EEC LAWNMOWER CERTIFICATION AND THE EFFECT OF GROUND ABSORPTION

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INTRODUCTION

Late in 1978 the Council of the European Communities approved a Directive approximating the laws of member states relating to the determination of noise emission of construction plant and equipment. This and subsequent amendments have provided the basis for the approved method of measuring the Sound Power emission from various types of plant and more recently that from Lawnmowers. The method of measuring the Sound Power of Lawnmowers is slightly different from that for other plant. It is this difference, the effect ground absorption has on the results, and the analysis of noise measurements over a number of different types of Lawnmower which is discussed in this Paper.

THE EEC DIRECTIVES

The EEC Council Directive 79/113/EEC and its annexes [1], subsequently amended [2], lay down the method of determining airborne noise emitted by machines used outdoors.

This method of measurement applies to EEC Directives on Power Generators [3], Welding Generators [4], Compressors [5], Tower Cranes [6], and Concrete Breakers and Picks [7]. It has been a legal requirement within member states of the EEC for equipment manufactured within the EEC, or imported into the EEC, to be tested and certified acceptable to these requirements since March 1986. A further development on Earth Moving Machinery [9] is currently being implemented for adoption from 1st January 1988.

The method of determining the "A" weighted Sound Power Level is by taking measurements of "A" weighted Sound Pressure Levels over an imaginary hemisphere surrounding the machine under test. The location of the six measuring points on this imaginary hemisphere are given in Figure 1.

The Directive 84/538/EEC [8] came into force on 1st July 1987 and applies to the permissible Sound Power Level of Lawnmowers. Initially this Directive is applicable only to rotary type machines but will apply to cylinder Lawnmowers from a date in the not too distant future.

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The permissible Sound Power Levels of a Lawnmower depend upon its cutting width as shown in the following Table.

Table 1

Cutting Width (L.mm)	Max Permissible Sound Power Level (dB(A)/1pW)	Test Hemisphere Radius (r.m)
$L \leqslant 500mm$	96dB(A)	4m
$500 < L \leqslant 1200mm$	100dB(A)	4m
$L > 1200mm$	105dB(A)	10m

The significant difference between this directive and those adopted earlier are that the machines must be tested on (dry) grass; that three sets of measurements, averaged in space, must lie within 1dB of each other, or additional measurements are to be taken; and the cutting height shall be set to at least 30mm from the ground. (This requirement has subsequently been modified to take into account the adjustment available to cylinder Lawnmowers). The grassed area of the imaginary hemisphere must first be cut with the Lawnmower set at the correct height of 30mm before measurements take place. In addition the Directive requires that there should be no reflective objects within a radius three times that of the imaginary hemisphere.

By calculating the surface area of the imaginary hemisphere the "A" weighted Sound Power Level can be obtained from :-

$$L_{WA} = L_{pAm} + 10Log_{10}\, S/S_o + K_2 \qquad (1)$$

where

L_{WA} = the Sound Pressure Level of the source tested in dB.

L_{pAm} = the Surface Sound Pressure Level in dB.

S = the area of the measuring surface in $m^2 = 2\pi r^2$.

S_o = the reference area of $1m^2$.

K_2 = a correction term for the test area in dB.

therefore where the hemisphere radius = 4m, $10Log_{10}S/S_o$ = 20dB.
10m, $10Log_{10}S/S_o$ = 28dB.
16m, $10Log_{10}S/S_o$ = 32dB.

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Site Qualification

The factor K_2 in equation (1) is quantified from the acoustic properties of the test area. This factor is taken to be zero when the Constant C, which indicates the acoustic properties of the test area, is between 0.5 dB and 2.0 dB determined by the following equation :-

$$C = L_{WAr} - L_{WAs}$$

where

L_{WAr} = normal Sound Power Level of the Reference Source in dB.

L_{WAs} = Sound Power Level of the Reference Source calculated on the basis of measurements made on the test area.

This factor is established by running a known Sound Power Level sound source such as the ILG Industries rotating vane sound source or the Bruel & Kjaer 4224 noise source in the centre of the hemisphere, after the grass has been cut to the prescribed height. (Both these sound sources have been calibrated in SRLs' 300m^3 Reverberation Chamber prior to their use under this Directive). The two devices produce Sound Power Levels of 82dB(A)/1pW and 108dB(A)/1pW respectively; the latter at its maximum setting without overload.

The Surface Sound Pressure Level L_{pAm} is the root mean square of the Sound Pressure Levels recorded on the measuring surface, and is determined by the formulae :-

$$L_{pAm} = L_{pAo} + 10\mathrm{Log}_{10}1/n \sum_{i=1}^{i=n} g_i = L_{pAo} + 10\mathrm{Log}_{10}g_m \qquad (2)$$

where

L_{pAi} = the sound pressure level of the i th measurement.

