Outdoor Warning Systems

Technical Bulletin (Version 2.0)

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FEMA

Prepared For

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PREFACE

This bulletin provides enhanced guidance to improve the usefulness of the Federal Emergency Management Agency's (FEMA) Civil Preparedness Guide (CPG) 1-17 policy.[1] FEMA's CPG 1-17 is a practical guide developed to aid public officials in determining the requirements for outdoor warning systems. Since the initial publication of FEMA CPG 1-17, *Outdoor Warning Systems Guide*, March 1980, there has been a significant evolution and expansion of technology that can be applied to public alert and mass notification in response to emergencies. This includes better ability to target warnings to affected populations, improved voice warning capabilities, highway electronic message signs, computerized control and system integration, cellular and radio communication methods and capabilities, improvements in telephone communications, as well as improved and faster digital communication methods.

All methods of alert and notification have advantages and disadvantages related to cost, population coverage, response time, the extent of public awareness, and awareness education. Additional considerations include the ability to operate with commercial utility power supply, from back-up power alone (e.g., batteries or emergency generator) when the commercial power grid is unavailable, in the absence of telephone line service when disconnected, and the manpower required to keep the system operating.

Given these numerous considerations—and the unique circumstances of communities of every size across the nation—it is important to understand that *there is no single method of alert and notification that meets the needs of every portion of every community in every situation*.

Accordingly, this bulletin has been prepared to assist states, Federal officials, tribes, and communities in determining the alert and notification methods that *best meet their individual needs*. This bulletin imposes no requirements on states, tribes, and localities with respect to the types or extent of public outdoor warning system they should have. It is, however, intended to help each community find a solution or set of solutions that are not only the most effective for its particular needs, but that are within the bounds of its available resources. Finally, if a community decides to install, modernize, or expand its public alerting system, this bulletin provides information that can facilitate the selection, purchase, installation, and operation of the system.

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[1] In FEMA Fiscal Year 2003 Appropriations Bill, House Report 107-740 directed FEMA to update CPG 1-17, *Outdoor Warning Systems Guide*, March 1980 (which is now out of print). This bill was enacted under Public Law 108-7, *Fiscal Year 2003 Omnibus Appropriations Act*. House Report 107-740 directed that the update to CPG 1-17 "*must* be updated to reflect *some* of the technological advances that have taken place since originally published in 1980" [*emphasis added*]. In addition, the House report specifies that the update to CPG 1-17 "*shall* reflect the benefits of using voice technology to address all natural and man-made hazards, including acts of terrorism, and *shall require* that all warning systems be operable in the absence of AC supply power" [*emphasis added*]. FEMA is also urged "to consult with other relevant agencies and use the updated guidance *as the baseline for formulating a national standard for outdoor warning and mass notification* that reflects the latest state-of-the-art technology" [*emphasis added*].

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EXECUTIVE SUMMARY

An outdoor Public Alert System (PAS) is critical to an effective alert and notification process.[2] PAS planning includes determining the best method for alerting and notifying the public by considering demography, topography, meteorology, potential hazards, man-made structures or systems (i.e., the built environment), ambient noise levels, and the available power supply.

This bulletin concentrates on providing guidance for site selection and operation of audible outdoor PAS devices as part of a larger PAS. It includes extensive sound propagation and system configuration information related directly to outdoor voice warning, including guidance related to locations where outdoor voice warning is the most effective. Electronic message signs used to provide visible warnings to motorists are also addressed.

The bulletin is structured to present basic information for emergency management officials in the documents main narrative. If a reader is interested in gaining a more detailed understanding of PAS topics (e.g., alerting a sleeping population or speech intelligibility) appendices provide this in-depth topic information.

Whether by use of topographic mapping or by more advanced methods such as geographical information system (GIS)-based design, the outdoor PAS planning process consists of the following condensed steps:

1) Identifying those areas where outdoor alerting methods will be most effective;
2) Identifying the populations in need of alerting;
3) Measuring the surrounding "ambient" noise levels;
4) Evaluating the terrain;
5) Examining weather conditions, including typical conditions and extremes;
6) Understanding where outdoor devices should be avoided;
7) Determining the best possible locations for individual outdoor PAS devices;
8) Evaluating outdoor PAS alternatives;
9) Selecting the appropriate system for local needs; and
10) Estimating the cost of the planned outdoor PAS.

To help emergency managers achieve alert and notification objectives, this bulletin also addresses planning, design, control, testing and operation *means* and *methods*, including:

- Changes in outdoor PAS technology;
- Improvements in analytical methods;
- Integration of electronic message signs into outdoor PAS;

[2] To facilitate the public's timely alert and notification on a consistent basis, complementary warning methods for special populations (e.g., hearing-impaired), institutions (e.g., hospitals, schools, large industrial or commercial facilities), or residences should be included in a comprehensive outdoor *and* indoor PAS.

- Use of computer-based activation, control, monitoring, and testing methods such as supervisory control and data acquisition (SCADA) systems;
- Outdoor voice warning intelligibility and locations where outdoor voice warning is most effective; and
- Audible range methodologies.

Also, the bulletin contains outdoor PAS requirement information. Key requirements include:

- Current warning system protocols;
    - three to five minute steady siren or horn alert signal for natural disaster warning,
    - three to five minute wavering or warbling siren alert signal or short horn blasts to warn of enemy attack,
    - one minute siren alert test signal, and
    - when voice capable equipment is in place, voice warning or instruction following the siren or horn alert
- Back-up power requirements;
    - adequate back-up power should be available to perform at least 15 minutes of alerting,
    - back-up power equipment should be recharged to 80% of the maximum rated capacity from the fully discharged state within 24 hours,
    - back-up power systems should be able to maintain the "standby mode" without alternating current (AC) power for at least 24 hours, and
    - when batteries are used for back-up power, they should be of a maintenance free design with a battery life of three years
- Requisite sound and component details;
    - the propagated sound must be 10 dB greater than background noise,
    - the outdoor PAS equipment must be able to project 120 dB of sound at least 100 feet, and
    - officials are encouraged to incorporate control mechanisms such as SCADA systems into outdoor PAS layouts whenever possible.

Finally, a list of outdoor warning systems installations and their associated costs is found in *Appendix G,* and checklist for use by local officials to guide the definition of system selection is included as *Appendix H.*

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1.0 INTRODUCTION

Outdoor warning systems are intended to save lives and minimize property losses by alerting and notifying those at risk in a timely manner. Outdoor warning systems—also referred throughout this document as outdoor "public alerting systems" (PAS)—play an essential part of the overall alert and notification process for a wide variety of emergencies. Even though this document contains information on indoor alerts and personal messaging, its focus is upon *outdoor warning*.

The purpose of this bulletin, then, is to set forth basic principles that are applicable to audible outdoor warning devices and to describe a method for planning and laying out an effective outdoor warning system. This bulletin concentrates on the selection, siting, testing, and operation of audible outdoor warning devices.

Traditionally, people have relied on outdoor PAS to alert them to an emergency in the area. Electro-mechanical sirens are typically the most effective way to alert a large number of people in the shortest possible time. These devices are very cost-effective, as well, in terms of installation cost, reliability, and maintenance. However, electronically amplified devices provide the versatility of producing many different sounds, most notably the human voice. Hence, such devices can provide the valuable benefit of additional alerts and notification flexibility.

If a community chooses to use outdoor devices for its PAS, the methodologies in this bulletin can help determine expected sound-making coverage based on the specific terrain features, demography, and weather conditions that may apply.

To this end, this bulletin reviews standards for any outdoor PAS and the need for all parts of the integrated PAS to be interoperable. This bulletin also includes extensive information related directly to outdoor voice warning, including guidance related to voice intelligibility and locations where outdoor voice warning is the most effective. In addition, electronic message signs used to provide visible warnings to motorists are also addressed.

However, because a typical outdoor PAS uses sound as the primary means of alerting the public to danger, this bulletin begins with a brief introduction to the terminology and principles of sound and how it is perceived.[3]

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[3] In most cases, other means are used to complete the alert and notification process either alone or in combination with the outdoor PAS. These other means include telephone; pagers; automated dialing; commercial radio; mobile route alerting; indoor alerting and/or loudspeakers; personal notification of individual residences; emergency alert system (EAS); special-purpose locally activated radio stations and receivers; tone alert radios (TARs); combinations of over-the-air, cable-based, and satellite-based broadcast methods; computer networks; the National Warning System (NAWAS); and National Oceanic and Atmospheric Administration (NOAA) all hazards weather radio (NWR). *These other methods are not addressed in detail this bulletin*.

This bulletin also sets minimum standards for back-up power supply in the absence of AC power for new and updated PAS. These standards are consistent with proven technology, will incorporate applicable codes and standards requirements, and, most importantly, meet public safety needs. The codes and standards, when applied, are also examined in the discussion of equipment purchasing, as is the level of support anticipated during the operational life cycle, including the testing, maintenance, and inspections necessary to ensure that an outdoor PAS will operate properly throughout its design lifetime.

2.0 Principles of Sound and How It Is Perceived

The principles of sound and its movement through the atmosphere are fundamental to understanding the way in which audible PAS devices work at both the device and system levels. This section will introduce the key components of sound and how they are measured, the atmospheric conditions that can influence how far sounds will travel, and the environmental "barriers"—be they buildings or noise—that can decrease our abilities to perceive certain sounds.

2.1 Loudness and Frequency

Sound is a form of mechanical energy that moves from a source (e.g., a voice, a musical instrument, or an emergency siren) through the air as tiny oscillations above and below the surrounding air pressure. Sound travels at a speed of about 1,000 feet per second through the air, but variations in this speed can be caused by wind, turbulence, humidity, and temperature. When people hear sounds, they can distinguish their: 1) *loudness* (volume); 2) *frequency* (pitch); and 3) *modulations* (variations) in loudness and frequency over time (i.e., the changes in sound that allow us to discern and interpret speech or a specific musical passage.)

Instruments used to determine loudness measure the magnitude of sounds in decibels (dB). The decibel scale is such that a sound that is twice as loud as another is 10 dB higher, meaning it is also 10 times more *intense* (i.e., it has 10 times the sound pressure.) In other words, a sound that is 80 dB is twice as loud as 70 dB, four times as loud as 60 dB, eight times as loud as 50 db, and so on down the scale. (For a more detailed discussion of loudness, variations of the decibel scale used by government and industry, and how these are applied by Occupational Safety and Health Administration (OSHA), see Appendix B: Weighted Decibel Scales.)

To help provide a common frame of reference, Table 1 below contains some common sounds and their decibel ratings, along with their magnitudes relative to 70 dB:

Table 1: Sound Levels (dB) and Relative Loudness of Typical Noise Sources[4]

dB	Outdoor Noise Levels	Subjective Loudness (Relative to 70 dB)
120	Military jet aircraft take-off from aircraft carrier with afterburner at 50 ft. - 130 dB	32 times as loud
110	Turbo-fan aircraft at takeoff power at 200 ft. - 118 dB	16 times as loud
100	Boeing 707 or DC-8 aircraft at one nautical mile (6,080 ft) before landing - 106 dB Jet flyover at 1,000 ft. - 103 dB Bell J-2A helicopter at 100 ft. - 100 dB	8 times as loud
90	Boeing 737 or DC-9 aircraft at one nautical mile (6,080 feet) before landing - 97 dB Motorcycle at 25 feet . . . 90 dB	4 times as loud
80	Car wash at 20 ft. - 89 dB Propeller plane flyover at 1,000 ft. - 88 dB Diesel train 45 m.p.h. at 100 ft. - 83 dB	2 times as loud
70	Passenger car 65 m.p.h. at 25 ft. - 77 dB Freeway at 50 ft. from pavement edge 10 a.m. - 76 dB	(70 dB)
60	Air conditioning unit at 100 ft. - 60 dB	1/2 as loud
40	Bird calls - 44 dB	1/8 as loud

Sound measuring instruments can also determine the frequency, or pitch, components of a sound and express these in terms of hertz (Hz). Average human hearing range is usually defined as running from a lower limit of 50 Hz to an upper limit of 20,000 Hz, with this latter number often expressed as 20 kilohertz (KHz). At the lower limit, as front row attendees at rock concerts can attest, one can literally feel the blast of sound, with much of what is felt consisting of "infrasound" that is below the range of human hearing. At the higher limit, "ultrasound," the high-pitched tone of dog whistles can exceed the threshold of most humans' hearing, but not that of canines.

As a general rule, lower frequencies carry farther in the air than higher frequencies because high frequencies *attenuate*, or lessen with distance, much more readily. Therefore, the frequency components of the sound from a PAS are extremely important in determining how far that sound will carry through the air and how well it will be heard. Hence, even though average human hearing extends well beyond their range, most audible PAS devices produce sounds within the frequency range from roughly 300 to 1,000 Hz.

2.2 Attenuation

It is well known that sound decreases in loudness at greater distances from its source. This is called "attenuation with respect to distance." An audible PAS device's effective range *is* the distance at which the sound is predicted to attenuate to a predetermined value, typically 70 dB. Factors that affect attenuation rate include frequency, prevailing

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[4] M.C. Branch, et al., Department of City Planning, City of Los Angeles, *Outdoor Noise and the Metropolitan Environment*, 1970.

wind conditions, terrain (e.g., flat vs. hilly), atmospheric stability, temperature, and humidity. Such effects, which are characteristic of the propagation of sound out-of-doors, are caused by the factors described below.

Divergence. As sound radiates away from a source, its intensity decreases with distance because the energy of its original sound pressure is spread over a larger and larger area.

Outdoor Sound Absorption. Absorption of sound outdoors is most affected by the terrain and the atmosphere. Those losses associated with the change of acoustical energy to heat are reasonably well understood as a function of atmospheric temperature, humidity, and pressure. This loss is directly proportional to the distance traveled, and, once again, high frequency sounds suffer more atmospheric absorption loss than lower frequency sounds.[5]

Refraction. One of the more complex—but important—effects in outdoor acoustics is the refraction of sound by temperature and wind velocity gradients. In a calm daytime atmosphere, temperature decreases with increasing height above the ground and is known as a *temperature lapse*. Because sound speed through the air is proportional to the square root of air temperature, sound velocity decreases with height, and, as a result, sound waves have a tendency to bend upward under calm conditions. A further result is that an *acoustic shadow* is formed at the ground level, an area where the sound reaching a listener is greatly reduced because the sound wave is being bent upwards and away from the listener. Under extreme conditions, such acoustic shadows can form very close to the source in the upwind direction.

Acoustic shadow zone formation is shown in **Figure 1** below:

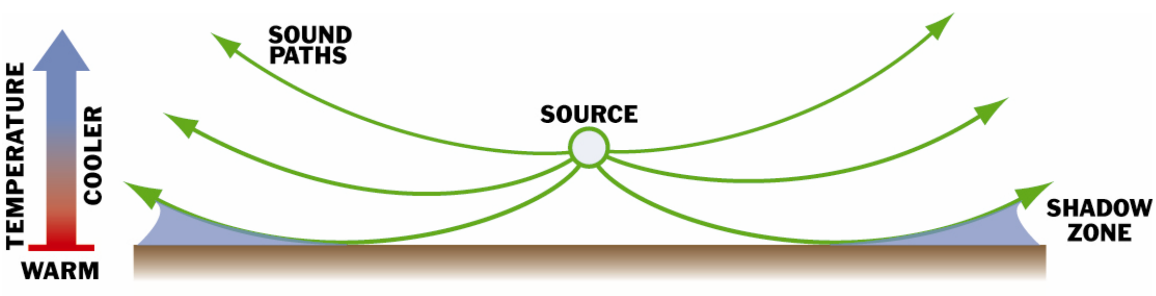

Figure 1: Sound Transmission in Temperature Lapse Conditions[6]

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[5] ANSI Standard S1.26, *Method for the Calculation of Absorption of Sound by Atmosphere*, should be used to calculate atmospheric absorption coefficients.

[6] Joint Departments of the Army and Air Force TM 5-805-4/AFJMAN 1090, *Noise and Vibration Control*, May 26, 1995.

The opposite effect occurs in a *temperature inversion* (i.e., in those instances when the temperature decreases the closer one is to the ground). Because of the ground's capacity to retain heat absorbed during daylight hours, temperature inversions typically occur at night when this heat is being released, and this is why the same sound source usually sounds louder at night than in the daytime.

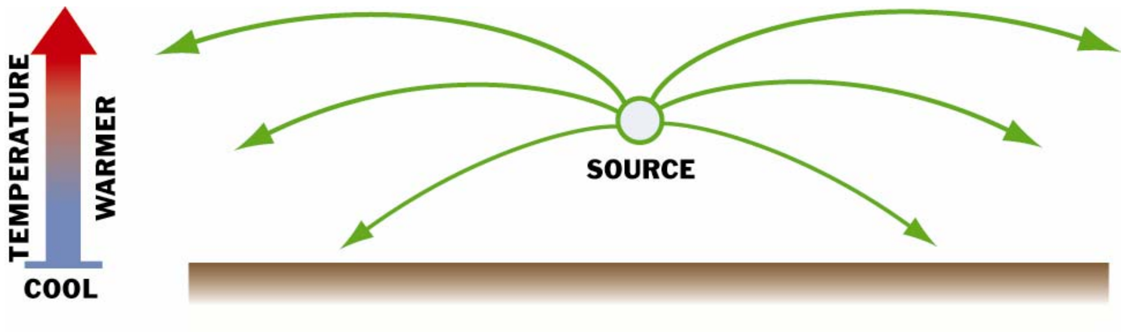


Figure 2: Sound Transmission in Temperature Inversion Conditions[7]

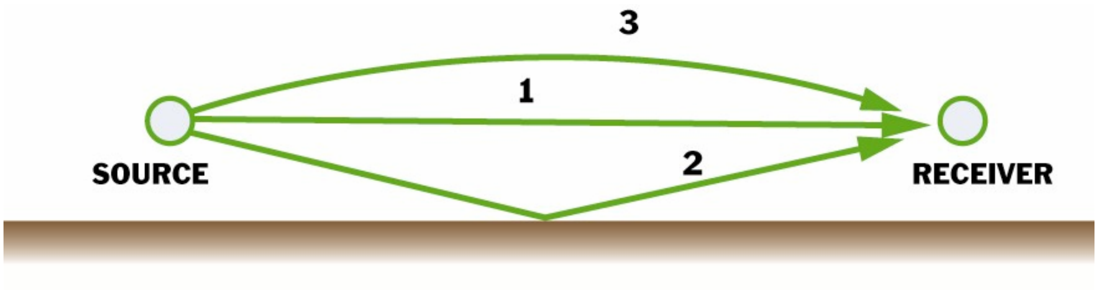
Ground Absorption. As noted above, when sound radiates away from its source, its loudness decreases with distance because its energy is spread over a progressively larger area. However, additional attenuation of sound can occur when the sound propagation path is close to the ground. For acoustically "soft" surfaces such as grass-covered soil, excess attenuation beyond roughly 250 feet can be significant, amounting to approximately 6 dB per distance doubled over large distances. Sound traveling through deep foliage and woods is affected by even greater vegetative absorption and, as shown in Table 2, 100 feet of travel through medium-dense woods can cause significant attenuation.

Table 2: Sound Transmission Loss through Medium-Dense Woods[8]

Octave Frequency Band, Hz	Sound Transmission Loss, dB per 100 feet
31	0.0
63	0.5
125	1.0
250	1.5
500	2.0
1,000	3.0
2,000	4.0
4,000	4.5
8,000	5.0

[7] *Ibid.*
[8] *Ibid.*

On the other hand, acoustically "hard" or "reflective" surfaces such as concrete, asphalt, water, or ice provide significantly less attenuation, and the loss can decrease to as low as 3 dB per distance doubled.



Path 2 in the figure above depicts how a "hard" acoustical surface can reflect sound upwards, increasing its perceived loudness.

Figure 3: Outdoor Sound Propagation near the Ground[9]

Wind. Wind velocity adds or subtracts from sound velocity depending on whether the sound is moving upwind or downwind. In addition, wind velocity typically increases with increasing height, thus further augmenting the refraction of sound away from the ground. As shown in Figure 4, the acoustic shadow will form in the upwind direction even closer to the sound source than under calm conditions, with the shadow's proximity to the source increasing with the speed of the wind; on the other hand, a downwind position will decrease or—given strong enough winds—totally eliminate the acoustic shadow.

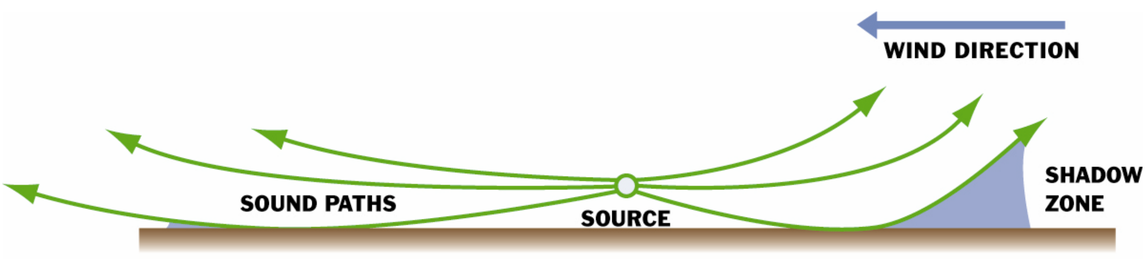


Figure 4: Upwind Sound Propagation[10]

Precipitation. Excess attenuation in precipitation is closely coupled to the effects of wind and temperature gradients that produce rain, snow, fog, or sleet. However, there is no measurable attenuation from precipitation on frequencies below 2,000 Hz.
Thus, audible PAS frequencies tend to be between 300 and 1,000 Hz, attenuation from precipitation in such applications is usually assumed to be zero.

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[9] *Ibid.*
[10] *Ibid.*

Obstructions. When the line of sight (LOS) between the source and the listener is blocked, the propagation of sound suffers what is termed "diffraction loss." This LOS blockage can be from terrain features or other obstacles such as buildings. In general, an obstruction can introduce up to 20 dB of additional attenuation.

