# 5 Alarm and Evacuation

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5.1 Summary

To save lives, hazard warning is indispensable. Conventional devices such as horns, sirens and bells may be economic, but people hardly follow such signals, ignoring them more and more often. Thanks to its plausibility, voice alarm is followed quickly and consistently, which is why it will spread rapidly in the future. The information of people in the building without delay by means of voice messages can be adapted to the current hazard situation and largely helps to prevent panic reactions.

To plan a voice alarm system, special knowledge of acoustics is absolutely necessary. This is the only way to achieve the necessary intelligibility with a cost-efficient system design. Voice alarm systems should be easy to integrate into the building infrastructure. In particular, automatic interfaces to the danger management systems are useful. The required control unit technology can be installed centrally or decentrally. The efficiency of the amplifiers is crucial for the size of the required emergency power supply unit.

Over the past decades, much experience with voice alarm systems has been gained. The quintessence of this experience is the quasi standard, aiming at first evacuating the endangered fire sectors, then the immediately adjacent ones. After that, all other areas are successively evacuated. This phased evacuation is definitely superior to the formerly habitual one-step evacuation and has many advantages. Panic prevention or the possibility of partial evacuation are only two of them. In addition, it makes fewer demands on escape routes. Advanced evacuation systems thus allow for phased evacuation matched to specific needs.

Alarm is initiated to make sure that the building users can leave the building in good time in case of hazard. And according to experience, hazards can only be handled smoothly if procedures have been rehearsed in advance. The emergency training sessions that are conducted regularly in Anglo-Saxon countries are thus indispensable and are of increasing significance in other countries as well. Automatic escape route guidance is increasingly paid attention to. It always guides people correctly and safely to the outside, independent of the seat of fire, so that nobody can accidentally get to the hazard zone.

Alarm devices not only save lives. In the case of voice alarm, they also have a valuable additional benefit, as they can be used to emit background music and voice messages. Digital technology makes possible simpler cabling, more flexible system programming and essentially more efficient amplification. Although cabling is the largest single post in the investment calculation, it lives as long as the building itself. Voice alarm is thus a worthwhile strategic investment.

Voice alarm systems are also the correct answer to the people’s and especially the building users’ increased demand for safety in view of an aggravated liability law.
5.2 Basics

The purpose of an alarm is to warn of hazards by means of alarm signals. Different target groups are addressed by an alarm. Especially two groups of people are of significance: The people for whom a hazardous situation has been detected, and the people who shall fight this situation. To alert the intervention forces has reached a generally high level in Europe, whereas threatened persons can still be considered the ones neglected by alarm systems.

In the past, the possibility of self-rescue of threatened persons has been considered only marginally. Today, however, people have become aware that priority must be given to successful self-rescue. This is even more important as the fire brigade do not begin extinguishing before the building has been evacuated. Hence, successful self-rescue is also a prerequisite for damage limitation.

While the first fire alarm bells were manually operated, the increasingly used sirens and alarm horns today are actuated automatically. However, regarding their information content, they must be considered inferior to fire bells. Because during the course of time, other types of hazards have emerged in addition to fire alarms. Beginning with flood alarm, intrusion alarm, environment alarm or bomb threats – a few new reasons for alarm that call for different kinds of behavior (e.g. closing the windows during environment alarm).

Doubts about the justification of an alarm (false alarm?) and ignorance concerning the appropriate reaction (what type of alarm?), however, are fatal for the response time. In the end, all the building operator wants to achieve is:

- Building users shall remain undisturbed as long as possible so that they are not impaired in their well-being and comfort.
- When a building requires evacuation, it shall be evacuated as soon as evacuation becomes indispensable. The fire might have been there for quite a while (even in consideration of the time passed before fire detection), so that fire resistance values of the building construction cannot be simply relied upon (T30, F60, etc.).
- Evacuation shall be performed as quickly and trouble-free as possible.

To achieve the two major goals, personal safety and damage limitation, self-rescue is of central significance and largely decisive for success. While a quick and panic-free self-rescue has a direct impact on personal safety, the conclusion of the self-rescue process is simply a prerequisite for the fire brigade to begin with damage mitigation.
Figure 5.1: Steps of successful self-rescue

The real innovation of voice alarm is to provide the endangered persons on the optic and acoustic channel enough information to allow a quick grasp of the events taking place and to let them accept the fact that they must act.

To trigger this recognition process successfully in a very short time is the central concern of voice alarm. After this, successful self-rescue is only a small step, simple to take for non-handicapped persons.

Successful self-rescue = main objective of voice alarm
5.3 Information Transfer of the Alarm

Alarm systems shall alert people. This automatically leads to the question which of our five senses shall be addressed. Especially the sense of hearing and the sense of seeing are competing. On the other hand, the question arises how much information shall accompany the alarm.