L_{pAo} = is an auxiliary sound pressure level to satisfy the calculation. (eg. the smallest of the L_{pAi} values.)

g_i = is the auxiliary value for the i th measurement: $g_i = 10^{0.1(L_{pAi} - L_{pAo})}$.

g_m = is the mean value of the g_i variables: $1/n \sum_{i=1}^{i=n} g_i$.

The quantity $\triangle L$ is defined by :-

$$\triangle L = L_{pAi} - L_{pAo}$$

Figure 2 gives values of g for different values of $\triangle L$.

Each measurement should be taken over a period of 15 seconds. No measurement may be made when the background noise level is less than 6dB below that of the machine, a correction factor of 1dB is made when the difference between the levels is 6dB,7dB or 8dB and 0.5dB when the difference is 9dB or 10dB; no correction is necessary when the difference is greater than 10dB. Also no measurement may be taken if the wind speed is greater than 8m/s.

Experience To Date

Experience has shown that the majority of machines only just meet the maximum requirements as laid down in Table 1. Whilst some tests have been carried out on cylinder Lawnmowers the bulk have been on rotary machines the effects of which are discussed in this paper. Of the seven sites used to date by SRL in the testing of some 150 plus machines not one site with its grass cut to 30mm has exceeded the 0.5 to 2.0 dB allowance. The variety of grassed surfaces between the seven sites is considerable, from fine sparse playing fields to thick matted domestic lawns. This allowance is obviously intended to take into account the variable degree of absorption afforded by varying type of grassed surfaces and its effect on the radiation of noise from a sound source such as Lawnmower.

However, whilst the intention is valid it can be seen that, in theory, a machine tested on a grassed surface having a C factor of 2.0 dB will appear 1.5 dB quieter than the same machine tested on a grassed surface having a C factor of only 0,5 dB.

The approximate method of averaging the readings as given in 79/113/EEC using Figure 2 can result in rounding errors which can mean the difference between a pass and fail situation. The method of calculating the root mean square Surface Sound Pressure Level, with the aid of a scientific calculator is preferred, correcting initially to two decimal places and finally rounding to the nearest whole number, ie. $\geq$0.50 rounded up, $<$,0.5 rounding down.

With most I/C engined Lawnmowers operating close to the permitted limits of the Directive the selection of the site and the method of calculation are quite critical. The effect on the overall Sound Power Level of these factors may depend on the ranking of the noise sources from the Lawnmower itself.

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Noise Source Ranking

Of the Lawnmowers tested by SRL ranging from a 25cm (12") cut to one of 4.80m (15'9") we have analysed in our Laboratory complex, ten different machines for the contribution to the overall noise level of the machine made by seperate noise generating or radiating sources. These can be identified as :=

1) Noise radiating from the engine casing (both cylinder head and sump).
2) Noise from the exhaust system.
3) Noise from the air intake.
4) Noise generated by air movement over the cutting blade.
5) Noise radiating from the mower deck caused by engine and/or blade vibration.
6) Noise from cutter transmission.

Our experience has shown that there is no one major source from Lawnmowers in general but that each machine or range of machines has a particular rank order of the noise sources listed above. However, in the majority of small domestic Lawnmowers where the I/C engine is mounted directly onto the mower deck and direct drives the cutter bar the major source of noise identified in the test laboratory is that from the air turbulence created by the cutting blade. In the test chamber the significance of the cutting blade noise is even greater on electrically powered Lawnmowers where the contribution of the electric motor is minimised.

This can be seen in Figure 3 where the noise levels generated with and without a cutting blade on an electric motor powered lawnmower are shown. These figures in octave bands for clarity of presentation were originally derived from one third octave measurements using a Real Time Analyser. For more detailed examination of noise sources a narrow band analyser with harmonic indicators was used. From Figure 3 the sound power levels were:

Overall	91.5 dB(A)
No blade	74.5 dB(A)

In this instance the only contribution to the maximum overall level was from the action of the cutting blade. Similarly Figure 4 shows the effect of exhaust noise on another machine where the sound power levels were:

Overall	103.0 dB(A)
No cutters	97.5 dB(A)
No cutters/	96.0 dB(A)
No exhaust	96.0 dB(A)

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Again Figure 5 shows the results of experiments carried out on different types of cutters based on a blade designed to reduce the rate of change of air over its surface by the introduction of a "wing".

Special blade	100% wing	93.5 dB(A)
	75% wing	93.0 dB(A)
	50% wing	92.0 dB(A)
	25% wing	91.0 dB(A)
	no wing	89.5 dB(A)

Whilst only small changes in overall noise levels are apparent these can mean the difference between a "pass" and "fail" situation.

