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MECHANICAL DRAUGHT COOLING TOWER ACOUSTICS PRACTICAL GUIDE

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PRACTICAL GUIDE

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Technical Secretariat

62 bd de Sébastopol

75003 PARIS

Tel (33) 01 49 96 69 80

Fax (33) 01 49 96 45 10

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1 - PURPOSE

The purpose of this EUROVENT Document is to give practical information on cooling tower acoustics and to serve as a guide. The Document is not in itself a test standard but it gives useful recommendations on applicable test standards.

2 - SCOPE

Only mechanical draught cooling towers are considered, regardless of their size and type. (Induced draught, counterflow, crossflow, evaporative fluid coolers and hybrid cooling towers). Some typical configuration are shown in the Annex.

3 - EXPLANATION OF TERMS USED IN THE DOCUMENT

3.1 COOLING TOWER

Apparatus in which water is cooled down by heat exchange with ambient air.

3.2 WET COOLING TOWER

Cooling tower in which the heat exchange between the water and the air is carried out by direct contact.

3.3 SOUND PRESSURE

Effective (root - mean - square) value of the instantaneous sound pressure variation produced at one point in the space when a sound wave is propagated through it. It is expressed in Pa.

3.4 SOUND PRESSURE LEVEL

The term applied to the specification of the sound pressure in decibels. It is defined as 20 times the logarithm to the base 10 of the ratio of the sound pressure p of a source to a reference pressure p_{ref}.

$$L_p = 20 \log \frac{p}{p_{ref}}$$

p_{ref} by convention is equal to 2.10^{-5} Pa. This reference pressure has been chosen because it was found that the average young adult can just perceive a 1000 Hz tone at this pressure.

3.5 ADDITION OF SOUND PRESSURE LEVELS

Addition of sound pressure levels has to be performed logarithmically using the following formula :

$$Lp = 10 \log \sum_{i=1}^{N} 10^{0.1 L_{pi}}$$

3.6 SOUND POWER

Total acoustical power radiated by a sound source and expressed in Watt.

3.7 SOUND POWER LEVEL

The term applied to the specification of the sound power in decibels. It is defined as 10 times the logarithm to the base 10 of the ratio of the sound power W of a source to a reference sound power W_{ref}.

$$L_W = 10 \log \frac{W}{W_{ref}}$$

W_{ref} by convention is equal to 10^{-12} Watt.

3.8 PARTIAL SOUND POWER LEVEL

Part of the total sound power radiated to the specified part of the space from a specified part of the source such as an intake or discharge of the cooling tower.

3.9 BAND SOUND PRESSURE LEVEL

The total sound pressure level for the sound energy contained within a specified frequency band (e.g. octave sound pressure level).

3.10 OCTAVE BAND

A bandwidth for which the upper limit frequency is equal to twice that of the lower limit frequency.

Octave bands generally used have the following central frequencies 63, 125, 250, 500, 1K, 2K, 4K, 8KHz.

3.11 THIRD OCTAVE BAND

A band for which the upper limit frequency is equal to $2^{1/3}$ times the lower limit frequency. Third octave bands generally used have the following central frequencies : 50, 63, 80, 100, 125, 160.... (see table page 7). Octave band sound level can be obtained by adding logarithmically three corresponding third octave sound levels.

3.12 A- WEIGHTED SOUND LEVEL

Sound pressure levels that have been weighted according to a particular weighting network or curves. The weighting curves and associated sound levels were developed as a method to better subjectively evaluate the impact of noise upon the human ear.

The A weighting network is now used almost exclusively in measurements that relate to the human response to noise, i.e. cooling towers, both from the perspective of annoyance and damage to the ear.

Octave band centre frequencies	One-third octave band centre frequencies	A-weighting values
Hz	Hz	dB
	50	-30,2
63	63	-26,2
	80	-22,5
	100	-19,1
125	125	-16,1
	160	-13,4
	200	-10,9
250	250	- 8,6
	315	- 6,6
	400	- 4,8
500	500	- 3,2
	630	- 1,9
	800	- 0,8
1000	1000	0
	1250	0,6
	1600	1,0
2000	2000	1,2
	2500	1,3
	3150	1,2
4000	4000	1,0
	5000	0,5
	6300	- 0,1
8000	8000	- 1,1
	10000	- 2,5

3.13 ATTENUATION

The loss or reduction in amplitude of a signal.

3.14 TONAL NOISE

Sound containing only a distinctive narrow band of frequencies.

3.15 BACKGROUND NOISE

Sound level of sources, other than the primary source under investigation, in the vicinity of the primary source and contributing to the measured sound level of the primary source. Generally, if the background sound pressure level alone (primary source is not operating) is at least 10 dB less than the measured level with the primary source operating, then the sound pressure level with the primary source operating is essentially the sound pressure level due to the source alone. This is the preferred condition, but it is frequently unattainable in the field. If the background noise level is between 3 and 10 dB quieter than sound level with the primary source operating, the following table can be used to correct the measured sound level for background noise. Most sound measurements standards do not endorse measurement of sound levels when the background noise level is within 3 dB of the primary source sound level. The table below provides additional guidance :

Background Noise Adjustment Table

Difference between measured sound level* and background sound level	Adjustment to be made to measured sound level (dB) to obtain corrected source level
4	-2,2
5	-1,7
6	-1,3
7	-1
8	-0,8
9	-0,6
10	-0,4
Greater than 10	0

** With primary source noise and background noise.*

3.16 FREE FIELD

A sound field in which the effects of the boundaries are negligible.

3.17 NEAR FIELD

That part of a sound field near to a source radiating sound in free-field conditions, wherein the sound pressure and particle velocity are not in phase. It is typically within 1 to 2 machine dimensions of the sound source. In the near field, sound pressure decreases by less than the « inverse square » rule. But, at more than about 30 m from cooling tower, there may be additional L_p reduction due to atmospheric sound absorption.

3.18 FAR FIELD

That part of the sound field from a radiating source in free field conditions wherein the sound pressure level diminishes at 6 dB per doubling of distance.

3.19 ATMOSPHERIC ABSORPTION

As sound propagates through the atmosphere its energy is gradually absorbed by a number of energy exchange processes in the air called atmospheric absorption. There are a number of international standards that detail the calculation of this absorption.

3.20 ENVIRONMENTAL EFFECTS

The propagation of sound close to the ground for horizontal distances less than 30m is essentially independent of meteorological conditions ; for this case the atmosphere can be regarded as homogenous and the ray paths approximated by straight lines.

