

Contents

Abstract	1
Introduction	3
1 Fundamentals of sound power	7
1.1 Sound power definition	7
1.2 Use of sound power	7
1.3 State-of-the-art in sound power measurements	9
1.4 Limitations of current methods.....	12
1.5 Traceability of sound power unit	14
2 Theoretical considerations for the substitution method	17
2.1 Reflection over impedance plane	17
2.2 Measurement surface	22
2.3 Angle resolution.....	26
2.4 Sound intensity calculation.....	26
2.5 Generalization of the results.....	27
2.6 Translation of the substituted source.....	28
2.7 Number of receivers and frequency resolution	30
2.8 Free field substitution	33
2.9 Substitution including an impedance plane	35
2.10 Geometry with two reflecting planes	41
3 Calibration procedure for transfer standards	43
3.1 Scanning apparatus.....	44
3.2 Measurable quantities.....	45
3.2.1 Sound pressure.....	45
3.2.2 Sound intensity.....	46
3.3 FFT windowing effects.....	46
3.4 Background noise contribution	47
3.5 Scan speed	47
3.6 Scan repeatability	48
3.7 Apparatus reflections	49
3.8 Comparison to meridional path	50

3.9	Calibration uncertainty	53
3.9.1	Corrections to cancel out during substitution	54
3.9.2	Corrections to be applied and uncertainty equation.....	55
3.9.3	Uncertainty due to background noise	56
3.9.4	Uncertainty due to FFT windowing	57
3.9.5	Uncertainty due to near field effects	57
3.9.6	Uncertainty due to microphone windscreens	58
3.9.7	Application of the substitution method under calibration conditions.....	58
3.9.8	Uncertainty of the primary source sound power level.....	59
3.9.9	Uncertainty due to the surface and time averaged sound pressure level difference	59
3.9.10	Uncertainty due to reference quantity correction	59
3.9.11	Uncertainty due to air absorption correction.....	60
3.9.12	Combined uncertainty for the substitution method under calibration conditions	61
4	Properties of transfer standards	63
4.1	Existing requirements	63
4.2	Temporal stability	64
4.3	Corrections for changes in environmental and operational conditions.....	67
4.3.1	Influence of atmospheric pressure	68
4.3.2	Influence of ambient temperature.....	70
4.3.3	Source directivity according to ISO 6926	73
4.3.4	Source directivity according to spherical harmonics	74
4.3.5	Influence of rotation speed.....	82
4.3.6	Comparison to existing correction	86
4.4	Near field effects	87
4.5	Uncertainty of sound power levels emitted by transfer standards ..	90
4.5.1	Uncertainty due to directivity	90
4.5.2	Uncertainty due to in situ sound power determination	92
5	Implementation of substitution method	95

5.1	Influence of the measurement surface	95
5.2	Influence of the surrounding environment.....	100
5.3	Comparison between sound pressure and sound intensity results	103
5.4	Uncertainty of device under test sound power level	107
5.4.1	Uncertainty of the measurement surface influence.....	107
5.4.2	Uncertainty of the surrounding environment influence	116
5.5	Dissemination combined uncertainty	120
6	Conclusions and outlook.....	123
7	Literature.....	129
Appendix A: Supplement for chapter 2		139
Appendix B: Supplement for chapter 3		149
Appendix C: Supplement for chapter 4		153
Appendix D: Supplement for chapter 5		163
List of figures		173
List of symbols		185
List of tables		197