As depicted in Figure 5, the combination of the numerous factors that can cause attenuation of sound in the lower atmosphere is complicated and has a level of uncertainty associated with it.

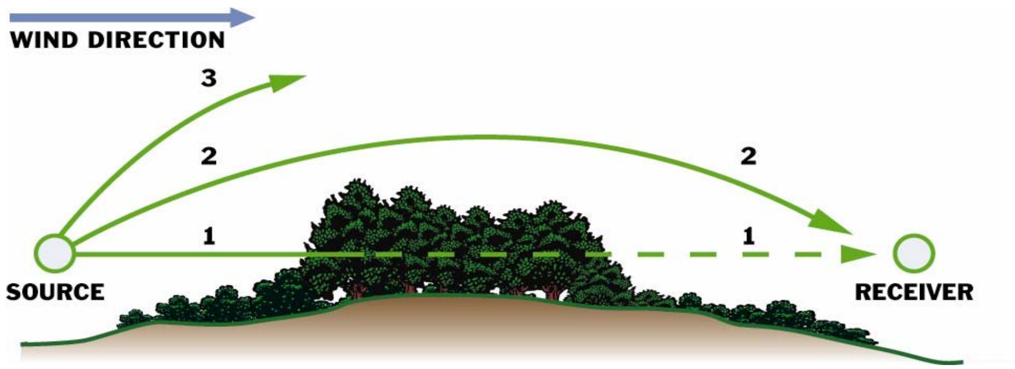

Figure 5: Downwind Sound Propagation with Terrain and Vegetation Effects[11]

Despite these numerous complexities; however, this bulletin addresses ways to account for most of the variables that affect attenuation in a reasonably conservative manner and provides a methodology for predicting the propagation range of sounds. The methodology accounts for device sound rating and frequency as determined by tests and considers prevailing wind conditions, atmospheric stability, and terrain type.

2.3 Perceiving the Warning Sound

Important factors determining the ability of a warning sound to alert potential listeners are the ambient, or "masking," noise at their location and the structural barriers to sound in the listener's immediate vicinity.

2.3.1 Ambient Noise

Ambient noise is the all-encompassing noise associated with a given environment, a composite of sounds from many sources from many directions and distances. This is often referred to as background noise, the sum of sound created by birds in one's back yard, traffic one block over, and industrial facilities miles away.

Ambient noises change continually in loudness and pitch, depend on noise producing activities near the listener, and typically have a strong correlation to population density. That is, the more people around the listener, the more noise-making activities. For example, typical ambient noise levels in rural areas are far lower than ambient noise levels in cities. Ambient noise levels also typically vary significantly by time of day. For

[11] *Ibid.*

example, it is generally typically quieter at night when there is less traffic and more people are indoors. (For further discussion of ambient noise levels and their impact on PAS design, see *Appendix C: Ambient Noise Levels* and *Appendix G: Estimated Cost Prediction Methodology*, respectively.)

2.3.2 Structural Barriers to Sound

As noted above, terrain features or buildings may block or muffle sound. Likewise, people inside motor vehicles or indoors are less likely to be alerted by an outdoor sound. In general, a PAS cannot be counted on to alert people in vehicles or buildings unless they are very close to a device.[12]

However, an outdoor PAS can reasonably be expected to alert *some* people inside buildings depending on the distance from the nearest audible device, outdoor conditions, building construction, indoor sound levels (e.g., stereo system or appliances), whether people are awake or sleeping, and whether or not windows are open. Typical outside to inside sound losses for various buildings or construction types are shown in Table 3 below. (In other words, these values would need to be added to the indoor decibel level required for arousal in order to determine the required outdoor decibel level.)

Table 3: Typical Outside to Inside Sound Losses for Various Types of Building Construction[13]

Building or Construction Type	Sound Loss (dB)	
	Open Windows	Closed Windows
Residences – light frame, single-pane windows	12	20
Residences – light frame, dual-pane or storm windows	12	25
Schools	12	25
Churches	20	30
Hospitals/Convalescent Homes	17	25
Offices	20	30
Theaters	17	25
Hotels/Motels	17	25
Masonry wall construction – single pane windows	12	25
Masonry wall construction – dual pane windows	12	35
Sealed glass wall –1/4-inch glass thickness more than 50 percent of exterior wall area	-	28
20 lb/ft² solid wall – no windows, no cracks, no openings	-	30
50 lb/ft² solid wall – no windows, no cracks, no openings	-	38

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[12] It is interesting to note that the current trend toward improving the energy-conservation properties of buildings will have the concomitant effect of increasing their sound-attenuating properties. Thus, it is even less likely in the future that people indoors will be alerted by outdoor audible warning devices.

[13] (1) Joint Departments of the Army and Air Force TM 5-805-4/AFJMAN 1090, Noise and Vibration Control, May 26, 1995; (2) City of Elk Grove, California, Grant Line Road/State Route 99 Interchange EIR, October 2001; and (3) Texas Department of Transportation, Guidelines for Analysis and Abatement of Highway Traffic Noise, June 1996.

The most critical time, however, when it comes to alerting an indoor population with an outdoor PAS, is at night when people are asleep and are least likely to have immediate access to other alerting methods operating (e.g., broadcasts via television or radio). As noted above in Section 2.2, nighttime conditions are usually the most favorable to outdoor sound propagation. In addition, indoor sound levels are typically at their lowest levels at nighttime. Hence, a properly designed outdoor PAS may also awaken sleeping members of the public in residential areas. (For further discussion of nighttime alerting studies, see *Appendix D: Alerting a Sleeping Population*.)

2.3.3 Audibility and Intelligibility

There are two factors of human perception that must be considered in planning and designing an outdoor PAS: *audibility* and *intelligibility*.

Audibility is the degree to which a sound can be heard by an individual. It is the key consideration for outdoor PAS, and the crucial first component of PAS audibility is whether the sound it produces is sufficiently louder than the surrounding ambient noise.

The second—but equally critical—component of audibility is getting the attention of the listeners away from what they are doing. Normally, people can ignore distracting sounds that are not pertinent to what they are doing. A warning sound, therefore, must penetrate this mental barrier. Tests have shown that to attract listeners' attention from what they are doing, a warning sound must be about 10 dB greater than would be sufficient to make it audible to someone who is listening intently for the same sound. This is why a typical outdoor PAS is generally required to provide at least 10 dB above the prevailing ambient noise. (For further discussion of ambient noise levels and their impact on PAS audibility and design, see *Appendix C: Ambient Noise Levels* and *Appendix G: Estimated Cost Prediction Methodology*, respectively.)

Intelligibility, as distinct from audibility, is the degree to which a sound can be "understood," an especially keen consideration for audible devices using voice function. Voice intelligibility, in particular, is the ability of the listener to *understand what is being said.*

In outdoor PAS using voice, a message's intelligibility is largely determined by the two fundamental components of sound discussed above: loudness and frequency. Human speech is characterized by variations in loudness as individual syllables are enunciated. In addition, speech consists of higher frequencies that extend beyond the 1,000 Hz range of the typical PAS, and these can likewise be crucial to intelligibility.[14] Finally, echoes and the varied arrival times produced by multiple devices also present concerns regarding a spoken message's ultimate intelligibility.(For more on speech intelligibility tests and the ways in which intelligibility can be measured, see *Appendix E: Speech*

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[14] Recommended speech intelligibility levels for audible warning devices based on indoor or enclosed space conditions (e.g., NFPA 72, *National Fire Alarm Code*) are not likely to be widely achievable for outdoor voice warning conditions. *Other or supplemental means of alerting may be needed for people who do not understand the language being used or who may be hearing impaired.*

Intelligibility Scales and Recommendations; further discussion of echoes and the "multiple arrival" effect can be found in Section 4.2.)

Many of the concerns related to public warning audibility and intelligibility center upon individuals with special needs and disabilities. These include non-English speaking populations and are being addressed by the Federal Communications Commission's (FCC) ongoing review of the EAS, as described in FCC 04-189 "Notice for Proposed Rule Making" dated August 12, 2004. Under a Presidential Executive Order dated July 22, 2004, the Interagency Coordinating Council on Emergency Preparedness and Individuals with Disabilities has announced: (1) an FCC effort to ensure that emergency management authorities give priority to restoring services that provide telecommunications services for hearing- and speech-disabled people; (2) a National Institute on Disability and Rehabilitation Research study earmarked for research aimed at developing Web-based software to teach emergency preparedness and response skills to the hearing impaired and improve the emergency exit skills of disabled people; and (3) an award from the Rehabilitative Services Administration to the National Organization on Disability Emergency Preparedness Initiative to help localities and Federal agencies craft preparedness plans to ensure the safety of the disabled.

3.0 Outdoor Warning Systems: Terminology, Components, and Current Technologies

This section describes the two principle types of audible PAS devices in use today as well as another key requirement in an integrated outdoor warning system, the electronic message sign. The component parts of individual devices are explained, as are the ways in which the devices work together in systems, the standards that are emerging in efforts to promote inter- and intra-system "interoperability," and the important requirement of back-up power.

3.1 Types of Audible Outdoor Warning Systems

Electro-mechanical sirens typically are very cost-effective, given their installation cost, reliability, and maintenance schedules. However, *electronic sirens* provide the versatility of producing the human voice as well as many other different sounds as well.

3.1.1 Electro-Mechanical Sirens

Sirens are by far the most widely used sound-making devices for PAS. An electro-mechanical siren produces sound by forcing compressed fluid, usually air, through a narrowed opening, or "vortex," in much the same way a musician blows air through the mouth piece of a trumpet. A motor driven device then chops air into a stream of air pulses, and this high-volume airflow is converted into high-pressure airflow as it passes through the "horn," the broadening exterior section of the siren that most often resembles a megaphone. Electro-mechanical devices, such as the one shown below in Figure 6, can only produce pure tones at frequencies that depend on the specific device design. *They cannot transmit voice messages*. As such, these can be used only as alerting devices for those people who can hear and understand the meaning of the signals.

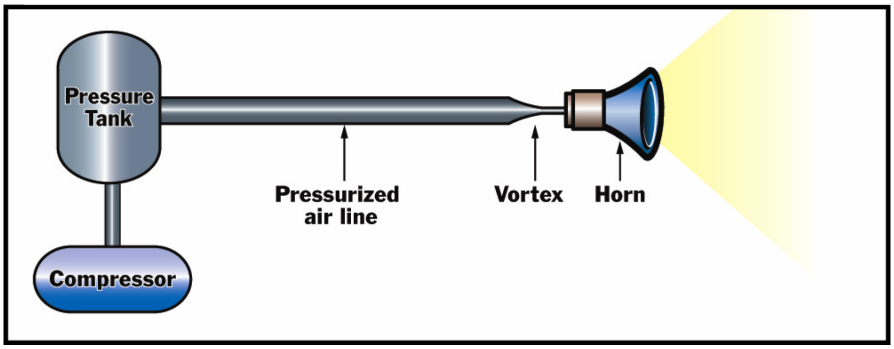

Figure 6: Electro-Mechanical Siren

3.1.2 Electronic Sirens

Strictly speaking, these electronically based systems are not sirens *per se*. Instead, in a manner similar to a home stereo or conventional public address system, they are powered by electronic amplifiers that drive speakers mounted as a horn assembly described above. Depending on the specific design, these devices have the advantage of producing an array of siren-like sounds and voices—all of which can be "broadcast" live or prerecorded—and thus, as shown in Figure 7, they can be used to issue messages as well as warning sounds to the public. However, because they are more complex than electro-mechanical sirens, these devices typically have a number of power amplifiers and other modules that are required to operate in parallel to produce the rated sound output for the device. Furthermore, their sound-output capability is often lower than that available from sirens, meaning more individual sources are usually required to cover the same area.

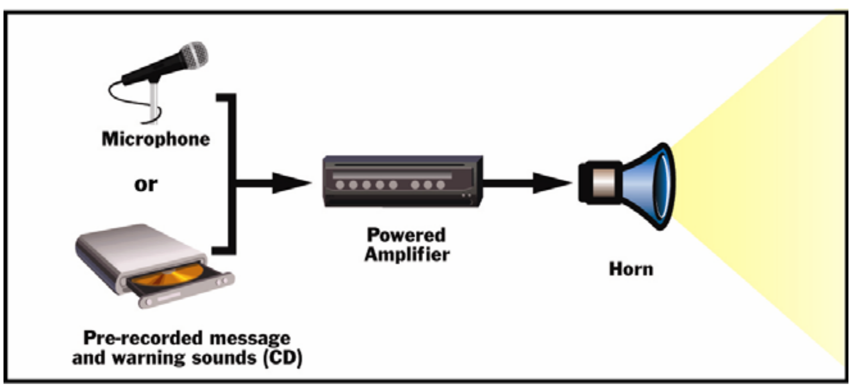

Figure 7: Electronically Amplified Siren

3.2 Directional, Rotating, and Omni-Directional Devices

The sounds from audible outdoor warning devices, no matter the type, are usually focused into the horizontal plane surrounding the device. Generally speaking, there are three coverage patterns that are employed: *directional*, *rotating*, and *omni-directional* (see Figure 8 below). Directional devices send out a highly focused cone of sound in the direction that they are pointing. Rotating devices usually spin completely several times per minute so that the sound "sweeps" 360° in the horizontal plane. Omni-directional devices are designed to have essentially the same sound power in all directions in a horizontal plane by having multiple horns radiating out from a center point, thereby covering the entire 360° simultaneously, i.e., without the need to rotate.

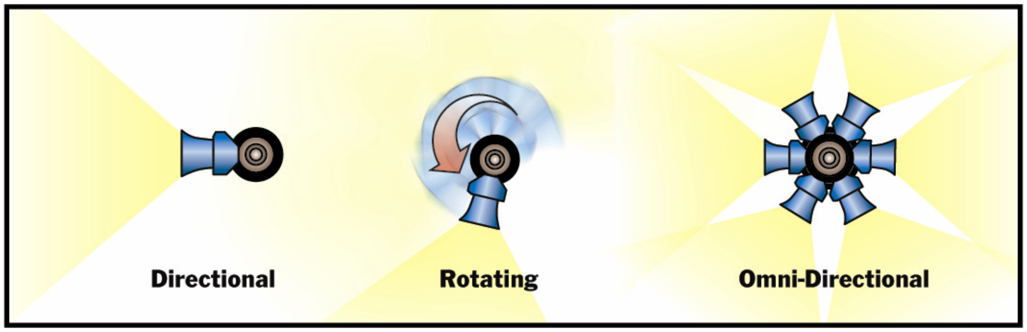

Figure 8: Coverage Patterns (Overhead View)

3.3 Electronic Message Signs

Electronic message signs are commonly deployed along major transportation routes, but they can also be deployed in any area with a large public presence. For example, coastal beach areas may deploy electronic message signs to warn swimmers of hazardous tide conditions. And on September 11, 2001, electronic message signs played a prominent alert and notification role in New York City by alerting traffic of emergency conditions when the region's telecommunication system was overburdened by severe demand.[15] Also referred to as variable message signs (VMS), state-of-the-art signs use reflective disc message displays with fiber optic lighting or light-emitting diode (LED) displays. In addition, current VMS have features that increase visibility in bright ambient light conditions and are modular in design, producing character heights that can be read as far as 900 feet away. They can also generate and transmit messages from a desktop computer, typically located at a central control point. Messages can be transmitted to each sign in a system via telephone leased or dial-up lines, twisted cable pairs, coaxial cables, microwave, radio, or fiber optic cable. In addition, the most current designs can have their messages travel left or right, scroll up or down, and flash.[16]

VMS along transportation routes generally serve multiple purposes, and the National ITS Architecture defines the common framework for planning, defining, and integrating

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[15] Effects of Catastrophic Events on Transportation System Management and Operations, New York City – September 11 (Draft Report), U.S. Department of Transportation Research and Special Programs Administration, April 2002. Online at http://www.itsdocs.fhwa.dot.gov//JPODOCS/REPTS_te/14129.htm.

[16] Communication protocols for such systems are described in NTCIP 9001, *The Updated NTCIP Guide*, jointly issued by the American Association of State Highway and Transportation Officials (AASHTO), the Institute of Transportation Engineers (ITE), and the National Electrical Manufacturers Association (NEMA)

intelligent transportation systems (ITS).[17] The Emergency Management Subsystem provides, in part, disaster response and evacuation functionality via Emergency Early Warning System equipment. This equipment is responsible for processes that manage wide area alerts and advisories where information associated with emergency situations that pose threats to life and property must be provided to the traveling public. Furthermore, VMS are a part of disaster response and evacuation in the Disaster Response and Evacuation User Service (5.3) defined in the National ITS Architecture.

Figure 9 illustrates a typical electronic message sign array, including components such as passive energy sources, controls, message generating apparatus, and both wireless and fiber communications.

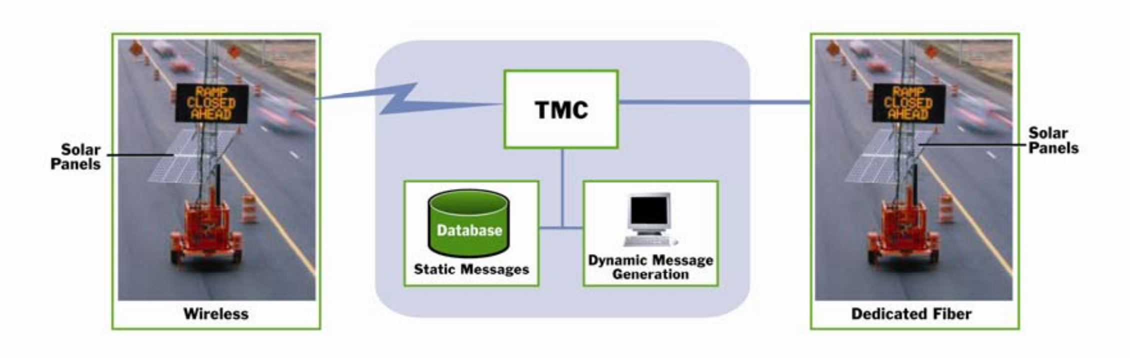

Figure 9: **Electronic Message Sign Array**

3.4 Outdoor Warning System Depiction and Components

Outdoor warning systems have made significant technological advances in the last two decades. Figures 10 through 14 depict a progression of warning advancements and highlight the capability improvements now available, from traditional siren systems to fully integrated outdoor warning systems with redundant controls. Current alert technology also now includes voice warning capabilities. These voice warning notification systems can follow siren-based alerts with voice messages providing emergency details noting the "when" and "where" of the event, the incident severity, and suggested protective actions. In addition, electronic message signs are now available to notify motorists of emergency highway conditions, road construction, and even broader public concerns such as Amber Alerts.

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[17] National ITS Architecture, Version 5.1, Department of Transportation. http://itsarch.iteris.com/itsarch/index.ht

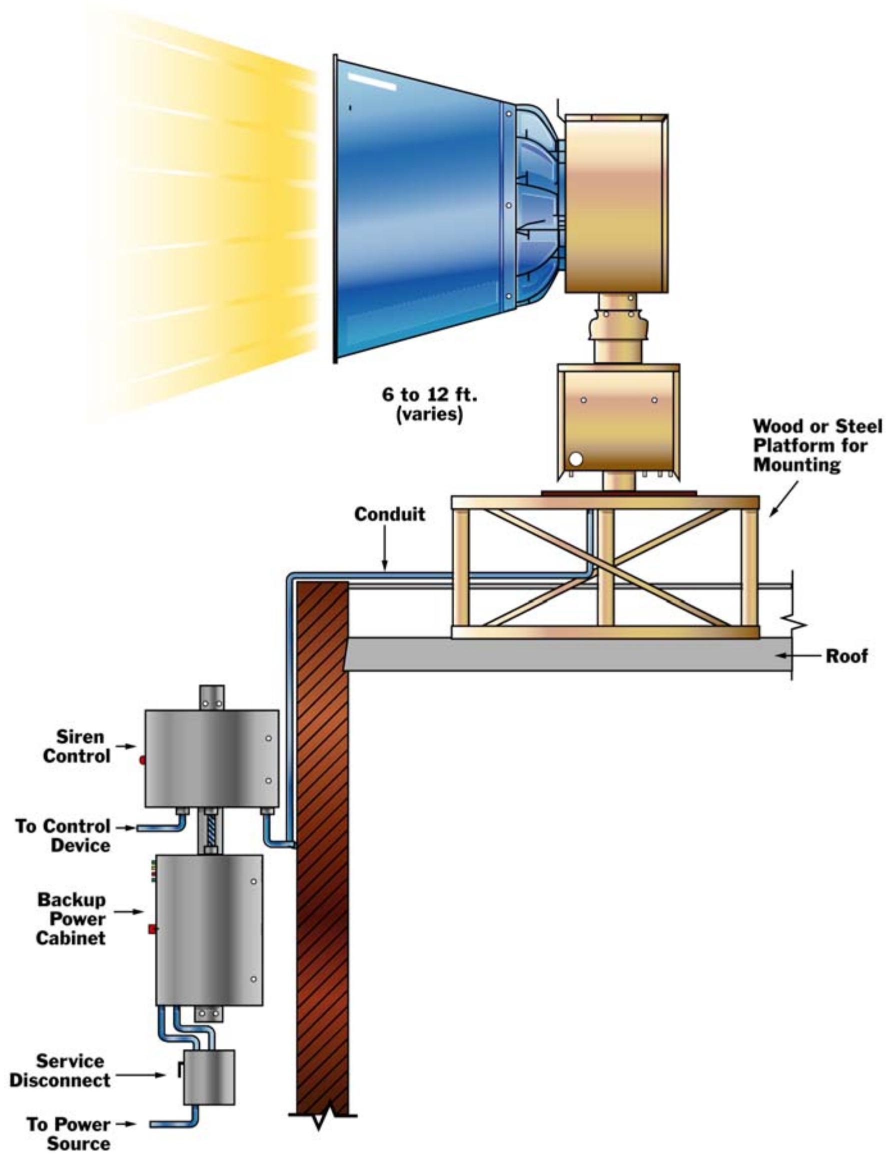
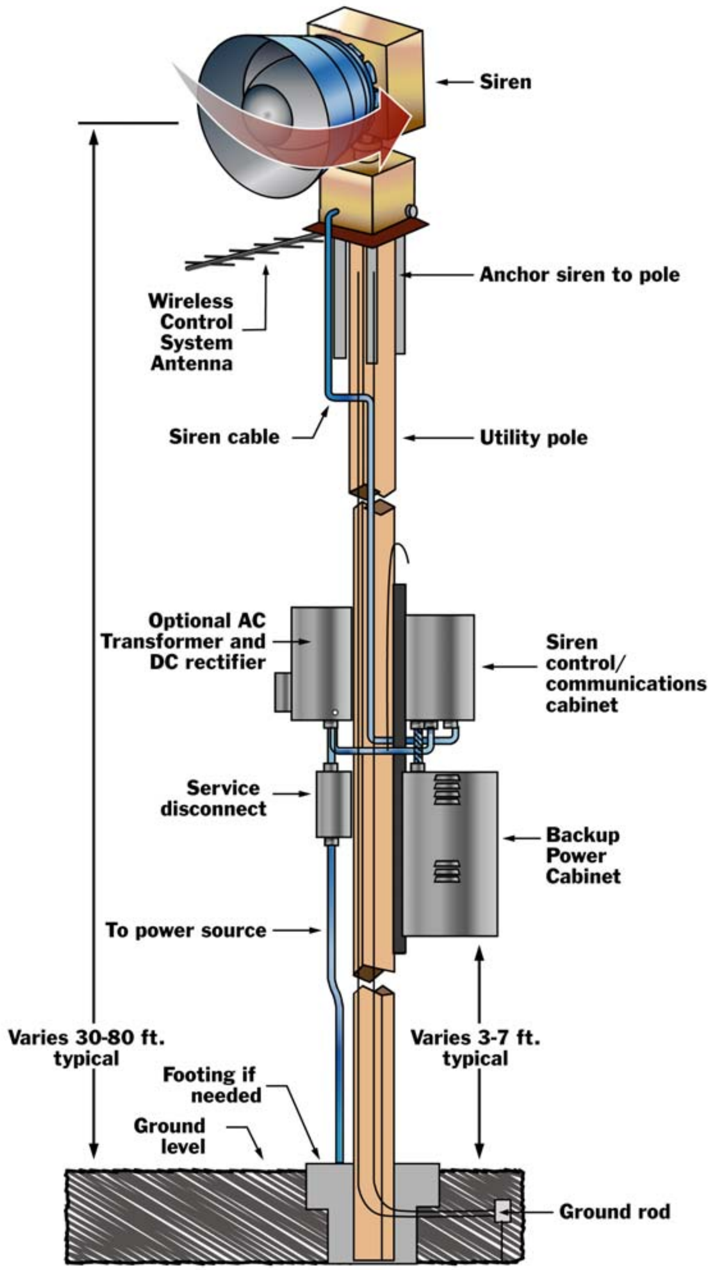