The following paragraphs present the different solution concepts used today and briefly highlight their most important aspects.

5.3.1 Sound Alarm: Sirens and Alarm Horns

Of course, it has been tried to distinguish the different meanings of sound alarms, varying regionally and partly even from one building to the next, by sound patterns (permanent sound, intervals, etc.). In spite of everything, doubts remain about what kind of alarm has been triggered. In Sweden, for example, a continuous tone over 30 seconds is used as all-clear signal. In England, the continuous tone is the signal for evacuation. Besides this, EN standards are interpreted differently by each nation. Some countries may have up to three different sound patterns all of which are standardized. International providers of fire detection systems are usually capable of fulfilling the different national requirements by appropriate configuration. This is important when, for example, internationally active companies wish to have a largely identical infrastructure in their different countries.

Another problem of sound alarm is the social change, such as the society’s turning away from a command-oriented behavior towards individualization, that is, to individuals that can best be motivated if explanations are given and if they may act out of conviction. Or changes in claim attitudes, such as taking comfort and safety for granted.

Tests with arbitrarily selected persons have resulted in the fact that alarm bells or sirens are not able to motivate building users to leave the building immediately. If there was any response at all, ten or more minutes passed until the test persons showed any interest in the alarm – this is precious time which can be decisive in an emergency case. Good and continuously repeated instruction of the staff or the building users is an absolute prerequisite for the use of sound alarm systems.

The cost factor of such periodic instructions should not be underestimated. The overall costs of the initially cheaper sound alarm system exceed the overall costs of voice alarm over the years. Voice alarm systems offer additional features, such as background music and the possibility of transmitting voice messages.

There is thus only one reason to restrict oneself to the classic sound alarm: The budget in the construction phase of the building. When, for financial reasons, sound alarm is the only alternative, multifrequency horns generating sounds consisting of various frequencies are advantageous for persons with impaired hearing.
The sound level to be reached must exceed the background noise by approximately 6dBA to make sure that people will hear the alarm. To generate any attention at all, a minimum sound level of 65dBA is necessary. In office buildings, usually a uniform level of 85dBA is provided to simplify matters.

Horns releasing intermitting signals must be synchronized, meaning that the quiescent and sound phases of neighboring horns must occur simultaneously. Today, this is usually ensured by the fire detection system. If two horns actuated by different control circuits or loops are placed next to one another, the synchronization deserves special attention.

State-of-the-art fire detection systems are capable of integrating horns into the fire detector lines, to directly feed and actuate them from the detector bus. This decreases significantly cabling costs for the horns. If financial reasons require considering only a sound alarm system, it must be ensured the horns will integrate into the fire detector line.

The sound alarm concept usually provides full acoustic coverage. Alternatively, only the escape routes are acoustically irradiated so that the alarm can still be heard in the individual rooms – accepting a higher sound level in the corridors, i.e. the escape routes as such.

5.3.2 Voice Alarm

An instruction to leave the building given by a voice alarm system is followed immediately. Especially when a preliminary warning signal has been given, the reaction periods confirmed in various tests are extremely short.

Over the past years, the costs of entertainment electronics have dramatically dropped, and this has also resulted in a cost decrease of voice alarm systems. The threshold to broad usage of voice alarm systems seems to have been passed:

- The market for voice alarm systems is served by an increasing number of system providers, which is a clear sign of a young, growing market.
- An increasing number of publications on voice alarm show that the topic becomes increasingly significant for the public.
- In most European countries, the “state of the art” is a benchmark to assess which safety measures are reasonable for a building owner. With respect to long-term investments in the building sector in particular, more and more building owners opt for future-proof solutions. With increasing spreading, voice alarm systems will become state of the art; in certain sectors, they already are today.
- The influence of the Anglo-Saxon jurisdiction as well as the aggravated EU liability law contributes to personal safety receiving more attention in a building.

For these reasons, we must assume that in a few years, voice alarm will be the rule rather than the exception. Therefore, and because the field is not commonly known yet, voice alarm systems will be described in detail starting on page 166.
5.3.3 Visual Alarm

People with an impaired hearing cannot respond to acoustic alarm devices. For these people, as well as for areas with especially high noise levels (ear protection), optical alarm devices which often flash stroboscopically are required.

To ensure the alarm is as correct as possible, all alarm devices, including optical ones, must be actuated by one alarm system. Advanced voice alarm systems feature special control outputs.

