# 9. Cooling tower components

## 9.1 Introduction

A cooling tower exists of a number of functioning components that can be found in every cooling tower in a certain form. As an example we consider a mechanical draught counter flow cooling tower. The main components of this cooling tower are:

1. The casing of the cooling tower. The casing is built from e.g. wood, steel or synthetic fabric. The casing may be self-carrying or it may be mounted on a metal frame.

2. The air inlet bars. These should take care that the minimal amount of water spurts through the air inlets and that the air is led into the cooling tower in an optimal way; i.e. the air should not choose the shortest way to the fan. Therefore, the bars are usually directed downwards, so that the air is led further into the cooling tower and streams into the cooling fill more gradually. These bars can be made of synthetic material, steel or wood.

3. The cooling fill. The different types of cooling fills and their functioning are already discussed extensively in part 2 of these series and therefore will not be further discussed here.

4. The water distribution system will be discussed in more detail in this part.

5. The drift eliminator will be discussed in this part.

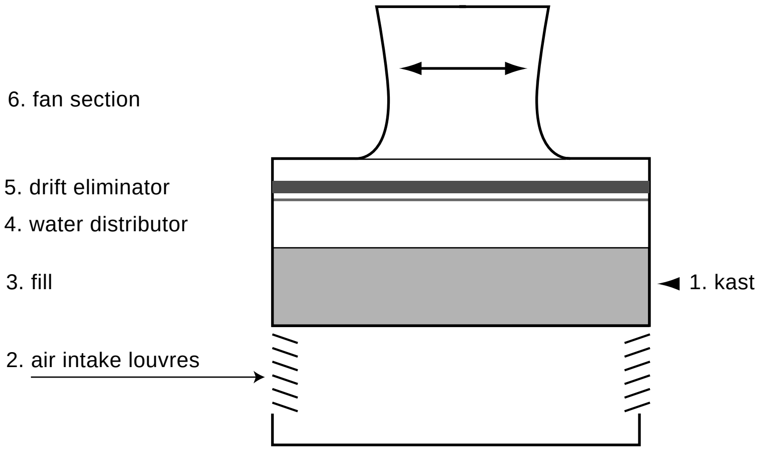


*figure 17. Functional cooling tower parts*

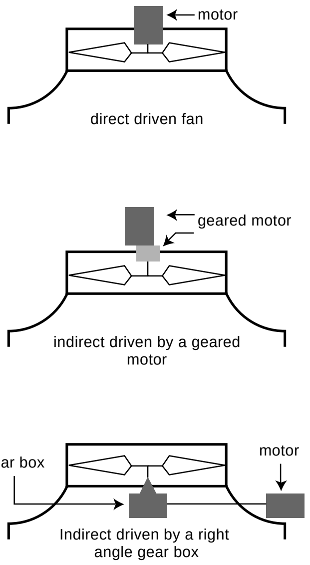


*figure 18. Impeller arrangement induced draft*

6. The fan section. For an induced draft cooling tower (see figure 18) this consists of an induced draft fan, driven by an electromotor. For bigger cooling towers the revolution speed of the electro motor needs to be reduced by means of a reduction component. This because of the maximum tip speeds that, for e.g. synthetic fans lie between 50 and 70 m/ s., depending on the construction and the choice of materials. This reduction component can exist of a geared motor that drives the fan directly or of a right angle gearbox with an intermediate shaft and a foot mounted motor, where this electromotor usually is outside of the fan stack (see figure 18).

Obviously, a good technical adjustment of these components and the optimal functioning of the cooling tower deserve extra attention.
The following points are taken into consideration:

- The relative proportion of the fan's diameter compared to the drift eliminator's surface and the cooling fill's surface. We choose a large enough fan, so that no extreme air speeds occur in the fan cone while there is a correct air speed in the cooling fill and the drift eliminator (the air speeds in the fan cone vary from 1-15 m / sec).
- The distance between the fan and the drift eliminator should be large enough to prevent local differences in air speed in the drift eliminator.
- The inlet shape of the fan cone and the fan's tip space in the cone are important to the ultimate fan profits and therefore for the energy consumption of the cooling tower as well.
- The nozzles should be distributed in such way that the water streams through the cooling fill instead of along the sides of the casing, for water streaming along the sides will not be in sufficient contact with the drawn-in air. This portion of water will then reduce the cooling capacity.

