EUROVENT 8/1-1981

ACOUSTIC MEASUREMENTS ON MACHINES AND EQUIPMENT IN THE FREE FIELD OR LARGE ROOMS ON A HARD REFLECTING PLANE

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Published by EUROVENT/CECOMAF
15 rue Montorgueil
F-75001 PARIS

Tel 33 1 40 26 00 85
Fax 33 1 40 13 75 44

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1. PURPOSE

This specification, issued by EUROVENT, has the intention to assist the buyers of air handling equipment such as cooling towers, air cooled liquid coolers, air cooled condensers, warm air generators, etc. in a clearly and easily to determine and evaluate the noise radiated by the equipment.

2. FIELD OF APPLICATION

This specification is applicable for all machines and equipment which - due to their size - cannot be conveniently measured in anechoic or reverberant test rooms. The measurements are performed at site outdoors or in large rooms over a hard reflecting plane, whereby the room noise is to be taken into account and considered according to ISO 3744, Appendix A.

The level and composition of the noise spectrum is not limited for the measuring procedure.

The sound pressure level is measured in dBA and the frequency spectrum preferably in octave bands.

The sound pressure levels recorded on a pre-determined measurement surface are converted to the A-weighted sound power level.

The sound power levels for the respective equipment determined according to these prescribed methods can be used for comparing equipment of the same or similar output.

These sound power levels may also be used to determine the sound pressure levels at a certain distance from the equipment.

3. STANDARDS

The following table contains the valid International Standards for determining the sound power levels, where **ISO 3744** is especially relevant for this specification.

TABLE I **International Standars specifying various methods for determining the sound power levels of machines and equipment**

1 Internat. Standard.	2 Classification of method	3 Test environment	4 Volume of source	5 Character of noise	6 Sound power levels obtainable	7 Optional information availablee
3741	Precision	Reverberation room meeting specified requirements	Preferably less than 1 % of test room volume	Steady, broad-band	In one third octave or octave bands	A-weighted sound power level
3742				Steady, discrete frequency or narrow-band		
3743	Engineering	Special reverberant test room		Steady, broadband narrowband discret frequency	A-weighted and in octave bands	Other weighted sound power levels
3744	Engineering	Outdoors or in large room	Largest dimension less than 15,0 m	Any	A-weighted and in one third octave or octave bands	Directivity information and sound pressure levels as a function of time other weighted sound power levels
3745	Precision	Anechoic or semi-anechoic room	Preferably less than 0.5 % of test room volume	Any		
3746	**Survey**	**No special test environment**	No restrictions limited only by available test environment	Steady, broad-band, narrow-band discrete frequency	A-weighted	Sound pressure levels as a function of time other weighted sound power levels

4. DEFINITIONS

4.1 Sound pressure level

$$L_P = 20 \lg \frac{P}{Po} \text{ in dB}$$

Reference sound pressure level : $P_o = 20 \mu P_a$

4.2 Sound power level

$$L_W = 10 \lg \frac{W}{Wo} \text{ in dB}$$

Reference sound power level : $W_o = 1 \text{ pW } (10^{-12} W)$

4.3 Noise spectrum

The frequency range of interest in this document includes the octave bands with centre frequencies between 63 Hz and 8000 Hz.

63	125	250	500	1000	2000	4000	8000	Hz

Measurements in the one-third octave bands should only be performed in special cases.

4.4 Measurement surface

The surface S should be determined of simple geometrical shape at a distance of approximately 1 m from the outside of the equipment to be measured. The sound measuring positions should be equally distributed over this surfaces.

The surface should be arranged in such a way that all measuring positions have approximately the same sound pressure level *(difference less than 5 dB)*.

When determining the measurement surfaces, any influences of reflecting walls have to be avoided. For compact equipment, a hemispherical surface
$S = 2 \pi R^2$ can be applied.

For simpler measuring, the sectioning into plane surfaces is recommended *(see Annex)*.

4.5 Background noise

Prior to starting a measurement, the background noise shall be determined without the equipment in operation. This background noise is to include any ancillary equipment necessary for the main equipment's operation.

