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Guide to the Most Effective Locations for Smoke Detectors in Residential Buildings

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GUIDE TO THE MOST EFFECTIVE LOCATIONS FOR SMOKE DETECTORS IN RESIDENTIAL BUILDINGS

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ABSTRACT

A simple procedure to determine the best locations for the installation of smoke detectors in residential buildings is presented. Consideration is given to both detection of fires and audibility of the alarm.

RÉSUMÉ

Ce document décrit une méthode simple à employer pour déterminer les meilleurs endroits où installer des détecteurs de fumée dans les bâtiments d'habitation. On y étudie la détection des incendies et l'audibilité de l'alarme.

INTRODUCTION

Statistics show that 90% of deaths caused by fire occur in residential buildings and 40–50% of these deaths could have been averted if an adequate fire detection-alarm system had been in use. Since relatively inexpensive integral smoke detector/alarms [1,2] are available, all residential buildings should be equipped with them.

If these smoke detectors are to be used effectively, it is imperative that some attention be paid to where they are located. Two questions must be answered if an optimum location is to be found. Where is the most effective location for fire detection, and where is the best location to ensure that the alarm is heard?

DETECTION

Obviously the most effective location for a smoke detector is close to those locations where a fire is most likely to originate. In one study it was found that 43% of fires originated in the living room, 22% in the bedroom, and 18% in the kitchen/dining room. These locations should be considered as high priority areas.

Most residential fires occur while people are sleeping; 79% of these fires occur between 8:00 p.m. and 8:00 a.m., with 40% occurring between midnight and 4:00 a.m. Therefore if only one detector is installed, it should be in the bedroom corridor, as close as possible to the bedrooms, and the bedroom doors should be kept open. If a fire were to start inside a bedroom with the door closed, the movement of smoke would be impeded. Lethal conditions would probably occur within the room before the detector could sense the smoke and respond. Similarly, when one detector is installed on each level of a residence whose only sleeping area is on the upper level, the detector on the upper level should be in the corridor, as close as possible to the bedrooms, and the bedrooms doors should be left open. The detector on the main level should be in the hallway close to the living room and dining room. The detector in the basement should be on the ceiling near the basement stairs.

To reduce the likelihood of a false alarm, a detector should not be too close to the bathroom, because water droplets may set off the alarm; similarly, the detector should not be too close to the kitchen, because fumes from cooking may also set off the alarm.

Smoke detectors may be installed on either the ceiling or the upper part of the wall but should not be within a “dead-air” space such as is found within 10 cm of a corner. No difference has been found in the response time of wall- or ceiling-mounted alarms.

AUDIBILITY

Since most fires occur while people are sleeping, an alarm must be sufficiently loud to awaken a sleeping person.

It is always possible to set a sound level high enough to awaken even the heaviest sleeper. Such a level however is unlikely to be practical; it is either too difficult to achieve in a small unit or too expensive for the average homeowner. If the background noise level is low, a level of 75 dBA at the ear is sufficient to awaken the majority of people; this is considered to be the minimum acceptable level for bedrooms.

Because of the high background noise level due to kitchen appliances, the sound level in the kitchen caused by the alarm must be high enough to be heard. For this reason a level of 75 dBA has been chosen as adequate for kitchens.

Thus the goal is to achieve a level of 75 dBA in the bedrooms and the kitchen, and 65 dBA in other rooms. Bathrooms are not included because it is impractical to produce a level high enough to be heard by a person taking a shower.

The *sound level* produced by an alarm is not a fundamental property of the alarm. The same smoke detector will produce different sound levels in rooms of different sizes or with substantially different furnishings. A more fundamental property is the *sound power*. This is a measure of the acoustical energy radiated by the alarm. The relationship between the *sound power* and the *sound level* can be illustrated by an analogy to a light bulb. Think of the *sound power* as the wattage of the light bulb and the *sound level* as the illumination provided by the light bulb. A 60 watt light bulb, while always radiating the same power, will provide more illumination in a small room than in a large room; or in a mirrored room compared to a room painted black.

Unfortunately there is no standard labeling, so it is not always possible to determine the sound power output of any particular device. The Underwriters Laboratory of Canada (ULC) standard S531 requires that all smoke detector/alarms be capable of providing a minimum *sound level* of 85 dBA at a distance of 3 m from the unit under specific test conditions. However, two detectors might both produce a *sound level* of 85 dBA in accordance with ULC – S531, yet have different *sound power* outputs, if they radiate sound in different manners.