The figures shown above are those actually measured (calculated) and do not indicate the contribution to the overall level of noise from individual sources. The number of tests needed to be carried out can be exceedingly complex in order to isolate these individual noise sources.

On a tractor type machine, a total of 21 tests were carried out in order to identify the contribution of the following sources:

Overall	103.0 dB(A)
Engine	98.5 dB(A)
Exhaust	97.0 dB(A)
Cutters	96.5 dB(A)
Cutter drive	94.0 dB(A)

On this larger machine it will be noticed that the engine becomes the major source of noise compared to the cutters for the smaller machines described earlier. Octave Band analysis of these contributions, derived from one third octave measurements are shown in Figure 6. The effect of the engine cover was evaluated in an attempt to reduce the overall noise. These tests (see Figure 7) indicated that with an engine cover only slightly extended (100mm) and lined with an absorbent material the contribution of the engine to the overall noise level could be reduced from 98.5 dB(A) to 93.5 dB(A) resulting in an overall reduction of 1.5 dB(A). This again may not sound much but one must also remember these tests are being carried out within a reverberation chamber on a hard surface not on dry grass as per the Directive.

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Effect of Ground Absorption

The effect of the ground absorption on machines where the cutter blade appears to be the major source of noise in reverberation chamber tests is significant. Tests carried out on an electric motor driven machine indicate drops of 0.0 dB(A) and 7 dB(A) between reverberation chamber and hard reflective plane and grassed area respectively. However, for an I/C engined machine the same tests resulted in only a 0.0 dB(A) and 1.5 dB(A) falls in level. Similar tests with the reference sound source produced falls in level of 0.0 dB(A) and 1.5 dB(A), ie. the C factor being 1.5 dB. Further tests on larger machines where the engine would appear to be a more significant noise source in tests in the reverberation chamber indicate losses of 4 dB(A) when subsequently tested on grass.

In the last example therefore where the overall Sound Power Level of 103 dB(A) was obtained, a reduction of 1.5 dB(A) was available for transfer of testing to grass and a further 1.5 dB(A) was available as a result of extending and lining the engine hood. This gave a predicted Sould Power Level for tests in accordance with the EEC Directive of 100 db(A), the limit for machines with cutting widths between 50mm x 1200mm.

Controlling Noise From Lawnmowers

In addition to this type of modification there are a number of other techniques for attaining the lowest noise levels from a Lawnmower, viz :-

1) Use an engine which has been run in for say two hours on a 15 minute run 15 minute rest cycle.
2) Set the cutting height to the lowest allowed (30mm).
3) Position the blade as high up into the deck as is possible for good cutting and grass collection. This allows for the uncut grass to act as a better absorptive seal around the edge of the deck.
4) Run the engine at its lowest rpm conducive with good cutting and collection. Every 200 rpm can result in 1 to 2 dB(A) reduction in overall Sound Power Level depending upon the blade/engine contribution.
5) Use a well balanced engine and blade assembly.
6) Eliminate rattles of wheel bearings, grass collectors, safety flaps, cables etc.
7) Use a spark arrester on the exhaust and point the exhaust outlet at one of the low level measuring points. The maximum noise level from exhaust tail pipes occurs at 45 degrees to their axis therefore by pointing the exhaust directly towards a measuring point the maximum level occurs between measuring points.

This deals mainly with the engine contribution to the overall Sound Power Level.

Where the blade noise is a significant contribution this can be reduced by :-

1) Reducing blade lift by reducing the frontal area.
2) Reduce rotational speed, at least 1 dB(A) reduction per 200 rpm (see also note 4 above).
3) Improve deck by reducing sudden changes in section, protrusions etc. This together with 1) above and despite a reduction in rpm as suggested in 2) can often result in lower noise levels with improved cutting and better grass collection by improving the air flow into the collecting bag.
4) Use holes or slots in the lift area of blades to reduce turbulence and pressure differentials across the blades.
5) Use a tapered trailing edge to blades with lift to reduce turbulence.
6) Use other devices to move the air and reduce blade lift to near zero.

Most if not all of the latter methods for reducing noise apply mainly to the smaller domestic type Lawnmower. The larger commercial machines have less contribution from the cutter blade(s) and more from the engine and exhaust and therefore the first set of techniques have greater effect.

Improvement In Test Sites

In an attempt to make tests on the two smaller ranges of Lawnmowers independent of the weather and dry grass an amendment to the Directive has been approved. This enables machines to be tested indoors on a special artificial surface provided the surface and its environment still meet the site conditions of C factor between 0.5 to 2.0 dB(A). The absorptive coefficient of the artificial is required to meet the following values :-

Octave Band Centre Frequency - Hz	125	250	500	1k	2k	4k
Absorption Coefficient	0.1	0.3	0.5	0.7	0.8	0.9

There is a tolerance on each of these figures of plus or minus 0.1 absorption coefficient.

