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MARTIN MARIETTA

ASSESSMENT OF THE NEED FOR DUAL INDOOR/OUTDOOR WARNING SYSTEMS AND ENHANCED TONE ALERT TECHNOLOGIES IN THE CHEMICAL STOCKPILE EMERGENCY PREPAREDNESS PROGRAM

by

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Assessment of the Need for Dual Indoor/Outdoor Warning Systems and Enhanced Tone Alert Technologies in the Chemical Stockpile Emergency Preparedness Program

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LIST OF ACRONYMS

A&N	alert and notification
CDC	Centers for Disease Control
CSDP	Chemical Stockpile Disposal Program
CSEPP	Chemical Stockpile Emergency Preparedness Program
EPZ	emergency planning zone
FEMA	Federal Emergency Management Agency
IRZ	immediate response zone
TA	tone alert

ABSTRACT

The need for a dual indoor/outdoor warning system as recommended by the program guidance and Alert and Notification (A&N) standard for the Chemical Stockpile Emergency Preparedness Program is analyzed in this report. Under the current program standards, the outdoor warning system consists of omnidirectional sirens and the new indoor system would be an enhanced tone alert (TA) radio system. This analysis identifies various tone-alert technologies, distribution options, and alternative siren configurations. It also assesses the costs and benefits of the options and analyzes what appears to best meet program needs.

Given the current evidence, it is recommended that a 10-dB siren system and the special or enhanced TA radio be distributed to each residence and special institution in the immediate response zone as preferred the A&N standard. This approach minimizes the cost of maintenance and cost of the TA radio system while providing a high degree of reliability for indoor alerting. Furthermore, it reaches the population (residential and institutional) in the greatest need of indoor alerting.

1. INTRODUCTION

The Chemical Stockpile Disposal Program (CSDP) was initiated in response to the 1986 Congressional mandate (by Public Law 99-145) to rid the United States of the aging stocks of chemical munitions by the year 1992. Many of the weapons had been in storage since the early 1940s. These munitions, located at eight army depots around the country, contain the chemical nerve agents VX and GB and the blistering agents H, HD, and HT (commonly called mustard gas), all of which are highly toxic to humans upon inhalation or skin contact. A technology using high-temperature incineration is to be used for the disposal of weaponry.

The law mandating disposal requires destruction in a manner that maximizes the health and safety of the public. Chemical agents, however, are among the most toxic hazardous materials in existence and are stored in large quantities. The probabilistic risk analysis for the disposal program identified a number of credible accident scenarios that could result in fatalities. The *Final Programmatic Environmental Impact Statement* for the CSDP (U.S. Army 1988) found that emergency planning for an accident was inadequate in the communities surrounding storage sites. The Army's record of decision subsequently committed the Army to enhanced emergency planning (Ambrose 1988). Currently, programs are being implemented at the eight sites. The Chemical Stockpile Emergency Preparedness Program (CSEPP), jointly managed by the Army and the Federal Emergency Management Agency (FEMA), has the ambitious goal of achieving state-of-the-art plans that provide maximum public protection.

Under the guidance of the planning subcommittee of CSEPP, a planning guidance document was prepared (Oak Ridge National Laboratory and Schneider Engineers 1990). The planning guidance provides general guidelines for implementing CSEPP. Program standards are also being developed to provide more detailed planning requirements. These requirements must be met by participants in the program to receive CSEPP funding for emergency systems. One of the areas in which detailed standards have been prepared is alert and notification (A&N) systems, often referred to as public warning systems.

This report analyzes the need for a dual indoor-outdoor warning system as recommended by the program guidance and A&N standard for the CSEPP. Under the current program standards, the outdoor warning system consists of omni-directional sirens. The indoor system would be an enhanced tone alert (TA) radio system. This analysis identifies various TA technologies, distribution options, and alternative siren configurations. It also assesses the costs and benefits of the options and analyzes what appears to best meet program needs. In doing so, it addresses several questions.