The measurement shall only be carried out when the background sound pressure level is lower by at least 6 dB in each corresponding octave band.

Corrections for background shall be carried out according to ISO 3744/7.3.4.

5. INSTRUMENTATION

A precision sound level meter with octave filters and free field incidence microphone according to CEI publications 179 and 225 is to be used, and calibrated prior to each measurement.

Outdoors the microphone is to be provided with a windshield, in order to minimize any wind noise interference.

Additional information can be found in ISO 3744, section 5, and Appendix C. Table 3 of para. 5.3 is to be observed with regards to instrument tolerances.

6. MEASURING CONDITIONS

During the measurements, the equipment has to be operated continuously at design output. Control measurements auch as discharged air rate, power consumption, etc. are required.

Any deviation should be recorded in the test report.

Noise not directly resulting from the equipment being tested is to be eliminated for the measuring period, or to be considered separately as background noise *(section 4.5)*.

When performing measurements in the free field, any wind noises are to be noted. The wind velocity during the measurements is to be recorded in the test report and should not exceed 5 m/s.

7. TEST PERFORMANCE

7.1 Détermination of measurement surface

In general, with larger equipment which cannot be measured in test rooms, the microphone positions are arranged on the surface of a parallelepiped *(7.2.1)*.

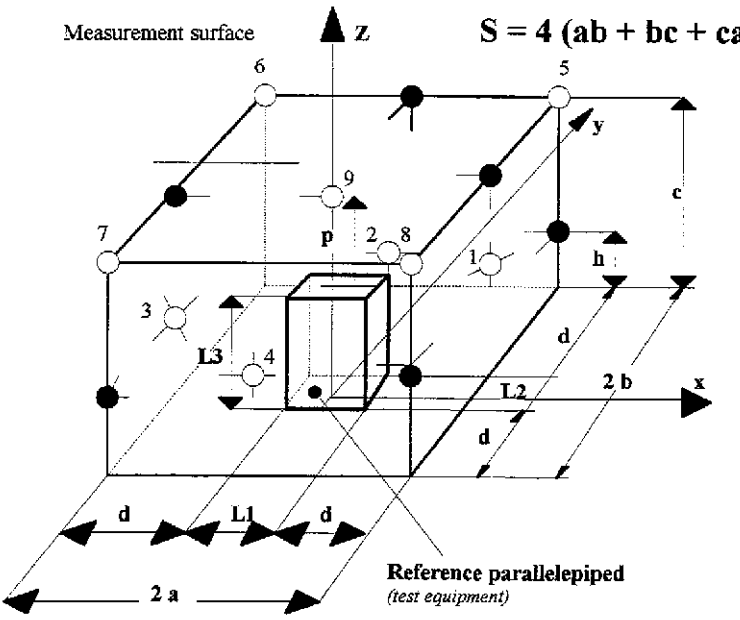
The measuring distance **d** to the equipment shall preferably be **1 m**.

Distances of 2, 4 or 8 m are acceptable.

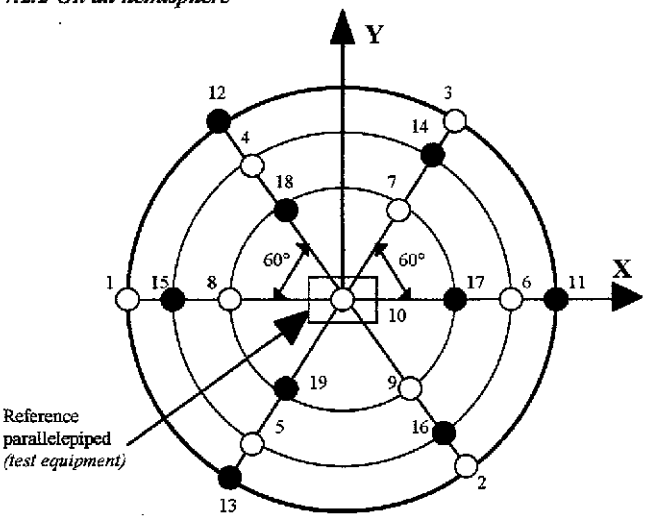
When using a hemisphere as measuring surface *(7.2.2)*, the radius R shall be at least two times the greatest linear dimension of the equipment to be tested.

