difference in sound power levels. The A-weighted sound power level emitted by the Nor-261 is 90 dB re. 10^{-12}W (i.e. 9.0 bel) when used with 50 Hz mains frequency and 94 dB re. 10^{-12}W (i.e. 9.4 bel) when used with 60 Hz mains frequency.

Juxtaposition method

The juxtaposition (*juxta* is latin for *beside* or *near*) method is used when the machinery to be measured cannot be switched off or moved.

The juxtaposition method works as follows:

1. Measure the A-weighted sound pressure level in the room from the machinery alone.
2. Start the Nor-261.
3. Measure the combined A-weighted sound pressure level.
4. The machinery's sound power level can now be calculated using the below equation.

The sound power level of the machinery can be calculated from:

$$10\log\frac{P_{Machinery}}{P_0} = 10\log\left(10^{10\log\left(\frac{P_{Tot}}{P_0}\right)} - 10^{10\log\left(\frac{P_{Source}}{P_0}\right)}\right)$$

in which:

$P_{Machinery}$ is the sound power of the machinery to be investigated, expressed in W.

P_{Tot} is the sound power with both the machinery and the reference sound source running, expressed in W.

P_{Source} is the sound power of the reference sound source, expressed in W.

P_0 is the reference sound power value, 10^{-12}W.

Since the only sound power level we know is that of the reference source and, since we are using a sound level meter, the above equation cannot be used.

However, consider the following, which expresses the relationship between the sound power and the sound power level:

$$P_{Machinery} = K \cdot 10^{\frac{L_{Machinery}}{10}}$$

$$P_{Machinery} + P_{Source} = K \cdot 10^{\frac{L_{Tot}}{10}}$$

in which:

$L_{Machinery}$ is the sound pressure level measured with the machinery running, expressed in dB re. 20µPa.

L_{Tot} is the sound pressure level measured when both the machinery and the reference sound source running, expressed in dB re. 20µPa.

K is the correction factor used when calculating sound power from the sound pressure. The exact value of K will depend on the reverberation time (i.e. the amount of absorptive materials) in the room.

Solving for P_{Source}:

$$P_{Source} = K\left(10^{\frac{L_{Tor}}{10}} - 10^{\frac{L_{Machinery}}{10}}\right)$$

which gives the following value for *K*:

$$K = \frac{P_{Source}}{10^{\frac{L_{Tot}}{10}} - 10^{\frac{L_{Machinery}}{10}}}$$

Since

$$P_{Machinery} = K \cdot 10^{\frac{L_{Machinery}}{10}}$$

substituting for K will produce the following

$$P_{Machinery} = \frac{10^{\frac{L_{Machinery}}{10}}}{10^{\frac{L_{Tot}}{10}} - 10^{\frac{L_{Machinery}}{10}}} \cdot P_{Source}$$

Solving for $L_{WMachinery}$ which is the sound power level in dB re 10^{-12}W:

$$L_{WMachinery} = L_{WSource} - 10\log\left(10^{\frac{L_{Tot} - L_{Machinery}}{10}} - 1\right)$$

in which:

$L_{WMachinery}$ is the *sound power level* of the machinery to be investigated.

$L_{WSource}$ is the *sound power level* of the reference sound source Nor-261.

L_{Tot} is the *sound pressure level* measured with both the machinery and the reference sound source running.

$L_{Machinery}$ is the *sound pressure level* measured with the machinery running and the reference sound source switched off.

Example 1: Assume that we measure in the 1kHz third-octave band and that the $L_{Machinery}$ is measured to 88dB SPL and that the sound pressure level within the same frequency band raises to 90dB when the reference sound source is switched on.

From the table on page ??? we see that the Nor-261 sound power level in the 1kHz third-octave band is 80dB for regions with 50Hz mains frequency, i.e. $L_{WSource}$ is 80dB.

Entering this in the equation will give $L_{WMachinery}$=82.3dB, corresponding to 8.23bel.

Example 2: Assume that we again measure in the 1kHz third-octave band and that the $L_{Machinery}$ is measured to 50dB SPL and that the sound pressure level within the same frequency band raises to 90dB when the reference sound source is switched on.

Entering this in the equation will give $L_{WMachinery}$=40 dB, corresponding to 4bel.

Approximation. The result of example 2 could be seen directly since the difference between the two levels is so significant.

The approximation

$$L_{WMachinery} = L_{WSource} - (L_{Tot} - L_{Machinery})$$

can be used when the difference between the machinery's sound pressure level and that of the reference sound source exceeds 10dB.