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CONCLUDING REMARKS

The only common denominator between machines of similar make, or other manufacturers, is the value of the ground absorption, a factor which can be worth 1.5 dB(A) on the calculated Sound Power Level. Each machine will have slightly different characteristics with regard to noise source contribution. In general, however, the smaller domestic machines will be controlled by noise from the cutting blade, and the larger commercial machines by noise from the engine. As always there are exceptions to every rule.

The imposition of maximum noise levels for lawnmowers has led manufacturers to consider in detail the performance of their cutter blades and engine manufacturers the noise levels generated by their engines. Only good has come from this imposition from Brussels. Lawnmowers are now not only quieter but also cut and bag the grass better and the engines should have a longer life. To achieve this has been a fairly long and painful path of discovery which is still going on.

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REFERENCES

[1] 79/113/EEC, 'COUNCIL DIRECTIVE of 19 December 1978 on the approximation of the laws of the Member States relating to the determination of the noise emission of construction plant and equipment.', Official Journal of the European Communities, No L33/15-30.

[2] 81/1051/EEC, 'COUNCIL DIRECTIVE of 7 December 1981 amending Directive 79/113/EEC on the approximation of the laws of the Member States relating to the determination of the noise emission of construction plant and equipment.', Official Journal of the European Communities, No L376/49-55.

[3] 84/536/EEC, 'COUNCIL DIRECTIVE of 17 September 1984 on the approximation of the laws of the Member States relating to the permissible sound power level of power generators.',Official Journal of the European Communities, No L300/149-155.

[4] 84/535/EEC, 'COUNCIL DIRECTIVE of 17 September 1984 on the approximation of the laws of the Member States relating to the permissible sound power level of welding generators.',Official Journal of the European Communities, No L300/142-148.

[5] 84/533/EEC, 'COUNCIL DIRECTIVE of 17 September 1984 on the approximation of the laws of the Member States relating to the permissible sound power level of compressors.', Official Journal of the European Communities, No L300/125-129.

[6] 84/534/EEC, 'COUNCIL DIRECTIVE of 17 September 1984 on the approximation of the laws of the Member States relating to the permissible sound power level of tower cranes.', Official Journal of the European Communities, No L300/130-141.

[7] 84/537/EEC, 'COUNCIL DIRECTIVE of 17 September 1984 on the approximation of the laws of the Member States relating to the permissible sound power level of powered hand-held concrete-breakers and picks.', Official Journal of the European Communities, No L300/156-170.

[8] 84/538/EEC, 'COUNCIL DIRECTIVE of 17 September 1984 on the approximation of the laws of the Member States relating to the permissible sound power level of lawnmowers.', Official Journal of the European Communities, No L300/171-178.

[9] 86/662/EEC, 'COUNCIL DIRECTIVE of 22 December 1986 on the limitation of noise emitted by hydraulic excavators, rope-operated excavators, dozers, loaders and excavator-loaders.', Official Journal of the European Communities, No L384/1-11.

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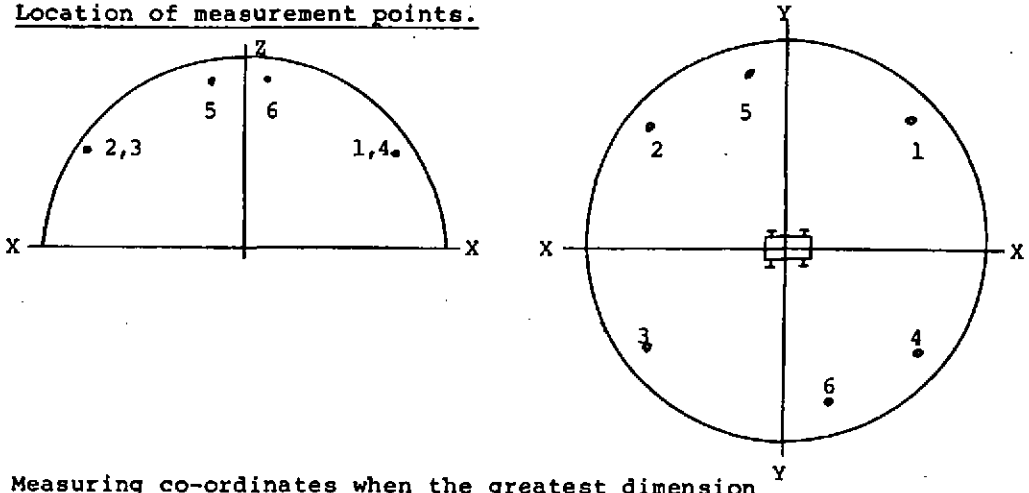
Figure 1

Location of measurement points.