## 9.2 The drift eliminator section

### Principle of operation

The functioning of a drift eliminator is based on the inertia of a drop of water. Every drift eliminator incorporates a specially constructed curve or turning brim that causes the air to change direction. Because of this change of direction, the drop flies out of the curve and is caught in the drift eliminator's profile. From this principle follows that for the drift eliminators there is a minimal speed for which the drops still fly out of the curve. Also, a drift eliminator is best in catching the drops when the speed is high (the flow-in speeds for a drift eliminator lie between 2 to 4 m / sec). Below the minimal speed the smaller drops can 'whirl' through the drift eliminator.
Of course there also is a maximum speed for the drift eliminator; this has to do with turbulence and too much resistance.

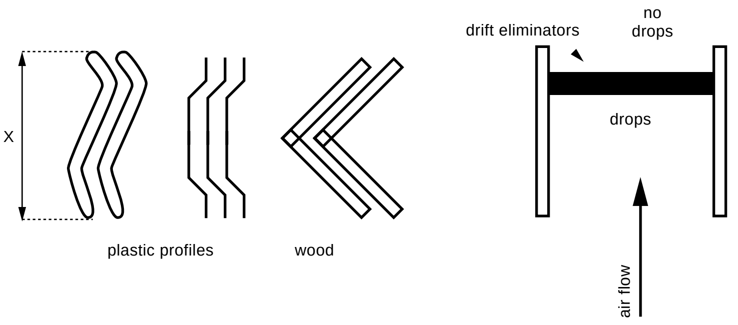
Drift eliminators for cooling towers are usually produced in synthetic materials like PVC and PP. The reason for this is that these materials are more aerodynamic in design than e.g. wood. For special uses in the process industry, where high temperatures can be reached, they can also be manufactured in stainless steel.
When placing the drift eliminators we make sure that the adjacent eliminators are fitted close together because if slits occur, drops could fall through them.

### Horizontal drift eliminator

This type of drift eliminator is used in counter flow cooling towers (see figure 17). The air speed in this drift eliminator is about 2-4 m / sec. In these drift eliminators the smaller 'whirling' drops are assembled into bigger drops which then fall back into the cooling tower (see figure 19).

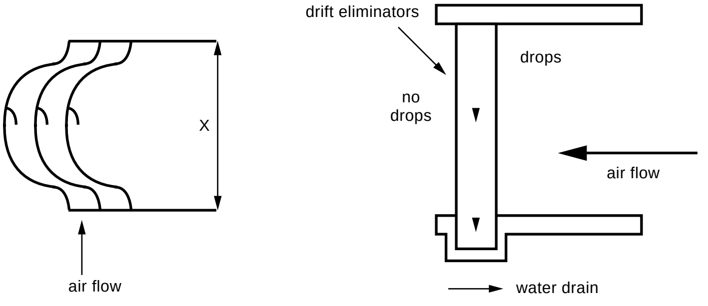
### Vertical drift eliminator

In this type of drift eliminator the drops are collected in special drains through which they are drained away in downward direction. When constructing this type of drift eliminator we take care that the water can be carried back from the bottom of the drift eliminator to the basin. The air speed of this type of drift eliminator may be between 2 and 8 m / sec, dependent on the design and construction.



dimension X between 150 - 200 mm.
intermediate distance between 25 - 40 mm.

*figure 19. Basic principle horizontal drift eliminators*



dimension X between 150 - 200 mm.
intermediate distance between 25 - 40 mm.

*figure 20. Basic principle vertical drift eliminators*

## 9.3 The water distribution system

For the distribution of water in a cooling tower several systems can be used.
A condition for a well-functioning water distribution system is that the water is equally distributed over the cooling fill in order to obtain optimal contact between water and air.

### Cross and counter flow cooling towers

In counter flow cooling towers (see figure 18) water distribution systems that disperse the water in a fine drizzle over the fill are always used. Two systems are recognised:

### Regular low pressure nozzles

These nozzles are usually carried out according to the full cone principle, in order that the entire surface beneath the nozzle can be wetted. The boosting usually lies between 20 and 50 kPa. The water is distributed by means of a so-called whirl-plate that causes a good spraying result. When the pressure over the nozzle drops too low, the spraying result decreases and the spraying angle will become smaller than that it was designed for. When the pressure over the nozzle is too high, the shape of the full cone nozzle changes to a hollow cone nozzle because the water is hurled out more. The spraying angle usually is 120°; therefore the building height of the part of the nozzles can remain low.