1. Will an outdoor siren system provide adequate nighttime alerting in summer or winter conditions when buildings are not open?

2. Will commercial off-the-shelf TA radios be adequate?

3. What benefits will be gained from an enhanced TA technology?

4. What distribution should be made of indoor alert devices?

5. Can an outdoor system be designed to replace indoor alerting?

2. PROGRAM POLICY OPTIONS

We have specified a limited set of options to use in the analysis. These were chosen to reflect viable program options that appear to be feasible at present. The baseline for the program is an outdoor siren system with sound levels that are 10 dB over ambient noise levels. The options vary for the distribution policy for TA radios, the technologies available in TA radios, and the substitution of a different outdoor system for the indoor alerting system.

2.1 DISTRIBUTION

Three different distribution options for indoor alerting units have been specified:

1. Provide a single unit to each private household and institution within the immediate response zone (IRZ) (with option for others to buy at cost).

2. Provide multiple units to each household and institution and to all inhabited buildings such as shops and industries within the IRZ.

3. Provide a single unit to all households/institutions and to inhabited buildings within the IRZ.

2.2 TECHNOLOGY

Although a variety of TA technologies can be specified, three options were chosen for review:

1. The special TA unit identified in the CSEPP Alert and Notification (A&N) standards. This unit is designed to have high reliability and low maintenance costs. Its features are outlined in the A&N standards (Anstech, et al. 1990).

2. A commercial off-the-shelf unit which is activated by the National Oceanic and Atmospheric Administration weather system.

3. A budget version of the special unit that does not have any of the special features except for a unique activation frequency.

2.3 SUBSTITUTION

Two substitution options have been identified:

1. Raise the standard for outdoor sirens from 10 dB to 20 dB over ambient. The rationale is that the higher sound output would solve the problem of nighttime alerting.

2. Substitute outdoor sirens for indoor alerting in high population areas and distribute TA radios in less populated areas. This would involve getting a noise level output from sirens in populated areas that would penetrate buildings and arouse people who are asleep (Carter 1990). The noise level required would be 85 dB at the wall of a house to achieve indoor alerting (Long 1990). The feasibility of indoor notification with outdoor sirens is not currently known.

3. COST

3.1 NUMBER OF UNITS REQUIRED

Table 1 contains estimates of the number of units required for each site under the three different distribution policies. These estimates were based on population estimates at each site and on field experience in developing emergency plans. They were chosen by consensus of the planning subcommittee, but more precise estimates will be required prior to procurement.

Table 1. Estimates of units required

Site	1. One unit to each home	2. Multiple units to homes and inhabited buildings	3. Single unit to homes and inhabited buildings
Aberdeen Proving Ground	23,000	50,000	37,500
Anniston Army Depot	18,000	30,000	22,500
Lexington-Blue Grass Army Depot	10,000	40,000	30,000
Newport Army Ammunition Plant	3,000	7,000	5,250
Pine Bluff Arsenal	30,000	70,000	52,500
Pueblo Depot Activity	100	200	150
Tooele Army Depot	300	300	225
Umatilla Depot Activity	5,000	8,000	6,000
Total	89,400	205,300	153,975

The choice of TA technology would not impact the number of units required. Raising the standard for outdoor sirens from 10 dB to 20 dB over ambient would involve increasing the number of sirens about 300–400% over existing estimates (Long 1990), and would eliminate the need for TA radios.

Outdoor substitution in high population areas is estimated to result in a 50% reduction in units required for any of the three distribution options, and would add three to six sirens per site (Carter 1990). This estimate requires additional substantiation on a site-by-site basis.

3.2 TONE ALERT UNIT COSTS

The following sections estimate the cost of a TA unit, including distribution.

3.2.1 Special Unit Costs

It is estimated that a special unit (one with a unique frequency and special features) would cost $125 based on cost estimates developed by SE Technologies.