5.3.4 Escape Route Guidance

Fire catastrophes are extraordinarily critical situations in which optical escape route guidance is of utmost importance. Optic escape route guidance has the task of facilitating the safe leaving of the building in case of emergency, especially in case artificial lighting breaks down. Fires often produce short-circuits or are caused by them, and in case of fire, it is to be expected that the electric lighting will break down. Escape route guidance is thus of prime importance.

In most cases, escape routes are still indicated by green signs mounted above doors. This pictographic indication usually shows a fleeing person, similar to the one in the figure below.

![Figure 5.2: Example for an escape route sign](image)

The problem with these signs is that they are practically no longer visible in smoky premises. This means that especially in the event of fire, they are of extremely limited use. For this reason, the concept of escape route guidance finds more and more acceptance.

Escape route guidance may consist of actively illuminated symbols (e.g. arrows) arranged at adequately short intervals, so that the next sign is clearly visible from each point, even in the case of smoke-filled rooms. This system must be supplemented by emergency lighting. Alternatively, it is possible to use phosphorescent signs integrated in equally phosphorescent, continuous guidance marks.
The advantages and disadvantages of each of these concepts are listed in the following table:

<table>
<thead>
<tr>
<th>System</th>
<th>Light-storing safety guidance system</th>
<th>Electric safety guidance system</th>
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<tr>
<td></td>
<td>(Safety marks and continuous guidance marks)</td>
<td>(Backlit safety mark and escape route illumination)</td>
</tr>
<tr>
<td>+ Advantages +</td>
<td>Continuous guidance function</td>
<td>Higher environmental brightness</td>
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<td></td>
<td>Short distances between safety marks</td>
<td>Higher absolute recognition distances of the safety marks</td>
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<tr>
<td></td>
<td>Information close to floor level</td>
<td>Higher lighting density</td>
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<td></td>
<td>Space dimensions are imparted</td>
<td>Static illumination parameters</td>
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<tr>
<td></td>
<td>No scattered light</td>
<td>Possibility of dynamic control</td>
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<td></td>
<td>Independent of mains supply</td>
<td></td>
</tr>
<tr>
<td>- Disadvantages -</td>
<td>Low environmental brightness</td>
<td>Missing continuous guidance function</td>
</tr>
<tr>
<td></td>
<td>Problems in recognizing people and obstacles</td>
<td>Scattered light from additional illumination</td>
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<tr>
<td></td>
<td>Decaying intensity</td>
<td>Problems in recognizing people and obstacles</td>
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<tr>
<td></td>
<td>Low lighting density</td>
<td>Distances between safety marks too long</td>
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<tr>
<td></td>
<td></td>
<td>Lack of information on floor level</td>
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<tr>
<td></td>
<td></td>
<td>Missing sense of space dimensions</td>
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<tr>
<td></td>
<td></td>
<td>Emergency power required</td>
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<tr>
<td></td>
<td></td>
<td>Maintenance required</td>
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Table 5.1: Comparison of different escape route guidance systems
(Source: see End Note 9)
5.4 Voice Alarm and Evacuation

A voice alarm system is an alarm system using electronically stored voice messages (and acoustic signals) for the purpose of alarm in case of emergency. Voice alarm systems can be activated manually or automatically, for example by an alarm of the fire detection system. The preprogrammed evacuation process can then be initiated. Typically, the system delivers an alarm signal, for example a gong or whistle, followed by a stored voice message.

Of the five human senses, especially the senses of hearing and seeing are suited for alarm, with sound being the preferred alarm medium as it penetrates walls and is thus better suited to wake people up. Thus, especially sound alarm systems and voice alarm systems are competing for the planners’ favors today. Voice alarm is alarm by spoken, electro-acoustically transmitted language. It is basically simply a further development of the original sound alarm, which transmits only tones.

Voice alarm systems offer by far the best prerequisites for successful self-rescue. People react virtually immediately. Whoever triggers the alarm convinces the building users of the necessity of the desired reaction. Another major advantage of voice alarm systems is that the people concerned are immediately informed about the correct reaction instead of merely being alerted.

The system is normally operated in automatic mode during the first minutes after the alarm. In a later phase, for example after the fire brigade has arrived, they, or other authorized staff, can give individual instructions. Instructions adapted to the current hazard situation are spoken into a microphone. The system transmits these instructions directly to the selected loudspeaker zones in the building (live transmission).

5.4.1 Benefits of Voice Alarm

One of the major problems in case of fire is immediate information and safe evacuation of all people endangered by smoke and fire. Alarms by conventional signal transmitters such as sirens, alarm clocks or alarm horns are, unfortunately, increasingly ignored. Even when people realize that the signal announces a fire alarm, they tend to doubt the alarm signal and assume it to be a test or a false alarm – due to missing communication or insufficient information.