3.21 SOUND PROPAGATION

The spreading out of sound can occur in a complex manner and is usually expressed as one, or a combination, of following ways :

- spherical way
- cylindrical way
- plane way

3.22 DIVERGENCE DECREASE

Without ground attenuation, the divergence decrease between 2 points at distances d_1 and d_2 from source is :

- spherical way : 20 log (d_2/d_1), if $d_2 = 2\ d_1$ ==> - 6 dB
- cylindrical way : 10 log (d_2/d_1) if $d_2 = 2\ d_1$ ==> - 3 db
- plane way : 0 dB

4 – COOLING TOWER NOISE SOURCES

4.1 PRINCIPAL NOISE SOURCES

In mechanical-draught cooling towers, noise with different characteristics is produced by the machinery needed to deliver the cooling air and by the water flow.

When seeking noise-reduction solutions it is useful to check the effect of both principal noise sources on the overall sound emissions of the cooling tower. Effective noise abatement is only possible if the effect of the dominant noise source is reduced first.

4.2 NOISE FROM THE WATER FLOW

Noise from the cooling water flow is generated mainly by the impact of the water droplets on the cooling tower pond.

Noise which is generally less significant for the overall sound emission is also generated by the water distribution equipment inside the cooling tower.

4.2.1 - WATER DROPLET IMPACT NOISE

In wet cooling towers, water droplet noise can be generated due to droplet impact on solid surfaces and on water surfaces.

Water droplets can impact on the splash bars, grids or other components which comprise the packing material. In addition, the structural members may present surfaces which also cause water droplet impact and consequential noise. The water pond also acts as a splash surface which can generate droplet impact noise.

The level and characteristics of the noise generated depend on the characteristics and velocities of the droplets as well and the angle of impingement at the contact surface. The size, number and velocity of the droplets, combined with the angle of the impingement, determine the total energy dissipated by the impacts and therefore the magnitude of noise generated. Other related variables may include the configuration, type and spacing of the packing, and the general configuration, size and design of the cooling tower.

In addition, the location of the droplet generated noise relative to the tower openings affect the overall tower noise level. The frequency distribution of the droplet generated noise may be significantly different in character to the noise generated by the mechanical and other noise sources.

4.2.2. WATER DISTRIBUTION

In a cooling tower, the water is mainly distributed over the packing in the form of fine droplets by means of a spray-system. The noise which is generated when the droplets hits the packing surface depends on the size, velocity and number of droplets. The droplet number depends on the water flow rate and on the energy-input to create droplet surface.

With gravity-systems a relatively small number of droplets can be achieved by means of baffleplates, since there is only a low energy-input. It therefore follows that the mean droplet size is relatively large, generally in the range of 1 to 3 mm, and the droplet velocity is low.

With water distribution systems employing nozzles, smaller droplets can be achieved which have higher velocities. The spray pressure is generally in the range of 0.1 to 1 bar.

Trickle-systems are very common in cross-flow cooling towers, where the water can trickle off the bottom of a distribution basin directly into the packing.

The proportion of this noise in the overall noise level depends very much on the design and operational data of the cooling tower such as water flow and spray pressure.

4.3 MECHANICAL PART

The mechanical part of a cooling tower can be of widely differing design, and is therefore of varying importance for noise emission. The main noise sources of the mechanical parts are fans, gearboxes or transmissions and drive motors.

4.3.1 - FANS

Fans are one of the prime noise sources of mechanical draught series cooling towers. The type of fan, fan speed and its location are important parameters when it comes to the propagation of noise. In mechanical draught series cooling towers both centrifugal and axial fans can be used. Centrifugal fans can produce a relatively high pressure and are therefore best suited for cooling towers with high internal pressure drop or large external pressures, which may be caused by accessories, such as sound attenuators or ductwork. The acoustical performance of centrifugal fans is good and can be improved by reducing the fan speed. For the same operational conditions of a cooling tower their noise output is generally better than with axial fans however they have a lower efficiency than axial fans and therefore their energy requirement will be higher than can be achieved with axial fans.

Centrifugal fans are commonly used in series cooling towers with forced draught arrangements, which means that their noise propagation is mainly in the horizontal plane.

Axial fans are best suited for cooling towers with lower internal pressure drop and high air flow. The most important parameter related to noise is the fan tip speed. For cooling towers the fan tip speed is generally in the range of 40 to 60 m/s. Changing the fan speed may be used as a method of controlling acoustical performance. The noise characteristics of an axial fan are also influenced by its location and installation. On induced draught cooling towers fans are located at the top, which means that the highest noise emission is coming from there. In forced draught arrangements, axial fans are located at the bottom of the cooling tower, which means that the highest sound emission is there.

Regarding the installation of axial fans it is important to avoid impeded inlet flow conditions, such as sharp bends, studs and obstructions immediately before the impeller, as these can result in increased noise level. Obstructions on the pressure side can impact on the flow through the impeller, which also adversely affects the generation of noise.

4.3.2 - FAN DRIVE

Fans drives are of different design, depending on the cooling tower size and type,

- Medium-power drives are mainly fitted with geared motor units with helical gears. The noise generated by gearboxes depends on the shape of the gears, the specific loading and the operating conditions. Errors in the gearing can lead to the production of tonal noises. The choice of small transmission ratios is also advantageous, so multi-pole drive motors are preferred. The transmission of solid-borne noise to the supporting structure and cooling tower walls can be reduced by flexible mounting of the gearbox.

- Drives with angular gearing and carbon fibre shafts are generally used for larger fan sizes and power consumptions.

- When a belt transmission is used, the belt must be properly tensioned and the pulleys accurately aligned with one another, to ensure that no additional noise arises. Incorrect assembly can be the cause of tonal noises. In the past, a frequent cause of noise was the belt joint in flat belts; with the use of modern belt drives this cause no longer occurs.

4.3.3 - DRIVE MOTORS

Small Induced-draught axial fans are generally of the direct-drive design, using electric motors with a high number of pole pairs. In this design, the drive motor is situated in the airflow it produces and the noise it generates is transferred directly to the air flow.

Vibrations can be caused in the stator by magnetic forces, which can be transmitted to the motor casing, supporting structure and fan hub as solid-borne noise. Conversion into air-borne noise can cause them to become unpleasantly discernible as humming or whining noises. Motors with more than 6 pairs of poles are particularly susceptible to this.

4.4 AERODYNAMIC ASPECTS

The aerodynamic design of a cooling tower also can have an effect on the noise radiation. The air flow moved through the cooling tower can generate mechanical noises or current rushes.

Mechanical noises occur when components located in the air stream, such as louvres are not properly fixed and start rattling. Rattling noises can be very disturbing but are generally easy to avoid by proper fixing design of the relevant components.

