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Design Guide for Occupant Warning Systems V2

Fire and Security Consulting Services is frequently required by ether the Building Certifier and / or the QFRS Building Approval Officer (BAO) to attend and witness acceptance testing of fire safety systems.

One of the areas that FSCS sees as having poor design and implementation is the occupant warning system and, in particular, the sound pressure levels (**SPL**) (dBa) achieved by the various systems. Accordingly this paper addresses the Code and Standards requirements and the design of the systems to meet these requirements.

Acoustic design is a specialist subject and it would be unusual for an Acoustic Consultant to be engaged on anything other that a project with complex audio requirements such as a recording studio. FSCS are not acoustics consultants but the author of this paper has carried out extensive research to present this paper which should cover simple requirements in most buildings.

Note that this paper references and reproduces certain parts from the two FSCS papers:-

- ***Occupant Warning in Aged and Health Care Facilities; and***
- ***Smoke and Heat Vents in High Rise Residential Buildings***.

DEFINITION

Sound Pressure Level is not defined in the Building Code of Australia (BCA) [1], the "Guide to the BCA nor in AS 1670.1 [2] or AS1670.4 [3]. Interestingly though, it is defined in AS3786 – Smoke Alarms [4].

For the purposes of this paper, the *sound pressure level* (SPL) or sound level is defined as logarithmic measure of the effective sound pressure of a sound relative to a reference value. It is measured in ***<u>deciBels</u>*** (dB) above a standard reference level.

Because the frequency response of human hearing changes with amplitude, three weightings have been established for measuring sound pressure: **A**, **B** and **C**. The "**A**" weighting, as in dBa is the frequency response that approximates the hearing response of the human ear and applies to sound pressures levels up to 55 dB, the **B** weighting applies to sound pressure levels between 55 and 85 dB, and the **C** weighting is for measuring *sound pressure levels* above 85 dBA.

Note the varying use of dBA, dB(A), dBa and dB(a) in various publications. All are considered acceptable.

Requirements

The requirements for occupant warning are contained in the BCA with references to Part E in that document and further references to references AS 1670.1, AS1670.4 or AS3786 which specify various sound pressure levels.

It is not the intent of this paper to analyse the requirements save for that part relating to the *sound pressure levels* in the building. Reference to the BCA and Australian Standards will provide these requirements.

Summarised below are the various SPL requirements specified in the BCA and AS1670.1.

BCA Specification E2.2a, clause 6 :-

- A building occupant warning system must comply with clause 3.22 of AS1670.1 to sound throughout all areas except that:-
  - For Class 2, 3 and 4 buildings with a Clause 3 smoke alarm system, an SPL of not less than 85dBA <u>at the door</u> providing access to the sole occupancy unit. **Notes 1, 2, 3 & 4**.
  - For Class 2, 3 and 4 buildings with a Clause 4 smoke detection system, an SPL of not less than 100dBA <u>at the door</u> providing access to the sole occupancy unit. **Notes 1, 2 & 4**
  - Note that Clause 3.22 in AS1670.1 is reproduced below and the Notes should be read in conjunction with the extract.

3.22 OCCUPANT WARNING

Occupant warning shall be provided to alert all building occupants to a fire alarm situation.

The warning system shall be one of the following:

(a) A sound system for emergency purposes in accordance with AS 1670.4, initiated by the fire detection system. The fire alarm system shall monitor the sound system for fault signals required by AS 1670.4.

(b) Electronic sounders, or amplified sound systems producing the evacuation signal (with or without verbal message). The evacuation signal shall operate simultaneously throughout the building. At all places where warning signals are conveyed to building occupants, the A-weighted sound pressure level during the 'on' phases of the audible emergency evacuation signal, measured with the time-weighting characteristic F (fast) (see AS 1259.1), shall comply with the following:

(i) The requirements of ISO 8201.

(ii) Exceed by a minimum of 10 dB the ambient sound pressure level averaged over a period of 60 s, not be less than 65 dB(A) and not more than 105 dB(A). These values shall be determined in accordance with AS 2659.1.

NOTES:

1 It is recommended that the default evacuation signal complying with ISO 8201 consists of a uniformly increasing frequency during the 0.5 s on phase of the signal. Other signals may be more appropriate for use where the ambient noise will mask the signal.

2 Measurement should be taken in the normal standing positions on the floor of coverage.

(c) Additional visual and tactile signals shall be provided to augment the audible emergency evacuation signal if the averaged A-weighted sound pressure level of the background noise is higher than 95 dB. The temporal pattern described in ISO 8201 shall be imposed on the visual and tactile emergency evacuation signals.