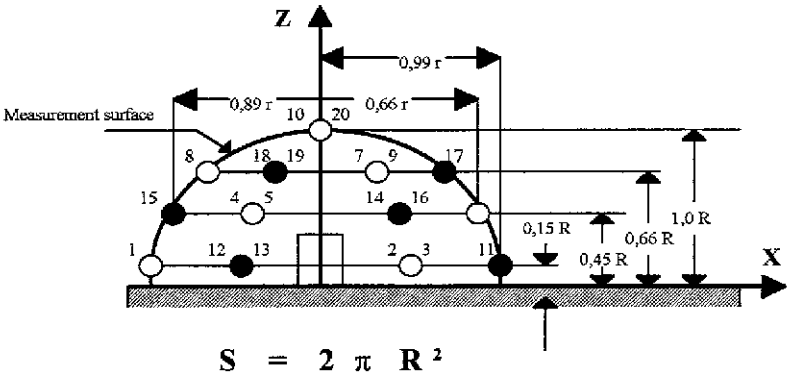
7.2 Microphone positions

7.2.1 On a parallelepiped



7.2.2 On an hemisphere





$$S = 2 \pi R^2$$

Co-ordinates of key measurements points

N°	X/R	Y/R	Z/R
1	- 0,99	0	0,15
2	0,50	- 0,86	0,15
3	0,50	0,86	0,15
4	- 0,45	0,77	0,45
5	- 0,45	- 0,77	0,45
6	0,89	0	0,45
7	0,33	0,57	0,75
8	- 0,66	0	0,75
9	0,33	- 0,57	0,75
10	0	0	1,0

○ **Key measurement positions**

● **Additional measurement positions**

7.3 Number of measuring positions

For equipment with a lateral lenght of 2 m or less, the number of measuring positions indicated in fig. 7.2 is sufficient. In case of larger dimensions dimensions or greater variations between the measuring positions, additional positions as shown are to be provided.

With very large units, further measuring positions have to be equally distributed on the measuring surfaces. As a guide, a distance of at least 2 m between the measuring positions usually applies. This distance can be increased considerably if there are only slight differences (approx. 1 - 2 dB) between the sound pressure levels on the measurement surface provided.

7.4 Sound pressure measurement - dBA

Each measurement position shall produce the time average of the A-weighted sound pressure level - dBA. Using the "slow" position of the precision sound level meter, the measurements shall be performed for at least 10 seconds.

In case of level fluctuations of less than or equal to $\pm$ 3 dB, the average value can be determined by eye.

In case of major deviations, sound level meters with impulsive response are to be used *(see ISO 3744, Annex C)*.

The measurements include the sound pressure levels with the equipment under operating conditions at all provided measuring positions, as well as the back ground noise with the equipment not in operation. If this background level remains constant, two or three control measurements of this background level are sufficient.

7.5 Sound pressure spectrum

Each octave band of noise is to be measured unweighted according to 4.3. For the octave bands of 63 and 125 Hz the time of measurement shall be at least 30 seconds at each measuring position. For ranges employing the 250 Hz octave band and higher octave bands, a measurement time of 10 seconds is sufficient.

Additionally to the sound pressure spectrum for the equipment under operating conditions, the background spectrum level shall be recorded without the test equipment in operation.

N.B *Ancillary equipment necessary for the operation of the main test equipment must be left operating during this background noise evaluation.*

7.6 Correction of measured values

Prior to evaluation of surface sound pressure levels and calculation of the A-weighted sound power levels, the measured values are to be corrected for background against the correction data according to ISO 3744 - tabulated below.