### Splash nozzles without pressure

These nozzles operate by the principle of gravity, which causes the water to stream through open drains or half-filled pipes to the spraying points.
The drawback of open drains is that there is the chance of heavy algae growth, which can cause blockages. Through an outlet pipe the water falls on a specially constructed disc, where it diffuses into a hollow spraying result. The advantage of this nozzle is that pressure is not required. The disadvantage is that these nozzles do not form a full cone because of the disc construction. For this reason the fill right beneath the nozzle does not get wet. In order to wet every fill, the nozzles must overlap one another. In general, the water distribution with splash nozzles is not as good as with low pressure nozzles. However, for the bigger cooling towers with somewhat coarser fill types the splash nozzles suffice.

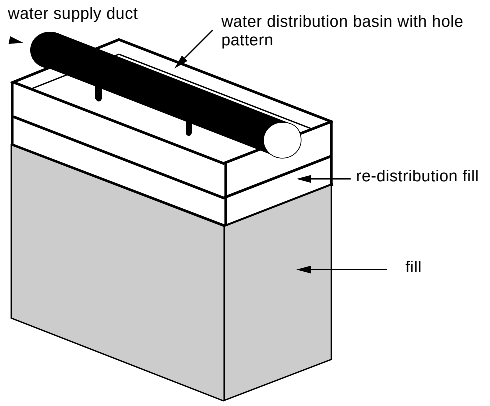


*figure 21. Water distribution cross flow cooling towers*

## 9.4 Water distribution system for cross flow cooling towers

In cross flow cooling towers a water distribution system without pressure is most commonly used. In this system the water is distributed over the fill by a distribution basin with a special perforated pattern (see figure 21). These perforations are usually carried out in the form of so-called tops, which are tubes with a fixed outer diameter and varying inner diameters. This enables us to adjust the diameters of the hole in the basin to a design for a different water debit. The large number of tops per m3 already deals with the water distribution quite well. By using a redistribution fill between the water distribution system and the cooling fill an optimal water distribution is realised.

# 10. Sound of the cooling tower

A cooling tower is always directly connected to the open air because the tower cools using surrounding air. Obviously, completely built-in constructions can be thought of that make use of ‘sucking’ and ‘draining channels’. This, however, is not a normal situation. Moreover, the cooling towers are usually located on a high level on the roofs of buildings or on wasted places on the terrain that may be close to a border.
The modern forced draught cooling tower is provided with a fan with drive, which is a potential sound source. Another source of sound may be the water falling in the cooling tower’s basin. This sound may be annoying because of its high pitch.
In the present nuisance acts and environmental laws increasingly higher demands are set up for cooling towers. In this chapter we will elaborate on the sound-production of cooling towers. We only consider elementary knowledge of a sound-source with a continuum devoid of peeks.

## What is sound?

Sound is a vibration of air that is caused by movement of an object. This movement causes differences in pressure that move through the air in the form of vibrations. Human beings sense these vibrations by means of sound.

Humans can sense sound pressures that range from 20µPa (audibility threshold) to 200 Pa (pain threshold). The force of the sound pressure is defined in decibels in the following manner:

$$Lp = 20*\log\frac{P}{P_{\circ}} \qquad (dB)$$

P = occurring sound pressure
$P_o$ = sound pressure of the audibility threshold (20uPa)

The value of the sound pressure always needs to be given together with the distance to the source. In our formula the sound pressure of the audibility threshold will be 0 dB and of the pain threshold this will be 140 dB.

Besides the strength (the loudness that can be heard), sound can also be heard in different pitches. These pitches occur because of the speed of changes in pressure; this is called frequency. For very rapid changes, a high frequency, we hear high pitches. For slow changes we hear low pitches; the bas tones. In general, the human ear can hear sound frequencies of 16-20.000 Hz.