Most smoke detectors available for residential use have sound power outputs in the range 95–105 dBA. A sound power output less than 95 dBA may not be adequate in some situations, thus 95 dBA is the minimum acceptable sound power. A smoke detector which satisfies ULC – S531 could have a sound power output as low as 90 dBA, which is clearly below the minimum acceptable.

DETERMINATION OF SOUND LEVELS

Determination of the sound level from a smoke detector in each room of a home can be broken down into several simple steps. First the sound level is determined for the room in which the smoke detector is located. Then the amount by which the sound level is reduced as it travels from one room to the next is determined.

Rooms can be divided into three categories depending on the type of furnishings. Table 1 defines these three categories.

Table 1 Definition of room categories

Hard
no carpet, drapes or upholstered furnishings (kitchen, bathroom, etc.)
Normal
carpets, light drapes, upholstered furnishings (living/dining, halls, etc.)
Soft
thick carpets, heavy drapes, soft furnishings (bedrooms, etc.)

Once the room category has been decided, it is a simple matter to determine the sound level in the room in which the smoke detector is located by using Table 2.

Table 2 Correction to be added to the sound power level of a smoke detector to determine the sound level

Area, m^2	Correction to sound power, dBA		
	Soft	Normal	Hard
2.4 - 2.9	0	2	4
3.0 - 3.6	-1	1	3
3.7 - 4.6	-2	0	2
4.7 - 5.8	-3	-1	1
5.9 - 7.3	-4	-2	0
7.4 - 9.2	-5	-3	-1
9.3 - 11.6	-6	-4	-2
11.7 - 14.7	-7	-5	-3
14.8 - 18.5	-8	-6	-4
18.6 - 23.3	-9	-7	-5
23.4 - 29.4	-10	-8	-6
29.5 - 37.0	-11	-9	-7
37.1 - 46.6	-12	-10	-8
46.7 - 58.7	-13	-11	-9
58.8 - 74.0	-14	-12	-10
74.1 - 93.2	-15	-13	-11
93.3 - 117.4	-16	-14	-12

Suppose the room in which the smoke detector is located has a floor area of 7.8 m^2, a carpeted floor and light drapes. This would be considered to be a 'normal' room so a correction of -3 dBA is found in the column headed 'normal'. This correction is then added to the sound power to get the sound level. If the smoke detector has a sound power of 95 dBA, then the sound level would be $95 + (-3) = 92$ dBA.

The next step is to determine the sound level in the next room. Although the sound will travel through the walls of a building, experience has shown that the sound reduction provided by the door is much less and that most of the sound leaves the room via the door. It is much simpler, therefore, and nearly as accurate to imagine that the sound travels from room to room the same way as a person does, that is, through doors and along corridors.

The attenuation of the sound level, or the amount by which it is reduced going from one room to the next, is given in Table 3. In this case the room category and area that should be used are those of the room into which the sound is going.

Table 3 Attenuation of sound level in going from one room to the next

Area, m^2	Attenuation, dBA		
	Soft	Normal	Hard
1.9 - 2.2	7	5	3
2.3 - 2.8	8	6	4
2.9 - 3.6	9	7	5
3.7 - 4.6	10	8	6
4.7 - 5.8	11	9	7
5.9 - 7.3	12	10	8
7.4 - 9.2	13	11	9
9.3 - 11.6	14	12	10
11.7 - 14.6	15	13	11
14.7 - 18.4	16	14	12
18.5 - 23.2	17	15	13
23.3 - 29.3	18	16	14
29.4 - 36.9	19	17	15
37.0 - 46.5	20	18	16
46.6 - 58.5	21	19	17
58.6 - 73.7	22	20	18
73.8 - 92.8	23	21	19
92.9 - 116.9	24	22	20

Again the use of this table can be illustrated with an example. Let us assume that the smoke detector is installed in the room described in the first example; this may be a hallway outside a bedroom. The bedroom has an area of 13.2 m^2, deep carpets, heavy drapes, and bedspread, which means that it would be considered a 'soft' room. Using Table 3, the attenuation is found in the column labelled 'soft'. The attenuation of 15 dBA is then subtracted from the sound level in the hallway (92 dBA) to give a sound level of 77 dBA in the bedroom.