Some of the marginal costs of the special features are as follows:

Feature	Marginal cost
Lithium battery[a]	$15
AC plug spring clip[a]	1
LED battery condition indicator[a]	10
110 volt output[a]	7
Strobe output jack	1
External antenna jack[a]	1
LED test status indicator[a]	10
Adjustable message volume	7
Visual activation indicator	1
Total	$53

[a]Essential items to achieve high reliability and low maintenance.
Source: Long, J. 1990 (SE Technologies) Memo to J. Sorensen, Oak Ridge National Laboratory, Oak Ridge, Tenn., August 28.

3.2.2 Commercial Unit Costs

It is estimated that a commercial unit (such as a Radio Shack unit) would cost $30 based on cost estimates developed by SE Technologies.

3.2.3 Budget Special Unit Costs

It is estimated that a budget special unit (one with a unique frequency but without the special features listed in Sect. 3.2.1) would cost $75 based on cost estimates developed by SE Technologies.

3.3 MAINTENANCE COSTS

It is assumed that maintenance would be done over an 8-year period.

3.3.1 Special

Annual cost for the special unit would be $1.50 per unit. The total cost over the program would be $12 per unit. It is assumed that the design features would eliminate the need for yearly inspection. If we assume that 5% of the radio units would require maintenance each year due to a problem, the yearly cost would be $1.50 per unit. The cost over an 8-year period would be $12.

3.3.2 Commercial

Annual cost for the commercial unit would be $30 per unit. The total cost over the program would be $240. It is assumed that one visit per year would be required per unit for inspection, verification of working condition, and battery replacement. The estimated per unit cost is based on an estimate by ERCE, Inc., for Oak Ridge National Laboratory (ORNL) (ERCE no date).

3.3.3 Budget Special

The annual cost of the budget special would be $30 per unit. The total cost over the program would be $240. This is the same as for the commercial unit.

3.4 TOTAL COST FOR TONE ALERT

Tables 2 shows estimates of the cost over an 8-year period.

Table 2. Costs of tone alert units over 8-year period

		Cost ($M)		
Type	Number of units	Capital	Maintenance	Total[a]
Special ($125/unit)	90,000	$11.3	$1.1	$13
	150,000	$18.8	$1.8	$21
	200,000	$24	$2.4	$27
Commercial ($30/unit)	90,000	$2.7	$21.6	$25
	150,000	$4.5	$36	$41
	200,000	$6	$48	$54
Budget special ($75/unit)	90,000	$6.8	$21.6	$29
	150,000	$11.3	$36	$38
	200,000	$15	$48	$63

[a]Rounded up to nearest million dollars.

Based on these estimates, the special TA technology is the best solution if maintenance costs are assumed to be covered by the program.

3.5 COST FOR THE SIREN SUBSTITUTION OPTION

3.5.1 20-dB Option

Raising the outdoor siren standard to 20 dB above ambient noise levels would increase the cost of the outdoor system by 300–400% (Long 1990). Based on an estimate of $5.3 M (Long 1990), this option would cost about $16–21 M.

3.5.2 High Population Option

It is estimated that the costs for installing outdoor sirens in populated areas that would achieve an 85-dB sound level would lower the costs of TA radios by 50% and raise the cost of the sirens by about $1.5 M (48 extra sirens maximum x $30 K each) (Carter 1990).

4. ESTIMATING SYSTEM EFFECTIVENESS

This section analyzes the effectiveness of the program alternatives. Effectiveness is defined by the portion of the population that is alerted and notified by the system in a rapid (15-min) time frame. It starts with defining the methodology used to measure system effectiveness for the Shearon Harris Nuclear Power Plant, introduces new data on warning system effectiveness collected in Nanticoke, Pennsylvania, and analyzes the options discussed earlier based on these two sets of findings.