Measuring co-ordinates when the greatest dimension of the unit is not more than 1.5m.

Point No	X	Y	Z
1	2.8m	2.8m	1.5m
2	-2.8m	2.8m	1.5m
3	-2.8m	-2.8m	1.5m
4	2.8m	-2.8m	1.5m
5	-1.1m	2.6m	2.8m
6	1.1m	-2.6m	2.8m

Measuring co-ordinates when the greatest dimension of the unit is more than 1.5m, but less than 4m.

Point No	X	Y	Z
1	7.0m	7.0m	1.5m
2	-7.0m	7.0m	1.5m
3	-7.0m	-7.0m	1.5m
4	7.0m	-7.0m	1.5m
5	-2.7m	6.5m	7.1m
6	2.7m	-6.5m	7.1m

Measuring co-ordinates when the greatest dimension of the unit is more than 4m.

Point No	X	Y	Z
1	11.2m	11.2m	1.5m
2	-11.2m	11.2m	1.5m
3	-11.2m	-11.2m	1.5m
4	11.2m	-11.2m	1.5m
5	-4.3m	10.4m	11.4m
6	4.3m	-10.4m	11.4m

Figure 2

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Value of g as a function of Δ L

The Table may be extended in either direction.

ΔL dB	g	ΔL dB	g	ΔL dB	g	ΔL dB	g	ΔL dB	g
-20.0	0.010	-10.0	0.100	0.0	1.00	10.0	10.0	20.0	100.0
-19.5	0.011	-9.5	0.112	0.5	1.12	10.5	11.2	20.5	112.0
-19.0	0.013	-9.0	0.126	1.0	1.26	11.0	12.6	21.0	125.9
-18.5	0.014	-8.5	0.141	1.5	1.41	11.5	14.1	21.5	141.3
-18.0	0.016	-8.0	0.158	2.0	1.58	12.0	15.8	22.0	158.5
-17.5	0.018	-7.5	0.178	2.5	1.78	12.5	17.8	22.5	177.8
-17.0	0.020	-7.0	0.200	3.0	2.00	13.0	20.0	23.0	199.5
-16.5	0.022	-6.5	0.224	3.5	2.24	13.5	22.4	23.5	223.9
-16.0	0.025	-6.0	0.251	4.0	2.51	14.0	25.1	24.0	251.2
-15.5	0.028	-5.5	0.282	4.5	2.82	14.5	28.2	24.5	281.8
-15.0	0.032	-5.0	0.316	5.0	3.16	15.0	31.6	25.0	316.2
-14.5	0.035	-4.5	0.355	5.5	3.55	15.5	35.5	25.5	354.8
-14.0	0.040	-4.0	0.398	6.0	3.98	16.0	39.8	26.0	398.1
-13.5	0.45	-3.5	0.447	6.5	4.47	16.5	44.7	26.5	446.7
-13.0	0.50	-3.0	0.501	7.0	5.01	17.0	50.1	27.0	501.2
-12.5	0.056	-2.5	0.562	7.5	5.62	17.5	56.2	27.5	562.3
-12.0	0.063	-2.0	0.631	8.0	6.31	18.0	63.1	28.0	631.0
-11.5	0.071	-1.5	0.708	8.5	7.08	18.5	70.8	28.5	707.9
-11.0	0.079	-1.0	0.794	9.0	7.94	19.0	79.4	29.0	794.3
-10.5	0.089	-0.5	0.891	9.5	8.91	19.5	89.1	29.5	891.3
-10.0	0.100	-0.0	1.000	10.0	10.00	20.0	100.0	30.0	1000.0