Once the attenuation of the sound level obtained by going from one room to the next is found, there are two further corrections to be considered. First, if the door between the rooms is closed, then 10 dBA of sound attenuation must be subtracted from the sound level. Second, the system of ducts required for a forced air heating system also provides a means for sound to travel from one room to the next. Since most homes have a forced air heating system, the tables have taken this into account. If, however, the building does not have forced air heating, then there is a further 6 dBA attenuation. Thus in the example above, if the door is closed there is a further 10 dBA attenuation to 67 dBA, and if the building does not have forced air heating, there is a another 6 dBA reduction, to 61 dBA, the sound level in the bedroom.

The sound level in a room is just the sound level in the previous room minus the attenuation between them. This sound level then becomes the initial sound level for calculating the sound level in the next room. The following example will help to demonstrate how the procedure works.

Consider the single family home shown in Figure 1. The pertinent information required can be entered into a table, and the attenuation found from Table 3.

Table 4 Attenuation associated with rooms in Figure 1

Room	Area m^2	Room Catetory	Atten. dBA	Door Closed	Combined Attenuation dBA
KITCHEN	10.9	hard	10.2		10.2
LIVING/DINING	20.3	normal	14.9		14.9
VESTIBULE	3.8	hard	5.6	10	15.6
LOWER HALL	6.5	normal	9.9		9.9
UPPER HALL	7.8	normal	10.7		10.7
BEDROOM 1	8.8	soft	13.3		13.3
BEDROOM 2	13.2	soft	15		15
BEDROOM 3	7.0	soft	12.3		12.3
BATHROOM	5.0	hard	6.8	10	16.8

For this example it is assumed that only the bathroom and vestibule doors are normally closed. If other doors would normally be closed, then the table would have to be modified. It is also assumed that the home has forced air heating; if it does not, then the final attenuation would be 6 dBA higher for all rooms.

It is now a simple matter to calculate the sound level in any room in the house. If the smoke detector is placed in the upper hall, which is a 'normal' room with an area of 7.8 m^2, then the sound level in the upper hall (using Table 2) is 92.0 dBA, assuming that the smoke detector has a sound power output of 95 dBA. To go to the kitchen from the upper hall you must walk first to the lower hall and then into the kitchen; similarly, to find the sound level in the kitchen you must first find the attenuation associated with going into the lower hall from the upper hall and then the attenuation associated with going from the lower hall into the kitchen.