4.1 SHEARON HARRIS FINDINGS

The most significant debate on what constitutes a state-of-the-art A&N system came in Atomic Safety and Licensing Board proceedings on the Shearon Harris Nuclear Power Plant. In their final decision the board defined what constitutes "essentially 100% notification within 15 min in the first 5 miles of the Harris emergency planning zone" (23 NRC 294, 1986). In this matter the board required the utility to prove that over 95% of the people within 5 miles would receive a warning in summer nighttime conditions, one of the most difficult warning times. The utility could not do so by relying solely on a siren system. To exceed the 95% level, commercial TA radios as well as siren alert were proposed for all households in the 5-mile radius. The board accepted this plan as exceeding 95% notification.

The basic logic behind the ruling was as follows. The board accepted a method for calculating sleep arousal by sirens. In this method a sound level in a bedroom is calculated based on the attenuation of sound from outside to inside. The method assumed four 3-min siren soundings. It was calculated that the probability of arousal for an individual was 62%. Household size was taken into account as it was assumed that one person over 12 years old hearing the sirens would wake others in the house. Based on the household size distribution, it was calculated that 83.5% of the households would be alerted. An additional 1% of the unalerted household would have someone awake at the time of the sounding, resulting in 84.5% alerting. It was assumed that those alerted would seek notification.

The board, based on evidence from other disasters, accepted that 50% of the households alerted would contact someone else after receiving the warning (informal notification). Thus, they held that 42.5% would notify another household. Since 15.5% of the households had not yet been warned, an additional 6.7% would be warned by someone who had received the warning, for a total of 91% notification—still too low to satisfy the 95% requirement. It was assumed that route alerting would not be feasible in a 15-min time frame.

If TA radios were also used, however, the board accepted that 83% of the households would receive an alert from a TA radio, based on the experience with the Ft. St. Vrain Nuclear Power Plant in Colorado, which uses TA radios and one siren in its 5-mile emergency planning zone (EPZ). Therefore, it was concluded that of the 9% not hearing a warning using a siren alone, 7.5% would hear a TA radio, raising the alert rate to 98.5%.

The major problem in this method for calculating siren effectiveness was the lack of distinction and often confusion over alert versus notification. The calculation of the 84.5% arousal by siren refers to the alert function only. At no time was the rate for the alert component of the siren system calculated. The informal and TA rates implicitly refer to both A&N components, although with informal notification officials have no control over the message contents.

4.2 NANTICOKE FINDINGS

The warning and evacuation at Nanticoke, Pennsylvania, was caused by a fire that threatened to burn toxic chemicals onsite at the Spencer Metal Processing Plant. The accident occurred about 15 min after midnight on March 24, 1987. Local officials were somewhat slow in assessing the gravity of the situation. After consulting the Chemical Transport Engineering Center, which is a part of the Chemical Manufacturers Association, officials decided to act on the worst-case scenario. The official evacuation began at about 2:20 a.m. Records indicate the sirens for the Susquehanna Nuclear Power Plant were sounded at 2:21 a.m. and the Emergency Broadcast System broadcasts commenced at 2:30 a.m. It is likely that due to fire truck responses the public was hearing other sirens from 12:30 on. The evacuation was a staged effort. The city was divided into quadrants. The quadrant nearest the plant was the first to evacuate. At 2:50 a.m. official decided to evacuate the northwest and west quadrants of the city. At 3:42 a.m. the evacuation of the remainder of Nanticoke began. Thus, we can identify three distinct geographically determined groups of evacuees.

Shortly after the incident, the Centers for Disease Control (CDC), in the Department of Health and Human Services, Atlanta, Georgia, conducted a telephone survey in Nanticoke. The general results of this survey along with the methodology are published elsewhere (Duclos, et al. no date; Duclos, et al. 1989).

4.3 METHOD AND TIMING OF FIRST WARNING

The CDC survey described ways in which people were warned to evacuate. These methods included sirens, officials going through the streets with loudspeakers, officials going door-to-door, friends or relatives going to someone's door, telephone calls from friends or relatives, radio, and television. In fact, these are all common means that are used to warn people in emergencies (Lindell and Perry 1987; Sorensen and Mileti 1990).