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Figure 3

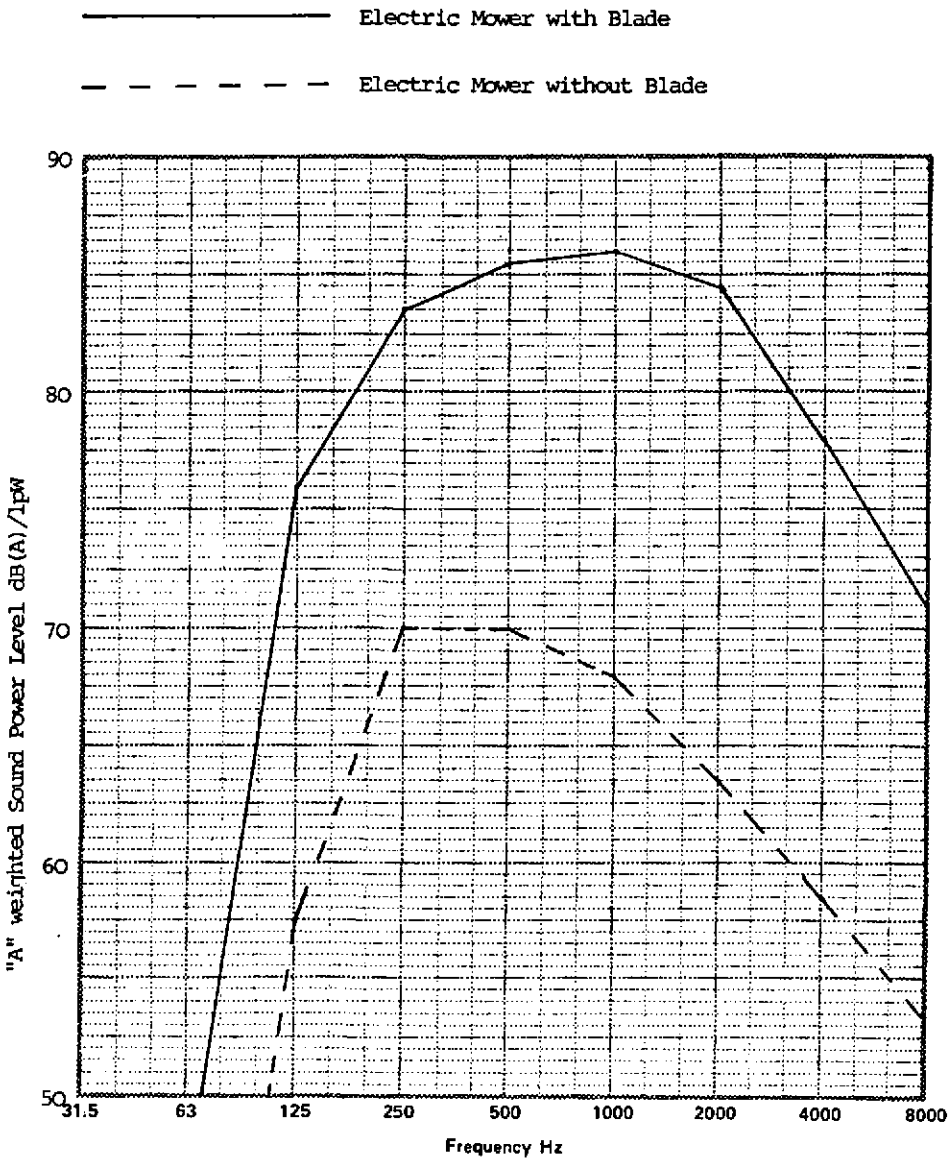

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Figure 4