By the transmission of situation-adapted voice messages over loudspeakers, people are informed and instructed to leave the building area concerned – or to remain there, depending on the situation. Voice messages indicate escape routes that shall be used or avoided in case of evacuation and can be transmitted in any desired language or in a combination of different languages. Especially these directly transmitted messages make it possible for building users to successfully rescue themselves without panicking in any given hazardous situation.
For these reasons, timely and correct behavior can only be ensured when voice alarm systems are applied.

Quite often, voice alarm systems are used as normal public address systems (PA) for other communication purposes such as paging, advertising or for the transmission of background music. By this, the building operator has a high-quality transmission system at hand, with a high degree of fail safety. The prerequisite is, however, that the voice alarm is controlled by fully automatic priority switching, to make sure that the information transmitted by the voice alarm system is at any rate and automatically allocated priority in case of alarm.

5.4.2 Prerequisites for Building Evacuation

Evacuation of a building is a drastic measure. Therefore, it is to be ensured that it is appropriate. The requirements to be met for an evacuation vary from building to building. In any case, the authorities’ regulations have priority. Unfortunately, these regulations differ from region to region and the locally organized fire brigades have usually very distinct and individual conviction of the proceedings required for an evacuation.

Since every evacuation starts with detection, it is of utmost importance that the fire detection system responds quickly and error-free. For this reason, the following considerations are helpful:

- The fire detection system operates with intelligent detectors. This avoids largely false alarms caused by deceptive phenomena. Also refer to section 4.10.4 on page 155.
- Deceptive phenomena must be recognized as such by the fire detection system. This is to be ensured by appropriate tests.

5.4.3 Methods of Building Evacuation

State-of-the-art voice alarm systems are able to handle the fully-automatic, step-by-step evacuation of a building. This results in the following advantages:

- Reduced capacity peaks of the escape routes and especially of staircases: When the complete building is evacuated at once, people flock to the staircases on all floors at the same time. This leads to considerable tailbacks.
- Low probability of panic reaction: The awareness of being subjected to danger without being able to do anything (blocked exits) easily leads to panic reactions, the consequences of which may be even worse than those of the actual fire.
- Restriction of evacuation to the minimum is absolutely necessary: The complete evacuation of an entire building is only recommendable when the fire can no longer be controlled. It is mostly sufficient to evacuate one or several fire compartment(s).
The method established as a quasi-standard provides for the floor on which a fire occurs, as well as those immediately above and below, to be evacuated during the first phase. Depending on region and usage, the attic floor and all basement floors can also be evacuated during this first phase. As the fire spreads, all other floors are evacuated one after the other in subsequent evacuation phases. During the first phases, a warning message instructed people on these floors to wait.
5.4.4 System

Voice alarm systems consist of a control unit protected against power failure, with relatively few input channels and serving a whole network of loudspeakers on the output side.

Figure 5.4: System overview of a voice alarm system

Voice alarm system control units are equipped with an emergency operation circuit covering all processing steps, which means that in case of failure of any of the modules, alarm capability is completely maintained. In cases where this emergency operation circuit is not (or only partially) available, it is most likely a public address system for background music and voice messages. To raise such systems to the safety standards of voice alarm systems normally requires unreasonably high labor and time expenditures.
5.4.5 System Configuration and Operation Concepts

With medium-sized and complex installations, voice alarm systems are increasingly designed as networks distributed all over the building, with different decentralized subsystems being responsible for the local loudspeaker periphery, for example grouped on floors. The subsystems are interconnected by means of a network, principally enabling a central parameter setting of the different system components. Whether these central parameter settings have indeed been made and how comprehensive the functionality of these settings is needs to be clarified in advance with each system.

Such a decentralized structure considerably reduces both the required cabling and the installation costs and guarantees optimum system flexibility in case of a change in building usage, for instance.

Relating to network technology, state-of-the-art systems even go so far as to combine several neighboring buildings. This means that each building has its own independent control unit, but can also be operated from some other remote control unit if required (campus structure), cutting staff costs significantly.

Of course, the loudspeakers’ cabling is made with copper cables of a diameter sufficient to transmit the required power, while the network cabling with digital transmission is made in the form of conventional bus cabling. The slightly higher material costs of a decentralized configuration are not only contrasted by the higher cabling costs of the central structure (length of the copper cables, cable diameters required for power transmission) but also by the transmission loss over the complete transmission distance, which also leads to additional costs on the part of emergency power supply. With longer distances, the use of fiber-optic cables has proven worthwhile, which is why more and more systems support this type of cabling.
Of course, several independent control units at one company location require considerably more staff, which is why decentralized, non-operated subsystems are generally preferred.