Perhaps the most significant aspect of the warning is that the town of Nanticoke is within the 10-mile EPZ for the Susquehanna Nuclear Power Plant. As a result, the town is blanketed with coverage by the sirens that would be used to alert the public to a potential emergency at that plant. This alert system consists of 110 sirens and includes 44 Federal Signal Thunderbolt 1000s, 50 FS STH10s, and 16 FS 5s. The sirens are rated at 125, 115, and 105 dB respectively. On July 30, 1986, a test of the sirens was made at 11:55 a.m., and a telephone survey was conducted to determine how many people heard the sirens. Results indicated that 76.5% of those persons polled heard the sirens. No data is available to ascertain the warning rate within the city of Nanticoke, but there is no reason to believe that it would be significantly different.

Table 3 presents the CDC survey data regarding how people first learned of the need to evacuate, which is the notification aspect of the warning process. It also presents the mean time which people cited as when they first were warned. The sirens were effective in providing notification to about one third of the sample. Informal notification, was the major means of notification, with about 40% hearing from a friend or relative in person or over the phone. The media—not unexpectedly, given the time of day—was attributed with 5% of the initial warning. Officials going door-to-door or with loudspeakers accounted for 20.5% of the notification.

When the mean times of warning are compared we see that media alert was substantially slower than other means. Door-to-door provided the earliest notification on average, while loudspeakers were somewhat slower. The other forms fall in between but are not substantially different from one another.

Table 3. Source and mean time of first warning

System	Percent warned[a]	Mean time warned
Sirens	34.1	2:30 a.m.
Route: loudspeakers	15.7	2:45 a.m.
Route: door-to-door	4.8	2:14 a.m.
Informal: door-to-door	18.6	2:24 a.m.
Informal: telephone	21.5	2:37 a.m.
Media (radio or television)	5.2	3:21 a.m.

[a]Percent of sample responding to the question with missing values excluded.

In Table 4, we have collapsed warning source into four major categories—sirens, route, informal, and media—to examine geographical differences in the warning process. The areas represent the first, second, and third areas of the city to be evacuated in sequence. Indeed, the table shows significant differences among the three areas. In area 1, route alerting was much more prominent than in the other two areas. In areas 2 and 3, informal notification was much more evident than in area 1. The role of sirens was similar in areas 1 and 3 and was slightly less important in area 2. Although the media played a minor role in the initial notification, their role was larger in areas 2 and 3 than in area 1.

Table 4. First warning source by area

	Area			
Source	One	Two	Three	Total[a](n)
Sirens	37.0	26.8	36.6	34.5 (152)
Route	36.2	18.6	10.7	20.5 (90)
Informal	25.4	47.4	46.3	40.0 (176)
Media	1.5	7.2	6.3	5.0 (22)
Total (n)	100 (138)	100 (97)	100 (205)	100 (440)

[a]Total percentages will differ from previous table due to missing data.

4.4 METHOD OF SUBSEQUENT WARNINGS

People usually receive more than one warning in an emergency. The Nanticoke survey allows us to examine which warnings were received subsequent to the initial warning. The results are shown in Table 5. The cells of the table are column percentages that are measured as those receiving a subsequent warning expressed as a percentage of those receiving a first warning from a source. For example, of those receiving a first warning from a siren, 31.3% also heard the warning from a loudspeaker, and 32.5% received a warning from a media source.

Table 5. Method of subsequent warning (in column percents)[a]

Subsequent warning	Source of first warning: Siren (n=163)	Route (n=98)	Informal (n=192)	Media (n=25)	Total (n=478)
Siren	23.9	53.1	44.3	44.0	39.1
Route: loudspeakers	31.3	19.4	24.0	40.0	26.4
Route: door-to-door	11.7	04.1	06.3	24.0	08.6
Informal: door-to-door	23.9	09.2	10.0	12.0	14.6
Informal: telephone	10.4	04.1	03.6	04.0	6.1
Media	32.5	03.1	17.7	12.0	19.5
Total	133.7[b]	93.0	105.9	136.0	114.3

[a]As percent of those receiving their first warning.
[b]Does not add to 100% because multiple responses are possible.