Air current rushes will occur when the air velocity is significantly raised due to local obstructions. This typically happens when air passages are too small or air gaps exist through which the air can escape with high speed. Air-tight designed equipment and in particular air-tight sound attenuators are a must. For sound attenuators it is also important to consider the distance between baffles. If the distance is chosen too small, the velocity of the air passing through the attenuator becomes too high and the sound attenuator may start producing noise rather than reducing it.

5 - PROPAGATION OF SOUND FROM COOLING TOWERS

5.1 GENERAL

The noise generated by cooling towers can be different, depending on the cooling tower type, its size, its accessories and its mode of operation. In addition the location of the equipment and its surroundings can have significant influence on the radiation of noise. These aspects are discussed below in more detail.

5.2 TYPES OF COOLING TOWERS AND THEIR NOISE CHARACTERISTICS

As explained above the total noise of a cooling tower is generated by different noise sources which operate together. The cooling tower noise greatly depends on the design of the noise sources and their relevant arrangement (cooling tower concept). For the same capacity requirement different cooling tower concepts can be selected which may have substantially different noise characteristics. Even within a given concept, noise characteristics may differ from one brand to another depending on their individual design. For this reason only general considerations can be described in this document. These general considerations will apply to cooling towers which are selected for optimal thermal performance, i.e. with high air flows and subsequent high fan speeds.

Conceptually cooling towers can be divided into induced draught and forced draft design. With induced draught designs the counterflow and the crossflow concepts can be used and fans are located at the top of the equipment. The induced draught design will usually utilize axial fans. In this case it is clear that the main noise source is the fan at the top of the equipment. Noise reduction for this type of tower will therefore generally start by reducing the fan tip speed, then by sound attenuation, or by both.

If the dominance of the fan noise has been reduced, then water noise comes into play and the number of air entries need to be considered.

Four sided air entries (usually induced draught counterflow units) have little directional effect, as the noise through each air entry is approximately the same.

Two sided air entries (for example induced draught crossflow units) have a noise directional capability, as the closed sides will generally generate less noise than the open ones. On the other hand it needs to be considered that by reducing the air entry face, larger air velocities creating more air noise will occur. With regard to the water noise there will be more splashing noise in counterflow units because of the larger height of these units. In crossflow units with film fill the falling water is guided by the fill all the way down to the pond and the splashing noise is less evident.

While acoustically speaking both designs are different, it is not possible to generally favour one design over the other. A proper analysis of performance, energy requirement and acoustics is needed for each project to determine which conceptual solution is the best.

In the forced draught concept either centrifugal or axial fans can be used but the thermodynamical concept will always be counterflow and the fans will be installed at the bottom of the equipment. If axial fans are used, the fan side will be the noise dominating side of the equipment, but with centrifugal fans the air intake noise and the discharge noise are generally at the same level. Forced draught units with axial fans are more difficult to attenuate and therefore most frequently used in non noise-critical applications.

The directional capability of the forced draught concept is generally high, as the difference in noise propagation between the closed and the open sides (air entry and air discharge) is large. It is therefore not possible to fully describe this concept acoustically by overall sound power levels.

With forced draught cooling towers the air inlet area is relatively small compared to the foot print of cooling tower. Hence, the air velocity in the area below the packing is generally higher than for induced draught cooling towers having large cross sections for the entering air. This may cause vibrations especially in casing walls with low weight per square meter. Finally, the structure-borne noise, which is propagated through the casing of the cooling tower may reach a sound power which is dominating, specially when a high level of sound attenuation is used.

5.3 COOLING TOWER SIZE

- Cooling tower size depends mainly on the thermal duty but also on the approach to be achieved and the cooling concept used.

- Generally, larger cooling towers have a greater sound power emission than the smaller ones, but there is no direct proportional link between cooling tower size and noise propagation.

- The size of the cooling tower comes into play when defining the criteria. For large cooling towers it is impractical to define an overall sound power level characteristic. In this case stating the sound power levels for intake and discharge or sound pressure levels at a given distance are more suitable providing the sound power radiated from cooling tower shell is low.

For sound pressure levels the size of equipment is additionally important as data established in the vicinity of the equipment may not be used to extrapolate sound performance to larger distances. Simple extrapolation of sound pressure data can only be done if these data have been established at a distance far enough from the equipment, in which case the cooling tower can be considered as a point noise source.

For this reason it is important to consider the dimensions of a cooling tower when establishing noise criteria.

5.4 COOLING TOWER LOCATION

The location of the cooling tower is of great importance with regard to acoustics. A major factor relating to location is whether the cooling tower is sited outdoors or indoors. Outdoor locations exist when the cooling tower is positioned outside for example on a roof or at ground level and when the noise can radiate in all directions. It is often found however, that the noise radiation is restricted in at least some directions, as buildings or walls frequently exist in the vicinity of the installation. In such cases the prediction of noise needs to take into account any reflection that may occur. Exact acoustical calculations of this kind are not always straightforward but it is possible to make estimates within a precision of +/- 2 dB(A).

For stringent sound criteria indoor locations are a good solution. Indoor locations can significantly increase the acoustical efficiency, as any noise radiated from the cooling tower shell can be maintained inside the machine room. With indoor locations the tower shell can also be kept inside the machine room and the efficiency of sound attenuators can be increased since the higher insertion loss data for the sound attenuator may apply which is not the case in a free field condition. For indoor locations care must be taken that the machine room noise stays within the building. This can be achieved by proper ducting of the intake and discharge or by acoustical insulation of the machine room walls to reduce or eliminate any reflection inside the room. For any indoor location care must be taken to ensure that the air flow to and from the cooling tower is unimpeded, that the fan drive and motors are selected for the right external pressure and that necessary maintenance access to the cooling tower is provided.

6 - SOUND ATTENUATION

6.1 NOISE ABATEMENT

Noise abatement is necessary if acoustic demands are made which cannot be met by using low noise equipment alone. The silencers used for this have influence on the design of cooling towers, component selection and operation of the cooling tower.

The fitting of noise reduction measures can substantially impact the operating parameters of a cooling tower and are likely to reduce cooling capacity. All aspects of the design must be considered and designed as a system, accounting simultaneously for sound and cooling performance.

6.2 SILENCERS

Duct silencers can be used to reduce the noise level only at the air-inlet and air-discharge openings. Their use may be necessary for severe noise level reduction.

The duct silencers usually contain baffles, with mineral wool packing and parallel air passages. The attenuation increases with the length and thickness of the baffles and decreases with the distance between them.

Noise attenuation by baffles is generally given as insertion attenuation for band sound levels (expressed usually in octave band levels). This means that the same arrangement of baffles may lead to different results for attenuation when the band levels of noise sources are different, even when the overall levels have the same magnitude.