5.4.6 Fail Safety and Amplifier Technology

In contrast to public address systems for background music and voice messages, the functions provided by a voice alarm systems must be available at any time, requiring a high degree of fail safety. This is ensured by generally high reliability of the different components. On top of this, these systems have redundant amplifiers that are automatically put into operation in case of breakdown of an amplifier (automatic “hot swapping”). Like the amplifiers, most components should be redundant – from internal and external cabling and the input interfaces (microphones) to the stored voice messages, many system components are available twice or even more. This is one of the reasons why a public address system cannot simply be used as an emergency warning system – as safety systems must ensure a considerably higher fail-safe standard than conventional systems applied for everyday use.

Digital audio technology opens up new application possibilities for voice alarm systems. Thanks to digital signal processing, it has become possible to simultaneously transmit multiple audio channels with different audio signals on one and the same digital system bus. Furthermore, due to the introduction of digitally switched amplifiers (class D amplifiers), it has become possible to significantly increase the degree of efficiency of the amplifiers. This reduces power consumption by approximately one third, the capacity requirement of the emergency power supply is reduced by approximately 50%, and waste heat generation by approximately two thirds (in comparison to analog amplifiers, which often convert more than half of the supplied energy into heat).

![Figure 5.6: 180W amplifiers – efficiency and energy loss](image)
Although the energy loss (in watts) indicated in the figure above is also relevant regarding the current consumption, the difference becomes obvious when sizing the emergency power supply. The decisive factor, however, is usually that systems with a low energy loss factor can also be applied for background music and public address (PA) purposes in unventilated and non-airconditioned rooms, whereas conventional systems generate much higher costs due to the necessity of air conditioning.

### 5.4.7 Amplifier Concepts

**Bulk amplification** is the “original recipe” of voice alarm: First, the correct sound source (e.g. music, message or evacuation) is selected, then the loudspeaker groups are determined to which the amplified input signal shall be connected. In most cases, one large amplifier is used which can support all loudspeaker groups if required. The advantage of this concept is ease of configuration. However, due to the required emergency amplifier size, this variant is not necessarily the most economic one. And, with this solution, the complete lengths of line for the loudspeaker cabling must also be considered, which has a negative effect on costs.

When two or more amplifiers and a relay-equipped distributor board are used, bulk amplification also provides for the simultaneous transmission of different channels.

**Zone amplification** benefits from modern, simple electronic channel allocation, enabling a cost-efficient, free allocation of the desired sound source to the zone amplifiers which in turn are connected to the respective loudspeaker zone. Zone amplification offers the following benefits:

- The backup amplifiers need not cover all loudspeaker groups and may thus be smaller. Frequently, several backup amplifiers are used, leading to a higher degree of fail safety.
- Different loudspeaker groups can transmit different messages simultaneously. This is a precondition for phased evacuation. The areas adjacent to the danger zone are acoustically alerted with the warning message, while the evacuation of the immediately endangered areas is already in progress.
- Decentralized concepts increase safety but can only be implemented with zone amplification.
Figure 5.7: Comparison between bulk amplification and zone amplification

In practice, neither pure zone nor pure bulk amplification is used. Due to the specific building situation, it makes sense to choose a “mix” of both principles, covering individual requirements in the best possible way.

5.4.8 Loudspeaker Line Cabling

The easiest cabling type, class B cabling, shows no redundancy and no relevant fail safety. In case of an open-circuit or short-circuit on one line, the complete loudspeaker line will break down. With class A cabling, an open-circuit does not impair the functionality, while a short-circuit leads to a breakdown of the complete loudspeaker circuit. With mixed class A/B cabling, every second loudspeaker is connected to a different loudspeaker circuit. In case of an open-circuit or short-circuit, every second loudspeaker is still available, which of course leads to reduced sound intensity.
5.4.9 System Embedding and Interfaces to Building Automation

The transmission of a fire alarm from the fire detection system control unit to the voice alarm system can, in the simplest case, take place by means of potential-free contacts. The signal can be transmitted as a collective alarm or as an alarm of a detection area or detector zone. In addition, the “Acoustics On/Off” or “Evacuation Alarm On/Off” signal should be transmitted to be able to interrupt the transmission of alarm messages if necessary. If the fire detection control unit has been reset successfully, the voice alarm system should be automatically reset as well. Any occurring faults in the voice alarm system must be transmitted to the fire detection control unit as a collective fault.

Figure 5.9: Interfaces to the fire detection system
### 5.4.10 Operating Concepts and Organization Principles

Voice alarm systems can be operated in different ways: With or without automatic connection to the fire detection system, by internal staff, or by the fire brigade, with recorded messages or live announcements, or with both message types – to mention only the most important influencing factors.