Among the conclusions reached are the following:

- People who initially were warned by sirens or the media received more secondary warnings than people who were warned by route or informal sources.
- Many (44–53%) who were warned first by non-sirens also heard the sirens.
- The media were a significant secondary warning source for those initially hearing sirens.
- Telephone calls were not a significant subsequent method of warning.

Table 6 shows the percent of the sample who reported either a first or subsequent warning from each source. This was calculated by taking the percent who heard the warning as a first source and adding the percentage who heard each source subsequently, but eliminating those who reported hearing a given source first and also subsequently. Overall, we calculate that 65.1% heard and understood the sirens or at least associated sirens with the accident event during the course of the emergency. A total of about 58% received an informal notification. Since people departed fairly rapidly, this number is likely lower than has been observed in other emergencies. Fifty-two percent received route notification and 26% heard a warning from radio or television.

4.5 DIFFUSION OF WARNINGS

The data collected allows us to construct diffusion curves for each warning technology. The curves show the cumulative percent of the population receiving the first warning over time by the four major methods of warning. These are shown in Fig. 1.

Table 6. Total receiving warning by source

Warning	Percent
Siren	65.1
Route: loud speakers	38.9
Route: door	13.2
Informal: door	30.5
Informal: telephone	26.7
Media	24.9

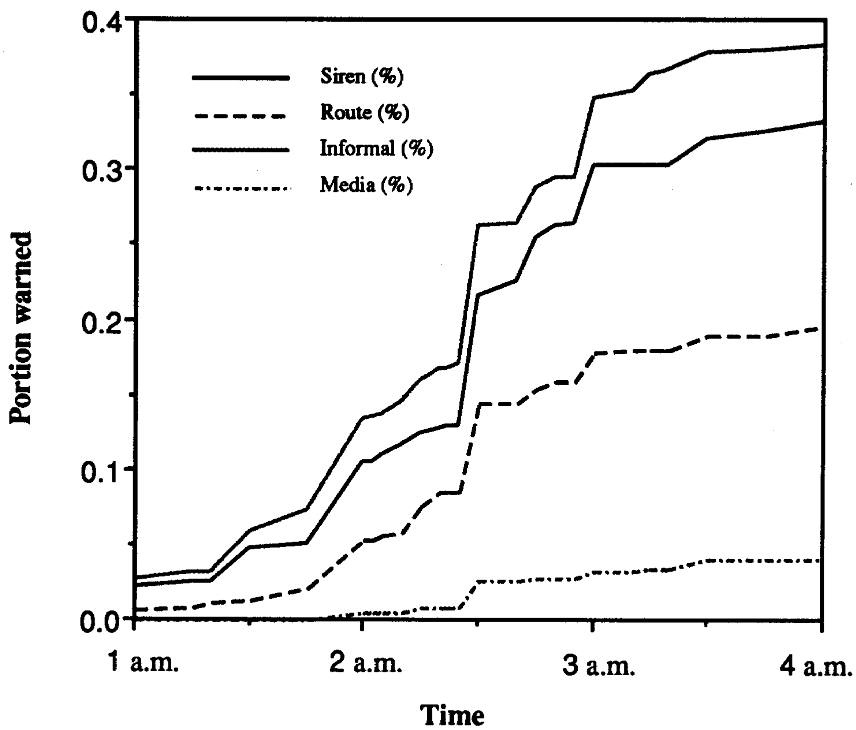

Fig. 1. Diffusion of warning at Nanticoke.

The timing of the diffusion of warnings is very similar for sirens, route, and informal alerting. Some of the early reportings of sirens and route were likely people who heard emergency vehicles responding to the fire. The curves show a steep increase in notification when the official warning activity ensued. By 15 min into the official warning, data indicate that about 65% of the public had been notified. About 22% of the public had received a siren warning at this point. The remainder had received an informal warning, from route alert or from media.