Applied to the levels in example 2 the approximation gives 40dB as the answer. However, when applied to the levels in example 1 the approximation gives 78dB, which is more than 4dB on the low side and therefore not acceptable.

The Reference Sound Source Nor-261 was carefully checked and inspected at the factory before shipment and is shipped ready for use after unpacking and inspection. Precautions, calibration and acoustical application notes are as follows. It now includes vibration-isolated feet.

Unpacking

Before deploying the Nor-261, please observe the following precautions.

1 Remove the Nor-261 from the corrugated kraft board container by pulling it upward by the cross-bar with spiral-wrap. Preserve container, shims, and top & bottom foam pads for subsequent use. Similar pads should be used when shipping the Nor-261 to distant locations.

2 Check for damage occurred during transport. Do not use the unit if damaged. Note that a damaged fan wheel or a loose shaft attachment may be a severe threat to health and safety.

3 The Nor-261 was tested with 220vac 50 Hz. The power cord end is to be fitted with a plug suited to the power main receptacles at your acoustical test site. Stripped and tinned wire ends are provided when the power cord is supplied without a plug. The GREEN wire is connected to the motor external frame and shall be grounded (earth). The WHITE wire may connected to the neutral. The BLACK wire may be the high voltage terminal of the 200-230 V single phase electric power mains.

Note: It is possible to operate this Nor-261 on 60 Hz 200-240 VAC power (different calibration). But operation on 115 VAC is possible **only** by motor internal connection changes involving a white wire, a blue wire and motor lugs 2, 4 and 5. These wire assignments are (**Verify! Damage occurs if wrong!**):

Motor Lug Connection (Under cover plate near power line inlet)			Rotation-Mandatory (do not change)	
Mains Voltage	Blue Wire Spade	White Wire Spade	Black Wire	Red Wire
200–240V as shipped	4	5	5	A
100–130V	5	2	5	A

Correct wiring for different mains voltages.

4 Supply 200–230 VAC, 50 Hz (See Note above), single-phase power (grounded pin receptacle). Fan will start immediately. Measure the Nor-261 RPM with a photo-tachometer aimed at the reflector-tape tab located on the fan wheel hub by the shaft. After a few minutes, the RPM should be 2940 and within +10 rpm of the RPM value at calibration. Sound power correction rates vs RPM is given on page 5. If the rpm is less than 2920 RPM (50Hz), or 3490 (60Hz) use increased mains voltage, or use a shorter extension cord or one of heavier gauge wire. (Typical maximum extension wire length vs US wire gauge: 1m to 30 m– #18; 50m– #16; 150m–#14).

Acoustical Application

1 Set the Nor-261 on its feet at the desired location. Maintain its spacing from vertical surfaces according to the applicable acoustical test requirements. Clear a 1.5 m diameter area of dust and loose papers (during normal operation; air flows out of the fan wheel, across the floor and back into the fan wheel center). If the Nor-261 is set on an elevated flat horizontal surface, that surface should be at least 1m square or round to assure that calibrated sound power is emitted into the test area.

2 The floor surface under the sound source should be firm and not act as a "sounding board" that radiates spurious test sounds. Vibration isolation provided by the springs between the Nor-261 frame and feet should prevent this on wood joist floors. If spurious sound is emitted from a thin supporting surface, then a more massive supporting surface must be used or a massive support placed under the reference sound source position.

3 Maintain fingers well clear of fan wheel! Apply power as described in the unpacking procedure. Operation may be continuous for ambient air temperatures below 35°C.

4 Install a windscreen on measurement microphones within 2 m of the Nor-261. Run acoustical tests. Use current certification calibration data. Typical values are provided on the next page.

5 Disconnect the reference sound source from electrical power when you are not actually producing acoustical test data to avoid inadvertent damage to fan wheel. Replace the sound source in its shipping container when not in use.