Figure 10: Surface-Mounted Directional Siren

Figure 10 depicts a traditional siren system. These systems enable responsible officials to easily and quickly advise the public of catastrophic events but they do not provide public action instruction. The figure illustrates a directional (or uni-directional) surface mounted siren device with primary grid power and a backup power supply. A directional outdoor warning device such as this is most functional when mounted on a building or structure and directs sound away from attenuating or reflective surfaces. The traditional siren sound can be energized by electronic or other motive force (i.e., forced air or steam).

An enhancement to the fixed, uni-directional siren device is the rotating siren (Figure 11). This device alerts in all directions, but the sound waxes and wanes as the device directs sound first toward, then away from, the listener. The rotational siren depiction displays the array of structural and control apparatus common to outdoor warning devices (i.e., power supply, siren controls, service connections, and structural components). Power supply to this device includes grid power with a backup power supply. Additionally, the illustration denotes that the pole's height can be varied to maximize sound projection and that component heights can be adjusted to meet maintenance/service requirements.



NOTE: Siren control cabinet should be mounted with consideration given to accessibility for maintenance/service requirements.

Figure 11: Rotating Pole-Mounted Siren

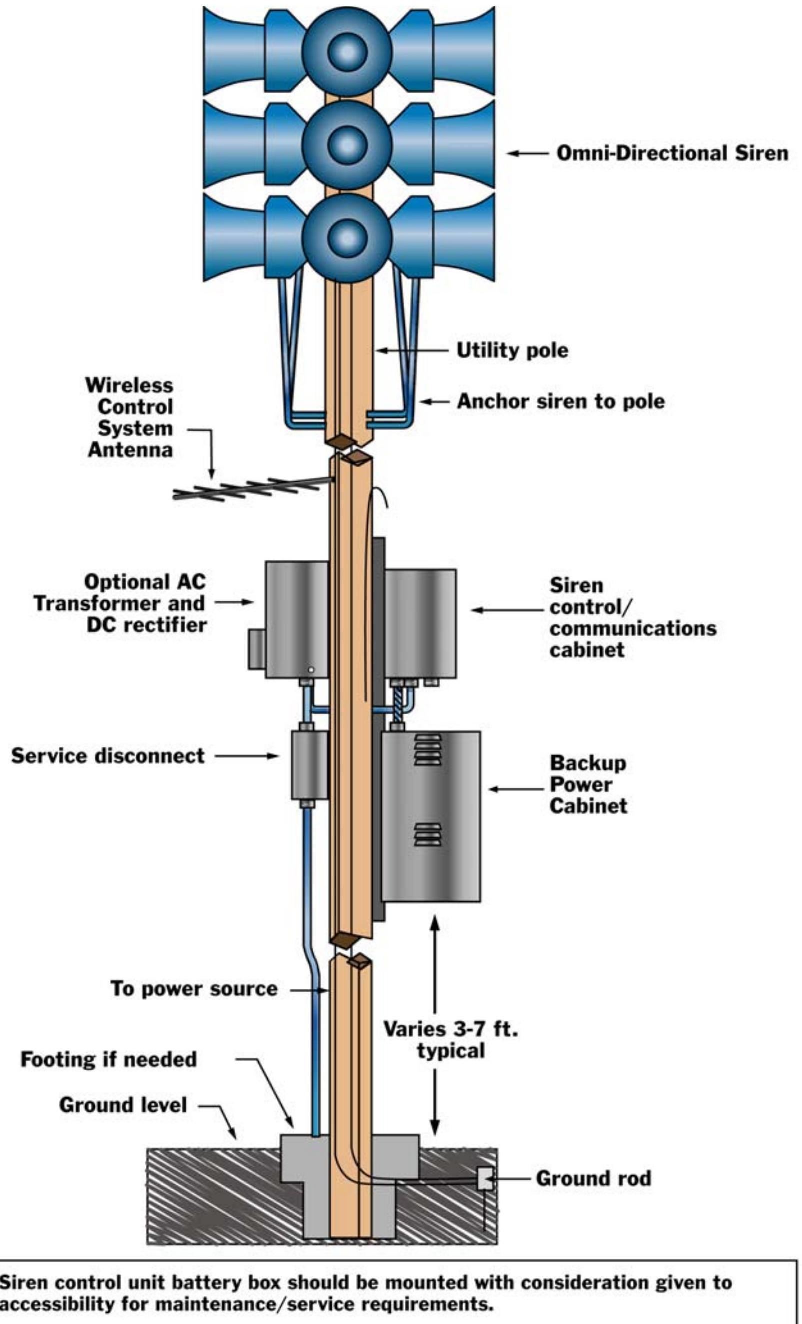


Figure 12: Omni-Directional Pole Mounted Siren

Figure 12 represents an omni-directional outdoor warning siren device. This omni-directional device, currently the most commonly used equipment, often includes public address capabilities. Omni-directional sirens emanate sound that spreads 360˚ around the sirens. Omni-directional sirens typically consist of a number of speaker "cells" or "modules" stacked on top of each other in a vertical column. The number of cells the tower has determines how powerful and far-reaching the sound will be.

Another difference in omni-directional siren technology is the content of each individual cell, particularly the number and strength of the "drivers" in each cell. Drivers are essentially the speakers of the siren system. Some siren models include multiple drivers per cell, while others contain a single, but more powerful driver in each cell. Typically, 1,500-2,500 watts are needed to produce 120 dBs at 100 feet (i.e., the required sound projection condition) with an electronically amplified system. Finally, the depiction above displays the structural array and the control apparatus common to outdoor warning devices (i.e., power supply, siren controls, service connections, structural components, and height adjustments for sound and service).

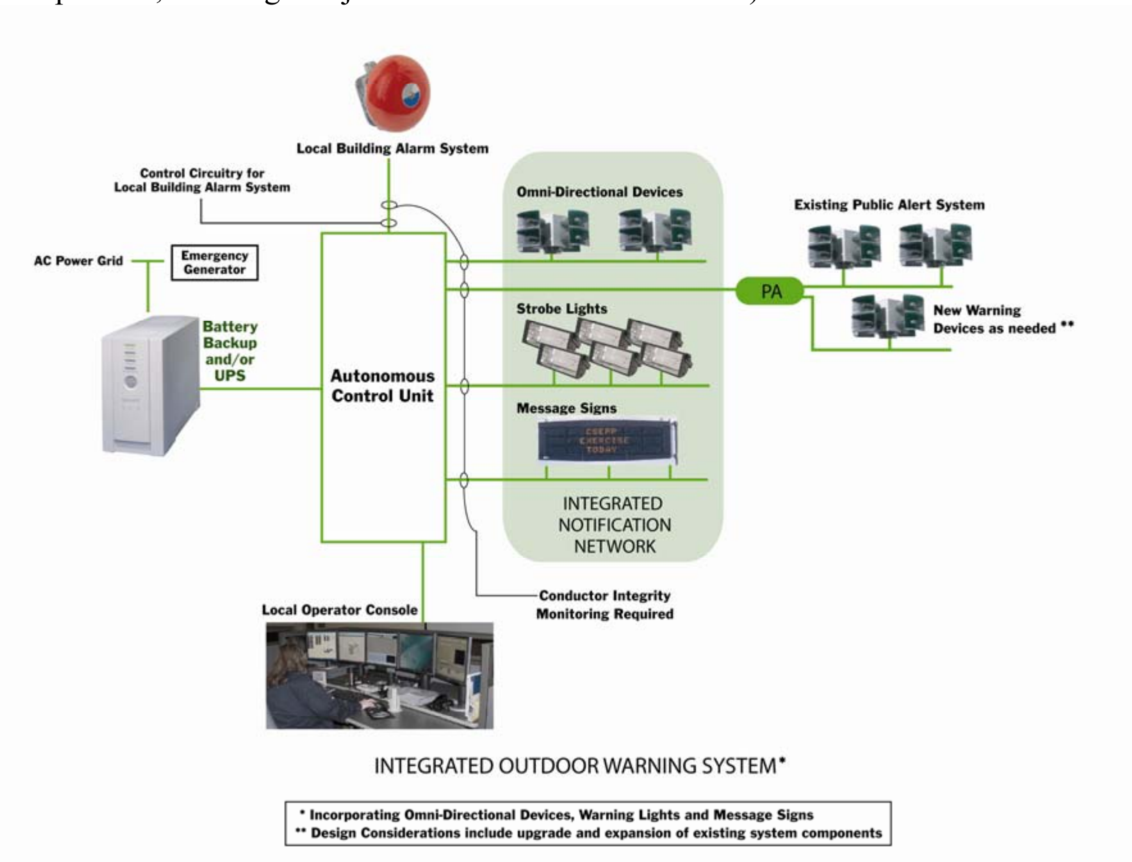


Figure 13: Integrated Outdoor Warning System[18]

Figure 13 graphically illustrates an integrated outdoor warning system. Here omni-directional siren devices are combined with light signals, including electronic message signs, into an integrated notification network. The illustration below depicts autonomous or local operator control, circuitry to utilize individual components of the notification network that allow for alerting of individual locations (i.e., hospitals or other special needs locations), and provisions for system upgrade or future design enhancements to the outdoor public warning network.

[18] DOD. Design and O&M: Mass Notification Systems. Unified Facilities Criteria 4-021-01. December, 2002.

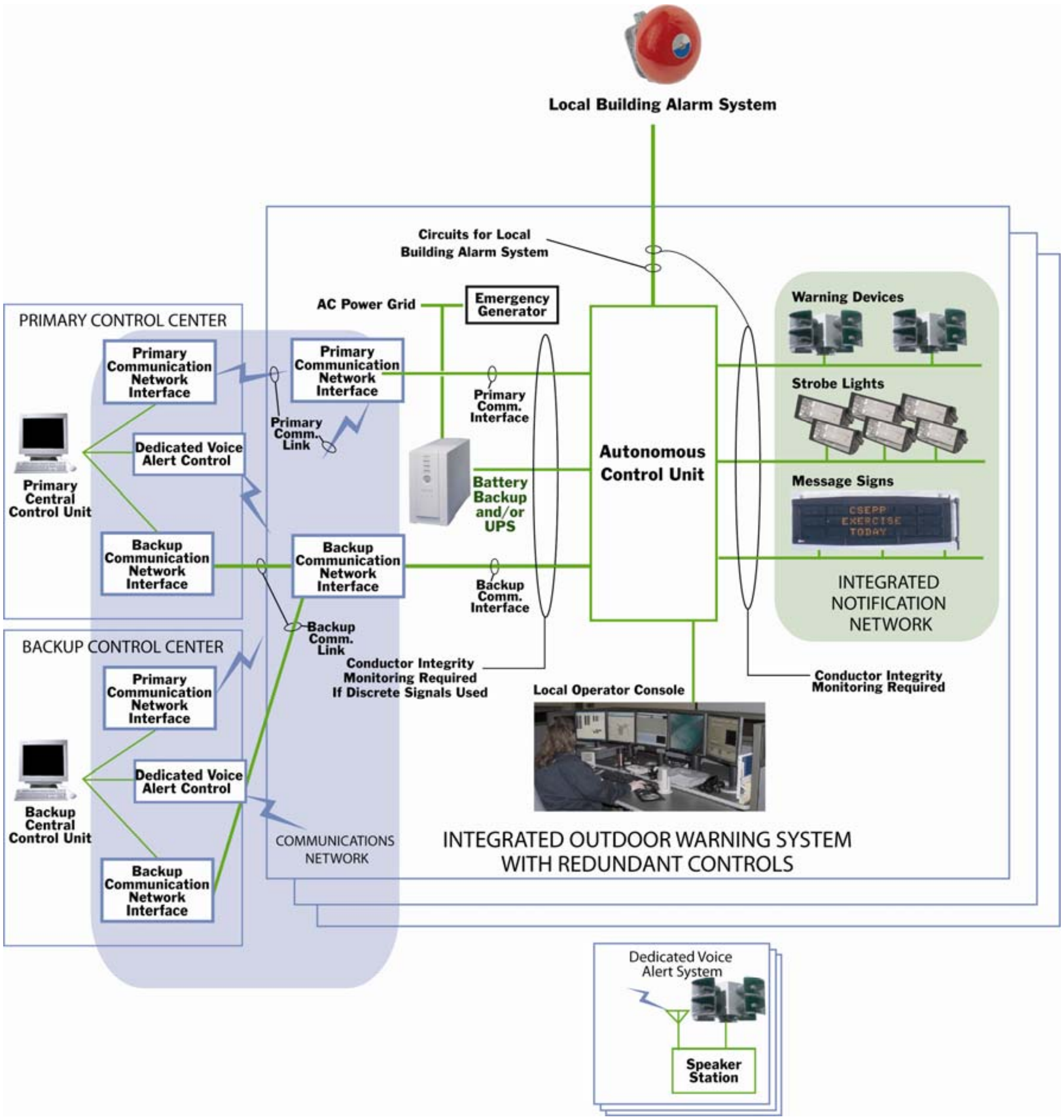


Figure 14: Integrated Outdoor Warning System with Redundant Controls[19]

Figure 14, an integrated outdoor warning system with redundant control and communication components, represents a more modern, sophisticated system. The depiction above illustrates the combination of sight and sound signals into an integrated notification network; portrays primary and backup power and communication controls; and details the circuitry required to alert individual locations and/or buildings. A dedicated voice alert system for notifying special need populations is also illustrated.

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[19] *Ibid.*

Finally, the separate, dedicated special needs voice alert system is controlled via the integrated outdoor warning system.

Each of the principle warning components—traditional sirens, electronic sirens with voice capability, and electronic message signs—shown in the systems above comes with its own sets of strengths and weaknesses, and this is why all three should be considered at the outset of the outdoor PAS planning process. Table 4 below summarizes some to the advantages and disadvantages inherent to each approach.

Table 4: Alert & Notification Methods–Advantages and Disadvantages

Method	Advantages	Disadvantages
Sirens	• Most cost-effective method to warn a large area. • Most people are familiar with siren tones. • Can target alerting signal to the most at risk population. • Control systems tend to be the least complicated.	• May not alert people indoors or in vehicles. • May not be effective in areas with high ambient noise levels. • May require special equipment to service (e.g., bucket trucks) • May be dependent on AC supply power that is lost due to event. • Requires sustained public education program so that people understand what the alert signals mean. • Not effective in warning special populations, e.g., hearing impaired.
Outdoor Voice Warning	• Can provide timely notification to people outdoors. • Does not require familiarity with the meaning of siren alerting tones. • Can target notification to population most at risk. • Most voice warning devices can also produce a wide variety of siren tones. • Provides additional flexibility in outdoor warning situations that other outdoor warning methods do not have.	• May not alert people indoors or in vehicles. • May not be effective in areas with high ambient noise levels. • May require special equipment to service (e.g., bucket trucks) • May be dependent on AC supply power that is lost due to event. • Voice warning may not be intelligible in every place that it is audible due to echoes and multiple arrival effect. • Requires pre-recorded messages or trained personnel to ensure maximum intelligibility. • May require installation of more devices than a siren system to ensure intelligibility. • Effectiveness depends on ability of listener to understand the language being used. • Warnings may need to be in several languages, which may result in less time to take action in response to the voice warning. • Not effective in warning special populations, e.g., hearing impaired.

Method	Advantages	Disadvantages
Highway Electronic Message Signs	•Increasingly more common along highways; hence drivers are familiar with seeing them and reading the messages. •Have been shown to be effective in communicating with the target audience. •Can provide timely notification to vehicle traffic. •Makes maximum use of existing infrastructure.	• Message length affected by how long drivers and passengers may have to view it. • Only can be used to alert vehicular traffic where it is being displayed. • Effectiveness depends on ability of listener to understand the language being used.

3.5 Warning Signal Protocols and Standards

3.5.1 Siren Warning Alerts

Many local governments continue to follow FEMA's CPG 1-17 guidance[20] and use a certain siren signal to warn people of an enemy attack, and a different signal to notify them of a peacetime disaster.

Attention or Alert Warning. This is a three to five minute steady signal from sirens, horns, or other devices. This signal may be used as authorized by local government officials to alert the public to peacetime emergencies. The types of emergencies in which this warning type is used, therefore, will vary by locale. For example, jurisdictions prone to tornadoes will use this warning signal when a tornado or funnel cloud is reported while in coastal regions, this warning signal may be employed under hurricane conditions. In addition to any other meaning or requirement for action as determined by local government officials, the Attention or Alert signal shall mean to all persons in the United States, "Turn on radio or television. Listen for essential emergency information." This warning signal may be used together with other PAS systems, such as electronic message signs (see Section 3.3) in order to provide additional information and instructions to the public.

Attack Warning. On sirens, this is a three to five minute tone warbling in pitch, or, on other devices, a series of short blasts. The Attack Warning signal shall mean that an actual attack against the country has been detected and that protective action should be taken immediately. The Attack Warning signal shall be repeated as often as warnings are disseminated over the National Warning System or as deemed necessary by local government authorities to obtain the required response by the population, including taking protective action related to the arrival of fallout. The meaning of the signal "protective action should be taken immediately" is

[20] FEMA. *CPG1-17: Outdoor Warning Systems Guide*. 1980.

appropriate for the initial attack warning and any subsequent attacks. This signal will also be used for accidental missile launch warnings.

The public should know what specific actions to take when they hear either signal type. Furthermore, the public should be educated regarding the difference between true alerts and test signals (for further discussion of public information campaigns, see Section 5.1.3). Many jurisdictions direct the public to acquire additional information via mass media channels such as radio or television.

Voice warning systems can be used together with siren systems when electronic siren systems are deployed. In this instance, the typical sequence is to issue a siren alert for several minutes followed by voice instructions.

3.5.2 Common Alerting Protocol

Technological advances and the proliferation of networked digital devices give emergency managers the opportunity to send timely, customized alerts. These alerts may be broadcast to the general public or they can target specific individuals (e.g., those with breathing difficulties). The Common Alerting Protocol (CAP) is a standard message format for such customized alerts and notifications. The CAP message format is implemented in eXtensible Markup Language (XML) and was formally adopted in April 2004 by the Organization for the Advancement of Structured Information Standards (OASIS). As of April 2005, the current CAP version is 1.1.

CAP is applicable to a wide range of warning systems, but it is likely to have the most positive impact on electronic message signs and voice warning systems. Standardized CAP message formats replace proprietary formats and single-purpose system interfaces, thus driving the cost of systems development and integration down. In addition, a standardized message format enables technical innovation by combining outdoor warning systems with other mass alerting technologies and personal digital devices.

CAP is designed for forward and backward compatibility. It supports existing national alert and notification formats such as the national EAS and the Specific Area Message Encoding (SAME) used by the National Oceanic and Atmospheric Administration (NOAA) Weather Radio transmissions. Several federal and state agencies are currently implementing CAP, including the Department of Homeland Security, the United States Geological Survey (USGS), the California Office of Emergency Services, and the Virginia Department of Transportation.[21]

As technology evolves, it is expected that CAP will become the primary message encoding standard for outdoor warning systems, specifically electronic warning systems and voice sirens because it allows separate systems to use pertinent information to automate their actions. For example, the CAP message could go to all sirens controlled by a particular county, but the sirens could be programmed so that only those that are

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[21] Common Alerting Protocol – CAP – Ratified as OASIS Standard, *EE Times*, 5 April 2004

identified to be in the immediate response area would sound. Other systems would use the exact same CAP message to do their jobs (e.g., dispatch systems for fire or police), but depending on the information in the CAP message, they could respond differently with different messages, instructions, or tones.