Hence it is necessary to know the partial band sound power levels for the cooling tower openings when determining effective noise reduction measures.

It should be noted that the use of silencers can result in an additional pressure drop which has a substantial effect on the operating point of the fan. The supplementary pressure loss can require a significant increase in drive power and/or numbers of fan blades in order to maintain cooling performance.

6.3 SCREENING

The use of screens can reduce the noise pressure level in the vicinity of a cooling tower. An insertion attenuation of 10 - 15 dB(A) can be achieved. The characteristic length is defined as the path difference from noise source to observer, with and without the screen. The noise reduction depends on the frequency and path difference. At low frequencies only minor reductions in noise level can be achieved. Furthermore, the noise reduction effect is dependant on weather conditions.

The effect of the screen increases as the distance to the cooling tower decreases and the margin by which the screen periphery is at a higher level than the noise source. Generally the screens are used for reducing the noise which is propagated by air inlet openings and cooling tower walls. To minimize the additional pressure drop, the distance to the cooling tower should not be less than the height of the cooling tower inlet area. The side facing the cooling tower can be coated with sound absorbing material to further reduce the noise level.

The reductions in noise level which can be achieved with series cooling towers vary, even with the same geometric conditions. The reason for this is the broad spread of spectra of the noise propagated from the air inlet. It must be stated clearly that the use of screens does not reduce the noise power levels of a noise source.

When it comes to the sizing and location of such sound barrier walls, it is recommended to closely cooperate with the supplier of the cooling tower and sound barrier wall and an acoustical engineer to ensure that the acoustical requirements are met. Sound barrier walls can provide an effective solution to a problem where sound radiation is only critical in certain directions, since they offer the possibility to "partially" encapsulate.

6.4 ENCAPSULATION

To further improve the acoustical performance of cooling tower with sound attenuation, encapsulation may be considered. By encapsulation any noise radiated from the cooling tower shell can be reduced. Such measure is only justified if the noise radiated from the shell has a dominating influence on the total noise radiated. For this reason encapsulation is only sensible if the air, water and mechanical (motor) noise of the tower are already attenuated.

An encapsulation is often applied with smaller equipment in an indoor location. In such a case only the intake and discharge areas radiate noise to the surrounding. The noise emitted from the shell will stay inside the enclosure. The prediction of this noise not only depends on the noise coming from the shell but also on the type of enclosure, as the noise will be reflected from the surrounding walls. Due to reflections the internal noise can increase but usually the noise inside a machine room is of less concern (protective measures may be required). For the external noise radiation it is recommended to specify partial sound power levels for the air intake and discharge areas.

When indoor location of the cooling cower cannot be considered it is possible to reduce the shell emissions by acoustical encapsulation. For such encapsulation to be effective it is necessary to use insulation material with a high mass. Heat insulation material is not suitable for this purpose. With properly selected insulation material it is possible to acoustically match an indoor installation. When applying the encapsulation it must however be assured that access to the cooling tower maintenance points is maintained, i.e. the encapsulation must not obstruct any access doors.

Encapsulation is acoustically feasible but generally requires a significant investment. It is recommended to closely cooperate with the supplier of both cooling tower and encapsulation and an acoustical engineer to ensure that the acoustical requirements are met.

Sound barrier walls are also a means of acoustical encapsulation. Such walls are built in the vicinity of the cooling tower either in the sound critical direction or as a total enclosure. Due to the distance between sound barrier wall and cooling tower the access to maintenance points is assured.

6.5 FREE FIELD VERSUS INSERTION LOSS

Ratings of sound attenuators can vary significantly, depending upon whether they are installed in an outdoor or close coupled indoor location. In outdoor locations "free field" data need be used, whereas in close coupled indoor locations "insertion loss data" may be applied.

6.5.1. Insertion loss data

Insertion loss data are measured as the difference in sound pressure of acoustic attenuation baffles installed in a duct. They do not take into account any noise radiating from other noise sources of the cooling tower, such as the shell.

6.5.2. Free field data

Free field data are measured as the difference in sound pressure between an unattenuated cooling tower and the same cooling tower with sound attenuators.

These data take into account all noise sources of the cooling tower including the shell.

6.6 FAN SPEED CONTROL DEVICES

Controlling the fan speed via motor speed control devices has proven to be an effective method of fan noise control. Noise due to the fan, motor, and air movement is reduced when fan speed decreases.

Multispeed motors offer one method of reducing fan noise during periods where full cooling capacity is not required or when the wet bulb temperature is low. An additional short time noise effect may occur during the switching from lower to higher speed.

Variable frequency control devices avoid the step change problem and provide more control of thermal capacity performance but vibration problems due to resonance with fan rotation frequency and structure natural frequency need to be avoided .

7 - RECOMMENDATION FOR SOUND CRITERIA AND SOUND TESTING

7.1 SOUND CRITERIA

Sound criteria can be specified in various ways : they can be expressed as sound pressure data at a given distance or as sound power levels describing the total sound energy radiated from the cooling tower. In some cases it may be desirable to specify partial sound power levels in particular when the cooling tower is very large or when it is installed indoors. The paragraph below describes the different methods of setting the criteria as well as the recommendations that apply for each method.

a) Sound pressure levels

Sound pressure levels must be specified at given distances from the equipment. The advantage is that they are relatively easy to verify but the disadvantage is that they may not fully describe the acoustic behaviour of the equipment. Sound pressures may in practice vary greatly, depending on the position of the measuring microphone relative to the cooling tower and on the measuring distance. The further the distance from the cooling tower, the more representative the data become in term of "averages". On the other hand, the further away a sound criterion is set from the tower, the more difficult it will be to measure, since the influence of the background noise will be increasing. It is therefore recommended to specify sound pressure levels in the vicinity (near field) of the equipment (1 to 3 m) and also at some distance which should be greater than the diagonal measurement of the cooling tower footprint. The data should be specified per frequency band as well as A-weighted values. Furthermore the criterion should be set as sound pressure data for all sides of the cooling tower. This is necessary because of the "directional" sound characteristic of many cooling tower concepts. For top values it is generally not practical to specify a "far field" criterion because one can not usually measure 10 or 15 m above the cooling tower. The influence of top sound can however be more easily assessed by horizontal measurements at the distance recommended above.