Decisive for the organization principle are usually the national and/or local directives. In France, for example, live announcements are forbidden. In Germany, some fire brigades do not accept automatic evacuation.

Such manifold requirements call for flexibility. The voice alarm system must thus be capable of taking into account all requirements resulting from the individual situation in such a way that the overall process is coherent and elaborate.

For the correct functioning of voice alarm, good implementation of the organizational fire protection is decisive. This means especially that the most important problem areas must be addressed:

- Make sure that the escape routes are adequately signaled so that they are easy to find, also in smoky premises.
- Make sure that the escape routes are and remain free. Employees must be constantly made aware of the fact that no material may be stored in escape routes.
- Organizational fire protection can only work when rehearsed and trained at regular intervals.
- All people in charge and their deputies are aware of who assumes which tasks and in which sequence in case of emergency.
- The information concept lays down who must be informed when, in which way and under which circumstances. The information flow is tested and permanently adapted to changing general conditions.

The weak points of organizational fire protection are virtually equivalent to the weak points of human beings. People work especially reliably when they have been able to rehearse situations they are not familiar with. This is another reason to take training extremely seriously (see “Emergency Training” starting on page 181).
5.5 Planning

The planning, execution and maintenance of voice alarm systems require special technical qualifications of planners, installers, operators and service staff. During the planning phase, intensive cooperation between planners, installers, operators, authorities and the fire brigade is required to define the alarm organization.

In doing so, especially the following topics have to be dealt with and tasks need to be resolved:

- Defining the alarm areas, in consideration of the fire sectors as well as the escape and rescue routes.
- Overlapping of fire detection and alarm areas.
- Determining the sound interference level and thus the required sound pressure levels.
- Calculation of the maximum acoustic irradiation area for each loudspeaker (see “Diagram of loudspeaker arrangement” on page 177 and Table 5.2 to Table 5.4).
- Consider the room-acoustic influencing factors such as reverberation time, echo and runtime delays, which may have an overall impact on the speech intelligibility.
- Determining the required number of loudspeakers and the required amplification power.

5.5.1 Loudspeaker Selection

Different loudspeaker types are available for project planning. Among others, these are:

- recessed loudspeakers
- wall-mounted loudspeakers
- horn loudspeakers
- spherical loudspeakers
- pressure-chamber loudspeakers

Some of these loudspeaker types are additionally available as both outdoor and indoor speakers, increasing the variety even more.

Added to this are different placement possibilities. Ceiling-mounted speakers are best suited to achieve a uniform, easily comprehensible sound irradiation. Wall-mounting requires fewer speakers and is consequently more economic, but wall-mounted loudspeakers generate high sound intensities in their immediate surroundings. Up to a mixed form of inclined loudspeakers, there is a variety of different types, helping to determine the optimum variant in consideration of the budget and the customer’s wishes.

Loudspeakers with a high degree of efficiency bring about a considerable reduction of the required amplifier performance. For good speech intelligibility, the effective sound level must be at least 10dBA higher than the noise level. Consequently, correct information on the noise exposure is required for proper planning of a voice alarm system.
5.5.2 System Layout / Decision on Full or Partial Sound Irradiation

Full sound coverage is of course the ideal case. But when it cannot be considered for cost reasons, partial sound irradiation is possible in such a way that – depending on the regulation – for example the aisles are irradiated and the sound intensity raised to a level where people in the adjacent offices become aware of the message. The sound absorption value of doors is in general between 29 and 40dBA. In such cases, it must be taken into account that the sound intensity in the aisles does not become unbearably high.

With partial sound irradiation, it must be taken into consideration that individual, soundproof rooms such as conference rooms, managers’ offices, electronics control rooms or archives are directly irradiated.

5.5.3 Irradiation areas

The so-called opening angle of the loudspeakers determines the loudspeaker’s angle of irradiation. The larger this angle, the larger the area that can be covered. This is, however, at the expense of speech intelligibility, due to the equally increasing sound reflection.

Decisive for the irradiation area is the room height at a given opening angle.