3.5.3 Integrated Public Alert and Warning System

The Department of Homeland Security's (DHS) FEMA, the national EAS, and the Association of Public Television Stations (APTS) have joined with NOAA and other federal departments and agencies in an effort to dramatically improve America's alert and warning systems. This effort will culminate in an Integrated Public Alert and Warning System (IPAWS).

The concept, known as datacasting, is to employ digital technology that can simultaneously transmit text, voice, and video messages. Employing digital technology allows all the advantages of the internet protocol environment to be used—with it's built in redundancies and capabilities—and also utilizes existing digital infrastructures such as land-based optical fiber, radio networks, satellite communications, and wireless service providers.

Public investments built 294 digital public television stations across the country, and these stations can act as the nexus of a wireless network capable of broadcasting digitally, so the transition to datacasting should be relatively straightforward. Moreover, while the old technology took at least seven minutes to send messages to public safety agencies, the proposed new method will take only a few seconds.

The IPAWS system is "turned on" when an official sends a digitally encoded alert and warning message to a public television station. The television station, in turn, sends the message from its digital transmitter to participating companies that are equipped with antennae and receivers hooked up to computers with commercial software. The messages are then sent using the CAP described immediately above in Section 3.5.2. With this software, the recipients—whether a television station, cellular phone company, radio station, or internet service provider—are able to interpret the data they can use for their particular medium from the CAP message and transmit an appropriate message to their customers.

In addition, the HazCollect Project at the National Weather Service (NWS) is likewise equipped with an Internet interface. An alert for a local area can be sent to Advanced Weather Interactive Processing System (AWIPS) (a NWS application that provides the ability to convert large amounts of weather data into more timely forecasts and warnings). AWIPS then forwards the alert to the EAS via its network of weather service radios. While all alerts go through the NWS, stations would only have to monitor the weather radio, thus providing the advantage of wide distribution beyond EAS for different events.

Emergency managers and government agencies will be able to use HazCollect to broadcast messages over NOAA Weather Radio All-Hazards or other NWS dissemination systems using a desktop toolkit from the Disaster Management Interoperability Service (DMIS). HazCollect can serve as a one-stop location for the collection, relay, and distribution of non-weather emergency messages (e.g., Civil Emergency Messages) to the NWS dissemination infrastructure, other national systems such as DMIS, and to the EAS. State and local emergency officials could also use this emerging technology during emergencies to target encrypted, nearly instantaneous messages at authorized individuals in certain regions. Finally, additional redundancy may be available through the use of EM-Net, a satellite-based warning and messaging system designed to meet the needs of the emergency management community.

3.6 Back-up Power Supply for Outdoor Warning Systems

House Report 107-740 directed that all warning systems be operable in the absence of AC power supply. More recently, language in the Energy Policy Act of 2005 mandated the following with respect to outdoor warning systems in the vicinity of nuclear power plants:

> (b) BACKUP POWER FOR CERTAIN EMERGENCY NOTIFICATION SYSTEMS.—For any licensed nuclear power plants located where there is a permanent population, as determined by the 2000 decennial census, in excess of 15,000,000 within a 50-mile radius of the power plant, not later than 18 months after enactment of this Act, the Commission shall require that backup power to be available for the emergency notification system of the power plant, including the emergency siren warning system, if the alternating current supply within the 10-mile emergency planning zone of the power plant is lost.[22]

Despite the emphasis above on nuclear power plants, warning systems are primarily used for severe weather and other emergency conditions. Due to the volatility of the high wind and lightning associated with severe weather, it is not feasible to depend solely on AC power. Therefore, all new outdoor warning systems should have alternative power supplies designed and built into the system. Existing outdoor warning systems should have alternative power supplies added to the system as part of the system's planned maintenance program and no later than two years from the date of the publication of this guidance. To overcome this concern, systems have been designed to allow operation that can be backed up by a battery supply or other alternative power supplies. As long as the batteries or other alternative power sources are in good condition, the warning system will operate until the alternative power source looses its capacity.

AC power supply is most commonly provided by the local electric distribution grid. In order to operate in the absence of AC power, the following configurations are typically used:

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[22] H. R. 6. "Energy Policy Act of 2005." p. 208

- Primary power from local electric distribution grid backed by emergency or standby power systems (e.g., engine-driven generators);
- Primary power from local electric distribution grid backed by stored emergency power supply system (SEPSS) (e.g., batteries);
- Primary power from on-site power system (e.g., engine-driven generator) backed by SEPSS;
- Primary power from uninterruptible power supply (UPS) that "floats" on local electric distribution grid; or
- Photo-voltaic or thermo-voltaic devices, (i.e., solar cells, used to charge SEPSS to supply steady electric power.)

Each outdoor PAS should receive adequate power to perform its design functions (e.g., maintain sound output, rotation, speech intelligibility, or brightness as applicable). This criterion includes the associated activation, control, monitoring, and testing components (e.g., radio transceivers, testing circuits, sensors to monitor critical operating parameters) co-located with the PAS.

At a minimum, UPS or SEPSS for each outdoor PAS device should be designed for PAS operation in standby mode (radio transceivers, testing circuits, sensors fully operational and providing polling data to the activation, control, monitoring, and test system located at central facilities) for at least 24 hours without AC power from the local electric distribution grid.

The UPS or SEPSS should also be capable of operating an outdoor PAS device in its alerting mode at its full design capability (e.g., maintain its full sound output) *without recharge* for a period of at least 15 minutes. Furthermore, this ability should be available under: 1) the most unfavorable temperature conditions specified for outdoor PAS operation; and 2) batteries that are approaching the end of their design life.

Automatic charging should be sized such that batteries in the UPS or SEPSS are fully recharged to at least 80% of their maximum rated capacity from the fully discharged state in a period of not more than 24 hours. The trickle and fast charge rates for the battery should not exceed the battery manufacturer-recommended rates in order to promote maximum battery life.[23]

Battery design life should be determined by the vendor. This can be based on either: 1) voltage per cell limits (such as specified in the National Fire Protection Association (NFPA) 1221 2002 Edition, Tables 10.4.3 and 10.4.4); or 2) on the time when deterioration to less than 80% of the battery maximum rated capacity at the one-hour rate is predicted to occur. Batteries should be of a maintenance-free design, and the

[23] Applicable standards for primary and secondary power sources used for PAS components located at central facilities are described in NFPA 1221 Sections 4.7 and 10.4 (Power). In addition to the NFPA 1221 requirements, these components should receive adequate power to perform their design functions upon loss of primary power (typically the local electric distribution grid provides primary power) for durations not less than those for the outdoor PAS.

charging system should be designed to ensure a minimum battery life of at least three years.[24]

3.7 Communication Channels

Outdoor warning systems depend on communications between the PAS device site and the central control site. Activation, operations, and monitoring are all activities that rely on communications between these sites.

3.7.1 Wired Versus Wireless Channels

Communication channels may be wired or wireless. Wired channel technologies are typically based on either copper lines (such as leased telecommunication lines) or fiber optic cable. Fiber optic cable is generally preferable to copper-based cable because of lower susceptibility to lightning strike surges, but fiber is more costly. In general, wired communication channels are considered unfeasible due to installation, material, and lifetime maintenance costs.

Wireless communication technology is quickly gaining acceptance in outdoor warning systems control because of its flexibility and lower costs. Technology using radio frequencies in the very high frequency (VHF) and ultra high frequency (UHF) ranges are common communication channel choices. In addition, radio technology[25] is commonly offered by vendors as a wireless solution. Other wireless technologies are also possible, including satellite communication channels, and in some jurisdictions, cellular towers may be co-located with siren and voice warning systems.

Radio technologies support one-way or two-way communication between the central control site and outdoor warning sites. One-way communications allow the central control site to activate outdoor warning sites, but communication from outdoor warning sites back to the central control site is not possible. This option has low initial costs, but it requires manual deployment of staff for inspections and operational testing. Two-way communications, on the other hand, enable outdoor warning sites to automatically send status reporting, operational testing, real-time tamper detection, and battery voltage indication back to the central control site, and this information can be logged in databases for on-line monitoring. The two-way communication option has higher initial costs but lower maintenance and operational costs over the lifetime of the outdoor warning system.

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[24] Refer to UL 2017, Section 58.2, Power Sources, for additional standards applicable to power supplies for an outdoor PAS device

[25] For example, trunked radio bundles several frequency channels and distributes them based on traffic level demands.

3.7.2 Range

The range of the communications links between central control sites and siren sites is determined by several factors, including transmission power level, loss of signal strength over long cable distances (for wired channels), signal attenuation[26] (for wireless channels), antenna gain, and sensitivity of the transceiver. Some of these factors may be alleviated with technical solutions, such as signal repeaters, but these solutions, of course, impose greater costs.

For wireless channels, LOS obstructions can severely limit communications and may necessitate the use of signal repeaters to create intermediate LOS channels. LOS between sites is desirable for optimal transmission, but it is not strictly necessary. An obstruction in the transmission path will weaken the radio signal, but this loss may be acceptable if signal strengths remain above critical levels. Multi-frequency technologies can reduce the effects of LOS attenuation and are becoming increasingly available commercially.

3.8 Supervisory Control of Outdoor Warning Systems

SCADA systems are those process control systems that electronically measure process state, change parameters associated with process control, and store or transfer process control data. The application of SCADA systems to the deployment of outdoor warning systems is a growing trend and, hence, these systems are increasingly being integrated into the realm of critical infrastructure.

SCADA setups vary with the type of process under control and monitoring, and control may be automatic or user controlled. A general SCADA configuration will involve several levels of control and monitoring devices. Remote terminal units (RTUs) are the primary interface to controllers, sensors, and actuators, and data acquisition and monitoring typically happens at an extremely rapid rate. Master terminal units (MTUs) form a second tier of control and monitoring by interfacing with RTUs at a slower rate. Typically, the MTU is a general computing platform dedicated to executing the SCADA software, and RTUs are dedicated hardened devices or processor cards. Operators interface with the SCADA system using a graphical host program through the MTU, and systems may include database systems for data storage. In an outdoor warning system, the MTU might reside in the Emergency Operations Center (EOC) while RTUs are distributed in the field to control and monitor sirens and message signs. In addition, MTUs may also have interfaces with other emergency systems such as EAS or the 911 call center.

The benefits of SCADA-based outdoor warning systems include:

- Emergency management system operators and decision makers gain secure activation and status monitoring of outdoor warning systems;

[26] Attenuation can affect any type of signal, including sound and radio signals. Attenuation is the loss of signal strength due to external effects such as scattering and absorption.

- Adaptation to changing community requirements, (e.g., support for multiple computers, zones, and digital tone alert receivers as coverage needs grow);
- Communication with RTUs by digital computer networks and dial-in modems (typically supervisory control only, but Transmission Control Protocol/Internet Protocol (TCP/IP) supports both wired and wireless communication channels);
- Complete configuration and reprogramming from MTUs, including zone mapping and device status visualization;
- Direct communication between RTUs;
- Automated call-outs to alert system operators of events (e.g., tampering or battery degeneration); and
- Storage and transfer of status and alarm logs.

Cyber-threats to SCADA systems result from integration with digital computer networks. The primary categories of cyber-threat to outdoor warning systems are:

- Unauthorized operations of outdoor warning systems, whereby malicious users gain the ability to activate warning systems from central control hosts or RTUs;
- Denial of service attacks, whereby malicious users prevent the proper operation of outdoor warning systems by making them unavailable, including "sleep deprivation" attacks that cause premature usage of battery power by sending control messages at sustained, high rate; and
- Intrusions into emergency networks, whereby malicious users gain access to networks via RTUs through the communication channels used to communicate with the central control system (which, in turn, may be connected to other systems at the EOC).

The best strategy for countering SCADA cyber-threats is to employ a "defense-in-depth" posture. This means placing detection and protection security mechanisms at several layers of the system. Threat mitigation technologies include digital encryption of control and data messages, device access control lists (ACLs), and password protection at both operator and administrator user levels.

As of this writing, standards for SCADA security are in development. Many government organizations are actively involved with industry and standards organizations to develop standards, guidance, and best-practices for SCADA systems developers, integrators, and implementers.

4.0 Planning and Designing a Public Alerting System

This portion of the bulletin introduces the basics of audible outdoor PAS planning, including PAS device range determination, layout considerations, and cost estimates. Because these aspects of PAS planning can quickly become very technical, the reader should note that all of the design elements discussed in this section are treated in much greater detail in this bulletin's appendices.

4.1 General Considerations for Outdoor Warning Systems

Omni-directional sirens provide greater area coverage than do rotating or directional devices. They provide a more constant signal that improves public alerting in areas with highly fluctuating ambient noise, along with the reinforcing effect of multiple sound sources (up to a 3 dB increase for two adjacent sound sources in the same environmental setting).

Therefore omni-directional sirens can be used to good advantage in areas with high population density, areas with high ambient noise levels (e.g., near factories, highways, or airports), and to cover "pockets" between directional sirens, particularly for partially hilly to hilly terrains. However, use of all omni-directional devices may not be desirable for all situations, particularly for voice address in areas where buildings and terrain features may cause echoes.

Optimal spacing between equally rated *omni-directional* sirens in the absence of special weather and topographical conditions will factor in the reinforcing of their Effective Range (ER)[27]. Of course, PAS design and spacing has to consider the very real world of atmospheric and terrain conditions, not to mention ambient noise levels, rights-of-way, and power supply availability.

4.2 Additional Considerations for Outdoor Voice Systems

As stated above in Section 2.3.3, there are two critical factors for voice warning: *audibility* and *intelligibility*. For public alerting tones (e.g., siren sounds), only audibility has to be considered. The upper limit on *loudness* is based on the maximum allowable sound exposure limits delineated in 29 Code of Federal Regulations (CFR) 1910.95, "Occupational Noise Limits" or other upper loudness limits set by a code or standard (e.g., NFPA 72, *National Fire Alarm Code*.) The lower limit of *audibility* is based on ambient noise levels and assumes people with normal hearing who are not actively listening for the alert signal. Hence, there should be a margin between the outdoor PAS loudness and the expected ambient noise levels.[28] (Section 4.5, "Audibility and Range Determination," addresses audibility considerations for outdoor PAS in greater detail, and a methodology for range determination, along with sample exercises, is provided in *Appendix F: Effective Range Prediction Methodology*.)

Speech intelligibility is measured by how much of the voice message can be understood, and there are a number of methods to determine speech intelligibility. These include:

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[27] Two sirens with identical intensities can result in an additive reinforcement system effect between each device.

[28] As noted in *Appendix A: Applicable Codes and Standards*, the standards for audibility endorsed by reference in NFPA 1221, *Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems*, to NFPA 72, *National Fire Alarm Code*, apply to indoor alerting systems or alerting systems for enclosed areas (e.g., stadiums). However, these are not representative of typical conditions for an outdoor PAS.

speech transmission index (STI); phonetically balanced word scores (PB); modified rhyme test (MRT); articulation index (AI) also called speech intelligibility index (SII); and percentage articulation loss of consonants (% Alcons).[29]

This bulletin recommends the use of STI and SII measures because they: (1) are objective measurements; (2) can be readily included in sound analysis programs to predict speech intelligibility; (3) are used in instruments that can be used for field measurements; and (4) do not require prolonged periods to obtain reliable results. (For a more detailed discussion of speech intelligibility than the general discussion below, see *Appendix E: Speech Intelligibility Scales and Recommendations*.)

For typical outdoor voice warning, the following general factors need to be considered for voice intelligibility:

4.2.1 Electro-Acoustic Parameters

These include amplification, frequency response, noise, and distortion. These are effects from the electronic circuitry used to produce or reproduce voice communication up to and including the loudspeaker's output.[30]

4.2.2 Signal-to-Noise Ratio

This is the reproduced voice's sound pressure level above background noise and includes human speech's variable loudness and high frequency components (see Section 2.1). For these reasons, the range of speech intelligibility from an electronic loudspeaker is likely to be far less than its audibility range when emitting a pure siren tone. To some extent, however, differential effects can be compensated for by using digital voice reproduction that restricts voices to the 500 Hz to 1,000 Hz range and ensures that voice dynamics levels do not fluctuate too greatly.

4.2.3 Echoes

An echo occurs when sound bounces off acoustically "hard" surfaces, causing multiple sound arrivals at different times from *one* sound source to the listener. Echoes are not usually a big concern unless there are highly reflective surfaces nearby, i.e., high-rise buildings, larges expanses of water, salt flats, dams, mesas, and bluffs.

4.2.4 Multiple Arrival Effect

When a listener receives the same voice message at a slightly different time from *multiple* sound sources, it causes the voice message to become less distinct or to "blur." This effect can be lessened by suitable placement of loudspeakers with the

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[29] Please refer to IEC 60849, *Sound Systems for Emergency Purposes*, for a more detailed description of each of these methods. The Common Intelligibility Scale (CIS) was developed to correlate these intelligibility scales. See *Appendix E: Speech Intelligibility Scales and Recommendations* for CIS conversion figures.

[30] UL 1480, *Speakers for Fire Alarm, Emergency, and Commercial and Professional Use*, provides acceptance standards for emergency loudspeaker systems for these effects.

understanding that *not all listeners within an outdoor PAS zone can have this effect completely eliminated*.

4.2.5 Voice Characteristics

These include the type of speech (speaker's language, dialect, and vocabulary), clarity of articulation, vocal effort (soft or loud voice), and speaking rate. To ensure optimal voice characteristics, prerecorded or pre-scripted messages read by trained speakers are recommended. As appropriate—and given the time constraints during an actual emergency—voice messages can be repeated in the languages that can be understood by the maximum number of listeners within the area covered by the PAS.

4.2.6 Listener Characteristics

These include hearing characteristics, level of concentration, and listeners' knowledge and familiarity with the spoken message. To provide maximum assurance that people will listen to a voice message or at least be aware that an emergency exists, the sequence should begin with an alerting tone, be followed by the voice message, and conclude with an end tone. A suitable public information program and regular outdoor PAS testing also provide maximum assurance that listeners will have appropriate knowledge of and familiarity with the message.

4.3 Determining the Best Means of Alert and Notification

4.3.1 System Considerations

A key task in planning an outdoor PAS is to determine the best method for alerting and notifying the public, considering demographics, topography, meteorology, potential hazards, man-made structures or systems (i.e., the built environment), ambient noise levels, and availability of AC power supply. If siren tones are used for alerting, the public should then consult EAS, NOAA Weather Radio (NWR) or other notification method(s) to determine the details on the hazard and what they are expected to do. Similarly, message signs may instruct motorists to tune to a particular radio frequency for details. All PAS alert and notification methods should be interoperable to the maximum extent possible. As of this writing, the methods to achieve such interoperability have not yet been fully implemented.

Voice capability is particularly advantageous in open areas where there are large numbers of transients (including visitors, business travelers, seasonal workers, hikers, campers, or tourists) who are not familiar with the types of emergencies characteristic of the area or what is expected of them in response to a siren activation. Voice capability, therefore, can provide timely alert and notification details. Voice warning can also be effective when complex instructions are required, or where it is critical that people outdoors need to leave an area or quickly take shelter.

Finally, the use of message signs is particularly advantageous for highways with large volumes of traffic (and associated high ambient noise levels) to provide timely alert and notification to motorists.

4.3.2 Special Needs Considerations

Complementary warning methods for special populations (e.g., hearing impaired, visually impaired), institutions (e.g., hospitals, schools, large industrial or commercial facilities), or residences that are located beyond outdoor PAS audibility or intelligibility range should also be included in the PAS. Other or supplementary means of alerting may be needed for special needs individuals to ensure that all members of the public receive timely alert and notification on a consistent basis.[31]

4.4 Outdoor Warning System Layout Considerations

Whether by use of paper maps or by more advanced methods such as GIS-based modeling and design of sound source placement, the PAS layout process can be broken down into the following steps:

4.4.1 Determining Where Outdoor Methods Will Be Most Effective

This assessment evaluates the appropriate methods for the potentially affected populations. This includes special populations (e.g., hearing impaired, visually impaired, physically impaired) for which outdoor alerting methods may not be effective. Supplementary means other than sound-based outdoor public alerts may be needed for these people.

4.4.2 Determining Ambient Noise Levels

This can be based on community noise surveys or by using Table C-1: Estimated Outdoor Ambient Daytime Sound Levels (see *Appendix C*). Add 10 dB to the ambient noise levels to determine the minimum required sound levels throughout the area to be covered by the outdoor PAS. This can be done by either determining ambient noise levels for all sub-areas, or by selecting a maximum ambient noise level within the area to be covered by the outdoor PAS. In addition to audible alerting, use of message signs should be considered for highways to ensure maximum alert and notification of motorists.

4.4.3 Determining Terrain

Terrain around an Outdoor Warning System has the potential for blocking the sound from the warning devices, significantly reducing their effective range. While the full calculation for sound propagation around terrain is complex, a good first approximation is to use the direct LOS rule. If there is a direct LOS between the warning device and the ground, the warning device will be able to reach its full range. Wherever the terrain blocks that LOS, that is the limit of the warning system's range.)See *Appendix F* for more details.)

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[31] Desirable features for any indoor PAS are also addressed by UL 2017, *General Purpose Signaling Devices and Systems*, as Type AM (Attendant-Monitored), Type SM (Self- Monitored) or Type UM (User-Monitored) devices. UL 2017, Section 59 through 61 contains standards applicable to alarm and trouble signals; annunciation, display and recording; power sources; and signaling paths for Type AM, SM and UM devices, respectively. Desirable features of an indoor loudspeaker used as a PAS are addressed by UL 1480, *Speakers for Fire Alarm, Emergency, and Commercial and Professional Use.*

4.4.4 Determining Suitable Locations For Outdoor PAS Devices

The best places to start are those areas that are located in public rights-of-way and that are near areas that have high ambient noise (e.g., highways, railroads, and commercial areas). Locations that have good line-of sight to the surrounding areas (e.g., hilltops and centers for radial street patterns) should then be identified. Locations for which permission to site a PAS device can be readily obtained (e.g., public buildings and parks) should then be identified.