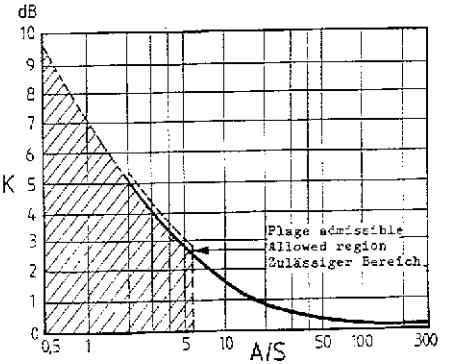
7.6.1Background noise : see ISO 3744/7.3.4

Level difference Total level Background level	**6**	**7**	**8**	**9**	**10**	**dB**
Correction : subtracted from total level	**1,0**	**1,0**	**1,0**	**0,5**	**0,5**	

7.6.2 Environmental influence K :

When measurements have been made in a large room, more exact values can reliably be determined by means of calibration with a reference sound source. In order to minimize the effect from reflecting surfaces, the ratio of the room's absorptive surface A to the measurement surface S shall be greater than 6.
The room's absorptive surface may be determined from a reverberation time or reference sound source measurement.

The correction factor K to compensate for the room acoustics, may be obtained from the following graph when A/S is greater than 6.
See also ISO 3744/Annex A.



Correction factor K for environmental influence

8. EVALUATION OF TEST RESULTS

8.1 Calculation of surface sound pressure level $\overline{L_p}$

After correction for background noise of the time averaged sound pressure levels, all individual values determined on the measurement surface are averaged to the surface sound pressure level $\overline{L_p}$ according to the following equations :

$$\overline{L_p} = 10 \lg \frac{1}{N} \left[\sum_{i=1}^{N} .10^{0,1 L_{pi}} \right] - K$$

$\overline{L_p}$ = Surface sound pressure level - average

L_{pi} = A-weighted surface sound pressure level of the ith measurement

N = number of measurements

K = correction factor for environmental influence

The above calculation method can be omitted and a simple arithmetic average can be made if the single value L_{pi} do not differ by more than 5 dB *(see also 4.4)*.

8.2 Calculation of sound power level L_W

L_W = A-weighted sound power level

$\overline{L_p}$ = A-weighted surface sound pressure level

S = Area of measurement surface in m^2

S_0 = Reference surface 1 m^2

C = Correction factor for atmospheric influences.
This factor has to be observed if the conditions are significantly different from **t = 20°C** and **p = 1000 mbars** *(see ISO 3745/8.1)*.

8.3 Measurement uncertainty

For a sound source with an essentially flat spectrum between 63 and 8000 Hz, a standard deviation uncertainty of approximately 2 dBA can be assumed for the evaluated and calculated dBA sound power level - L_W.

For taking into account the different influences on the accuracy of the test results in the various octave band frequency ranges, ISO 3744 gives the following values :

Octave band centre frequencies	**Standard deviation of mean value**
Hz	**dB**
63	5,0
125	3,0
250 - 500	2,0
1000 - 4000	1,5
8000	2,5

Nota : *Measurements close to the equipment (less than 1/3 of the length, width or height) give a slightly higher sound power level than those measurements performed at larger distances.*

In critical cases, a reference measurement at larger distances is recommended.

9. TEST REPORT

The following information shall be recorded in the test report, advantageously with the aid of sketches where appropriate.

9.1 Description of equipment

Output, dimensions and type of equipment.

9.2 Acoustic conditions

Test environment, including potentially reflecting surfaces.

Weather conditions, such as air temperature, barometric pressure, relative humidity and wind speed.