	Third-octave bands		Octave bands		Dir.
Freq. [Hz]	50 Hz	60 Hz	50 Hz	60 Hz	dB
12.5	59 dB	65 dB			
16	61 dB	67 dB	66 dB	71 dB	
20	64 dB	67 dB			
25	66 dB	68 dB			
31.5	74 dB	72 dB	77 dB	79 dB	
40	73 dB	78 dB			
50	74 dB	77 dB			6.8
63	73 dB	78 dB	79 dB	83 dB	5.9
80	75 dB	79 dB			4.5
100	76 dB	80 dB			3.5
125	76 dB	81 dB	81 dB	85 dB	2.7
160	78 dB	81 dB			2.1
200	77 dB	81 dB			2.4
250	76 dB	81 dB	82 dB	86 dB	1.6
315	77 dB	81 dB			1.8
400	76 dB	81 dB			1.7
500	76 dB	80 dB	81 dB	85 dB	2.7
630	76 dB	81 dB			3.1
800	77 dB	82 dB			3.1
1000	79 dB	84 dB	83 dB	88 dB	2.1
1250	80 dB	85 dB			2.7
1600	80 dB	84 dB			2.4
2000	79 dB	84 dB	84 dB	89 dB	2.7
2500	78 dB	83 dB			2.7
3150	78 dB	82 dB			2.5
4000	78 dB	82 dB	83 dB	87 dB	2.2
5000	78 dB	82 dB			1.5
6300	78 dB	81 dB			1.2
8000	77 dB	79 dB	81 dB	84 dB	3.1
10000	75 dB	77 dB			1.6
12500	73 dB	75 dB			1.7
16000	73 dB	72 dB	77 dB	78 dB	3.3
20000	72 dB	70 dB			3.6
A-weight	90 dB				

Sound power levels for Nor-261.Reproducibility is ±2 dB or better. Figures are for 50 and 60 Hz mains voltage frequency. Dir. = Directivity index, i.e. the difference between the maximum SPL and the average SPL as per ISO 6926-1999.

	50 Hz	60 Hz
Wideband (Flat)	91 dB	95 dB
A-weighted	90 dB(A)	94 dB(A)

The wideband and A-weighted sound power levels of the Nor-261 for 50 and 60 Hz mains voltage frequency.

Notes on the calibration:

1 Calibration was performed on other Nor-261 units at a hemianechoic outdoor site per ISO 6296 (Revised). Test radius was 78.8 inches (2.0 m). Twenty different and uniformly spaced microphone heights were used. L_W values are correct at STP*(sea level pressure and 15×C (59 ×F)). The RPM was 2950 for 50 Hz operation at 220 Vac and 3500 for 60 Hz operation at 120Vac.

2 These data may be used to determine test sound power by the substitution method:

Your test site sound power, L_{WSite}, emitted depends on site air temperature, (C), in °C and site air density & pressure (via site *Elev*ation in metres above sea level) as:

$$L_{WSite} = L_{WCal} - 35\log\left(\frac{C + 273}{288}\right) - \frac{Elev}{1830}$$

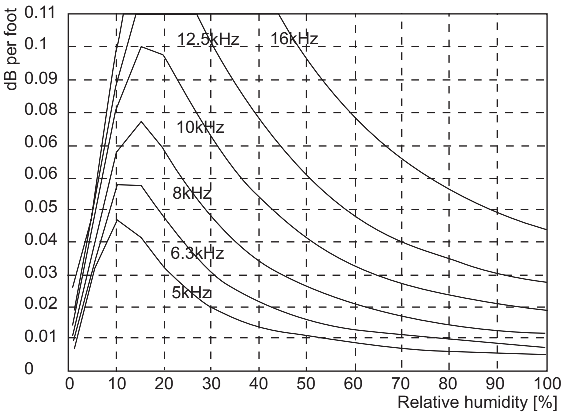
For Fahrenheit, F, use [(F+459)/518]. For altitude in feet, use 6000. This is under study.

The L_{WSIte} will be expresed in dB re 10^{-12}W.

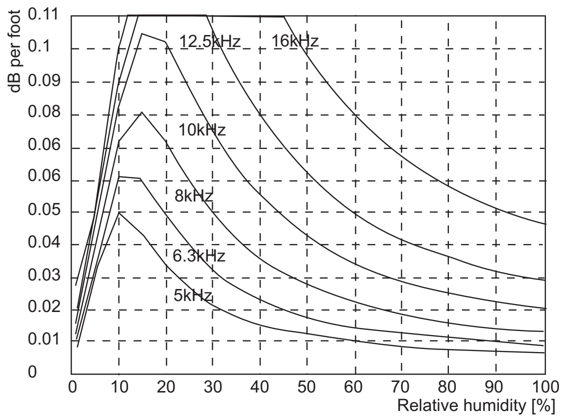
3 These data may be used to determine surface material absorption in a room through the relation:

$$SPL = L_{WSite} - 10\log(\alpha A + 6.2)$$

in which *SPL* is the sound level in the room, L_{WSite} is the sound power level from the above tables, α is the average room surface random incidence absorption coefficient and A is the surface area in square meters with that absorption. If A is in square feet, this constant is +16.3_dB.



Humidity effect on sound absorption in dB per foot @ 20°C



Humidity effect on sound absorption in dB per foot @ 0°C

Sound power corrections vs. rpm

The rpm should be measured using an optical tachometer. If the average rpm that occurred during the test departed more than 10 rpm, the sound power values in the table on page *4* should be corrected as indicated in the below table.