4.6 ANALYSIS OF SYSTEM EFFECTIVENESS

In this section we calculate warning rates using the approach adopted by the Atomic Safety Licensing Board in the Shearon Harris hearings for nighttime and daytime notification. The assumptions used reflect our estimates of the most likely warning rates given available data and knowledge. For the nighttime scenario we assume a 35% siren notification after 15 min, which is in line with the Nanticoke data. This was estimated as follows. First, after 15 min the Nanticoke data indicate about 22% were alerted by sirens. It is likely, however, that some of those being alerted by route notification would have also heard the sirens. Since 53% of those notified by route alert were also alerted by sirens and about 22.5% of those had learned by 15 min we have calculated that an additional 11.6% had heard the sirens. In a similar manner we calculate that at 15 min 1.1% who were initially notified by the media had heard the sirens. This leads to 35% as a reasonable assumption for the total portion of the population that was alerted by sirens in a 15-min time frame.

Second, we assume that 69% of the TA radios functioned and aroused people. This assumption is based on the Hatch survey adjusted by the 97% arousal rate of TAs. A 50% informal alerting rate is also assumed based on results of a number of studies as identified in the Shearon Harris findings. The effectiveness of enhanced TA technologies is based on engineering estimates.

For the daytime scenario we used different assumptions. For sirens we used the results of the FEMA tests at fixed-site nuclear power plants. Overall the mean rate of warning receipt based on these tests is 85%. For TA under the residential distribution policy we have used the same assumption as for nighttime adjusted for the percent of the population not at home who would not have received the warning. For TA under the 100% distribution option, we used the same assumption as for nighttime but adjusted for people in transit during peak travel times (8%).

The nighttime results are shown in Table 7, and the daytime results are in Table 8.

Table 7. Estimated 15-min notification rates: nighttime (expected percent warned)

System	Direct	With informal[a]
Siren (10 dB)	35[b]	46
Siren (20 dB)	45[c]	57
Siren (85 dB at window)	?	?
Tone alert	69[d]	80
Sirens (10 dB) and tone alerts	80	88
Enhanced tone alert	90[e]	95
Sirens and enhanced tone alert	94	97

[a]50%: Based on acceptance by Atomic Safety Licensing Board in Shearon Harris Nuclear Power Plant decision.

[b]Based on experience at Nanticoke with first alert rate for sirens.

[c]Based on 10% additional arousal derived from testimony at Shearon Harris.

[d]Based on alert rate from Hatch Nuclear Power Plant survey and Atomic Safety Licensing Board finding of 97% arousal.

[e]Based on conservative engineering estimates.

Table 8. Estimated 15-min notification rates: daytime (expected percent warned)

System	Direct	With Informal[a]
Siren (10 dB)	85[b]	91
Tone alert	40[c]	52
Sirens (10 dB) and tone alerts	91	95
Enhanced tone alert (residential)	55[d]	63
Sirens and enhanced tone alert (residential)	93	96
Enhanced tone alert (all)	85[e]	91
Sirens and enhanced tone alert (all)	99	99+

[a]50%: Based on acceptance by Atomic Safety Licensing Board in Shearon Harris Nuclear Power Plant decision.

[b]Based on experience with rep.

[c]Based on alert rate from Hatch Nuclear Power Plant survey adjusted for percent at home (60%).

[d]Based on conservative engineering estimates and adjusted for percent at home (60%).

[e]Based on conservative engineering estimates and adjusted for percent in transit (8%).