9.3 Instrumentation

Manufacturer and type of all instruments.
Date and method of calibration

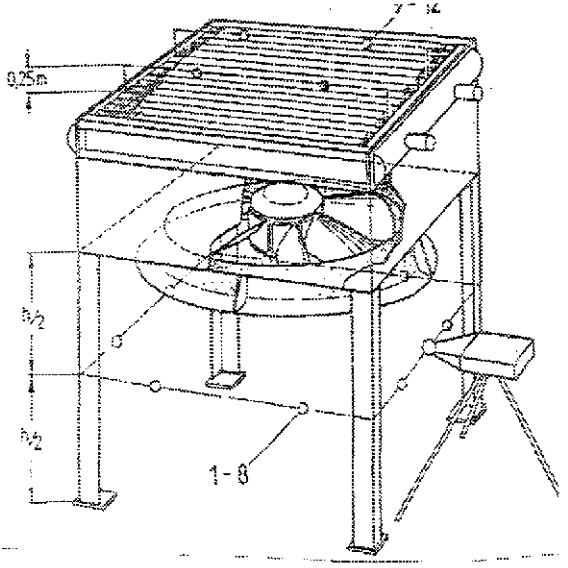
9.4 Acoustical data

- Arrangement of measuring positions (sketch) with measuring distance.
- Shape and size of measurement surface S.
- A-weighted sound pressure level for each measuring position.
- A-weighted sound pressure level of background noise.
- Noise spectrum in the octave bands.
- Correction values for background noise, microphone, etc.
- Correction factor K for environmental influence.
- Surface sound pressure level $\overline{Lp}$ in dBA
- Sound power level L_W in dBA.
- Remarks on the subjective impression of the noise, i.e. discrete tones, impulsive character, etc.

TEST EXAMPLES

A.1 Air cooler

For equipment with obvious sound emitting surfaces the arrangement of the microphone is recommended on these surfaces.

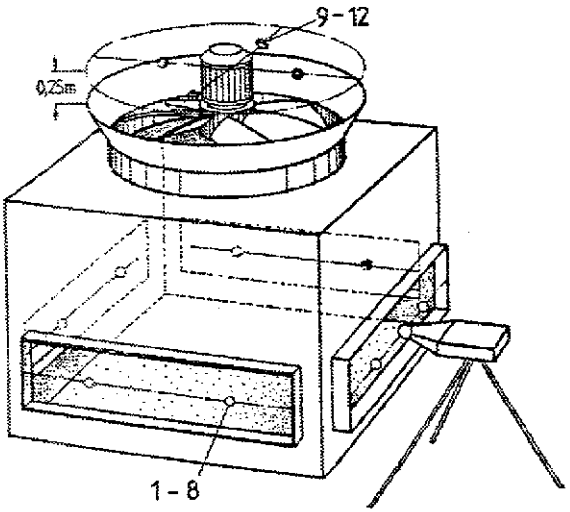


S_1 (MP 1 - 8) = 13 m^2

S_2 (MP 9 - 12) = 6 m^2

Note: *The number of microphone positions on the surface S1 and S2 should nearly correspond to the ratio of surface areas.*

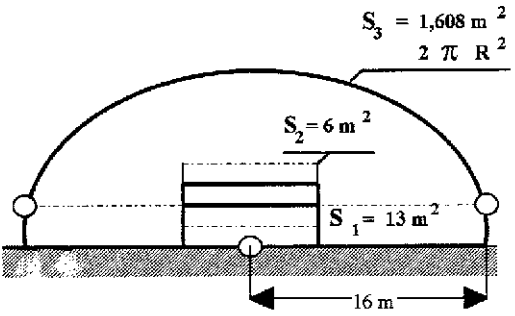
A2. Microphone positions on cooling tower surfaces



S_1 (MP 1 - 8) = $8m^2$
S_2 (MP 9 - 12) = $3m^2$

Note: *A cross-reference measurement on a larger measurement surface (see 7.2.1) is recommended for comparison, if in the near field any interferences due to reflections or higher air speeds are suspected.*

A3. Measurement procedure



Near field measurement :

Measurement surface : **S1** MP 1-8
S2 MP 9-12

Far field measurement

Measurement surface : **S3** MP 13-16

Note: *The far field measurement can be considered as being correct, if by doubling the distance to the sound source the sound pressure level is reduced by 6 ± 1 dB (control measurement to be performed at half distance).*

A3.1 Near field measurement

Measurement surface	S_1 = 13 m^2								S_2 = 6 m^2			
Measuring points	1	2	3	4	5	6	7	8	9	10	11	12
Sound pressure level L_{pi} - dBA	72	73	75	73	72	73	74	76	71	72	72	73
Background noise level L_{pi} - dBA	47				45			46				47
Correction value *(acc. to 7.6)*	-	-	-	-	-	-	-	-	-	-	-	-
Corrected value	72	73	75	73	72	73	74	76	71	72	72	73
Surface sound pressure level $\overline{L_p}$ - dBA	73											

- As all measuring positions are differing by less than 5 dB, the arithmetic average value could be established. Otherwise, the formula according to 8.1 had to be used.