4.4.5 Determining Locations Where Outdoor PAS Devices Should Be Avoided

Locations to be avoided include noise-sensitive locations such as hospitals. In addition, for radio-controlled systems, areas that are known to have weak signals or high amounts of radio frequency interference (RFI) should either be avoided or use hardwire connections instead (e.g., electrical or fiber optic cable.) For systems that use radio systems, avoiding strong signals near buildings or areas that ban or restrict the use of cellular telephones (e.g., hospitals and commercial airports) must also be considered. In some cases, other PAS methods such as special purpose radio receivers may be necessary to ensure that these areas receive timely alert and notification.

Multiple layout options are possible for most communities. Several trials may be necessary to obtain a layout that features the minimum number of devices, but planning can be greatly facilitated by the use of GIS. Generally, the fewest number of devices that provide adequate sound coverage will result in the most cost-effective outdoor PAS (see Section 4.6). However, there are some tradeoffs.

Covering the same area with the fewest PAS devices may require devices with higher effective range (i.e., dB at 100 feet). However, devices with greater effective ranges generally require higher mounting height to ensure that nearby pedestrians do not receive harmful noise exposure. It is also important that the PAS device mounting heights do not exceed the capacity of available equipment required to service them (e.g., bucket trucks). Also, louder voice devices do not always correlate to greater intelligibility, particularly in environments such as urban areas that may be prone to echoes.

In situations where there are high fluctuations in the ambient noise level, or near the limits of the audible device range, omni-directional devices present a distinct advantage, in terms of their signal consistency, over rotational devices. For example, because of the reduced duration of its peak sound level in any single direction during it's 360^{o} sweep, a rotational device will have an overall lower dB level when *assessed across a given time period* than an omni-directional device operating at the same frequency. Additionally, because sound has a reinforcing effect, omni-directional devices can act as sound "boosters" with adjacent audible devices. The effect applies for adjacent omni-directional audible devices as well as to omni-directional devices that are adjacent to rotational or directional devices.

However, omni-directional audible devices typically use more power than rotational or directional devices of the same sound output and the same design (electro-mechanical or electronic). Thus, use of all omni-directional audible devices may not be desirable for all outdoor PAS situations, particularly where there are electrical power availability limitations.

4.5 Audibility and Range Determination

The focus of this section is those factors that must be addressed in order to ensure that an audible outdoor PAS is compliant with applicable test methods. The range of a PAS device is a function of loudness, operating frequency, mounting height, atmospheric conditions (including wind speed and direction), terrain effects (including natural barriers and large structures that can change sound paths), and ambient noise levels.

Testing should be conducted on a device that is representative of what is to be installed. It is strongly advised that copies of the actual test reports be obtained from the vendor for each device model that is to be supplied. Rated sound output is determined by testing in accordance with applicable American National Standards Institute (ANSI) standards. These are:

4.5.1 Device Ratings Determined By Outdoor Testing

The preferred method to obtain test rating of these devices is in accordance with ANSI Standard S12.14, which sets the methods for the field measurement of the sound output of audible PAS devices. As an alternative, ANSI Standard S1.13, which outlines the measurement of sound pressure levels in air under normal meteorological conditions, may be used.

4.5.2 Device Ratings Determined By Use of Test Chambers

Test ratings should be conducted in test chambers that meet the requirements of ANSI Standard S12.35, the standard that applies to test methods for sound power level of a sound source in test chambers. The test rating of devices in a test chamber can be obtained either by use of ANSI Standard S12.35 (for multi-point measurements) or use of ANSI Standard S1.13 (for single point measurements).

4.5.3 Mounting Height

The minimum mounting height should be in accordance with vendor recommendations based on ANSI S12.14 testing results. The minimum mounting height is typically 35 to 50 feet above the local terrain and is based on the assumption that the device output centerline is in the horizontal plane. This height and orientation ensures that that 29 CFR 1910.95 noise exposure limits or the Committee on Hearing, Bioacoustics, and Biomechanics (CHABA) of the National Academy of Sciences recommended limit of 123 dB is not exceeded for anyone at ground level in the immediate vicinity of the PAS device.

The minimum mounting height should also ensure that the device output is unobstructed by barriers to sound such as trees, hillsides, or buildings. Trees within at least 100 feet of each PAS device should be identified for potential removal or cropping to a height well below the device elevation. Buildings under construction or tree growth that cannot be removed or cropped in the immediate vicinity below the device mounting height likely will require that the PAS device either be supplemented or relocated. Finally, an outdoor PAS device mounted on a hillside must also account for uphill slope to ensure adherence to minimum mounting height requirements. (For a more in depth discussion of audibility and range determination in the PAS design process, see *Appendix F: Effective Range Prediction Methodology*.)

4.6 Preliminary Cost Estimations

A critical planning concern is the ultimate cost of the outdoor warning system. The number of devices needed and their control circuitry, in turn, is central to the system's eventual installation and maintenance costs. During system planning, the responsible officials may want to iteratively adjust system layout and device capabilities to balance costs while maximizing the alert coverage area. This balancing may include decreasing the total number of devices by increasing the sound level rating for each device used. *Appendix G* presents equipment cost information to assist in determining system planning level cost estimates.

A pair of recent "best practice" installation cases in the United States illustrated in *Appendix G*, Table G-2 can help demonstrate the costs associated with installing comprehensive systems. A good example of a mid-sized system (in terms of both area *and* population covered) can be found in Little Rock, Ark. The system went on line in April 2004 at a total installation cost of $1.7 million. This included 56 audible PAS devices at a unit cost of $30,400 each and provides coverage for 184,000 people.

The Oklahoma City, Okla. outdoor warning system gives a better idea of the costs involved in covering a larger populace and geographic area. Completed in 2002, the Oklahoma City system serves 750,000 people across a 620 mi² area. Comprised of 182 electronic, battery-powered sirens, the system is designed to provide alerts for tornadoes, severe storms, flooding, and terrorist acts and is designed around two principle siren types. In urban areas, omni-directional sirens with voice capability were installed, while in rural areas, rotating sirens were used. The finished system cost $4.5 million and has an annual operational and maintenance budget of $200,000 a year.

Responsible officials can partition more complicated projects into several uniform regions using the Sample Cost Tables in *Appendix G*.

4.7 Activation, Control, and Monitoring

The activation, control, and monitoring system should include features that provide maximum outdoor PAS operational reliability and flexibility. These include:

4.7.1 Redundancy

This includes features such as primary and secondary power (see Section 3.4), multiple locations for system activation and control, and multiple communication paths (e.g., use of more than one radio frequency, use of digital repeaters, and multiplexing).

4.7.2 Interoperability

Activation, control, and monitoring hardware and software should be designed so that it can interface with sensors and other PAS methods (e.g., dynamic message signs, tone alert radios, and automatic telephone ring-down systems.) and control points without requiring operator intervention. The Department of Defense (DOD) defines *interoperability* as: "The condition achieved among communications electronics systems or items of communications-electronics equipment when information or services can be exchanged directly and satisfactorily between them and/or their users." [32]

4.7.3 Backward Compatibility

NFPA 1221, Chapter 12, Public Alerting Systems, requires that PAS be "backward compatible." However, the standard does not define the term. In computer networks, a system is *backward compatible* if it is capable of being used with, or connected to, earlier versions of itself without modification or the systems it intends to supplant. Expanded to a more general context, this means that replacement hardware and software should be compatible with pre-existing hardware and software and should perform in an essentially identical manner. Some older hardware may become obsolete, however, and require replacement.

4.7.4 Other Features

NFPA 1221, Chapter 12, Public Alerting Systems, contains standards applicable to security and trouble signals in response to a low-battery condition. Underwriters Laboratories Inc. (UL) 2017, Section 58.3, contains standards applicable to software and programs required to operate PAS. UL 2017, Section 59, contains standards applicable to Type AM (Attendant-Monitored) alarm and trouble signals; annunciation, display and recording; power sources; and signaling paths. Sections 60 and 61 of this standard address similar requirements applicable to Type SM (Self-Monitored) and Type UM (User-Monitored) devices, respectively. (For additional guidance related to activation, control, monitoring, and testing of an outdoor PAS, please refer to Section 5.0, "Testing of Outdoor Warning Systems.")

5.0 Testing of Outdoor Warning Systems

This section provides an overview of audible PAS testing, at both the device and system communications levels. In addition, the field testing of audibility and intelligibility are discussed as well.

5.1 General Testing Considerations and Guidance

The information below concerning regular system testing is intended as a general guide. Testing type and frequency should be determined based on the specific function of the outdoor system, the specific PAS devices installed, and vendor recommendations for the specific components. For example, for a PAS whose primary function is to serve as a

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[32] DOD Joint Staff Publication No. 1-02, *Department of Defense Dictionary of Military and Associated Terms,* 1994.

tornado warning system, it may be appropriate to increase testing during tornado season and to decrease testing throughout the rest of the year. However, a PAS that is designed primarily to alert the public about technology-related hazards (e.g., chemical or radiological releases) should be tested at equal intervals throughout the year.

5.1.1 Harmful Effects of Warning Sounds

Because audible warning devices are used "in earnest" to alert a population of impending disaster, it seems surprising that anyone would be concerned about the deleterious effects of the sounds themselves. Indeed, many local noise ordinances specifically exempt warning sounds from noise-level restrictions. Nevertheless, in some communities sirens are tested so frequently that complaints about their noise levels have been reported.

PAS device installations should be sited to avoid exposing anyone to sound levels exceeding 123 dB[33]. In general, this requirement can be achieved by mounting the device high enough above ground level so that the sound is directed mostly over the heads of people standing on the ground near the device. The minimum mounting height needed to meet this requirement, as calculated for a device rated at 120 dB, should be 32 feet above the ground. Of course, a higher mounting may be desirable to place the source above the prevailing rooftop height.

In those cases where it is impossible to mount the device high enough to achieve a safe sound level on the ground, large signs, such as the one depicted in Figure 15, should be prominently displayed on the PAS device.

Figure 15: PAS Device Warning Sign

For test purposes, audible warning devices should be located and operated so that no person is likely to be subjected to a sound level great enough to cause hearing damage.[34] Loud sounds, however, even if not potentially damaging, can be viewed as a disturbance by some residents of a community. Operators of audible outdoor warning systems should realize this fact, and should:

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[33] A suitable limit for this purpose, based upon recommendations of the Committee on Hearing, Bioacoustics and Biomechanics (CHABA) of the National Academy of Sciences, is 123 dB(C).
[34] *Ibid.*

- Minimize the frequency and duration of outdoor warning device tests;
- "Growl tests" (tests that energize the siren rotor for just a few seconds and that produce just enough sound that personnel can make sure it is functioning) can be conducted when the source is a siren;
- Refrain from conducting tests at night when people are relaxing and sleeping; and
- Avoid locating warning devices too close to noise sensitive activities.

5.1.2 Testing Protocol

Detailed information on the testing of outdoor warning systems is given in CPG 1-14 and includes recommendations that local officials:

- Test the outdoor warning system once a month;
- Publicize the testing day and time each month;
- Test by sounding the "Attention" or "Alert" signal (the steady sound) for no more than one minute;
- Follow with one minute of silence;
- Finish by sounding the "Attack Warning" (rising/falling signal or series of short blasts) for no more than one minute; and
- Emphasize, in all public announcements, that testing signals are sounded for less than one minute only, while in an actual emergency, all warnings would be sounded for three to five minutes and then repeated; and
- Personnel should visually inspect and/or test PAS devices after severe weather events such as hurricanes, tornadoes, ice storms, and hail.

An outdoor PAS that has multiple activation points should alternate PAS testing and activation equally among the activation points to ensure that all PAS activation and testing components are functioning within their respective design limits. Ideally, electrical schematics and logic diagrams should be reviewed against testing procedures to ensure that all portions of the system are tested, including: 1) each individual PAS device; 2) control, test, and activation circuitry (including communications circuits); and 3) system electrical power (both primary and backup). All relays, contacts, control switches, motors, batteries, and other relevant electrical and electronic components should also be included. Wherever possible, direct readings should be used (e.g., electrical continuity at main contacts instead of at auxiliary contacts or rotation rather than belt tension on a directional device).

A modern outdoor PAS typically uses computer-based SCADA systems for system activation, control, monitoring, and testing. Such systems are increasingly affordable and provide significant system performance improvements, including multiple paths for PAS device activation, other functional redundancies, better and more detailed testing capabilities, ability to transmit prerecorded voice messages, easier integration with detection systems, and faster overall warning system response.

A properly designed PAS allows for regular system polling and testing without the need to sound the sirens or electronic devices (i.e., silent testing). These elements include suitable interface testing equipment installed in each PAS device and suitable two-way system communication methods between each PAS device and the SCADA system used for activation, control, monitoring, and testing. In addition, SCADA software quality control and configuration management are keys to assuring that proper PAS activation, control, monitoring, and testing can be performed.

5.1.3 Public Information Campaigns

The responsible officials who initiate public information campaigns that focus upon warning system tests and the meanings of sounds they employ have the inherent benefits of working with messages that are neither lengthy nor hard to understand and, more important, perhaps, *addressing people regarding their own safety*. Officials should involve all available media in the community—newspapers, radio stations, and both broadcast and cable-based television stations—in the campaign and should not overlook such useful forms of communication as posters in public buildings, newsletters sent out by community organizations, flyers enclosed in utility bills, and opportunities to address school assemblies.

The message must be straightforward, and the best campaign will repeat the same announcement, in the same words, multiple times. Suggestions for conducting a public information campaign are contained in "Ideas for Conducting Awareness Campaigns," FEMA document MP-83.

5.2 Systems with Automatic Testing and Feedback Features

The following outdoor PAS minimum testing frequency is recommended:

- Silent tests should be conducted at least every 24 hours. This testing also should involve sending appropriate test messages to any message signs that are part of the outdoor PAS.

- For electro-mechanical sirens, growl tests should be conducted at least quarterly and as part of post-maintenance testing.

- For any rotating PAS device, rotation through at least one complete cycle (either at least one rotation or one oscillation) should be conducted at least quarterly and as part of post-maintenance testing.

- For loudspeakers, voice testing should occur at least annually using a predetermined test message (e.g., "This is a test. This is a test.") For directional loudspeakers, this testing includes stopping at each predetermined direction and making the test announcement.

- Full-scale device testing, including full activation of each device, should occur at least annually and as part of post-maintenance testing. Testing should not be longer than about one minute in duration (as opposed to at least a three-minute sounding for an actual emergency). Depending on specific system requirements, it may be desirable to perform testing on groups of devices rather than the entire outdoor PAS at one time. However, each outdoor PAS device should have a full-scale test at least annually.

- Testing of each outdoor PAS device without primary power should be performed at least annually. As appropriate, this testing can be performed in conjunction with scheduled maintenance (e.g., battery load testing).

- Electronic message signs should be observed at least annually to ensure that they remain readable in full sunlight.

5.3 Systems without Automatic Testing and Feedback Features

System designs without automatic testing features typically require frequent test activations to ensure that they are functioning as designed and to identify components that require corrective maintenance. Testing of these systems involves stationing people near each PAS device to verify that each device functions. The overall testing is similar to that described above, including:

- For rotating devices and loudspeakers, a test of at least one complete cycle (either at least one rotation or at least one oscillation) should be conducted at least monthly and as part of post-maintenance testing to ensure that it can give the required area coverage.

- For loudspeakers, voice testing should occur at least monthly using a predetermined test message (e.g., “This is a test. This is a test.”) For rotational loudspeakers with the capability to stop at several pre-determined positions and produce messages, this testing should include checks of the announcement’s audibility at each of these positions.

- Full-scale device testing (including full activation of each PAS device) should occur at least monthly and as part of post-maintenance testing. Such testing can be reduced to quarterly if growl tests can be performed instead. Testing should not be longer than about one minute in duration (as opposed to at least a three minute sounding for an actual emergency). Depending on specific system requirements, it may be desirable to test in groups of devices rather than the entire outdoor PAS at one time. However, each outdoor PAS device should have a full-scale test at least monthly.

- For electro-mechanical sirens, growl tests can be used to substitute for the monthly siren test and as part of post-maintenance testing.

- Testing of each PAS device with a UPS should include operating it without primary power at least annually. As appropriate, this testing can be performed in conjunction with each PAS device scheduled maintenance (e.g., battery load testing).

- Sending appropriate test messages to any electronic message signs that are part of the outdoor PAS should be done at least quarterly. This includes observation to verify that they remain readable in full sunlight.

5.4 Special Considerations for Modular Sirens and Voice Warning Devices

Typical electronic PAS devices require multiple speaker-drivers operating in parallel to produce the device tested output. (This is in contrast to typical electro-mechanical sirens that have a single module required to produce their sound output.) Hence, electronic PAS devices may still make sounds, but not produce sufficient sound output to meet the level assumed in the PAS design if one of the component modules is not operating. Therefore, the modular device testing methods used to determine siren operability should be capable of demonstrating that the minimum required modules are functioning and the test methodology should account for each speaker-driver pair.

5.5 Periodic Audibility and Intelligibility Testing

In addition to the regular outdoor PAS testing program, periodic "near-field" sound testing (every several years *or* following corrective maintenance) should be performed to verify audible sound output from the PAS devices. This can be conducted in conjunction with post-maintenance testing or scheduled PAS testing.

Near-field sound testing is conducted at ground level, 200 to 400 feet from the audible PAS device and does not require the use of a bucket truck. It should be conducted cross-wind from the device (or during calm wind conditions), in direct LOS from the device and not over a "hard" acoustic surface (e.g., water, ice, asphalt or concrete), and be free of sound reflecting surfaces (e.g., buildings, walls, or large rock formations) in the immediate vicinity of the measuring point, i.e., *no closer to the measuring point than the distance to the sound source being tested*. (For further discussion of range determination methodology, including exercises, see *Appendix F: Effective Range Prediction Methodology*.)

Near-field attenuation is 6 dB per distance-doubled over grass or low shrub-covered surfaces. Thus, a sound output measurement taken at 200 feet plus 6 dB can be compared to the rated output at 100 feet to determine if the device meets its tested rating. Only minor degradation in sound output from design rating (less than about 1 dB) should be considered acceptable.[35]

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[35] Consult ANSI Standard 12.14, *Methods for the Field Measurement of the Sound Output of Audible Public Warning Devices Installed at Fixed Locations Outdoors*, for details.

For loudspeakers, specifically, periodic speech intelligibility testing (every several years *or* following corrective maintenance) should be performed. This can be performed in conjunction with the periodic near-field sound testing method described above. This is to ensure that the minimum design speech intelligibility is being maintained. There are a number of objective and subjective methods that can be used for this purpose, with objective methods typically being preferred. (For further discussion of speech intelligibility, see *Appendix E: Speech Intelligibility Scales and Recommendations*.)

6.0 Maintenance and Inspection

Maintenance and inspection are necessary to ensure that an outdoor PAS will operate properly throughout its design lifetime. The amount of maintenance that is likely to be required over the system design life is an important factor in determining system life-cycle costs and should be an important consideration during the initial system design and vendor selection phase. To minimize the total life-cycle cost of an outdoor PAS, a suitable preventive maintenance program should be developed, and the program and its associated costs (e.g., training and required spare parts) included as an integral part of the vendor bidding and evaluation process. Thus, such items as guaranteed minimum time for availability of spare parts, specification of backward compatible components and software design, initial and follow-up training, and operating and maintenance experiences with similar systems should be included in the outdoor PAS bid request so that PAS life-cycle costs can be determined and appropriate long-term resource requirements understood and budgeted.

6.1 Scope of Maintenance Program

Maintenance should address all components in the outdoor PAS and reflect the system testing methods described earlier in this bulletin. The maintenance program should encompass minor adjustments, and the repair and replacement of components based on predetermined performance criteria. The performance criteria are based on the relevant component design requirements. For example:

- An electro-mechanical siren is intended to produce an alerting signal for a specified duration at a specified frequency at a specified sound pressure level.
- An electronic siren requires a minimum sound output and a number of modules (e.g., drivers) to be functioning to achieve the output rating required for the PAS design.
- An electronic loudspeaker should have a minimum specified speech intelligibility at a minimum specified range at the maximum specified ambient noise level.
- A back-up power supply is to provide sufficient stored electrical energy to ensure that a device can operate for a specified duration without AC power and be fully recharged within a specified duration after AC power is restored.
- A message sign should be readable at a minimum specified distance for a person with a minimum specified visual acuity in full sunlight.

A suitable PAS maintenance program addresses both *preventive maintenance* and *corrective maintenance*.[36] In most circumstances, preventive maintenance is more cost-effective than corrective maintenance. However, system maintenance and testing methods should be developed in an integrated manner. For example, checking only battery voltage can be acceptable if the maintenance program includes a regular battery loading test and replacement of batteries on a regular schedule consistent with the vendor recommendations and/or field experience. Likewise, lubricants should be selected based on temperature extremes to avoid giving a misleading reading of adequate motor current draw during cold weather conditions.

Suitable PAS maintenance also needs to be provided for testing, activation, and control components to ensure that the outdoor PAS will perform reliably when it is needed. Electronic components typically need to operate within tight limits to ensure that the integrity of audible PAS design sound output is maintained. Relatively minor degradation in output to just below recommended minimums (e.g., minimum motor voltage or minimum speaker-driver voltage) can have significant negative effects on audible PAS range and area coverage.

6.2 Preventive Maintenance

A suitable preventive maintenance program should typically address the items listed below. Visual inspection normally occurs more often than other preventive maintenance tasks. Most preventive maintenance tasks should be performed at least twice a year, but preferably on a quarterly basis.