Note that it is not good practice to apply the "inverse square distance reduction" for sound pressure levels in the vicinity of the cooling tower. It could be very erratic to apply such procedure to data measured for example at 1 m distance from the tower air intake, because in this position the influence of the discharge noise is generally very small. The influence of the discharge noise will increase with increasing distance until a point is reached where the sound pressure actually includes the influence of air intake and discharge to its full extent. This is another reason why sound pressure levels should be specified as "near field" and "far field" data.

b) Sound power levels

Sound power levels indicate the total sound energy radiated from the cooling tower. Therefore they are a good means of specifying the acoustical behaviour of a cooling tower. Sound power data can be established following the "surface" or the "helocoidal" method. If measured properly both methods should give the same results. The surface method may in some cases be easier to execute since data can be measured in the vicinity of the tower where background noise is of less concern. When specifying sound power levels one must disregard any useful "directional sound" capability of the cooling tower which enables it to be oriented with its quiet side towards a critical neighbour. When such "directional capability" could be used as an advantage, sound power levels should not be specified.

It also needs to be noted that the verification of sound power levels is costly, as such measurement requires a large amount of microphone positions. Sound power levels should be specified per frequency band and as A-weighted values.

For multi cell installations, measuring points must be defined in the way that they take into account the real radiating surfaces as they exist on site.

c) Partial sound power levels

Partial sound power levels are particularly useful when it comes to specifications for very large cooling towers or indoor locations. For larger equipment with a rigid shell (for example concrete) it is sufficient to establish sound criteria for the air intake and discharge areas. The same situation occurs for smaller equipment when it is installed indoors. In such situations the importance of "directional sound" capabilities is greatly reduced and hence partial sound power levels are an ideal method of criterion setting, because with these data the acoustical performance of the cooling tower can easily be integrated into the acoustics of a total system.

Partial sound power levels can be established either by surface or helocoidal methods, however for practical purposes the surface method is preferred. The effort to establish partial sound power levels is substantially less than establishing total sound power levels. It must however be noted that partial sound power levels are only applicable in cases where the sound emission from the shell can be ignored.

7.2 SOUND TESTING

Listed here are the major considerations with regard to preparation and execution of a test.

a) Test preparation

Before starting the actual acoustical test it is necessary to verify some specified performance parameters of the cooling tower, i.e. fan speed, fan power and spray pressure. It must also be checked that the air flow to and from the tower is unimpeded, that all tower components are fixed as required, and that the nozzles are clean and the spray pattern is correct. For belt driven units, belts must be properly tensioned. To accomplish this it is recommended to contact the manufacturer of the cooling tower and provide him with the data that have been collected during the preparation, to allow adjustments should the actual performance parameters differ from the manufacturer's specification. It is also necessary to inspect the test site with all parties concerned and to determine the microphone locations and the sequence of the test. At that stage it can also be decided what the logistical requirements of the test are (measuring equipment, personnel, scaffolding, etc...)

Note that an acoustical test may be void, if the cooling tower is not operated under the conditions specified and contractually agreed upon, therefore the data collected prior to test need be registered and sent to all parties involved.

b) Execution of the test

Before testing, the background noise must be measured. For this purpose the cooling tower must be idle. The A-weighted background noise should be at least 9 dB lower than the noise criterion to be verified. Due to this requirement it may be required to test during nighttime. Background noise measurements must be repeated during the test in particular when the back ground noise is high or greatly variable. For this purpose the cooling tower installation must be regularly switched on and off and a technician who is authorised to do the switching needs be available. During the acoustical test itself the cooling tower must run under stable conditions in terms of water and air flow. While it is not necessary to run the tower with a heat load it must be ensured that during the test fans run at continuous speed and that no fan cycling or modulation of fan speed occurs unless specified otherwise. If sound criteria for reduced fan speed need be verified, the fan must run at the specified speed. The sound from the cooling tower should be measured per frequency band and as A-weighted. If the influence of the background noise can be neglected it is sufficient to measure only its A-weighted level. Otherwise the background noise must be measured per frequency band.

For the verification of sound pressure levels it is essential to put the microphone into the exact positions for which the sound data were given. This eliminates the need to adjust the test data to the location of the specified data, which could be a source of errors and argument. For the verification of sound power levels the measuring points are indicated by the relevant test standard. The measuring distance however can sometimes be chosen. In such case it is recommended to choose measuring distances in the vicinity of the equipment, preferably in distances for which the manufacturer has predicted data.

Measurement locations close by the equipment always require a microphone location at the top of the equipment, in particular when the direction of the air (either discharge or intake or both) is vertical. For this purpose it may be required to install some scaffolding prior to test. For the verification of sound pressure levels further away from the equipment microphone locations at the top are impractical and are mostly not needed, because the top of the cooling tower will be in the line of sight. As explained above however such test conditions offer a number of disadvantages and should be avoided.
The noise measurements must be made close to design conditions :

circulating water flow :	+/- 10 %
temperature range :	+/- 20 %
fan drive power :	+/- 10 %
fan speed :	+/- 5 %

The measurements points (distance, direction, etc) should be in accordance with local requirement and the standard to be used.

8 - REFERENCES

The sound power level of a cooling tower is the only value which is dependant on the equipment and not on the environment. Therefore manufacturers can be responsible only for the sound power level, and not for the sound pressure level in a particular point in the space.

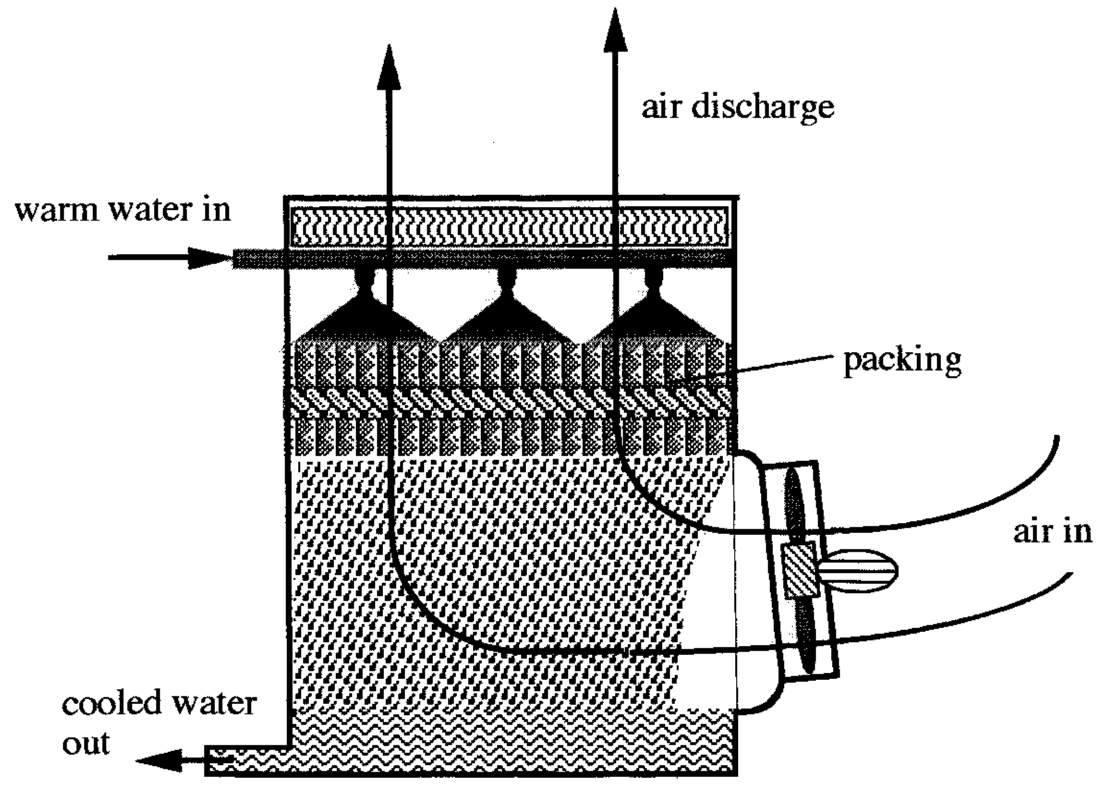
Unfortunately, the sound power level cannot be measured directly. It is calculated from the measured values of the sound pressure level at specified points in the space. Sound power level must be tied to a specified measurement method or specification.