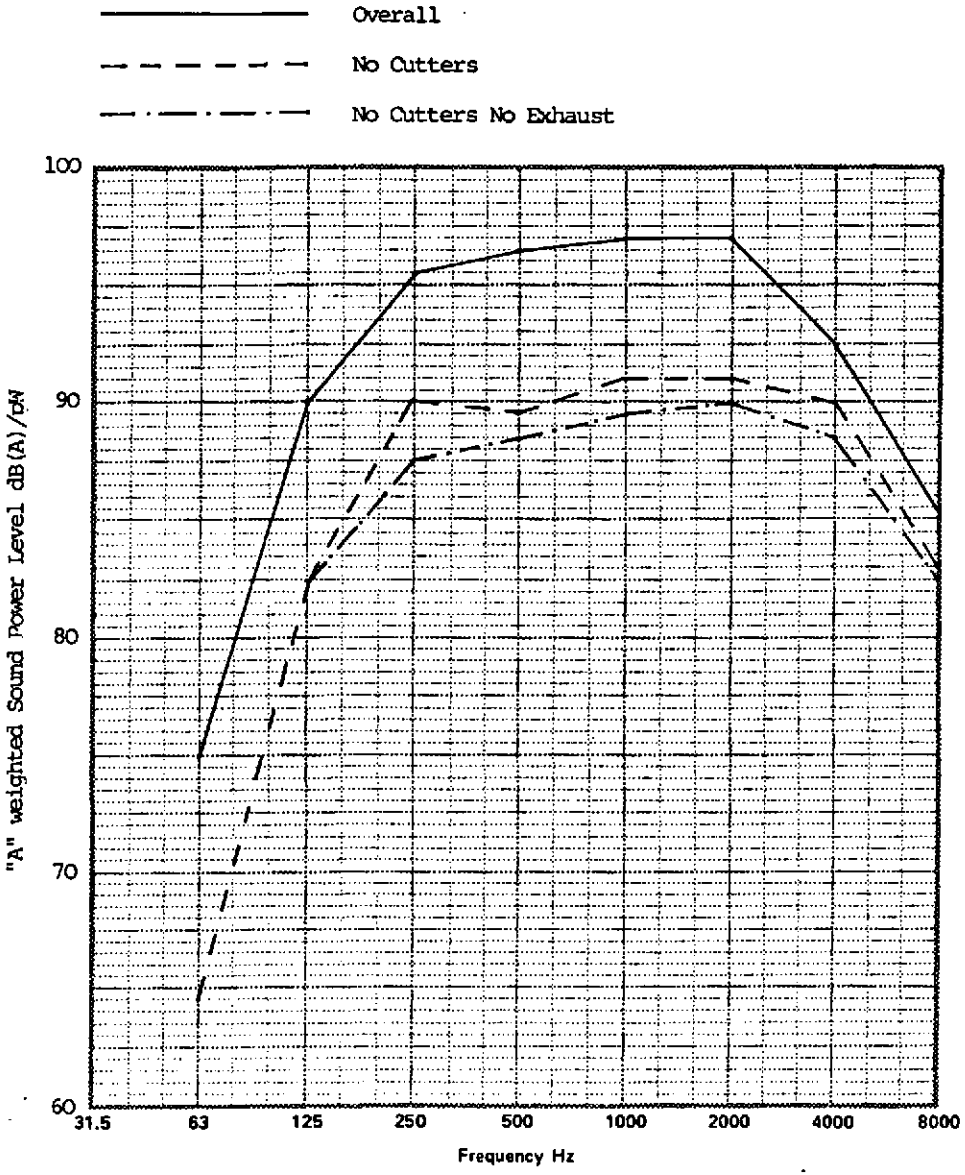

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Figure 5

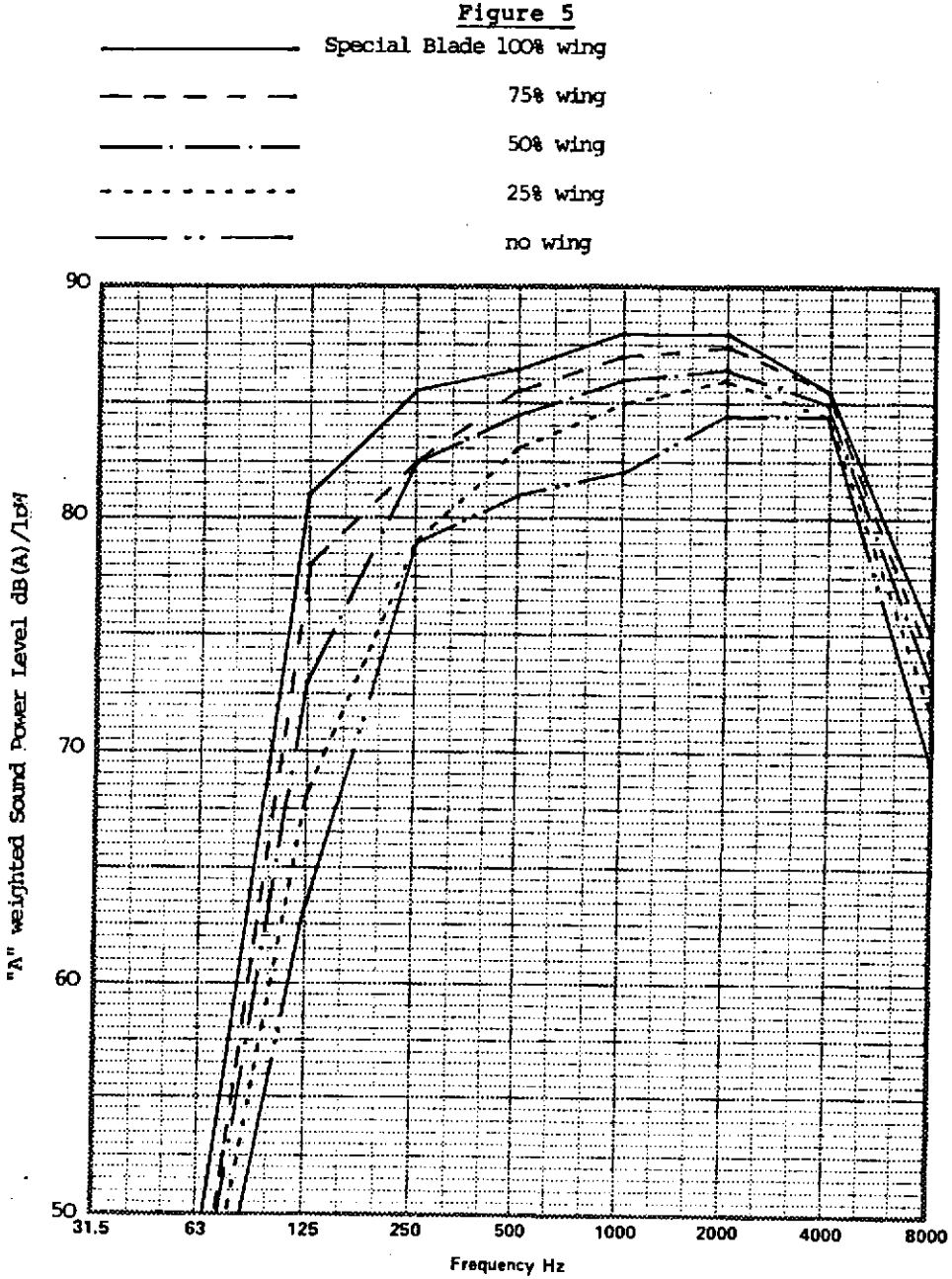