Visually inspect PAS device support and interfacing components:

- Grounding systems and junctions;
- AC service, disconnect, fuses and breakers;
- Utility pole (general condition and plumb);
- Mounting devices;
- Conduits and weather seals;
- Optical/electrical cables, wires, connections, and junctions;
- AC surge protection; and
- Cabinets, housings and coated surfaces, including such miscellaneous items as control cabinet desiccant bag, Z-Rust, debris, emergency shut-off switch, and cabinet lock.

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[36] There also can be some aspects of *predictive maintenance* involved in PAS maintenance efforts (e.g., being able to predict when a component will fall outside its required performance limits and performing suitable maintenance before that occurs). Predictive maintenance is particularly helpful in evaluating sensitive electronics to ensure that they will not fall below output voltage, impedance, and current tolerance levels before the next round of scheduled preventive maintenance. Hence, predictive maintenance is usually incorporated into a suitable preventive maintenance program that includes documenting “as-found” and “as-left” conditions, then trending and extrapolating the results.

Inspect and service PAS device:

- Grease and transmission fluid levels (electro-mechanical sirens and rotating devices);
- Belts, gears, and clutch tension (electro-mechanical sirens and rotating devices);
- Motors and collector bushings (electro-mechanical sirens and rotating devices);
- High-current relays/contactors; and
- Lights and optical cables (message signs)
- Radio frequency (RF) equipment inspections should include the following:
  - RF output
  - Antenna System Reflected Power
  - Compute VSWR (voltage standing wave ratio)
  - Antenna mechanical stability and alignment
  - Antenna cable mounting
  - Transmitter frequency
  - Transmitter modulation level
  - Receiver sensitivity
  - Critical operating levels/voltages between radio equipment input/output and the RTU input/output
  - Battery voltage to the radio during transmit mode

Test and adjust or replace as appropriate:

- Controller and status-monitoring devices;
- Radio communications integrity (for radio-controlled PAS devices);
- Antenna system (for radio-controlled PAS devices);
- Current sensors;
- Rotation transmission inspection/testing (electro-mechanical sirens);
- Individual speaker-driver impedance (electronic devices); and
- Inspect and test electrical power systems:
  - Back-up power supplies;
  - Transformer rectifier;
  - DC chargers, regulator settings, and limiting circuits;
  - Batteries (in addition to regular inspection, batteries should be replaced at vendor recommended intervals);
  - Solar charging panels (for solar-powered devices).

Inspect and test activation, control, monitoring, and test system:

- Physical inspection of control components, wiring, connections, and any other aspect that has the potential to negatively impact said equipment operation;

- Electronic inspection of computers and PAS activation consoles, including file and other program management and any other aspect that has the potential to negatively impact equipment operation;
- RF equipment inspections including RF output, VSWR measurement and other RF tests, along with any other aspect that has the potential to negatively impact equipment operation;
- Telephone line or Internet connections;
- Determine that the equipment is operating within vendor specifications; and
- Verify communication links for system.

6.3 Corrective Maintenance

Corrective maintenance is performed after a specific operational problem has been identified and reported. Corrective maintenance should be performed immediately, if possible, or—at the outside—within 72 hours (three days). However, weather conditions, the availability of personnel, specialized equipment (e.g., bucket trucks), and spare parts can sometimes lead to delays beyond 72 hours. If this should be the case, mangers should produce a written report that: 1) describes the problem in detail and 2) identifies a specific time when the siren will be returned to service. This report should then be forwarded to the responsible official.

Corrective maintenance is also a function of exposure to the elements and overall age of the system. Personnel should visually inspect and/or test PAS devices after severe weather events such as hurricanes, tornadoes, ice storms, and hail. At some point, however, it will become more economical to install new components rather than to repair existing devices, especially when spare parts for existing devices are no longer readily available.

6.4 Audibility and Visibility Barriers

In addition to the tasks listed above, maintenance and surveillance also should include regular checks for vegetation growth and new building construction near outdoor devices. Trees within at least 100 feet of an audible PAS device should be identified for potential removal or cropping to a height well below the device's elevation. New buildings under construction or tree growth that cannot be removed or cropped in the immediate vicinity of an audible device should be identified. These can either block sound or cause excessive sound levels to reach people inside the buildings. Existence of these conditions can necessitate relocating the device or adding another device to cover areas that are adversely affected by the barrier. Similar concerns exist for vegetation growth in the immediate vicinity of electronic message signs, namely ensuring that clear sight lines are maintained and that these devices remain visible.

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Acronym Index

AC	Alternating Current
ACL	Access Control List
AI	Articulation Index
ANSI	American National Standards Institute
APTS	Association of Public Television Stations
AWIPS	Advanced Weather Interactive Processing System
CAP	Common Alerting Protocol
CFR	Code of Federal Regulations
CHABA	Committee on Hearing, Bioacoustics, and Biomechanics
CIS	Common Intelligibility Scale
CPG	Civil Preparedness Guide
DHS	Department of Homeland Security
DMIS	Disaster Management Interoperability Service
EAS	Emergency Alert System
EOC	Emergency Operations Center
ER	Effective Range
FCC	Federal Communications Commission
FEMA	Federal Emergency Management Agency
GIS	Geographical Information System
IEC	International Electrotechnical Commission
INPAWS	Integrated Public Alert and Warning System
ITS	Intelligent Transportation System
LED	Light-emitting Diode
LOS	Line of Sight
MRT	Modified Rhyme Test
MTU	Master Terminal Unit
NAS	National Academy of Sciences
NAWAS	National Warning System
NFPA	National Fire Protection Association
NOAA	National Oceanic and Atmospheric Administration
NWR	NOAA Weather Radio
NWS	National Weather Service
OASIS	Organization for the Advancement of Structured Information Standards
OSHA	Occupational Safety and Health Administration
PAS	Public Alert System
PB	Phonetically Balanced
RFI	Radio Frequency Interference
RTU	Remote Terminal Unit
SAME	Specific Area Message Encoding
SCADA	Supervisory Control and Data Acquisition
SEPSS	Stored Emergency Power Supply System
SII	Speech Intelligibility Index
STI	Speech Transmission Index

TAR	Tone Alert Radio
TCP/IP	Transmission Control Protocol/Internet Protocol
UHF	Ultra High Frequency
UL	Underwriters Laboratories Inc.
UPS	Uninterruptible Power Supply
USGS	United States Geological Survey
VHF	Very High Frequency
VMS	Variable Message Sign
VSWR	Voltage Standing Wave Ratio
XML	eXtensible Markup Language

Glossary

Acoustic Shadow
Acoustic shadow is an area where the sound reaching a listener is greatly reduced, often by daytime conditions and wind effects that are fairly typical. In a calm daytime atmosphere, temperature decreases with increasing height above the ground and, because sound speed through the air is proportional to the square root of the air temperature, sound velocity decreases with height. As a result, sound waves have a tendency to bend upward—and away from listeners on the ground—under calm conditions.

Alternating Current
An alternating current (AC) is an electrical current where the magnitude and direction of the current varies cyclically from positive to negative. Typically, AC refers to the form of electricity delivered to residences, business, and industry. AC is often contrasted with direct current (DC), the form of electricity produced by batteries.

Ambient Noise
Ambient noise is the all encompassing background noise that exists in most environments at any given time. Outdoors, it is usually composed of sound from all sources near and far—bird calls, traffic the next block over, or industrial operations several miles away—the sum of which affects the listener's ability to hear sounds such as warning sirens.

American National Standards Institute
The American National Standards Institute (ANSI) is a private, non-profit standards organization that produces industrial standards in the United States. ANSI facilitates the development of standards by accrediting the procedures of independent standards developing organizations that work in cooperation to create voluntary, consensus standards for the entire nation. ANSI is also a member of **ISO** and **IEC**.

Atmospheric Attenuation
A still atmosphere **attenuates** sound as a function of the sound's **frequency**, temperature, relative humidity, and propagation distance. The loss is directly proportional to the distance traveled, and high frequency sounds have more atmospheric absorption loss than low frequency sounds, i.e., low frequency sounds tend to carry further.

Attenuation
When sound radiates away from its source, its loudness decreases with distance because its energy is spread over a progressively larger area. Additional factors that can affect the attenuation rate include the sound's **frequency,** prevailing weather conditions that can create **atmospheric attenuation**, and varied terrain/vegetation densities that can create **ground absorption**.

Audibility
Audibility is the degree to which a sound can be heard, and it is considered a key metric for evaluating outdoor warning systems. Important components of audibility include whether the sound is louder than the surrounding **ambient noise** and its ability attract the attention of otherwise occupied individuals.

Back-up Power
In the event that that AC power is lost in an emergency situation, battery back-up of outdoor warning devices such as **electronic message signs**, **electro mechanical sirens**, and **electronically amplified systems** is an absolutely integral requirement. Typical back-up battery approaches include stored emergency power supply systems (**SEPSS**) and uninterruptible power supply (**UPS**) that "floats" on local electric distribution grid, with regulations calling for full output capacity without recharge for a period of at least 15 minutes.

Code of Federal Regulations
The United States Code of Federal Regulations (CFR) is the codification of the general rules and regulations promulgated by the Federal Government's executive departments and agencies. Because specialists at the agency level are best equipped to develop detailed applications of legislative statutes, the U.S. Congress grants broad authority to these executive bodies to interpret the statutes that they have been directed to implement and enforce.

Common Alerting Protocol
The Common Alerting Protocol (CAP) is a standard message format for alert and notification, one that allows technical innovation by combining outdoor warning systems with other mass alerting technologies and personal digital devices.

Decibel
As a measure of sound pressure levels, the decibel (dB) scale is used to indicate **loudness**. The dB is a relative unit of measure, where 1 dB's difference between two sounds is generally accepted as the smallest increment that the human ear can distinguish. Because the human ear is capable of detecting a very large range of sound pressures and our perception of loudness is roughly a logarithmic ratio, the dB scale is logarithmic as well. That is, a sound that is perceived as twice as loud as another is 10 dB higher, meaning it has 10 times the sound pressure.

Direct Current
Flow of electric charge that does not change direction is defined as direct current (DC) or "continuous current." DC is produced by batteries, fuel cells, rectifiers, and generators with commutators. DC has largely been supplanted by **alternating current** in most common applications.

Emergency Alert System
The United States replaced the old Emergency Broadcast System with the Emergency Alert System (EAS) in 1997. Administered by the Federal Communications Commission (FCC), the EAS is a national system that covers radio, broadcast television (including low-power stations), and cable television companies.

Electro Mechanical Sirens
An electro-mechanical siren produces sound by forcing compressed air through a narrowed opening called a vortex in much the same way a musician blows air through the mouth piece of a trumpet. This high-volume airflow is converted into high-pressure airflow as it passes through the "horn," the broadening exterior section of the siren that typically resembles a megaphone. Compared to **electronic sirens**, electro-mechanical sirens are typically very cost-effective in terms of their installation cost, reliability, and maintenance.

Electronic Sirens
Depending on the specific design, electronically amplified sirens have the advantage of producing an array of siren-like sounds and voices—all of which can be "broadcast" live or prerecorded. They can, therefore, be used to issue messages as well as warning sounds to the public. Because they are more complex than **electro-mechanical sirens**, these devices typically have a number of **power amplifiers** and other modules that are required to operate in parallel to produce the rated sound output for the device. Furthermore, their sound-output capability is often lower than that available from sirens, meaning more individual sources are usually required to cover the same area.

Electronic Message Signs
Electronic message signs, also called variable message signs (VMS), are commonly deployed along major transportation routes, but they can also be deployed in areas with a large public presence. Modern message signs have light-emitting diode (LED) displays and features that increase visibility in bright, ambient light conditions. Message signs are typically modular in design and can produce character heights that can be read as far as 900 feet away.

Effective Range
The effective range (ER) of a warning device is dependent on three major components: the rated warning device noise level, the atmospheric conditions, and the local terrain.

Frequency
In the simplest terms, frequency is the number of sound waves that pass a given point in one second. One single oscillating wave per second corresponds to 1 **Hertz (Hz),** the standard unit of measurement used for frequency. To the human ear, frequency is closely correlated to our perception of pitch, with fog horns and tympani drums generating low frequencies while piccolos and police whistles produce high frequency sounds.

Ground Absorption

Ground absorption is a form of **attenuation** that occurs when the sound propagation path is close to the ground. For acoustically "soft" surfaces such as grass-covered soil, excess attenuation beyond 250 feet can be significant and, over large distances, is approximately 6 dB per distance doubled. Sound traveling through thick foliage and woods is affected to an even greater extent.

Growl Test

"Growl tests" involve energizing the siren rotor for just a few seconds. Although the process does not produce full sound output, personnel near the siren can determine that it is functioning without causing undue disturbances in noise-sensitive areas.

Hertz

The hertz (Hz) is unit of measure that equals one cycle per second; hence 100 Hz means "one hundred per second," 5,000 Hz means "five-thousand per second," and so on. Although the unit may be applied to any periodic event, in terms of a sound wave's period, the Hz correlates with its **frequency** or perceived "pitch." Average human hearing ranges from 50 to 20,000 Hz, but because high frequencies **attenuate** more rapidly than those lower on the scale, most outdoor warning applications restrict frequency to roughly the 300 to 1,000 Hz range.

International Electrotechnical Commission

The International Electrotechnical Commission (IEC) is an international standards organization dealing with electrical, electronic, and related technologies. Made up of representatives of other national standards bodies, many of the IEC's standards are developed jointly with **ISO** and **ANSI**.

Intelligibility

Intelligibility is the degree to which a sound can be "understood" and is a critical consideration for audible warning devices using voice function. Voice intelligibility, in particular, is the ability of the listener to understand what is being said. There are a number of measures of speech intelligibility, but all rely upon statistical analysis of how well various components of human speech are understood by listeners.

International Organization for Standardization

The International Organization for Standardization (ISO) is the world's largest developer of standards. The organization's primary concern is the creation of technical standards, standards that offer an international conformity that allows industrial organizations of all types, along with governments and other regulatory bodies, to enhance the development of products that range from the high-tech to everyday consumer products.

Loudness

Loudness (or "volume") is the human perception of a sound wave's amplitude or sheer sound pressure, and it is typically measured in **decibels (dBs)**. Psychologists have found that our perception of loudness is roughly logarithmic, and hence the decibel scale is logarithmic as well.

NOAA Weather Radio
NOAA Weather Radio (NWR) is a nationwide network of radio stations broadcasting continuous weather information direct from nearby National Weather Service offices. NWR broadcasts National Weather Service warnings, watches, forecasts, and other hazard information 24 hours a day.

Omni-Directional
An omni-directional speaker assembly is capable of radiating sound equally in all directions simultaneously. It is important to note, however, that such an array is made up of multiple speakers directed outward. Hence, if six radial speakers are employed in an **electronically amplified system**, it would take six times the **power amplification** as a single speaker and, likewise, six times the **backup battery** capacity.

Power Amplifier
Power amplifiers (or "amps") are electronic devices that increase the **loudness** of a signal. They are key components of all **electronically amplified systems** designed for outdoor warning applications. Frequently, power amps will also provide basic control of their sonic output, with functions such as level (loudness) and tone (**frequency** emphasis.)

Radio Frequency Interference
Radio signals from external sources can disrupt the performance of **electronically amplified systems** such as those used in outdoor warning. A naturally occurring by-product of a wide variety of electrical circuits, RFI is electromagnetic radiation that is created by rapidly fluctuating signals. This radiation amounts to an unwanted radio signal that introduces noise into nearby sound-generating electronic chains, even if these are not radio-based, i.e., systems not intentionally equipped to "receive" radio signals.

Reflection
Reflection is term that describes the phenomenon of sound "bouncing" off of hard surfaces. Reflections can be caused by vertical planes such as those created by buildings and walls, as well as acoustically "hard" horizontal surfaces such as water and desert floors.

Supervisory Control and Data Acquisition
Supervisory control and data acquisition (SCADA) systems are those process control systems that electronically measure process state, change parameters associated with process control, and store or transfer process control data.

Stored Emergency Power Supply System
A Stored Emergency Power Supply System (SEPSS), for the most part, takes the form of multiple battery cell arrays that can provide **backup power** in the event of power failures.

Underwriters Laboratories
Underwriters Laboratories (UL) is a well-known testing laboratory that develops standards for consumer products, chiefly those dealing with product safety.
A product with Underwriters Laboratories approval is said to be "UL Rated," and is identified as such for consumers and purchasing agents.

Uninterruptible Power Supply
An Uninterruptible Power Supply (UPS) is a device or system that provides an unbroken electric **backup power** supply to equipment that is considered "essential," i.e., equipment that cannot be shut down unexpectedly. Most often, UPS devices will be installed between the primary power *source* coming from a commercial utility and the primary power *input* of equipment to be protected.

Appendix A: Applicable Codes and Standards

There are a number of codes and standards that are applicable to public alerting systems. New or updated public alerting systems should be consistent with these codes and standards. The detailed citation for each code or standard is found in the "References" section of this bulletin. *When selecting a new or updated PAS, the latest approved versions of these standards should be referenced for details.*

The list below is fairly comprehensive, but it is not exhaustive. For example, codes cited below may also reference other codes such as NFPA 70, *National Electrical Code*, or NFPA 111, *Standard on Stored Electrical Energy Emergency and Standby Power Systems*. Neither does the list include additional standards that apply to a particular type of hazard (e.g., Federal regulations and guidance applicable to commercial nuclear power plant alert and notification systems). Applicable local codes and regulations also need to be considered. In addition, new or revised codes and standards that have been developed after the publication of this bulletin may become applicable.

Table A-1: Summary of Codes and Standards Applicable to PAS

Code or Standard	Title	Applicability
NFPA 1221	Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems	See Chapter 12, Public Alerting Systems. Warning systems are called "Public Alerting Systems" (PAS). NFPA 1221 applies to all forms of PAS, including outdoor public alerting systems. It requires that all PAS be "backward compatible," i.e., replacement hardware and software must be compatible with pre-existing hardware and software and perform in an essentially identical manner. Refers to NFPA 72 as the standard for recommended audible characteristics.
NFPA 72	National Fire Alarm Code	Applies to outdoor PAS used for fire warning. Recommends an objective standard for speech intelligibility and references IEC 60849 as the basis for determining speech intelligibility. However, the recommended (normative) standards apply to indoor alerting systems or alerting systems for enclosed areas (e.g., stadiums) that are not representative of typical outdoor public alerting situations. Please refer to Section 4.2, "Additional Considerations for Outdoor Voice PAS," and *Appendix E: Speech Intelligibility Scales and Recommendations* for appropriate guidance.

Code or Standard	Title	Applicability
ANSI S1.13	Measurement of Sound Pressure Levels in Air	Applies to measurement of sound pressure levels in air under normal, relatively quiescent meteorological conditions. Uses single measuring point. Can be used to determine audible outdoor PAS devices rating using anechoic test chambers or outdoors under certain conditions. Please refer to ANSI S12.35 for test room requirements. Please refer to Section 4.5, "Audibility and Range Determination," and *Appendix F: Effective Range Prediction Methodology* for more details.
ANSI S1.26	Method for the Calculation of Absorption of Sound by the Atmosphere	Methods that are used to determine attenuation through the air from audible outdoor PAS devices must be consistent with this standard. Thus, range calculations must be consistent with this standard. Please refer to Section 4.5, "Audibility and Range Determination," and *Appendix F: Effective Range Prediction Methodology* for more details.
ANSI S3.2	Method for Measuring the Intelligibility of Speech over Communications Systems	Applies to voice warning systems. This standard includes the measurement of intelligibility of speech over entire communications systems, including evaluation of the factors that affect speech intelligibility. Please refer to Section 4.2, "Additional Considerations for Outdoor Voice PAS," and *Appendix E: Speech Intelligibility Scales and Recommendations* for appropriate guidance.
ANSI S3.5	Methods for the Calculation of the Speech Intelligibility Index (SII)	Applies to voice warning systems. SII is one method to determine speech intelligibility. Its correlation to STI and other speech intelligibility methods are shown in ISO 9921 and IEC 60849 Annex B. Please refer to Section 4.2, "Additional Considerations for Outdoor Voice PAS," and *Appendix E: Speech Intelligibility Scales and Recommendations* for appropriate guidance.
ANSI S12.14	Methods for the Field Measurement of the Sound Output of Audible Public Warning Devices Installed at Fixed Locations Outdoors	The sound power rating (i.e., dBC at 100 feet) and frequency characteristics of audible outdoor PAS devices can be determined in accordance with this standard if field measurements are used to determine an audible outdoor PAS device rating. Please refer to Section 4.5, "Audibility and Range Determination," and *Appendix F: Effective Range Prediction Methodology* for more details.
ANSI S12.35	Precision Methods for the Determination of Sound Power Levels of Noise Sources in Anechoic and Hemi–Anechoic Rooms	Applies to test methods for sound power level of a sound source in test chambers. This standard delineates test room requirements, sound source location, operating conditions and instrumentation. This standard also power levels in octave or 1/3-octave bands. The sound power rating (i.e., dBC at 100 feet) and frequency characteristics of an audible outdoor PAS device can be determined addresses in accordance with this standard if testing chambers are used to determine the audible outdoor PAS device rating. Please refer to Section 4.5, "Audibility and Range Determination," and *Appendix F* for more details.