5. ANALYSIS

5.1 DISTRIBUTION OPTIONS

The main rationale for the distribution policy recommended in the current planning standard was to achieve maximum warning coverage of the IRZ. Even given this mandate, the policy appeared excessive to some members of the planning subcommittee. The main logic for assessing the option to distribute one unit to private residences is that people primarily need the indoor warning when they are at home and asleep. A single unit would likely be sufficient to wake people in the sleeping area of a house. It is likely someone at home and awake would also hear the unit. The logic behind not distributing units to private buildings such as shops and industry are that people are in such buildings primarily during the day and would likely hear sirens. The previous analysis helps to demonstrate this. Our analysis indicates that 96% of the public would receive a notification in an emergency given the one unit per household distribution policy. The policy of mass distributing TAs would increase the likelihood of alert in a daytime scenario, although we could not demonstrate that it would produce a statistically significant increase in protection. Under this distribution policy, no measurable improvement would occur in a nighttime scenario.

5.2 TECHNOLOGY OPTIONS

The special TA offers a high degree of reliability, and the benefits of prompt notification are more likely to be achieved. The special TA technology provides a higher degree of indoor nighttime notification than does a commercial unit. When maintenance costs are factored in, the enhanced technology is clearly more cost effective than commercial units. If the maintenance of the commercial units is not done, the effectiveness of the units becomes very questionable. Effectiveness is likely to decrease by 10 to 20% per year (or greater). The "budget special" radio has the maintenance problems of the commercial unit and none of the benefits of the special unit. It is therefore not an attractive option.

5.3 SIREN SUBSTITUTION OPTIONS

5.3.1 Raise The Standard

One option would be to raise the standard for outdoor sirens from 10 dB to 20 dB over ambient. This option would be almost impossible to implement as it would require a very dense distribution of sirens and obtaining agreements to site them may be extremely time consuming and difficult. The benefits would also be small. It is estimated that the increase in arousal would only be an additional 10% greater than the proposed 10 dB requirement. The system would be inadequate for nighttime alerting. In addition, the system is unlikely to have significant marginal benefits under a daytime scenario. This option, therefore, is unlikely to provide an acceptable alternative to indoor alerting.

5.3.2 Substitute Outdoor Sirens

Another option would be to substitute outdoor sirens for indoor alerting in high population areas and distribute TA radios in less populated areas. This has a potential political problem of not being accepted by the people who do not receive the TA radios. The effectiveness based on whether this option would achieve indoor nighttime alerting is also somewhat uncertain. It is unclear whether an 85-dB sound pressure would result in voice penetration of a structure. It is unlikely that it would be fully audible. This also may encourage people to leave their houses to hear a message. Originally the thinking was to have the outdoor messages tell people to go inside to listen to TA messages, which would no longer be feasible under this option. Additionally, outdoor warning systems designed under the existing standards, which FEMA has told the states to follow, may have to be redesigned for additional sirens. Furthermore, the estimates of sirens required would need to be verified at all sites.

6. CONCLUSIONS AND RECOMMENDATIONS

The conclusion of this analysis is summarized in Table 9, which compares the costs and benefits of the most likely options to be adopted by CSEPP. Benefits as measured by the expected percentage of the population to receive an A&N are different for a nighttime versus a daytime scenario.

Table 9. Summary of estimated costs and benefits

Option	Incremental cost	Nighttime alert rate	Daytime alert rate
Siren	Baseline ($ 6 M[a])	46%	91%
Siren/commercial tone alert (residential distribution)	+ $25 M	88%	95%
Siren/enhanced tone alert (residential distribution)	+ $13 M	97%	96%
Siren/enhanced tone alert (all distribution)	+ $27 M	97%	99%
20 dB siren	+ $16 M	57%	91%

[a]Estimated at $5.3 M and rounded up. *Source:* Long, J. 1990. Memo to J. Sorensen, Oak Ridge National Laboratory, Oak Ridge, Tenn., August 28.

Given the evidence developed to date, it is recommended that a 10-dB siren system plus the special or enhanced TA radios distributed to each residence and special institution in the IRZ be the A&N standard of choice. This minimizes the cost of maintenance and the total cost of a TA radio system and still provides a high degree of reliability for indoor alerting. Furthermore, it reaches the population (residential/institutional) in greatest need of indoor alerting.

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