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Figure 6

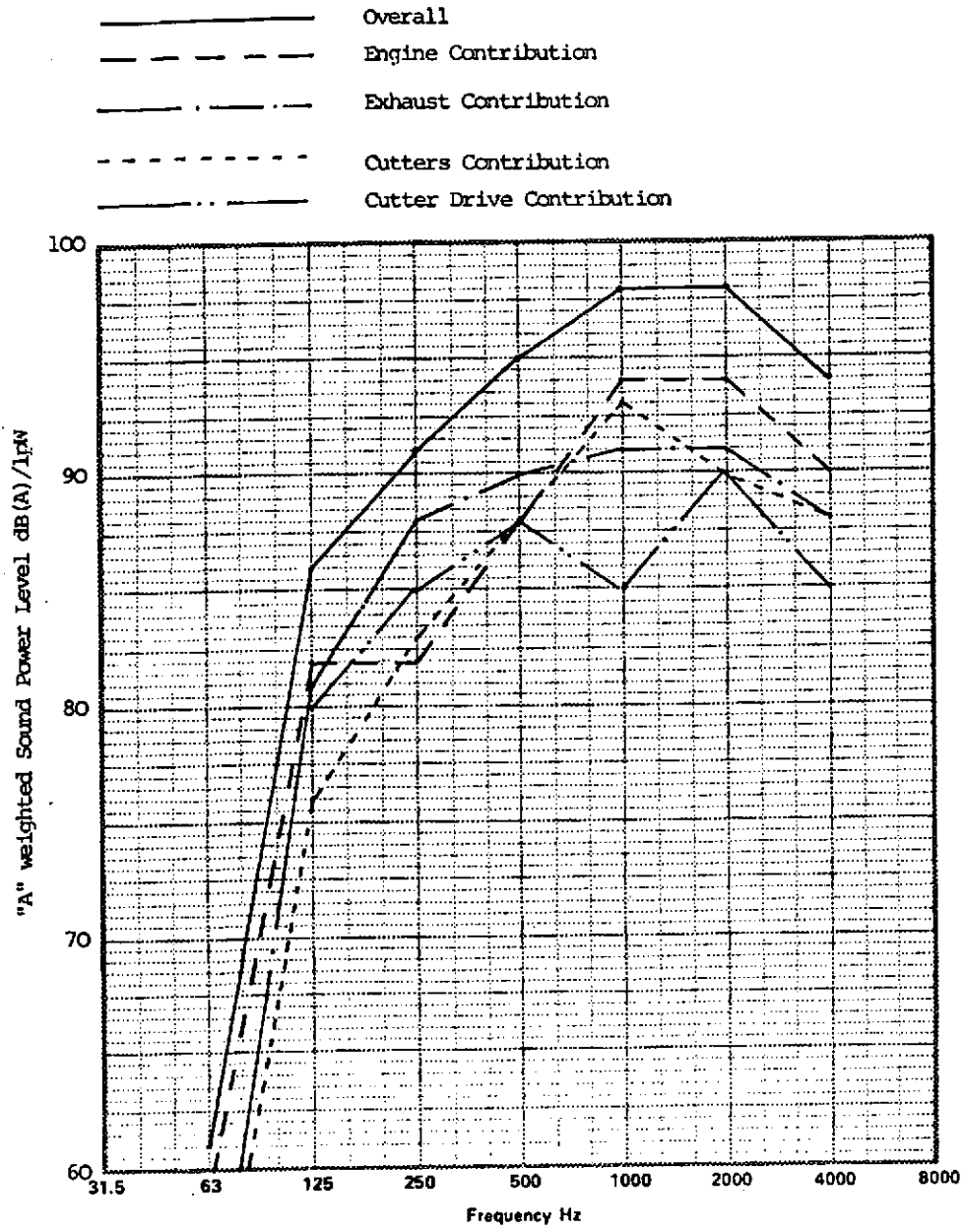

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Figure 7