(d) If the audible evacuation signal is intended to arouse sleeping occupants, the minimum A-weighted sound pressure level of the signal shall be 75 dB at the bedhead, with all doors closed.

NOTE: 75 dB(A) may not be adequate to awaken all sleeping occupants.

(e) Where occupants, such as patients in hospital wards, must not be subject to possible stress imposed by loud noises, the sound pressure level and message content shall be arranged to provide warning for the staff and minimize patient trauma.

(f) The sounders shall be connected to a supervised output at the CIE.

Note 1 – The term "at the door" is confusing, there have been various interpretations of "at the door", some as inside the door and others as outside the door. For a fire resistant door with an STC rating of 40+dB, this makes an enormous difference to the selection of sounders and calculations.

For the purposes of this paper, FSCS assumes an interpretation of <u>outside and at the door</u>.

Note 2 – the 2014 edition of the BCA, in Specification E2.2 Clause C3 (c) (i) requires smoke alarms in sole occupancy units to be interconnected.

Note 3 – In addition to either smoke alarms or smoke detectors (as appropriate) in the sole occupancy units, Specification E2.2a also requires detection in other parts of the building not protected by sprinklers. These include public corridors, fire isolated stair landings, lift / stair lobbies and at the head of the lift shaft.

FSCS has seen projects where interconnected smoke alarms have been used in the public areas with the smoke alarm acting as the occupant warning sounder on the various lobbies. This will **NOT** meet the requirements for either the 85 or 100dBA at the door to the sole occupancy unit.

This requirement is best met by the installation of an AS1670.1 detection and occupant warning system with a separate system of sounders speakers) within apartments and the public areas.

Note 4 – Where buildings have sprinkler systems such as in car parks, the sprinkler system shall initiate an occupant warning system. This requirement is best met by the installation of an AS1670.1 detection and occupant warning system with sounders within apartments and the public areas.

Notes to AS1670.1 Clause 3.22

- The requirement that the sound pressure level exceeds the ambient level by 10dDB and not be less than 65dBA; and
- Dot point (c) reads…..if the audible evacuation signal is *intended to arouse sleeping occupants,* the minimum A-weighted sound pressure level of the signal shall be 75dB at the bedhead with all doors closed……Note the "Note" that *"75dB (A) may not be adequate to arouse sleeping occupants".* This phrase in AS1670.1 is an important statement because it recognises the limitations of any warning system. That phrase was discussed in the FSCS paper entitled ***Occupant Warning in Aged and Health Care Facilities.*** Readers of this paper are encouraged to read that paper.
- The term "*intended to arouse sleeping occupants*" has been the subject of much debate and **FSCS is of the opinion that for a Clause 3 smoke alarm system, the 75dBA requirement cannot be enforced** because in BCA Specification E2.2a Clause 3 (c) (ii), the only reference to AS1670.1 is in relation to the location of the smoke alarms and that they are to *…..be located in accordance with the requirements of smoke detectors in AS1670.1….*

  The only reference to AS1670.1 Clause 3.22, where the phrase ... *intended to arouse sleeping occupants…*occurs is in Clause 4.

  Even then, there is no definition or explanation as to who "intends" this. A Fire Engineer, in assessing the risk profile of the occupancy in accordance with the procedures in "The International Fire Engineering Guidelines", might come to the conclusion that there should be some intent to awaken sleeping occupants. Otherwise in a "Deemed to Satisfy" (DtS) design, there are no persons with the legislative authority to impose this intent.
- FSCS research revealed that the 75dB requirement was based on BS 2750[5] and various additional research documents that FSCS had viewed, and all those documents based the minimum requirement on that figure.
- AS1670.4 is referenced as a requirements and clause 4.3.4 in AS1670.4 states:-

> **4.3.4 Output of loudspeakers**
>
> At all places within the evacuation zone within a building where warning signals are conveyed to building occupants, the A-weighted sound pressure level during the 'on' phases of the audible warning signals, measured with the time-weighting characteristic F (Fast) (see AS 1259), shall exceed by a minimum of 10 dB the ambient sound pressure level averaged over a period of 60 s, shall not be less than 65 dB and not more than 105 dB. These values shall be determined in accordance with AS 2659.1.
>
> NOTE: Measurement should be taken in the normal standing positions on the floor of coverage.
>
> If the audible warning signals are intended to arouse sleeping occupants, the minimum A-weighted sound pressure level of the signal shall be 75 dB at the bedhead, with all doors closed.
>
> NOTE: 75 dB(A) may not be adequate to awaken all sleeping occupants.