A third well-known entity is the sound capacity. This sound capacity is defined analogous to the sound pressure. The difference is that for the sound capacity the starting point is not a pressure, but a capacity (Watt) that is brought into the air.

$$Lw = 10*\log\frac{W}{W_{\circ}} \qquad (dB)$$

Lw = Current sound capacity
w0 = Reference sound capacity (10-12 Watt)

This value is independent of the distance and cannot be measured directly with the measuring equipment. The sound capacity is frequently used to characterise the force of a specific sound source.
We can calculate the sound capacity and the sound pressure (on a specific distance) with the help of for example the formula mentioned below. This formula only accounts for a point source in an acoustically free field without influence from the soil or reflections:

$L_w = L_p+10\log(4*\pi*R^2)$
R = distance to the source, the radius (m).

## To work with these entities

In practice, the entities mentioned above are put to use in different ways. In fact, we can determine the sound pressure for all frequencies with a spectrum-analyser. However, this is so extensive that in practice –for the sake of simplicity as well as for

comparison- a number of middle frequencies are used, for which the total spectrum is divided into ranges that are shown in the table below.
Additionally, in order to reflect the sound with a simple number, a filter spectrum that is in accordance with the human audibility can be used. For this spectrum, it is researched which pitches are the most annoying for human beings. The commonly used dB(A) filter is also shown in the table below:

| Medium frequency | Band limits | dB(A) filter |
|---|---|---|
| 63 | 45 - 90 | -26 |
| 125 | 90 - 180 | -16 |
| 250 | 180 - 355 | -9 |
| 500 | 355 - 710 | -3 |
| 1000 | 710 - 1400 | 0 |
| 2000 | 1400 - 2800 | 1 |
| 4000 | 2800 - 5600 | 1 |
| 8000 | 5600 - 11200 | -1 |

From the A-spectrum can be concluded that high pitches especially are experienced as annoying.
In order to determine the value from the dB(A) spectrum, the middle frequency values are added logarithmically according to the formula below:

In practice, the sound meter is provided with a dB(A) filter, so that the dB(A) sound pressure level can be read directly.

$$
\begin{aligned}
dB(A) = 10\log[10^{\frac{(\text{value - correction value})}{10}} &+ \\
+10^{\frac{(\text{value - correction value})}{10}} &+ \\
+10^{\frac{(\text{value - correction value})}{10}} &+ \\
+\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots)
\end{aligned}
$$

## Rules of thumb for calculations with sound

For calculations with sound there are a number of rules of thumb that can be applied quite easily. For several sources counts that the sound pressures of the sources in a measuring point can be added logarithmically using the following formula:

$$L_{ptotal} = 10 \log[10^{\frac{(Lp_{source\ 1})}{10}} + 10^{\frac{(Lp_{source\ 2})}{10}} + 10^{\frac{(Lp_{source\ 3})}{10}} \ldots]$$

For several equal sources for the sound pressure increase in the example counts the following:

-For 2 equal sources = 10 log(2) = +3 dB
-For 3 equal sources = 10 log(3) = +5 dB
-For 4 equal sources = 10 log(4) = +6 dB

When the distance from measuring point to source changes, counts theoretically, preserving air- and ground dampening, a resonance of other influences:

$$L_{Pnew} = L_{Pold} - 20\log\left(\frac{\text{distance new}}{\text{distance old}}\right)$$

For rotating machines it counts that when the revolutions are changed, it can be stated (theoretically) that LPnew can become LPold following the following formula:

$$L_{Pnew} = L_{Pold} - 50\log\left(\frac{\text{original speed}}{\text{new speed}}\right)$$

An example for electrically driven machines is:

- 2/3 rotations = +50log(0.67)= -9 dB
- 1/2 rotations = +50log(0.5) = -15 dB

We must note here that for fans more influences are of importance, which we will examine in due course of this booklet.

## The sound of the fan and the drive

The fan is a possible sound source. This source is examined thoroughly, in the course of which it is tried to grasp the sound production in an empirical formula:

$$L_{WA} = L_{WAS} + 10\log W + 10\log \frac{U^3}{D}$$

$L_{wa}$ = the sound capacity of the fan dB(A)
$L_{was}$ = the specific sound capacity of the used fan dB(A)
W = the fan capacity kW
U = rotation speed $\frac{m}{sec}$
D = the fan diameter m

From the above we can conclude, concerning an optimal fan-sound, the following:

- The rotation speed of the fan is the most influential factor. This rotation speed is equal to the rotation. A fan having the same amount of air and boosting with a lower rotation speed will therefore produce less sound.
- The diameter also influences the sound production of the fan. A fan with a large diameter with the same design conditions will bring about less sound.
- The used capacity of the fan is also an influence on the sound. Because the capacity is the same as the (air debit) boosting divided by the profit, starting from a given required debit and boosting, only the profit is relevant. Therefore, a fan with a higher profit will produce less sound.