Freq. range	12–40Hz	50–160Hz	200–10000Hz
rpm−cal. rpm	Correction [dB]		
+30	0	+0.3	+0.6
+20	0	+0.2	+0.4
+10	0	+0.1	+0.2
cal. rpm	0	0	0
–10	0	–0.1	–0.2
–20	0	–0.2	–0.4
–30	0	–0.3	–0.6

Sound power corrections to be applied when the rpm varies from the nominal value. Nominal values are 2950 rpm @ 50 Hz mains voltage frequency and 3525 rpm @ 60 Hz mains voltage frequency.

Maintenance

The maintenance procedures description includes fan-wheel inspection procedure, how to replace the fan wheel and motor security. Apply no maintenance until you have read through this chapter.

Fan wheel security. After long-term usage (several hours of operation), inspect fan wheel for secure attachment to the shaft. Two Allen-head screws secure the fan wheel to the 12.5mm (½") shaft. The first indication of loose fan wheel Allen screws is a slight **"rattling"** sound emitted from the wheel during start-up or normal operation. Obtain the 4mm Allen key attached to one of the motor bolts.

Tighten these screws as follows.

1 Remove top screen cover. The screws have been secured using Loctite 222 glue and may be slightly hard to unscrew.

2 Press the fan wheel down with about 1 kg force.

3 Seat the two Allen screws onto the flats of the shaft while rapidly rotating the fan wheel left and right a few degrees to assure that each Allen screw is seating on the lowest point of the flats.

4 Torque the first (deeper) Allen screw to at least 0.35 to 0.45 kg-m (30 to 40 inch-pounds).

5 Turn in the second Allen screw and torque it to 0.25 to 0.35 kg-m (20 to 30 inch-pounds).

6 Put the top screen cover back in place. Use Loctite 222 glue or similar to secure the screws. Do not use normal super glue or a bolt securing agent which prove difficult to remove

Caution: Allen key must be completely seated into the screw head for this final torque. Inadequate seating and torque beyond these values will damage the Allen screw.

Fan wheel condition. The fan wheel geometry precisely determines the sound level emitted by the Nor-261. Fan wheel distortions and dust-accumulation alter the sound output. Dust can be removed with a dry clean brush. Be careful not to dislodge the acoustical mask interior to the fan wheel. Substantial fan wheel and mask distortions that are repaired may alter the sound field, and recalibration is advised. Bends of individual blades in excess of 1mm should be repaired by reshaping. Radical changes in blade or fan wheel shape require repair and recalibration by Norsonic.

Fan wheel removal. We strongly recommend that the fan wheel **not** be removed from the motor shaft. However, if certain maintenance procedures necessitate this, then proceed **carefully** as follows. Be aware that removal may require some effort since a burr will form under the Allen screw contacting the shaft radius. Extreme caution is necessary to avoid damaging the fan wheel, Allen screws and motor shaft.

Remove the top screen and the side screen on the wheel key holster side. Mark exact screen orientations. Access the two Allen screws through the top wheel hole. Loosen the Allen screws one to two turns counterclockwise. Lift the fan wheel upward by hand with a few pounds (1 kg) force. If it does not slide up immediately, then insert a 9 mm to 12 mm diameter rod down into the shaft hole and tap it lightly with a hammer while a second person lifts upward on the fan wheel with about 10 kg (20 lbs) force. When clear of the motor shaft, the fan wheel can be slipped the side to clear the 8 mm protective frame and grid-attach lugs. Retain and replace the lock washer placed on the shaft as a fan wheel spacer to prevent contact of the fan wheel to the motor bearing boss.

Fan wheel replacement.

1 Clear all burrs (produced by previously located Allen screws) from the shaft's curved (not flat) surfaces with a fine machinist's file. These burrs cause fan wheel removal and replacement difficulty.

2 Verify that the Allen screws are backed out far enough to clear the shaft surfaces.

3 Align one set screw onto the shaft flat. The other screw must fall onto a smaller flat at 90° ground into the shaft perimeter. The wheel must slip onto the 12.7 mm motor shaft with less than 1 kg (2 lbs) force. If it does not, do not force it further. Rather, remove it, more thoroughly file off the burrs, then try again. Alternatively, pass the chuck end of a 0.500" (12.7mm) drill bit into the motor end of the hole. Twist the bit by hand while inserting further toward the cutting end. Some resistance will be felt as the burrs are cut clear. Do not insert the bit any further! Remove the drill bit from the motor end of the hole (drill bits are larger at the cutting end, smaller at the chuck end).