Accordingly both the BCA and AS1670.1 have various requirements which must be attained, and the following describes sound transmission, sound losses and the methodologies used to calculate the losses through various elements of building construction.

SOUNDERS

In occupant warning systems, the “sound” is transmitted by one of the three following means:-

1. By a bell, the action of the metal hammer on the metal surface generating the sound. Sound pressure levels from bells vary according to bell diameter and frequency of hammer stroke but for occupant warning, they are rarely used.
2. By a “loud” speakers. Traditionally used for music or public announcements, occupant warning speakers can either be used for speech warnings from a microphone or a “tone generator in the panel which generates the specified “beep, beep, beep” alert tones or the “whoop, whoop, whoop” evacuate tones as specified by the Australian Standards referenced in AS1670.1 and AS1670.4.

   The speakers are on separate circuits to the detectors and are powered by amplifiers, either in modules or racks contained in the Fire Indicator or Evacuation Control Panels as appropriate. Tappings on the amplifiers are use to adjust the power levels (Watts) to the speaker arrays. This type of system can have prerecorded verbal messages as well as for a public address system.

   Ceiling mounted cone speakers are usually used in office, shop or residential areas and horn speakers in car parks and industrial areas.

   It is important to note that tone generators have varying frequencies and unless the system is designed to have speakers from the same tone generator in the same evacuation zone, it is possible the transmission phases may be *asynchronous*, that is the sine wave frequencies may not be in sync. If they are 180^{o} apart, it is possible that “white” noise will be generated.

   Sound pressure levels from cone speakers are usually in the range of 85 to 100dB at 1metre with horn speakers up to 120dB.
3. In analogue addressable detection systems, a “sounder base” “beeper” with or without an associated detector is used. This is an electronic piezo device mounted in the base with its own frequency generator and driven by firmware on the printed circuit board. The wide operating voltage of 1 – 30 V and low current draw (5 mA at 9 V) make it easy to power multiple units by modern addressable loop technology and on some advanced systems each sounder can be “addressed” separately dependant on the alarm zoning required. It is not known if these sounders can be synchronised.

   Sound pressure levels from these devices are usually in the range of 85 to 90dB at 1metre.These devices only provide an alarm similar to the “beep, beep, beep” alert tones but cannot provide the “whoop, whoop, whoop” evacuate tones.

In AS3786 smoke alarms, the same piezo technology is used with only a “beep, beep, beep” alert tone. Note that where interconnected devices are used, certain manufacturers are able to provide synchronous setting switches. AS3786 required the alarm signal from smoke alarms to be not less than 82dB at 3m after operation for a minimum of 4 minutes. For the purposes of this paper and as a comparison with other systems, this equates to ~85dB at 1 metre.

TRANSMISSION LOSSES

Sound Transmission losses are influenced by various phenomena such as:-

Distance – Tests in anechoic chambers have found that sound levels are reduced by about 6 dB for each doubling of the distance from the source. This would be typical of outside areas or inside buildings with predominately soft furnishings and carpets where the sound is absorbed.

Sound levels are reduced less when spreading inside an unfurnished building compartment with hard surfaces such as tiled floors and walls – typically corridors and building entrance lobbies. Hard surfaces can reflect up to 90% of the sound. This does not mean that the sound level is increased

Where interior areas have soft absorbent surfaces such as such as carpet and furnishings, the reduction is generally 3 dB for each doubling of distance ceilings.

For the purposes of this paper, a figure between 3 and 6dB is used for calculating sound transmission losses over distance.

Doors and walls - when a door or wall is struck by sound, only a small portion of the sound is transmitted through, while most of it is reflected. The door or wall's ability to block transmission is indicated by its transmission loss rating, measured in decibels. The rating of a wall does not vary regardless of how it is used.

The BCA Clause F5.5 requires that a wall in a Class 2 or 3 building must have an Rw not less than 50, if it separates sole-occupancy units from a public corridor or sole-occupancy unit from each other. For the purposes of this paper, it will be called the STC rating because we are not interested in the impact absorbing capacity of the wall.

Any door will reduce the insulation value of the surrounding wall. The common, hollow core wood door has an STC rating of ~17dB. Fire and solid core doors typically have STC ratings of between 35 and 45dB. The addition of smoke, weather or acoustic seals will increase the STC by about 5dB.