There are a number of national and international standards concerning determination of sound power levels.

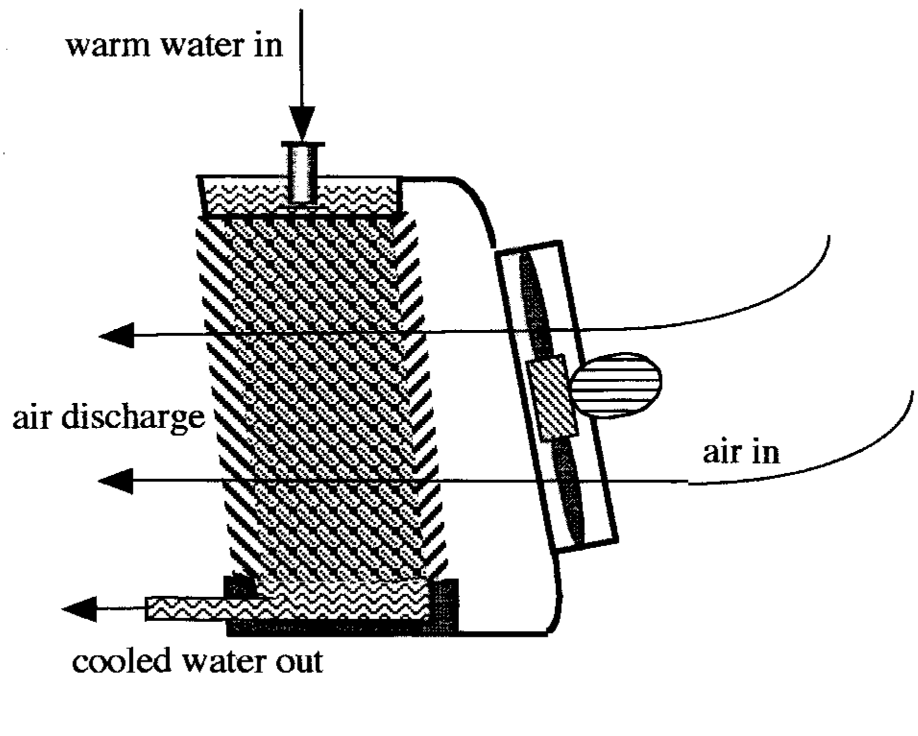
1. **ISO 3744** - Sound power level determination in free field over a reflecting plane.
2. **EUROVENT 8/1** - Acoustic measurements on machines and equipment in the free field or large rooms on a hard reflecting plane.
3. **CTI ATC-128** - Code for measurement of sound from water-cooling towers.
4. **DIN 45 635 Part 46** - Measurement of noise emitted by machines - Airborne noise emission of cooling towers - Enveloping surface method.

Some practical guides may also be useful :

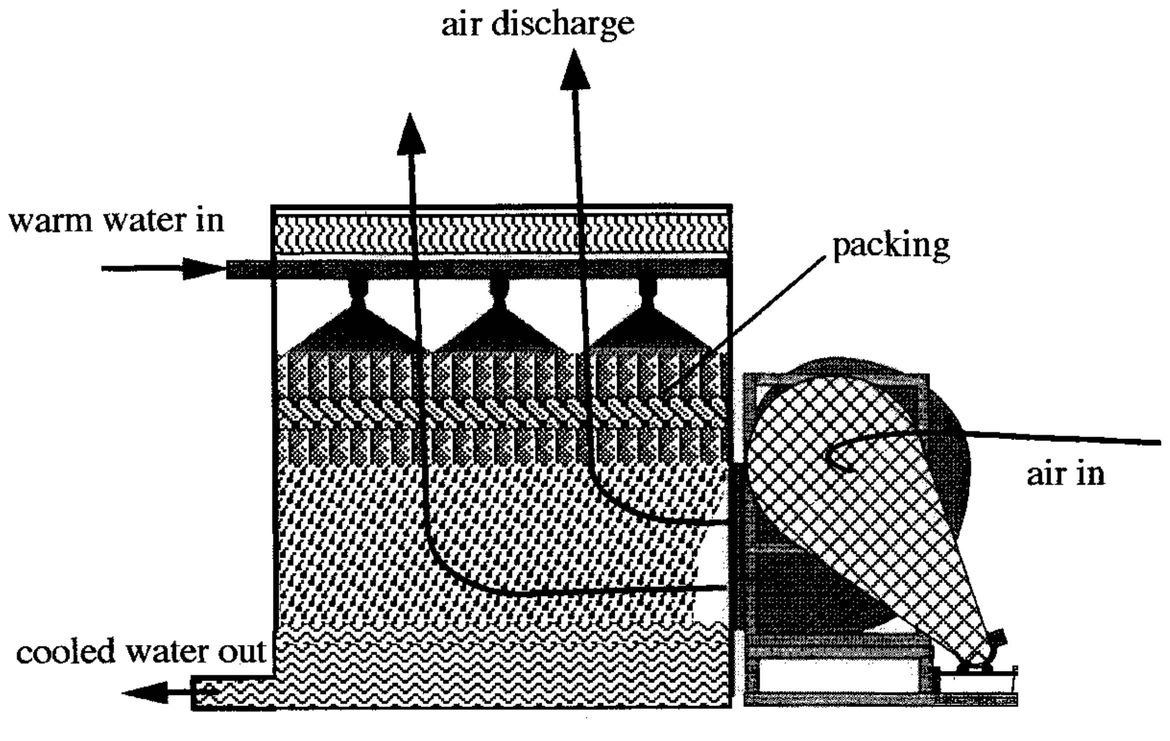
1. **VDI 3734 Part 2** - Characteristics noise emission values of cooling towers.