Code or Standard	Title	Applicability
UL 1480	Standard for Speakers for Fire Alarm, Emergency, and Commercial and Professional Use	Applies to voice warning systems. Includes speakers for emergency use, not for security applications, and not located in hazardous or underwater locations. Sections of this standard that are to take effect January 31, 2005, give performance and testing acceptance criteria for harmonic distortion, power input, variable voltage, frequency response, audibility, etc. Speakers intended for use in emergency systems that have integral amplifiers also must comply with UL 2017.
UL 1989	Standard for Standby Batteries	Applicable to enclosed batteries, emergency power batteries, and uninterruptible power supply (UPS) batteries. Please refer to Section 3.3, "Back-up Power Supply for Outdoor Warning Systems" for appropriate guidance.
UL 2017	Standard for General-Purpose Signaling Devices and Systems	Applies to signaling devices used for emergency use in outdoor locations, are associated with property or life safety, and are of a non-fire and non-security alarm nature. Outdoor PAS devices meet the definition of Type AM (Attendant-Monitored) emergency signaling devices. These are devices that are intended to be constantly operated and monitored by competent and experienced personnel, either locally or at a remote station.
IEC 60268-16	Sound System Equipment – Part 16: Objective Rating of Speech Intelligibility by Speech Transmission Index	Applies to voice warning systems. Provides the detailed method by which the speech transmission index (STI) can be determined. STI is a physical quantity that represents the transmission quality of speech with respect to intelligibility. Prediction and measurement of STI should be done in accordance with this standard. Please refer to Section 4.2, "Additional Considerations for Outdoor Voice PAS," and *Appendix E: Speech Intelligibility Scales and Recommendations* for appropriate guidance.
IEC 60849	Sound Systems for Emergency Purposes	Applies to systems that provide voice or tone signals for emergency purposes. This standard contains useful information concerning speech intelligibility for voice systems, automatic status indication, automatic fault monitoring, interface with detection systems, monitoring of software controlled equipment, back-up power supply capability, environmental conditions, installation requirements, maintenance and operating procedures. As pointed out in NFPA 72, the methods outlined in Annex A to this standard should be used to determine speech intelligibility for voice systems. Annex B correlates these methods. Annex C contains useful information concerning audibility and applicable sound measurement methods.

Code or Standard	Title	Applicability
ISO 9921	Ergonomic Assessment of Speech Communication	Applies to voice warning systems. The latest version of this standard (2003) gives minimum performance ratings for intelligibility for alert and warning systems and the interrelationship between various intelligibility ratings. It also contains median hearing threshold information for males and females. Please refer to Section 4.2, “Additional Considerations for Outdoor Voice PAS,” and *Appendix E: Speech Intelligibility Scales and Recommendations* for appropriate guidance.

Appendix B: Weighted Decibel Scales

C-weighted sound level measured in decibels (dBC) is used for many industrial machinery applications. C-weighting reduces the influence of component sounds below 200 Hz and above 1,250 Hz and accounts for all sound in between equally. C-weighting was adopted by FEMA to rate the sound output of audible devices that typically operate in the frequency range above 400 Hz and below 1,250 Hz. Sound output for outdoor PAS devices is most commonly rated at 100 feet from the device directly facing the decibel meter, i.e., dBC at 100 feet.

A-weighted sound level measured in decibels (dBA) is the measurement system that more closely simulates the response of the human ear to different sound frequencies. The dBA scale is used because of its close correlation with human judgment of loudness and annoyance. The sensitivity of the human ear to the sound of different frequencies varies greatly, being most sensitive at frequencies between 1,000 and 4,000 Hz, and falling rapidly for frequencies outside that range.

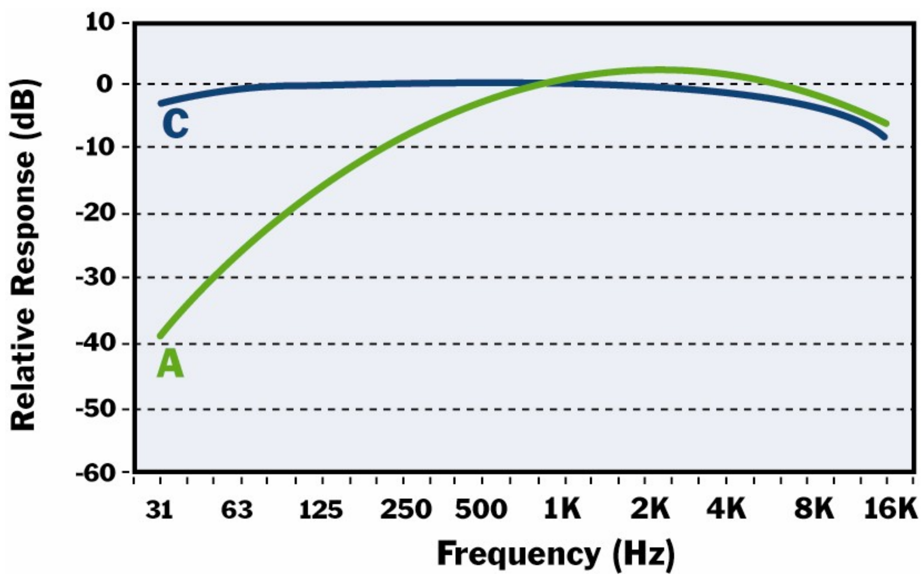

Figure B-1: A- and C-Weighted Decibel Scales[1]

The dBA scale is also used by the EPA and OSHA, and widely used in the measurement of environmental noise and for noise exposure limits. Noise exposure limits based on dBA are codified by OSHA in 29 CFR 1910.95, "Occupational Noise Limits." The graph below in Figure B-2 is extracted from this regulation.

[1] http://www.e-a-r.com/pdf/hearingcons/FAQdba.pdf

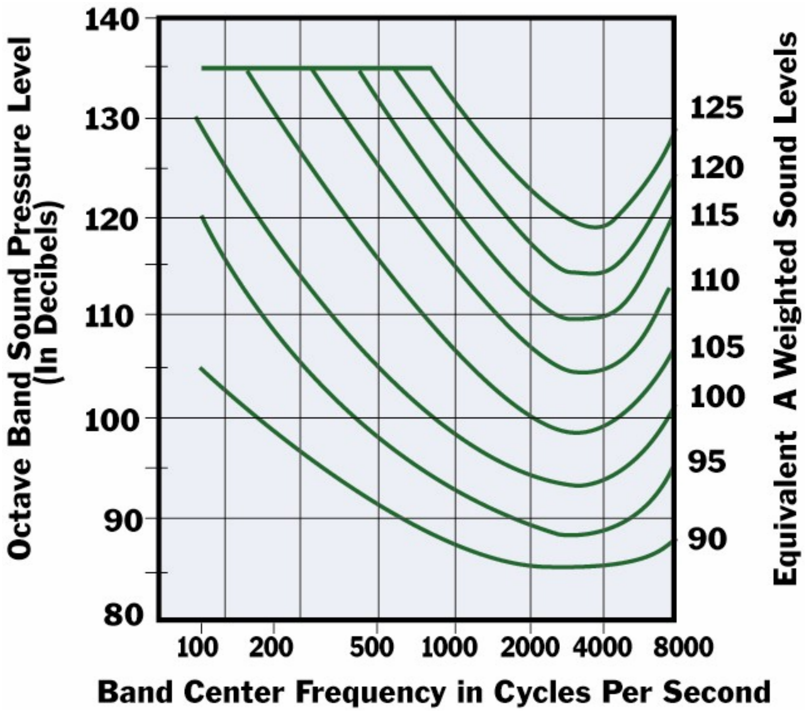

Figure B-2: OSHA Occupational Noise Limits[2]

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[2] 29 CFR 1910.95. Occupational Noise Limit

Appendix C: Ambient Noise Levels

Table C-1 below shows estimated average outdoor ambient noise levels during the daytime when ambient noise is usually at its highest. These can be used to determine a suitable minimum sound level for the outdoor PAS if community noise surveys or noise standards are not available.

In populated areas, nighttime ambient noise levels are typically about 10 dB lower than daytime because fewer people are outdoors, there is less vehicle traffic and there is less construction noise. The difference between dBC and dBA levels indicates the amount of low frequency sound present (between 20 and 500 Hz). Outdoor urban environments are characterized by a difference (dBC - dBA) of 10 to 15 dB while motorized traffic gives a 20 to 30 dB difference. In natural environments, the difference is typically close to zero. The table below uses these estimates and other studies to develop corresponding dBA and dBC values.

Table C-1: Estimated Outdoor Ambient Daytime Sound Levels[1]

Location	Average Ambient Sound Level	
	dBA	dBC
Rural areas – single-family housing density less than 1 dwelling per 100 acres	30	30
Suburban residential areas – primarily single-family housing density less than 1 dwelling per 5 acres, agricultural land use or recreation areas with transient populations, no significant industrial or commercial activity	35	40
Residential areas – primarily single-family housing density less than 1 dwelling per ¼-acre, no significant industrial or commercial activity	40	50
Urban residential areas – primarily single- and multiple-family housing density greater than 1 dwelling per ¼-acre, no significant industrial or commercial activity	50	60
Commercial and industrial areas – land use is primarily commercial or industrial, daytime population density greater than 2,500 persons per square mile or containing major highways or thoroughfares with vehicle counts > 300 per hour	55	70
Piers and other water-surrounded structures	40	45
Thoroughfares – rural and suburban	45	60
Light traffic – at 100 feet from right-of-way	50	70
Highways – medium density urban at 100 feet from right-of-way	55	80
Highways – high density urban at 100 feet from right-of-way	65	90

To quantify a varying signal which lasts over a period of time, an Energy Equivalent Sound Level (Leq) is used. This is the equivalent steady sound level that would contain the same sound energy as the varying signal during the same time period. Although

[1] Sources: (1) U.S. Department of the Army and Federal Emergency Management Agency, Planning Guidance for the Chemical Stockpile Emergency Preparedness Program, May 17, 1996; (2) US EPA Report 550/9-74-004, Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare, March 1974; and (3) Acoustic Technology Incorporated, various ambient sound studies.

transient noise sources (e.g., aircraft flying overhead and traffic) often cause increases in short-term or instantaneous noise levels, they may not necessarily produce increases in time-weighted measurements. Average noise exposure over a 24-hour period is often presented as a "day-night average sound level," called DNL. DNL values are calculated from hourly Leq values, with Leq values increased by 10 dB during the night-time period (10 p.m. to 7 a.m.) to reflect the greater potential annoyance from night-time noise under temperature inversion conditions. A value that encompasses 90% of all ambient sound levels is used to determine ambient background sound levels and is called the "L90 sound level."

In 1972, in response to the requirements of the Noise Control Act of 1972[2], the EPA issued a report[3] that identified indoor and outdoor noise limits necessary to protect public health and welfare (communication disruption, sleep disturbance, and hearing damage). Outdoor DNL limits of 55 dBA and indoor DNL limits of 45 dBA were identified as desirable to protect against speech interference and sleep disturbance for residential, educational, and health care areas. Urban areas typically have an outdoor DNL of 65 dBA.

[2] The Noise Control Act of 1974 (NCA); PL 92-574.

[3] "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety." EPA Office of Noise Abatement and Control 550/9-74-004. (March 1974). http://www.nonoise.org/library/levels74/levels74.htm

Appendix D: Alerting a Sleeping Population

There have been a number of studies conducted that address the likelihood of a given sound level awakening people from sleep at night. One such study was conducted for a fixed siren warning system for a U.S. commercial nuclear plant that used rotating sirens with an alerting frequency in the 500 Hz octave band. Table D-1 summarizes this study in light of typical outdoor PAS conditions with the following results:

Table D-1: Probability of Arousal from Sleep as a Function of Siren SEL Inside the Bedroom and Age Group (One Person Household)[1]

Siren SEL in Bedroom (dBA)	Probability of Arousal from Sleep (Percent)		
	Age group: 18-34	Age group: 35-54	Age group: 55+
75	38	43	52
70	31	36	45
65	26	30	37
60	22	26	28
55	17	22	19

U.S. Census data from the year 2000 shows an average of 2.62 persons per household with 1.93 persons over the age of 18 and a median population age of 48.7 years. The probability of arousal from sleep of at least one person in an average household that has about two adults of at least 18 years of age is significantly higher than the numbers in Table D-1 above because it is reasonable to assume that *the person awakened would awaken the other members of the household* as appropriate.

For example, assuming two adults in a household in the 35-54 age group and a device SEL of 60 dBA *inside* the bedroom means that there is a probability of 45.2% that *at least* one adult will be aroused from sleep (26% for adult #1 + 26% for adult #2 - [26% x 26%] that BOTH adults will be aroused from sleep). A device SEL of 75 dBA inside the bedroom would ensure that there is 67.5% probability that at least one adult would be awakened under these conditions.

[1] Testimony of Karl D. Kryter in the Matter of Carolina Power and Light Company and North Carolina Eastern Municipal Power Agency (Shearon Harris Nuclear Power Plant Units 1 and 2) Docket No. 50-400 OL, October 18, 1985 – Figure 7A

However, as was discussed in Section 2.3.2, “Structural Barriers to Sound,” achieving 75 dB inside the bedroom requires 87 to 110 dBA sound SEL immediately outside the residence, depending on the specific type of residence construction and whether or not the windows are open. Using the above information in conjunction with the appropriate demographic information for the area in question, special studies to determine the probability of awakening sleepers using an outdoor audible PAS device—in conjunction with an indoor, household PAS devices—may also be necessary.

Appendix E: Speech Intelligibility Scales and Recommendations

Voice warning can be used most effectively in open areas where there are people who: 1) may be unfamiliar with local emergency notification methods; 2) where complex instructions may be required; or 3) where it is critical that people outdoors evacuate or shelter quickly. Such locations include military bases, chemical plants, military chemical stockpile locations, and public gathering places such as parks, amusement areas, and other tourist destinations.

In most outdoor alerting situations, a minimum Common Intelligibility Scale (CIS) score of 0.70 (STI and SII score of 0.5)—which correspond to an 80% word-comprehension rate and a 95% sentence comprehension rate—is impractical. This conclusion is based on consideration of: 1) physical effects in the outdoor environment that are not significant in indoor environments or within enclosed areas (e.g., terrain, echoes, and atmospheric instability); 2) the likelihood that a more complex voice message would be required; and 3) economic considerations (the cost of many low-output loudspeakers versus the cost of fewer high-output loudspeakers). In addition, for most outdoor PAS applications, voice capability is a secondary consideration to the ability to provide audible warning tones, a feature that provides flexibility in public warning methods that only using siren tones can not.

Figure E-1 below shows the relationship among the large number of intelligibility scales that are used by universities, business, and industry with respect to the CIS and allows for their conversion to the CIS standard.

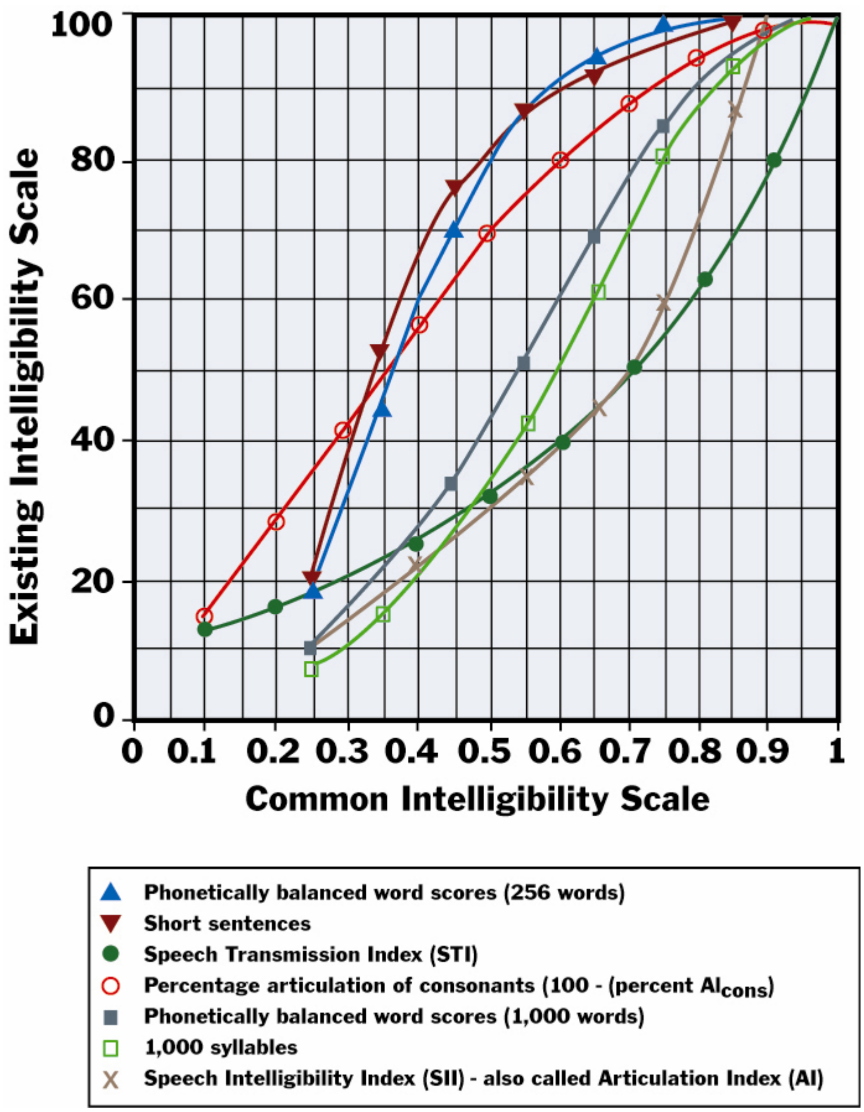

Figure E-1: Conversion of Existing Intelligibility Scales to the Common Intelligibility Scale (CIS)[1]

Table E-2 below shows the relationship of STI, SII, and CIS with intelligibility ratings ranging from "excellent" to "bad." This information was derived from ISO 9921, *Ergonomic Assessment of Speech Communication*. Table E-3 was also derived from ISO 9921. It shows that "poor" speech intelligibility (a CIS > 0.48) is sufficient for correct understanding of simple sentences (e.g., "Please leave the area." or "Seek shelter immediately.") Further, it shows that "fair" intelligibility (CIS > 0.65) is sufficient for correct understanding of critical words that would be necessary to understand more complex voice instructions.

[1] IEC 60849. *Sound Systems for Emergency Purpose*

Thus, a CIS > 0.6 appears to be a reasonable limit for speech intelligibility for an outdoor voice PAS, as this value addresses both simple and complex voice instructions. As shown in Figure E-1 at the outset of this appendix, this corresponds to STI and SII values > 0.4.

Table E-2: Relationship of Objective Intelligibility Ratings[2]

Intelligibility Rating	Speech Transmission Index (STI)	Common Intelligibility Scale (CIS) Equivalent	Speech Intelligibility Index (SII)	Intelligibility Scale (CIS) Equivalent
Excellent	> 0.75	>0.87		
Good	0.60 – 0.75	0.78 – 0.87	> 0.75	>0.82
Fair	0.45 – 0.60	0.65 – 0.78		
Poor	0.30 – 0.45	0.48 – 0.65	< 0.45	<0.65
Bad	< 0.30	<0.48		

ANSI S3.5 provides two benchmarks for SII: good > 0.75, poor < 0.45.
STI in accordance with IEC 60268-16 or ISO 9921
CIS determined by use of Figure IV-1, OSHA Occupational Noise Limits, above.

Table E-3: Recommended Minimum Intelligibility Ratings and Maximum Vocal Effort for Alert and Warning Situations[3]

Level of Understanding	Minimum Intelligibility Rating	Maximum Vocal Effort	Minimum Intelligibility Index Score		
			SII	STI	CIS
Correct understanding of simple sentences	Poor	Loud	0.29	0.30	0.48
Correct understanding of critical words	Fair	Loud	0.45	0.45	0.65

[2] ISO 9921, Ergonomic Assessment of Speech Communication
[3] *Ibid*.

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Appendix F: Effective Range Prediction Methodology

The effective range of a warning device is dependent on three major components: the rated warning device noise level, the atmospheric conditions, and the local terrain. In cases where the local terrain is flat and there is a direct LOS between the warning device and the ground, the process is fairly simple. In cases where there are terrain features that block the LOS, an additional calculation must be made. The next two sections describe the procedures for estimating the effective range for a warning device based on these considerations.

F.1 Flat Terrain (LOS)

For areas that are relatively flat where there is an unbroken LOS between the warning device and the ground, the range can be estimated using Figure F-1. This chart indicates, for example, that a warning device rated at 120 dBC will have a range of about 3,700 feet (1.1 km) in suburban and rural areas when mounted above the rooftops. In an urban area, when the device is mounted below the rooftops, its effective range will be about 1,200 feet (0.35 km). The coverage of an omni-directional or rotating warning device is determined by a circle (centered on the warning device) whose radius is defined by Figure F-1.

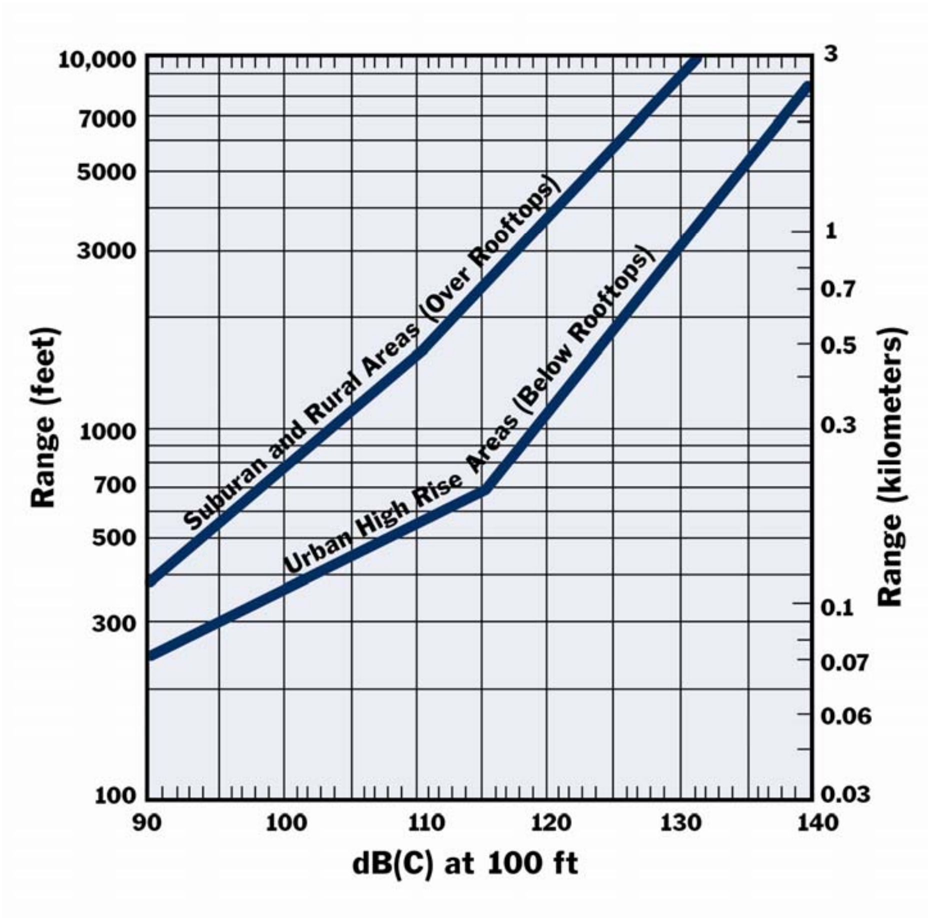

Figure F-1: Rated Output of Warning Device in dB at 100 feet[1]

The upper curve in Figure F-1, applicable to suburban and rural areas, is very close to 10 dB per doubling of distance. The lower curve is applicable to urban areas and takes into considerations the additional shielding and scattering caused by high-rise buildings.