For masonry walls, BCA Specification F5.2 table 2 advises that a 100mm unrendered concrete block has an STC of 50. This would typically be the bounding construction between a Class 2/3 apartment and a lobby, requited to have an FRL of 90/90/90. The BCA and supplier data provides STC ratings for other construction methods.

For drywall construction, CSR technical data reproduced in Figure 1 below indicates that:-

- 172mm overall, 120mm timber stud wall (wall between apartment and lobby) with 2 x 13mm Fyrchek plasterboard either side and insulation with Soundscreen batts has an Rw or STC rating of 50.
- Internal, 90mm timber stud wall with 10mm plasterboard either side gives an Rw or STC rating of 30.

FRL Report/Opinion	SYSTEM N°	WALL LININGS	STUD DEPTH mm	70	90	120	140
			CAVITY INFILL (Refer to Section 'A')	Rw / Rw+Ctr			
–/120/120 and 90/90/90 FAR 2303	CSR 375	*Both Sides* • 2 x 13mm GYPROCK FYRCHEK plasterboard.	(a) Nil	42/36	44/38	45/39	46/40
			(b) 75 Gold Batts™ 1.5	46/38	48/40	49/41	50/42
			(c) 75 Soundscreen™ 2.0 batts	47/38	49/40	50/41	51/42
			(d) TSB3/ASB3 Polyester batts	44/38	46/40	46/40	47/41
			WALL THICKNESS mm	122	142	172	192
–/–/–	CSR 305	*Both Sides* • 1 x 10mm GYPROCK Plasterboard CD.	(a) Nil	30/23	32/25	33/26	35/28
			(b) 75 Gold Batts™ 1.5	34/25	36/27	37/28	39/30
			(c) 75 Soundscreen™ 2.0 batts	35/25	37/27	38/28	40/30
			(d) TSB3/ASB3 Polyester batts	32/25	34/27	34/27	36/29
			WALL THICKNESS mm	90	110	140	160

Figure 1 – Typical acoustic data

Where the barrier is a door within a wall, there are means to determine the sound transmission loss through the combined barrier. Generally this is dependant on the relative areas of each element.

BACKGROUND NOISE LEVELS

As discussed earlier, AS1670.1 in Clause 3.22 requires the occupant warning signal to have a sound pressure level greater than the background noise.

NFPA 72 [6] in Table 1 provides the following general data on average ambient sound level. More meaningful data within residential and office occupancies is given in Table 2.

An interesting comparison is when the author (being on holiday and much to the chagrin of his wife) measured the background (ambient) sound levels in Adelaide Casino. In the gaming rooms the levels were between 70 and 80 dBA, in the bar area, 85Dba and in the external courtyard, 10dBA.

Type of Location	Average Ambient Sound Level
Business Occupancies	55 dBA
Educational Occupancies	45 dBA
Industrial Occupancies	80 dBA
Institutional Occupancies	50 dBA
Mercantile Occupancies	40 dBA
Piers and Water Surrounded Structures	40 dBA
Places of Assembly	55 dBA
Residential Occupancies	35 dBA
Storage Occupancies	30 dBA
Thoroughfares, High Density Urban	70 dBA
Thoroughfares, Medium Density Urban	55 dBA
Thoroughfares, Rural and Suburban	40 dBA
Tower Occupancies	35 dBA
Underground Structures and Windowless Buildings	40 dBA
Vehicles and Vessels	50 dBA

Table 1

Computer equipment room	110
Gymnasium	90
Noisy office	80
Noisy restaurant	70
Living room	40
Bedroom	40
Library	30
Broadcasting studio	20

Table 2

CALCULATIONS

As discussed above, we can calculate the sound transmission losses through open air as well as through barriers such as doors and walls.

Simple Elements

Sound loses through simple elements of construction can be calculated with complex algebraic algorithms used by Acoustic Engineers in the design of high fidelity sound systems. For the purposes of this paper where relatively simple sound transmission losses through open spaces are required to be calculated, a logarithmic (two cycle $\log_{10} - \log_{10}$) graph where the 3dB and 6dB losses are plotted for each doubling of distance. Figure 2 below shows the baseline data plotted for both 100 dBA and 50dBA sounders with the "x" axis extending up to 40 metres and the "y" axis extending up to 120dBA being the maximum allowable under AS16670.1.

Note that this graph uses a source sound level of 100dBa (at 1 metre), being a typical occupant warning sounder level. Also note that there is a maximum allowable sound level of 120dBa.

Note that losses from the 50dB sounder follow a decaying phenomenon, i.e. the losses increase at a greater rate. ,

Note the typical sound levels discussed on page 3 with AS3786 piezo alarms and some loop powered sounders generally having a maximum output of ~85dBA at 1 metre.