A3.1.1. Sound power level

$$Lw = \overline{Lp} + 10\,lg\,\frac{S_1 + S_2}{S_o} + C$$

$$= 73 + 10\,lg\,\frac{13+6}{1} + C$$

$$= 73 + 12{,}8 + C$$

$$= 85{,}8\,dBA + C$$

A3.2 Far field measurement

Measurement surface		$S_3 = 2$	$R_2 = 1{,}608\ m^2$		
Measuring points		13	14	15	16
Sound pressure level	L_{pi} - dBA	54	52	55	53
Background noise level	L_{pi} - dBA	46	45	47	46
Correction value acc. to 7.6		1	1	1	1
Corrected value	L_{pi} - dBA	53	51	54	52
Surface sound pressure level	$\overline{Lp}$ - dBA	52,5			

A3.2.1 Sound power level

$$Lw = 52{,}5 + 10 \lg \frac{1608}{1} \quad C$$

$$= 52{,}5 + 32 + C$$

$$= 84{,}5 + C$$

A3.3 Correction factor c *(ISO 3745/8.1)*

$$C = - 10 \text{ Lg} \left[\left(\frac{293}{273 + t_l} \right)^{0,5} \cdot \frac{p}{1000} \right]$$

Measuring conditions

t_L = 10°C
p = 970m bar

$$C = - 10 \lg \left[\left(\frac{293}{283} \right)^{0,5} \cdot \frac{970}{1000} \right]$$

$$= - 10 \lg \quad 0{,}987$$

$$= - 10 . (- 0{,}00568)$$

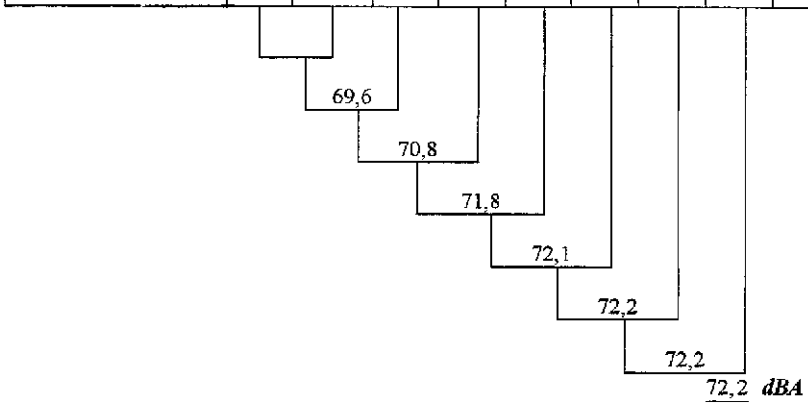
$$= + 0{,}0568 \quad dB$$

In this case, the influence of the atmospheric conditions is negligible.

A4. Sound pressure spectrum

Recorded at measuring

Octave band	63	125	250	500	1000	2000	4000	8000	Hz
Unweighted sound pressure level	92	83	74	68	61	57	51	43	dB
Background sound	38	40	42	40	38	36	39	37	dB
Corrected sound pressure level	92	83	74	68	61	57	51	42	dB
Pondération A	- 26,	- 16,1	- 8,6	- 3,2	0	+ 1,2	+ 1,0	- 1,1	dB
A-weighted	65,8	66,9	65,4	64,8	61	58,2	52	41,9	dBA

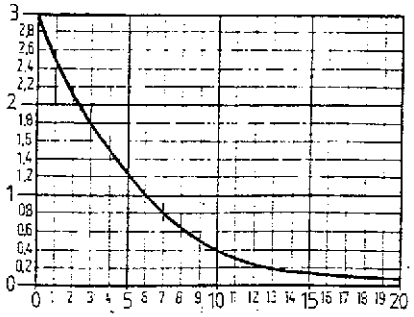


Hence the dBA sound pressure level computed from the sound pressure spectrum is 72,2 dBA at position 5.
The directly measured value was recorded as 72 dBA.