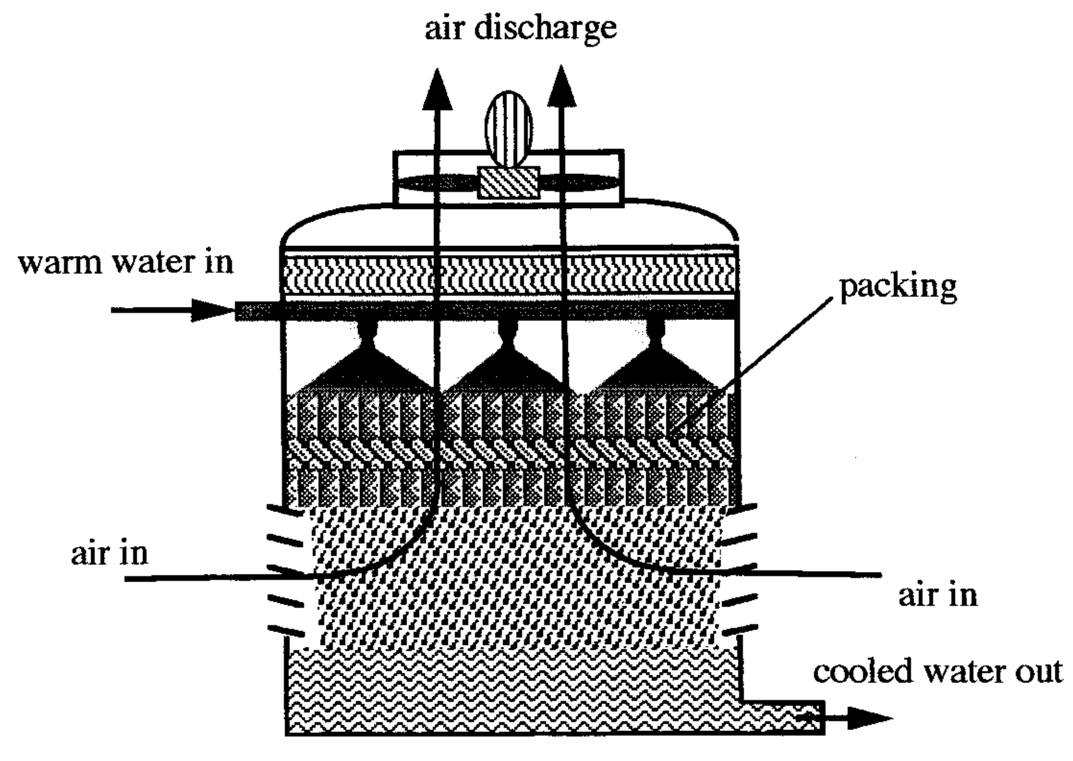
Counter Flow Cooling Tower (schematic)
Fan Arrangement: Forced Draught, Horizontal



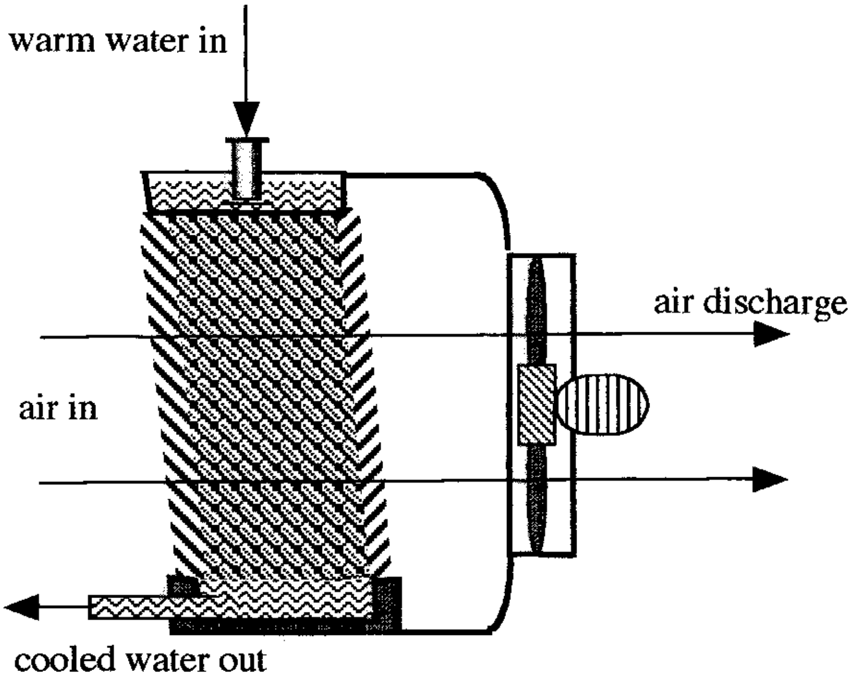
Cross Flow Cooling Tower (schematic)
Fan Arrangement: Forced Draught, Horizontal



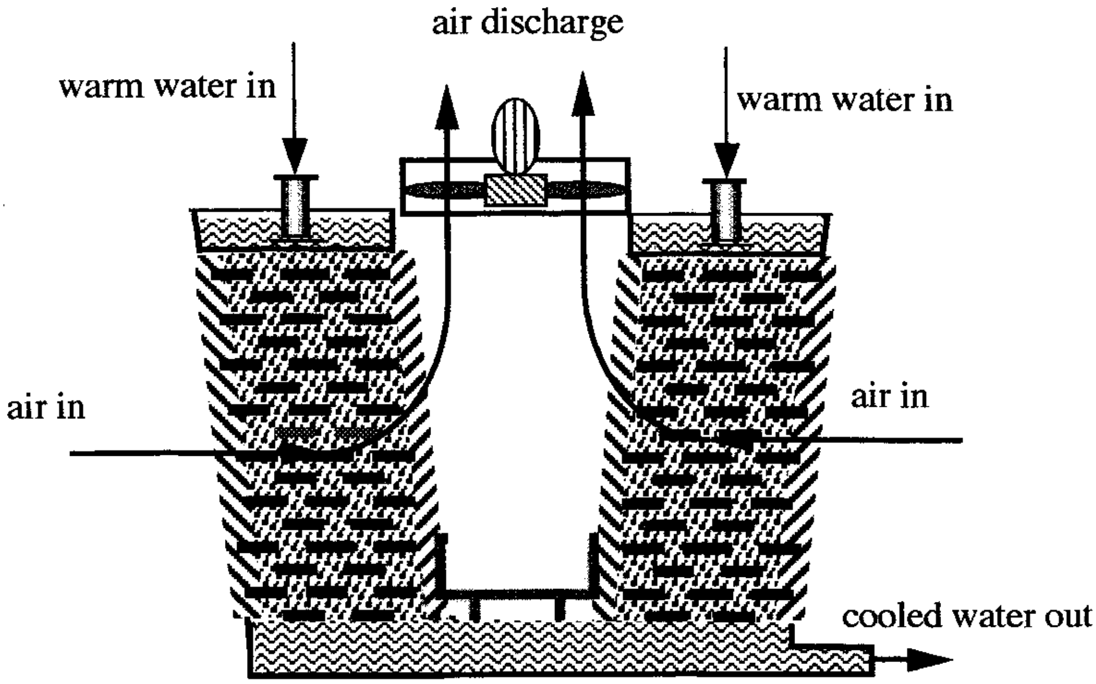
Counter Flow Cooling Tower (schematic)
Fan Arrangement:Forced Draught, Horizontal