When the above technical design aspects are thoroughly examined but too much sound is produced anyway, we can check the outlet dampers on the cooling tower (see figure 21). The disadvantage of an outlet damper is that it causes additional air- sided resistance, which increases the fan capacity. The production of the sound source (the fan) then increases according to the formula above. It may now be clear that from a technical and economical viewpoint maximising the fan drive by a relatively more expensive fan and one that is as large as possible (with a maximised blade shape and more profit for lower rotation speeds) is preferred.

Good reduced-sound fans are available these days, so that now the drive of the fan plays a part. For a cooling tower drive we pay attention to the electro-motor for electric sound and cooling fan sound. When, on top of that, a rotation-reduction by a gearbox or by a reductor is being used, we also pay attention to sound of the gear wheel. When this happens, a quickly rotating intermediate stage can cause problems. When the sound of the drive is significantly less than the fan sound in practice, a minimal difference of 10 dB is stated and the drive will, as a rule, not cause problems.

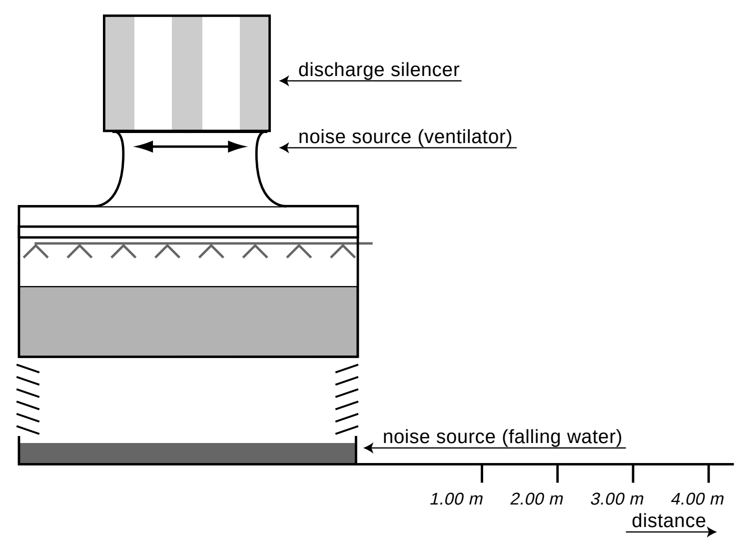


*figure 21. Cooling tower with discharge silencer*

It is advisable to compare this for the entire spectrum, so that possible peak sounds in specific frequencies are not annoying.

## The sound of falling water

A counter flow cooling tower produces not only fan sound but also splash sound of the water that falls from the cooling fill into the basin. A counter flow cooling tower is explicitly mentioned, because in a cross flow cooling tower the water streams directly from the fill into the basin, an activity which does not produce sound and is therefore one of the advantages of a cross flow cooling tower. For the modern smaller counter flow cooling tower with a film fill (e.g. the Polacel CMC and CMD type) it counts that in general the sound pressure measured in the air inlet bar is about 81-84 dB(A).

The sound production is, however, very much dependent of construction matters as:

- Falling height in the cooling tower;
- Water load over the cooling fill;
- Type of cooling fill and the size of the drops;
- Construction of the basin and the possible water level.

Every manufacturer of cooling towers will give a personally measured sound level that is determined by means of equal cooling tower types. As an example of a sound pressure level that can happen in practice, the following sound pressures are given for a CMC-type cooling tower of about 2.5 *2.5 meter:

| Medium frequency | Air intake | Sound pressure level at 10 m. |
|---|---|---|
| 63 | 72 | 50 |
| 125 | 72 | 50 |
| 250 | 70 | 48 |
| 500 | 75 | 53 |
| 1000 | 78 | 56 |
| 2000 | 77 | 55 |
| 4000 | 78 | 56 |
| 8000 | 76 | 54 |
| dB(A) | 83 | 61 |

In order to reduce the sound of the falling water, we can place side-wing dampers around the cooling tower or we can place a sound wall at some distance of the cooling tower (see figure 22).
It is also possible to make sound facilities in the basin yourself. Slanting fences or especially constructed, floating mats that catch the drops and break them, causing less splash sound, could be placed in the basin. These dampers can reduce the sound about 10 to 11 dB(A).