This procedure must be repeated for each measuring position if the dBA sound pressure level is being calculated from the sound pressure spectrum.

The a-weighted sound pressure levels in the octave band can be summed to the total sound level either by calculation or by means of the following cumulative curve.
(This cumulative curve has been employed in the tabulated example above).

Level increase *(dB)*



Level difference *(dB)*

For the arithmetic determination, the following equation will apply :

$$L_p = Lg \sum_{i=1}^{8} \cdot 10^{0,1 \cdot L_{pi}}$$

$$= 10\ Lg\ (10^{0,1 \cdot 65,8} + 10^{0,1 \cdot 66,9} + + 10^{0,1 \cdot 65,4} + ...)$$

$$= 10\ Lg \cdot 17280595$$

$$= \mathbf{72,3\ dBA}$$

Both methods are in good agreement.

A5 Evaluation of test results

All results of the near and far field comply in such a manner that in the present case the sound power level can positively be indicated as :

Lw = 85 dBA

(see A3.1.1 and A3.2.1)

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LIST OF THE MEMBER ASSOCIATIONS

BELGIUM
FABRIMETAL
21 rue des Drapiers -
B-1050 BRUXELLES
Tel. 32/2/5102518 - Fax : 32/2/5102563

GERMANY
FG ALT im VDMA
Postfach 71 08 64 - D-60498 FRANKFURT AM MAIN
Tel. 49/69/6603 1227 - Fax : 9/69/6603 1218
E-mail: Lorenz_ALT@VDMA.org

SPAIN
AFEC
Francisco Silvela, 69-1°C - E-28028 MADRID
Tel. 34/1/4027383 - Fax : 34/1/4027638

FINLAND
AFMAHE
Etaläranta 10 - FIN-00130 HELSINKI
Tel. 358/9/19231 - Fax : 358/9/624462

FINLAND
FREA
P.O. Box 118
FIN-00811 HELSINKI
Tel : 358/9/759 11 66 - Fax : 358/9/755 72 46

FRANCE
UNICLIMA
F-92038 PARIS LA DEFENSE CEDEX
Tel : 33/1/47176292 - Fax : 33/1/47176427

GREAT BRITAIN
FETA (HEVAC and BRA)
Sterling House - 6 Furlong Road - Bourne End
GB-BUCKS SL 8 5DG
Tel : 44/1628/531186
Fax : 44/1628/810423
E-mail: info@feta.co.uk

ITALY
ANIMA - CO.AER
Via Battistotti Sassi, 11 - I-20133 MILANO
Tel : 39/2/73971 - Fax : 39/2/7397316

NETHERLANDS
NKI
Postbus 190 - NL-2700 AD ZOETERMEER
Tel: 31/79/353 12 59 - Fax : 31/79/353 11 15
E-mail: nki@fme.nl

NETHERLANDS
VLA
Postbus 190 - NL-2700 AD ZOETERMEER
Tel. 31/79/353 11 00 - Fax : 31/79/353 13 65
E-mail: vla@fme.nl

NORWAY
NVEF
Postboks 6697, St Olavs Plass –
0129 OSLO
Tel. 47/22202790 - Fax : 47/22202875

SWEDEN
KTG
P.O. Box 5510 - S-114 85 STOCKHOLM
Tel. 46/8/782 08 00 - Fax : 46/8/660 33 78
E-mail: bo.gostring@isab.postnet.se

SWEDEN
SWEDVENT
P.O. Box 175 37 - S-118 91 STOCKHOLM
Tel : 46/8/762 75 00 - Fax : 46/8/668 11 80

TURKEY
ISKID
ARCELIK A.S.
Klima Isletmesi
TR-81719 TUZLA ISTANBUL
Tel : 90/216 395 45 15
Fax : 90/216 423 23 59
E-mail: alatli@arcelik.com.tr