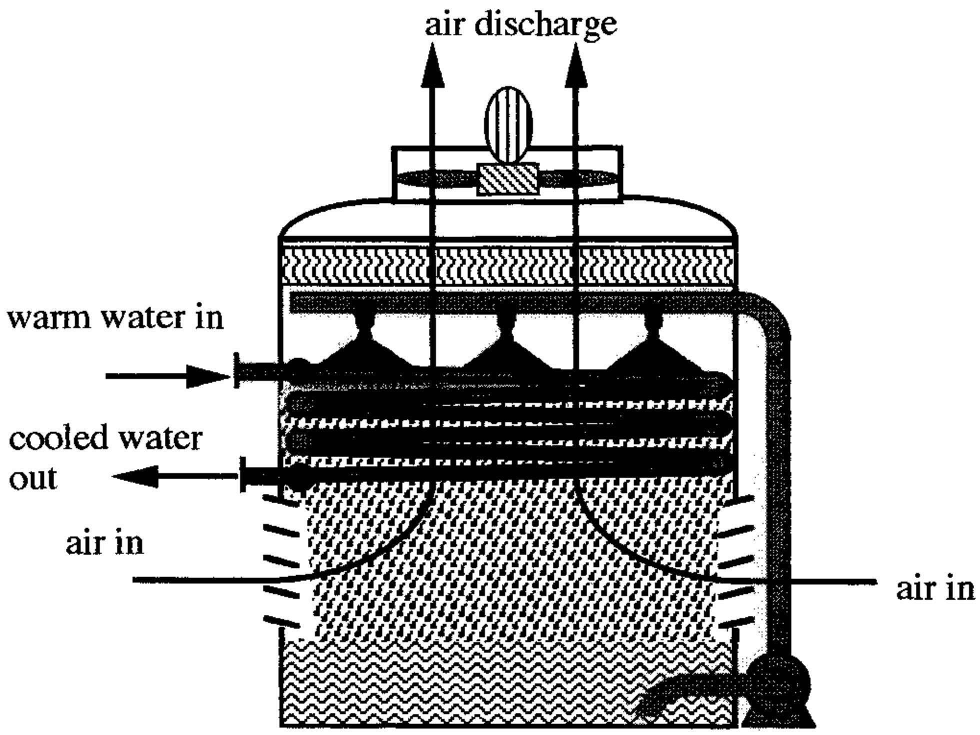
Counter Flow Cooling Tower (schematic)
Fan Arrangement:Induced Draught, Vertical



Cross Flow Cooling Tower (schematic)
Fan Arrangement: Induced Draught Horizontal



Cross Flow Cooling Tower (schematic)
Fan Arrangement: Induced Draught, Vertical



Closed Circuit Cooling Tower (schematic)

LIST OF THE MEMBER ASSOCIATIONS

BELGIUM **FABRIMETAL** 80 Bd Reyerslaan - B-1030 BRUSSELS E-mail: info@fabrimetal.be **Tel 32/2/7067985 - Fax 32/2/7067966**	***NETHERLANDS*** **VLA** Postbus 190 - NL-2700 AD ZOETERMEER E-mail: vla@fme.nl **Tel 31/79/3531266 - Fax 31/79/3531365**
FINLAND **AFMAHE** Eteläranta 10 - FIN-00130 HELSINKI **Tel 358/9/19231 - Fax 358/9/624462**	***NORWAY*** **NVEF** Postboks 6697, St. Olavs Plass – N-0129 OSLO **Tel 47/22202790 - Fax 47/22202875**
FINLAND **FREA** P.O. Box 318 FIN-00811 HELSINKI **Tel 358/9/7591166 - Fax 358/9/7557246**	***SPAIN*** **AFEC** Francisco Silvela, 69-1°C - E-28028 MADRID E-mail: afec@afec.es **Tel 34/9/1/4027383 - Fax 34/9/1/4017927**
France **UNICLIMA** F-92038 PARIS LA DEFENSE CEDEX E-mail: uniclima@wanadoo.fr **Tel 33/1/47176292 – Fax 33/1/47176427**	***SWEDEN*** **KTG** P.O. Box 55 10 – SE-11485 STOCKHOLM **Tel 46/8/7820800 - Fax 46/8/6603378**
GERMANY **FG ALT im VDMA** Postfach 71 08 64 - D-60498 FRANKFURT/MAIN E-mail: ALT@VDMA.org **Tel 49/69/66031227 – Fax 49/69/66031218**	***SWEDEN*** **SWEDVENT** Box 175 37 - SE-118 91 STOCKHOLM E-mail: christer.backstrom@foreningen-v.se **Tel 46/8/7627500 - Fax 46/8/6681180**
ITALY **ANIMA - ANIMA - CO.AER** Via Battistotti Sassi, 11 - I-20133 MILANO E-mail: anima@anima-it.com **Tel 39/02/73971 - Fax 39/02/7397316**	***TURKEY*** **ISKID** Ruhi Bagdadi Sok. No:1 Balmumcu – TR-80700 ISTANBUL E-mail: formas@superonline.com **Tel 90/2122881570 - Fax 90/2122725652**
NETHERLANDS **NKI** Postbus 190 - NL-2700 AD ZOETERMEER E-mail: nki@fme.nl **Tel 31/79/3531258 - Fax 31/79/3531365**	***UNITED KINGDOM*** **FETA (HEVAC and BRA)** Henley Road, Medmenham MARLOW Bucks SL7 2ER E-mail: info@feta.co.uk **Tel 44/1491/578674 - Fax 44/1491/575024**