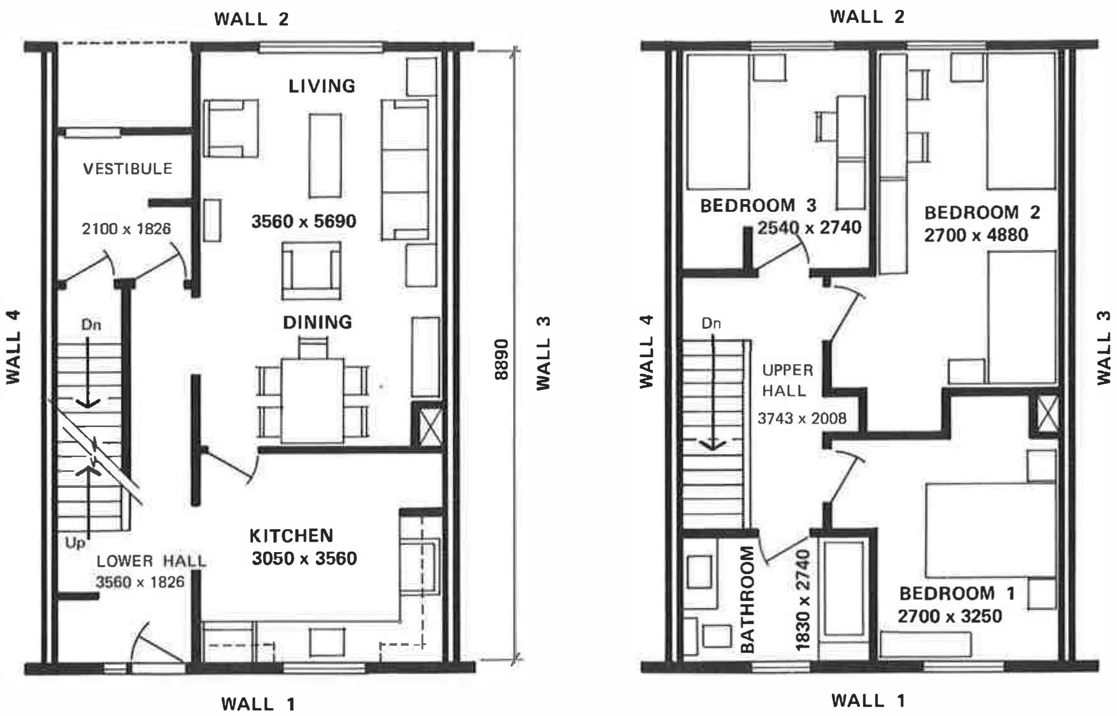

Figure 1

Sound level in upper hall	92.0 dBA
Attenuation associated with passing to lower hall (Table 4)	9.9 dBA
Sound level in lower hall	92 − 9.9 = 82.1 dBA
Attenuation associated with passing to kitchen (Table 4)	10.2 dBA
Sound level in kitchen	82.1 − 10.2 = 71.9 dBA

The sound level in the rest of the rooms in the house can be found in a similar manner.

UPPER HALL	92.0 dBA
LOWER HALL {UPPER HALL → LOWER HALL}	92.0 − 9.9 = 82.1 dBA
LIVING/DINING {UPPER HALL → LOWER HALL → LIVING/DINING}	92.0 − 9.9 − 14.9 = 67.2 dBA
VESTIBULE {UPPER HALL → LOWER HALL → VESTIBULE}	92.0 − 9.9 − 15.6 = 66.5 dBA
BEDROOM 1 {UPPER HALL → BEDROOM 1}	92.0 − 13.3 = 78.7 dBA
BEDROOM 2 {UPPER HALL → BEDROOM 2}	92.0 − 15 = 77.0 dBA
BEDROOM 3 {UPPER HALL → BEDROOM 3}	92.0 − 12.3 = 79.7 dBA
BATHROOM {UPPER HALL → BATHROOM}	92.0 − 16.8 = 75.2 dBA

It is clear from these figures that all of the bedrooms exceed the minimum 75 dBA required and, in fact, the other rooms exceed the 65 dBA recommended. The amount by which the minimum is exceeded is not large and it is possible that were a stereo or TV operating in the living room, the alarm would not be heard. The kitchen is below the recommended 75 dBA and if an appliance were operating, it is doubtful that the alarm would be heard. In such a case it would be prudent to install a second smoke detector in the lower hall. It is important to note that if the bedroom doors were closed, the sound levels would not be adequate to awaken a sleeping person. In a home where it is customary to close bedroom doors, it would be necessary to install a smoke detector in each room. These would then have to be interconnected so that triggering any one of them would cause all alarms to sound, otherwise it is unlikely that adequate warning would be given in case of a fire.

A single smoke detector installed in the lower hall would provide levels 10.7 dBA lower in the bedrooms than a detector installed in the upper hall. This would probably not be adequate to awaken sleepers.

No information is given for the basement in this example but it is easy to estimate the expected sound levels. If there is a single smoke detector in the lower hall, there would be a reduction of 15 dBA for the vestibule plus 10 dBA for each of the closed doors (one into the vestibule and one at the top of the basement stairs). This is a reduction of 35 dBA even without including the reduction for going from the vestibule into the basement. The basement would thus have a sound level no higher than 57 dBA; if the smoke detector was on the second floor, the level would be even lower. Clearly this would not provide adequate warning to a person working in the basement. If adequate warning is to be provided for a sleeping person of a fire which may start in the basement, it is imperative that a detector be in the basement. This detector, however, would not be heard in the bedrooms. To overcome this problem it is recommended that all smoke detectors be interconnected so that if any one is triggered, all of the alarms will sound.

This example was calculated on the assumption that the smoke detector alarm produced a sound power level of 95 dBA. If in fact the sound power level were only 90 dBA, then the sound level in all of the bedrooms would have been 5 dBA lower, and hence below the minimum recommended level of 75 dBA. Installation of a smoke detector in each bedroom would be required to achieve adequate protection. There is no simple answer to this problem and until such time as a minimum required sound power is established, or all smoke detectors are clearly labelled with the sound power output, the problem will remain.

CONCLUSION

If the sound power output of a smoke detector is known, it is possible to use this procedure as a guide to installation and be confident that the occupants of the building are adequately protected.

REFERENCES

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