![Diagram of loudspeaker arrangement](image)

Figure 5.10: Diagram of loudspeaker arrangement
Based on this diagram, the coverage areas listed in the tables below result as a function of the opening angle and ceiling height:

<table>
<thead>
<tr>
<th>Ceiling height</th>
<th>3</th>
<th>3.5</th>
<th>4</th>
<th>4.5</th>
<th>5</th>
<th>5.5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>[m]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance between loudspeakers</td>
<td>m</td>
<td>11.2</td>
<td>14.9</td>
<td>18.7</td>
<td>22.4</td>
<td>26.1</td>
<td>29.9</td>
</tr>
<tr>
<td>[m²] Coverage area per loudspeaker</td>
<td>125</td>
<td>223</td>
<td>348</td>
<td>501</td>
<td>682</td>
<td>891</td>
<td>1'128</td>
</tr>
</tbody>
</table>

Table 5.2: Coverage area with moderate intelligibility – alpha = 150°

<table>
<thead>
<tr>
<th>Ceiling height</th>
<th>3</th>
<th>3.5</th>
<th>4</th>
<th>4.5</th>
<th>5</th>
<th>5.5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>[m]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance between loudspeakers</td>
<td>m</td>
<td>5.2</td>
<td>6.9</td>
<td>8.7</td>
<td>10.4</td>
<td>12.1</td>
<td>13.9</td>
</tr>
<tr>
<td>[m²] Coverage area per loudspeaker</td>
<td>27</td>
<td>48</td>
<td>75</td>
<td>108</td>
<td>147</td>
<td>192</td>
<td>243</td>
</tr>
</tbody>
</table>

Table 5.3: Coverage area with normal intelligibility – alpha = 120°

<table>
<thead>
<tr>
<th>Ceiling height</th>
<th>3</th>
<th>3.5</th>
<th>4</th>
<th>4.5</th>
<th>5</th>
<th>5.5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>[m]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance between loudspeakers</td>
<td>m</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>[m²] Coverage area per loudspeaker</td>
<td>9</td>
<td>16</td>
<td>25</td>
<td>36</td>
<td>49</td>
<td>64</td>
<td>81</td>
</tr>
</tbody>
</table>

Table 5.4: Coverage area with good intelligibility – alpha = 90°

The above tables give the calculated, correct coverage area. In practice, these areas are usually considerably exceeded for cost reasons, or fewer loudspeakers are installed than should be required based on this formula – this is especially the case with low ceiling heights. The crux of the matter is to maintain the required speech intelligibility with possibly few loudspeakers.

The number of required loudspeakers thus decreases with the ceiling height. However, it must not be overlooked that with constant sound performance, the sound pressure on ear level decreases to the square of the distance. If the sound pressure shall remain constant, however, a square increase of the electric performance per loudspeaker is required.

As a rule of thumb, sound-absorbing surfaces such as carpets and curtains reduce both sound intensity and reflections, at the same time increasing the speech intelligibility. As on the one hand the standards require minimum speech intelligibility, while on the other hand the number of loudspeakers constitutes a massive cost factor, we are faced with an optimization problem. Planners specialized in acoustics are capable of calculating the speech intelligibility in advance and performing the required system optimization in advance, in compliance with individual conditions.
5.5.4 Emergency Power Supply

In case the voice alarm system is part of a fire detection system, the emergency operating time for the supply of the voice alarm system, ready for operation, must be ensured by the battery.

<table>
<thead>
<tr>
<th>Emergency operating time</th>
<th>Prerequisite / precondition</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 hours</td>
<td>A standby mains system must be available for the voice alarm system, being able to maintain operation for at least 30 hours. A mains failure must be recognized at any time (permanently manned, responsible monitoring station).</td>
</tr>
<tr>
<td>30 hours</td>
<td>The fault is recognized in time (permanently manned, responsible monitoring station) and maintenance is ensured within 24 hours.</td>
</tr>
<tr>
<td>72 hours</td>
<td>If the conditions for the emergency operating time cannot be fulfilled, neither for 4 hours nor for 30 hours.</td>
</tr>
</tbody>
</table>

Table 5.5: Emergency operating time and prerequisites

In voice alarm systems integrated into a danger management system, the battery capacity must be calculated so that at the end of the emergency operating time, the battery is still capable of continuing alarm signaling for 30 minutes. This means that at the end of the emergency operating time, the batteries must be able to supply a multiple of their nominal discharge current without any admissible voltage drop (see section 4.6.1.2 on page 121).
5.6 Installation and Commissioning

The system components used must comply with the relevant standards and must bear the corresponding approvals (EN 54-16, BS 5839 part 8, UL 864, etc.).

During installation, a careful selection of the loudspeakers regarding their opening angle, nominal sensitivity and loading capacity must be taken into consideration:

- Ensure the correct placement and alignment of the loudspeakers, i.e. an even coverage of the areas to be irradiated. If in doubt, consult a specialized acoustics planning office.
- Calculation of the emergency power requirements and the required capacity of emergency power supply according to EN 54, Part Emergency Power Supply (EN 54-4).
- The cabling must comply with the relevant local regulations. This is especially important in terms of fail safety.
- Alarm signals must at any time be at least 10dBA above the noise level, based on the highest noise level to be expected.
- Speech intelligibility must be measured at a sufficient number of representative points and must be larger than or equal to 0.7 CIS throughout the complete coverage area (see Glossary starting on page 297).