## Example of a sound-situation

As an example we choose a standard cooling tower of 2.5 * 2.5, with a height of 3.5 meters and with a standard fan. This fan should move 19 m3 / sec air with a boosting of 140 Pa. The used capacity of the fan is then 4.8 kW with a rotation of 720 rpm.

For this fan counts on 10 meters a sound pressure release of:

| Hz | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 | dB(A) |
|---|---|---|---|---|---|---|---|---|---|
| dB | 61 | 63 | 64 | 62 | 59 | 54 | 48 | 42 | 64 |

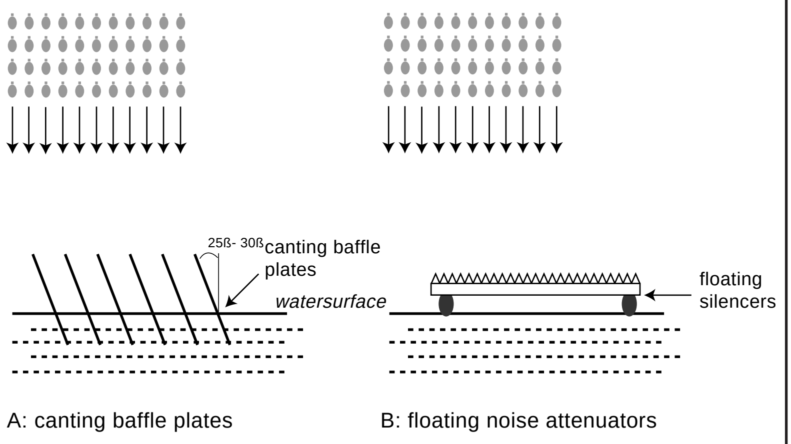


figure 22. Attenuation of the noise by the falling water

If we want to replace this type of fan by a reduced-sound type that can do with less revolutions, we can realise less sound release. For a used capacity of 4.9 Kw and a revolution of 501 rpm this fan suffices. For this fan counts a sound pressure release on 10 meters of:

| Hz | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 | dB(A) |
|---|---|---|---|---|---|---|---|---|---|
| dB | 53 | 56 | 58 | 56 | 53 | 49 | 42 | 35 | 58 |

For the falling water of this cooling tower counts, as already mentioned in the former section, a sound pressure release on 10 meters of:

| Hz | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 | dB(A) |
|---|---|---|---|---|---|---|---|---|---|
| dB | 50 | 50 | 48 | 53 | 56 | 55 | 56 | 54 | 62 |

When we consider the total sound pressure level of this cooling tower we will find as a sum of the water sound and the fan sound for the standard situation on 10 meters a sound pressure release of:

| Hz | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 | dB(A) |
|---|---|---|---|---|---|---|---|---|---|
| dB | 61 | 63 | 64 | 62 | 61 | 57 | 56 | 54 | 66 |

In the situation with a reduced-sound fan counts on 10 meters a sound pressure release of:

| Hz | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 | dB(A) |
|---|---|---|---|---|---|---|---|---|---|
| dB | 55 | 57 | 58 | 58 | 58 | 56 | 56 | 54 | 63,5 |

Considering the above, we see that especially in the reduced-sound situation the water sound plays a great part. In this situation we could with the help of for example floating dampers (sound attenuators) reduce the sound of falling water to a sound release from 10 meters of:

| Hz | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 | dB(A) |
|---|---|---|---|---|---|---|---|---|---|
| dB | 50 | 50 | 48 | 48 | 44 | 45 | 45 | 39 | 52 |

For the total sound of the combination reduced-sound fan with dampened water sound, counts on 10 meters:

| Hz | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 | dB(A) |
|---|---|---|---|---|---|---|---|---|---|
| dB | 55 | 57 | 58 | 57 | 53 | 50 | 47 | 40 | 59 |

## Conclusion

We find that by the use of a sound-reduced fan and by dampening of the splash water sound a sound reduction from 66 dB(A) to 59 dB(A) of the standard fan and the sound of the water is possible at a distance of 10 meters. Obviously, this situation is just an example. Every situation should be considered separately.