F.1.1 Single Tone Frequency Correction

Both of the curves shown in Figure F-1 were developed using a 400 Hz siren. If the warning device uses a different frequency, the actual range may be different because of the effects of atmospheric absorption. Lower frequencies travel farther while higher frequencies do not travel as far. If the warning device is a single tone siren, Table F-1 provides a correction for the frequency of that siren. To use this correction, add the listed value to the rated warning device output level (noting the sign) before determining the range in Figure F-1. For example, if the warning device is a siren with a single tone of 128 dB at 100 feet at 790 Hz, this falls in the 710 Hz to 900 Hz range. The correction

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[1] D. Keast, "Outdoor Warning Systems Guide", Bolt, Beranek, and Newman Inc. report number 4100, June 1979 (Work Unit 2234E).

factor for this is -6 dB. Therefore, the correct level to use when looking up range in Figure F-1 is 128 – 6=122 dBC.

Table F-1: Correction for Single Tone Sirens

Frequency Range	Correction (dB)
180 Hz – 224 Hz	5
224 Hz – 280 Hz	4
280 Hz – 355 Hz	2
355 Hz – 450 Hz	0
450 Hz – 560 Hz	-2
560 Hz – 710 Hz	-4
710 Hz – 900 Hz	-6
900 Hz – 1120 Hz	-7

F.1.2 Multi-Tone Frequency Corrections

If the warning device uses multiple tones for its alert signal, a different correction is used. Table F-2 presents dual-tone corrections. To use this table, take the value at the intersection of the row containing the upper frequency with the column containing the lower frequency. For example, if there is a siren that has two tones at 500 Hz and 670 Hz, the correction factor is -3 dB. If that siren has a rated output level of 119 dBC, the level to use in Figure F-1 would be 119 – 3 = 116 dBC. If one of the tones is 6 dB or more above the others, use Table F-1. If the warning device has more than two main tones, all within 6 dB of each other, select the two tones with the highest frequencies.

Table F-2: Correction for Multi-Tone Sirens

Upper Frequency \ Lower Frequency	180 Hz – 224 Hz	224 Hz – 280 Hz	280 Hz – 355 Hz	355 Hz – 450 Hz	450 Hz – 560 Hz	560 Hz – 710 Hz	710 Hz – 900 Hz	900 Hz – 1,120 Hz
180 Hz – 224 Hz	5	4	4	3	3	3	3	2
224 Hz – 280 Hz	4	4	3	2	2	1	1	1
280 Hz – 355 Hz	4	3	2	1	0	0	0	-1
355 Hz – 450 Hz	3	2	1	0	-1	-1	-2	-2
450 Hz – 560 Hz	3	2	0	-1	-2	-3	-3	-4
560 Hz – 710 Hz	3	1	0	-1	-3	-4	-5	-5
710 Hz – 900 Hz	3	1	0	-2	-3	-5	-6	-6
900 Hz – 1,120 Hz	2	1	-1	-2	-4	-5	-6	-7

F.1.3 Intelligibility Correction

It is possible to estimate the range of a voice message system based on Figure F-1, but be advised that this is an approximation. There are a large number of assumptions that need to be made that might not be appropriate for all situations. However, by using conservative estimates of effects such as atmospheric attenuation and ambient noise level, a correction of -8 dB has been determined for a voice message system. This -8 dB correction should be applied to the speakers rated output (in dBC) and the result can be used to lookup the range from Figure F-1 Note, however, that a more thorough analysis of the propagation should be conducted to estimate the actual Common Intelligibility Scale (CIS) for the voice messaging system.

F.2. Hilly Terrain (No LOS)

For situations where there is the potential for the terrain to block the direct LOS between the warning device and the ground, the determination of range becomes more complex. If the goal is to provide coverage for an entire area, this will likely become an iterative process. The main portion of this iteration will be to first select a location for the warning device (see Section 4.4). The next step will be to determine where the limits of the LOS (and therefore the limits of the devices range) are. Depending on the combined coverage of the surrounding devices, it may be necessary to adjust the location and determine lines of sight from the new location.

The best practice for selecting a location is described in Section 4.4. It is important to have maps of the area to make a first estimate for the warning system layout. The USGS has a large number of different map types and resolutions. Geographic Information Systems (GIS) are powerful computerized alternatives to printed maps. If printed maps are used, they should have enough resolution to allow 500 foot intervals to be easily determined.

Once all of the necessary maps have been collected, a location and pole height should be selected for the warning device. Typical pole heights range from 30 feet to 80 feet. Note that raising the pole above 50 feet may create problems for both installation and maintenance because of the need for specialized equipment. Once the location and pole height have been selected, 16 radials should be drawn on the map at even 22.5 degree intervals. Then, the distance to the LOS for each of these radials should be determined, remembering that the warning device is set on top of the pole. There are a number of computer tools available to assist with this calculation. It is, however, possible to determine this distance with printed topographic maps.

Starting at the warning device location, determine the elevation along each of the 16 radials in 500 foot increments up to the maximum distance as determined by Figure F-1. Then plot these elevations for each radial. These plots provide the elevation change along each radial. The next step is to determine if it is possible to draw an unbroken line or uninterrupted curve between the warning device and the ground at the expected range distance from Figure F-1. If an unbroken line or uninterrupted curve cannot be drawn, then the LOS is broken, and the limiting distance is the furthest point to which an unbroken LOS can be drawn.

Figure F-2 shows a stylized example of the range of a warning device with a hill. Here the maximum range as determined by Figure F-1 is drawn along each of the 16 radials. Where the LOS distance is shorter than that maximum distance from Figure F-1, it is used. Figure F-3 shows the elevation along the 67.5 degree radial, with the break in the LOS coming at 2,500 feet. A curve similar to Figure F-3 should be drawn for each radial where there is a chance that the LOS could be broken by the terrain. (There is no need to go through this process when the terrain is obviously flat). All of these distances are then plotted around the warning device, and the lines are connected. The dark red line in Figure F-2 shows the results once all of the terrain calculations have been completed.

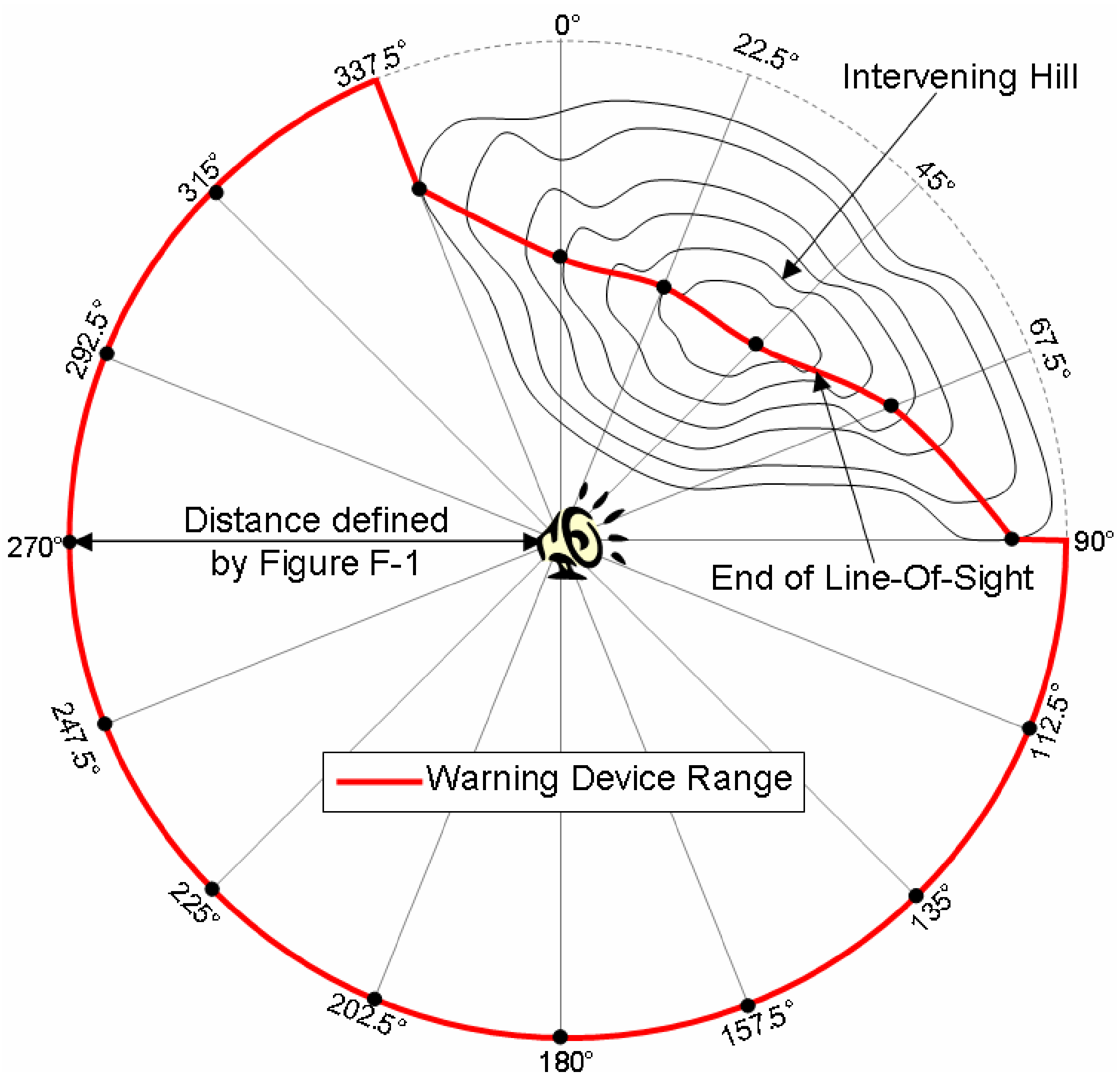

Figure F-2: Example of terrain blocking the LOS of a warning device with a device height of 50 feet and elevation isopleths of 30 feet.

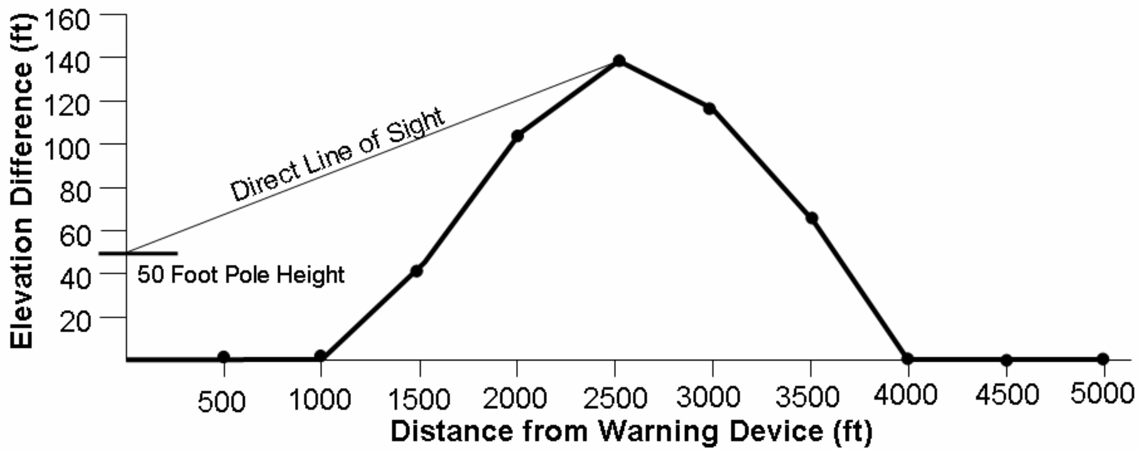

Figure F-3: Plot of the elevation changes along the 67.5 degree radial in Figure F-2

The process illustrated in Figures F-2 and F-3 is conservative, placing the limit of coverage at the point where LOS is broken. If terrain is modest, however, and the depression beyond LOS is shallow, there can be coverage beyond that point. Calculation of the actual coverage in complex situations should be conducted by personnel who are well versed in outdoor sound propagation and warning system design.

Although weather can play a significant role in acoustic propagation, the curve show in Figure F-1 is from data that suggests that propagation over urban and suburban areas is driven primarily by the effect of the buildings rather than by weather[2].

Weather effects can, of course, be complex. The data in Figure F-1 are conservative in that they represent conditions of moderately high sound absorption conditions, so unless conditions are extreme the effects of temperature and humidity are not a major issue. Wind effects may or may not have a significant effect. Upwind propagation tends to increase the coverage distance and downwind propagation tends to decrease it. The net effect is to shift the area covered, rather than significantly increase or reduce it. In a full system with multiple sources, if wind eliminates coverage from a siren on one side of a location, this is often filled in with coverage from another siren on the other side.

[2] M. E. Delany, "Range Predictions for Siren Sounds," NPL Aero Special Report 033, 1969 (NTIS N70-24408).

Appendix G: Estimated Cost Prediction Methodology

This appendix presents equipment cost information to assist the user in determining planning level system cost estimates.

Table G-1 below shows mid-range rated equipment prices. This price table notes equipment with varying device noise levels and capabilities. These prices include all related equipment and installation.

Table G-1: Equipment Prices

dBC Rating @ 100 feet	Omni-Voice	Omni-Siren Only	Rotational-Siren Only	Rotational-Voice
118			$10,300	
119	$18,000			
121	$20,400	$10,200		
125	$26,700	$13,400		
126				$23,000
129			$14,000	

Table G-2 presents the costs for recently installed outdoor warning systems. The table notes the installation location and date, the number of sirens in the stem, and a unit cost for each siren device. Features for specific outdoor warning systems are noted in the comments column.

Table G-2: Recent Outdoor Warning System Installations in the United States and their Costs

Location	Installation Date	Number of Sirens	Total Cost	Cost Per Siren	Comments
SOUTH					
Moody, AL Pop: <20,000	May 2005	1	$14,740	$14,740	Type: Vortex, radio activated
Gadsden, AL Pop: 21,000	Apr. 2005	5	$127,200	$20,400 and $26,700	The less expensive units were 121 dB omni-voice devices; the more expensive units were 125 dB omni-voice devices.
Jefferson County, AL Pop: 658,141	July 2004	60 new sirens and 127 siren upgrades	$2 million	-	Additions and upgrades systems will cover 90% of the county's residents. System can also pinpoint problem areas so sirens only sound in areas where people are in danger
Little Rock, AR Pop: 184,000	Apr. 2004	56	$1.7 million	$30,357	Type: Electronic
MIDWEST					
Fitchburg, WI Pop: 12,000	Mar. 2005	5	$110,000	$22,000	n/a
Walkerton, IN Pop: <20,000	Dec. 2004	2	≈ $34,000	$17,000	n/a
Champlin, MN Pop: 9,000	Nov. 2004	1	$15,000	$15,000	n/a
Danvers, IL Pop: 20,000	Sept. 2004	1	$14,000+	$14,000+	n/a
Vigo County, IN Pop: 105,000	Aug. 2004	20	$300,000	$15,000	n/a
Madison, WI Pop: 218,000	July 2004	3	-	$20,000	n/a
Crumstown, IN Pop: <20,000	Apr. 2004	2	-	$13,500	n/a
Champaign, IL Pop: 58,100	Nov. 2003	6	$93,840	$15,640	Type: electro-mechanical (not electronic, which are more expensive)
Ellettsville, IN Pop: <20,000	Oct. 2002	1	$16,000	$16,000	n/a
Woodridge, IL Pop: 22,000	Dec. 2001	1	$17,639	$17,639	n/a
St. Joseph County, IN Pop: 266,348	1999	62	$1.2 million	$19,355	n/a

Location	Installation Date	Number of Sirens	Total Cost	Cost Per Siren	Comments
NORTH					
Malta, NY Pop: <20,000	July 2005	3	$45,000	$15,000	n/a
WEST					
Benbrook, TX Pop: 14,000	Feb. 2005	6	$73,407	$12,234	Type: Battery-operated
North Platte, NE Pop: 25,000	Mar. 2004	12+	$300,000	≈ $25,000	n/a
Friendswood, TX Pop: 11,000	Nov. 2003	10	$160,000	$16,000	n/a
Douglas County, NE Pop: 477,000	Oct. 2003	67	$1.4 million	$20,895	n/a
Oklahoma City, OK Pop: 750,000	Apr. 2002	181	$4.5 million	$24,862	n/a
Stillwater, OK Pop: 38,000	Apr. 1999	6	$56,708	$11,342	Type: Sirens have "two-way status"

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Appendix H: Checklist

This Checklist is a summary and guideline for the Outdoor Warning System Technical Bulletin.

Below, users should mark the yes (Y) box to denote that the checklist item, element, or concept has been considered and addressed. The no (N) box should be checked it the item, element, or concept has been considered and the decision has been made that it will not be addressed. Finally, users should mark the not applicable (n/a) box if the item, element, or concept does not apply to their PAS needs.

			Planning and Designing a Public Alerting System
			Considerations for Outdoor Warning Systems
Y	**N**	**n/a**	**Types and Systems**
			Electro-Mechanical and Electronically Amplified Sirens
			Directional, Rotating, and Omni-Directional Devices
			Electronic Message Signs
			Voice Capability
Y	**N**	**n/a**	**Siren Warning Types**
			Three to five minute steady siren or horn alert signal for natural disaster warning
			Three to five minute wavering or warbling siren alert signal or short horn blasts to warn of enemy attack
			One minute siren alert test signal
			When voice capable equipment is in place, voice warning or instruction following the siren or horn alert
Y	**N**	**n/a**	**Back-up Power Supply**
			Adequate back-up power available for at least 15 minutes of alerting
			Back-up power equipment should be recharged to 80% of the maximum rated capacity from the fully discharged state within 24 hours
			Back-up power systems able to maintain the “standby mode” without alternating current (AC) power for at least 24 hours
			When batteries are used for back-up power, the batteries are of a maintenance free design with a battery life of 3 years
Y	**N**	**n/a**	**Sound**
			Loudness and Frequency
			Attenuation
			Perceiving the Warning Sound
			Audibility and Range
			Determination
Y	**N**	**n/a**	**Communication Channels**
			Wired Versus Wireless Channels
			Range

Planning and Designing a Public Alerting System			
Preliminary System Development			
Y	**N**	**n/a**	**System Definition Method**
			Define the goals to be accomplished with the system: outside audibility/intelligibility alerting, arouse sleeping households, etc.
			Ascertain the ambient sound levels (via sound measurement or modeling).
			Survey community surroundings and terrain for device placement considerations.
			Determine decibel requirements to achieve the various alerting goals.
			Map the community into zones with respect to needed decibel levels versus terrain and/or ambient noise.
			Assess the midrange device rating.
			Calculate radial range for each zone and the given siren rating.
			Determine location & number of electronic omni-directional sirens (standard siren tones have a frequency within the band of 200 Hz to 1,100 Hz
			Considered applicability (i.e. use, location & number) of uni-directional or rotating sirens
			Evaluate the applicability and potential locations of messaging signs
			If the system is voice capable establish the frequency range employed by the system (typically restrict voice to the 500 octave band—500Hz to 1,000Hz).
Y	**N**	**n/a**	**Development of Planning Level Cost Estimate**
			Estimate siren costs by element, including:
			• Planning, design, installation, operation and maintenance costs.
			• Components: horns/devices, modulators, communications, controllers/SCADA systems, power supply and backup components, wiring/structural/utility elements, and land/easement.
			Once the number, location, and siren requirements are established, collect example equipment cost information from multiple vendors.
			Use the best value vendor cost (from different vendors' equipment) for each selected location.
			Experiment with the use of directional sirens to reduce cost, if applicable.
			Consider cost adjustments for optimal locations or irregular regions.
			Add the costs for all of the locations.
			Adjust for inflation, if needed.
			Calculate a total system planning level cost using a range of –30% to +50%.
			Consider operation and maintenance costs and establish the system present worth value (i.e., life cycle cost).

Testing and Maintenance of Outdoor Warning Systems			
Y	**N**	**n/a**	**Testing Considerations and Guidance**
			Assess the Harmful Effects of the Warning Sounds
			Develop a System and Device Test Protocol
			Inform and Educate the Public on the Use and Testing of the System
			Evaluate System Features such as Automatic Testing and Feedback Mechanisms
			Consider Modular Sirens and Voice Warning Device Testing
			Conduct Periodic Audibility and Intelligibility Testing
Scope of Maintenance Program			
Y	**N**	**n/a**	**Preventive and Corrective Maintenance of Outdoor Warning Systems and Components**
			Determine Electro-Mechanical and Electronically Amplified Siren System Maintenance Requirements
			Assess Directional, Rotating, and Omni-Directional Device System Maintenance Requirements
			Evaluate Voice Capable Device System Maintenance Requirements
			Determine Electronic Message Sign System Maintenance Requirements
			Assess Associated Components Requirements

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