In case of automatic actuation of the voice alarm system by the fire detection control unit, it must be ensured that no false alarms will occur in the fire detection system. Therefore, a possibly high performing and false alarm-free detection is to be ensured. Manufacturers, whose products are really able to distinguish between deceptive and real alarm are also in a position to give proof of this (e.g. in a fire test room for customers where fire and deception tests can be carried through).
5.7 Emergency Training

By emergency training we understand the simulation of emergency situations by building users and operators. This must be clearly distinguished from the fire brigade’s emergency training sessions, which are not taken into account in this section.

While in the United States emergency training sessions are stipulated by the authorities and performed regularly, in Europe – with the exception of Great Britain – only few people really care about emergency training. Both the more complex and different building structures and the unfavorable fire statistics of the United States partly explain this discipline. The American fire damage statistics are decisively influenced by wood construction habitual for detached houses and by the disadvantageous mains voltage. The mains voltage, with 110V half of that in Europe, requires twice the amperage to ensure equal performance, at the same time producing four times as much heat on wires and bad contacts. However, it should not be overseen that the size of building structures is growing continually in Europe, due to an advancing concentration process.

Most countries oblige building operators to perform emergency training sessions. But these requirements are usually limited to companies subject to the statutory order on hazardous incidents or companies that store toxic or fire-promoting substances, such as gases, or that concentrate their activities on biotechnology, thus representing a considerable hazard potential. But emergency training sessions make sense in every building. This becomes obvious with the example of the administrative building in which the director remained in his sound-isolated office while the building was evacuated! Only by the aid of training sessions can such weak points of the protection concept be recognized without endangering people.

Experience continues to show that an evacuation is never complete because only a maximum of 95% of the building occupants are reached. Toilets, electronic rooms, cleaning rooms and other remote zones such as archives in the basement, etc., must be checked by the people in charge. Major problems are also caused by the evacuation of employees of external companies, for example electricians and cleaning personnel. Quite often, these people are literally left out of the evacuation process. In addition, there is the problem of foreign workers who often do not understand voice messages as they do not master the language. These reasons underline the importance of emergency training sessions: Good evacuation is only possible when people are trained accordingly and faults occurred in the past can be corrected.

By means of previous instructions, checks in parallel with the training and subsequent evaluation, emergency training sessions therefore aim at ensuring the following:

- If possible, all people in the building are evacuated, including the employees of foreign companies, guests, etc.
- The behavior of people correctly considers the type of danger.
- Evacuation is quick and smooth.
As soon as the people have reached the meeting point, presence checks must follow immediately so that any missing persons can be informed in good time.

To perform emergency training sessions, it is recommended to call upon the help of experts. This is the only way to guarantee that the best possible results can be achieved within the shortest possible time.
5.8 Profitability and System Evaluation

Profitability assessments should encompass the following aspects:

- The costs of a voice alarm system are contrasted by even higher benefits when the system is also used as a public address system. This becomes possible when the system overrides the public address system in case of alarm by means of an automatic priority switching function. However, some voice alarm systems have a frequency range that is insufficient for music; this can easily be clarified.

- The cost of the emergency power supply is substantial if the required run times for emergency operation are adhered to. Not all suppliers observe such regulations, but adherence to them can be decisive in case of emergency.

- Digital amplifiers of class D have a degree of efficiency of 80% minimum. A simple extrapolation shows that such amplifiers quickly amortize their additional costs. Their advantage lies not only in their low power consumption but especially in emergency power supply as well as building air conditioning that needs to carry off the dissipated heat. Furthermore, the use of a control unit room is not only limited by the heat released by the control units (room temperature) but also by the noise generation when a large number of fans are used.

- Voice alarm is part of safety technology and, as part of the building automation and control system, must by no means be confused with entertainment electronics. The performance of modern entertainment electronics systems is still unparalleled, but what is much more important than the final pinch in performance is the long-term availability of spare parts and an efficient maintenance department. For this reason, provider and maintenance organization are often more decisive than technology itself.

- More than ever, voice alarm has become a standard. Setting the course for voice alarm today means bringing the right infrastructure to a building that may well have a service life of 50 years or more. The largest cost pool of voice alarm is the loudspeaker cabling – this is an investment into the entire life of a building.

- Voice alarm is more than a simple trend. Its continuous spread is favored by such different factors as technological progress, decreasing price levels, the development in liability law and social changes. Last but not least, we must ask ourselves whether long term, we can really afford doing without something that may save people’s lives.