Press the fan wheel down with about 1 kg force, then seat the two Allen screws onto the flats of the shaft while rapidly rotating the fan wheel left and right a few degrees to assure that each Allen screw is seating on the lowest point of the flats. Torque the first (deeper) Allen screw to at least 0.35 to 0.45 kg-m (30 to 40 inch-pounds). Turn in the second Allen screw and torque it to 0.25 to 0.35 kg-m (20 to 30 inch-pounds).

Caution: Allen key must be completely seated into the screw head for this final torque. Inadequate seating and torque beyond these values will damage the Allen screw. Replace the side and top screens precisely as marked.

Motor electrical system. The electric motor is a capacitor-start induction motor with an internally switched starting circuit. If overheated (200-240vac applied to 100-120vac connections - see Note 1, page 2), fire damage to the motor windings will occur!!

Service cord replacement. Use 16 gage flexible copper service cord not more than 3m (11 feet) long. If screw- lug connectors are installed, use extreme caution to torque the terminal connector nuts. Rotation of the terminal studs causes internal motor short & burnout. The red and black motor internal jumpers shall not be moved during inspection or wire replacement since this will reverse the direction of fan rotation. For factory calibration and full sound power noise emission spectrum, the direction of fan wheel rotation is mandatory to be counter-clockwise looking down into the Nor-261.

Motor security. The 5/16" motor bolts and nuts are not normally inspected unless repair or electrical inspection requiring motor removal is performed. Upon re-assembly, include the lock-washer under the nut. Torque the motor bolts and nuts to 8 ft-lbs (1.1 kg-m) before placing the Nor-261 into routine use.

Motor lubrication. The motor ball bearings will serve the entire life of this Reference Sound Source. No lubrication is needed.

Protective screen. The screen should be flat within ±5 mm near the fan wheel. If a screen is bent or dented in service, remove it (remove the 8-32 screws) and flatten it by hand on a flat surface.

Carrying frame. The frame of the Nor-261 series is reinforced with interior lateral braces. The motor and fan should stand erect ± 5 degrees within the frame. If the motor bolts have loosened, then realign and tighten bolts per *Motor security* above. If the motor support or frame is bent, but the motor/fan wheel axis tilt is less than 5 degrees, no corrective action is necessary. Larger deformations or bent frame members should be corrected by good metal (steel) shop practices. To do so, remove the motor/fan wheel as a unit by unfastening the four motor bolts. Take precautions to *not* apply any deforming forces to fan wheel during removal, storage and replacement. Store motor/fan wheel on a short 50mm (2") thick support block because the fan wheel radius is 30mm greater than the motor shaft height. Replace motor/fan wheel per *Motor security* above. Vibration isolation feet spring adjustment is described in 3) of *Unpacking*.

Periodic calibration and recertification

The Nor-261 should produce a constant sound emission indefinitely as long as proper power is applied. However, significant fan wheel distortions, screen deformation toward the fan wheel and dust accumulation can alter the sound output. Dust can be removed with a dry and clean brush. Be careful not to dislodge the acoustical mask interior to the fan wheel. Substantial fan wheel and mask distortions that have been repaired will alter the sound field, and recalibration is advised. This can be done by an acoustical sound-power testing laboratory according to ANSI S1.31-1980 or ISO 6926 (rev).

In need of service?

In case of difficulties, contact your local Norsonic representative or the factory. Do not ship the sound source to the factory without prior written consent from Norsonic AS.

Provided that return shipment is agreed upon, proceed as follows:

1 Do *not* pack this bare-framed instrument surrounded by only bubbles or pellets, as the fan wheel can be damaged in this environment.

2 Instead, place the source unit in a close-fitting corrugated kraft box as originally shipped.

3 Install shipping stabiliser strips and top/bottom blocks to support the perimeter of the exterior frame. (If you expect abusive surface shipment, place this box in a larger container with cushioning foam, bubbles or pellets). Seal and ship as agreed upon with Norsonic or your local representative.

Nominal performance specificatons:

Sound Power Output Uniformity; (dB re 1 Picowatt):
A- weighted:90dB
Full Octave Level:81,5±3dB(125–8000Hz)
1/3 octave level:77±3dB(100–8000Hz)

Weight: 13.4Kg (30lbs)

Size: 25x25x38.5 [cm] (10"x10"x15.4")

Power:
200–230Vac, single phase, 50-60Hz, 1kVA.
100–130 Vac, single phase, 50–60Hz, 1kVA by internal jumper