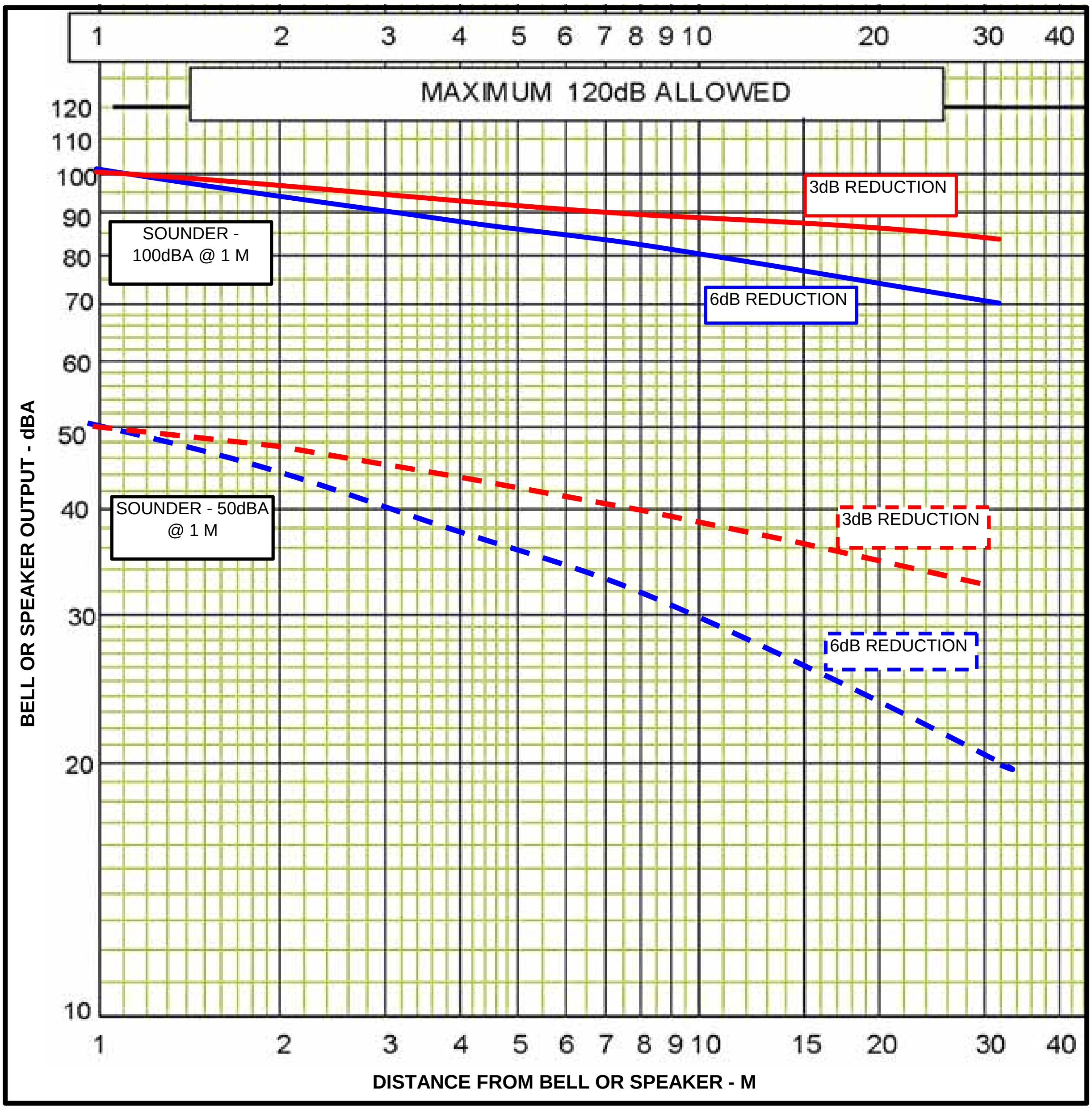

Figure 2 – Sound losses due to distance – 100dBA and 50dBA Sources

As discussed earlier, and for the purposes of this paper, a figure between 3 and 6dB is used for calculating sound transmission losses over distance, this is depicted in Figure 3 and FSCS considers that a straight line can be used for the purposes of realistic distances.

When using this graph for calculations, a line parallel to the baseline reduction line is drawn from a point on the "'y'" axis coincident with the sounder output to a point intersecting with the distance on the "x: axis equal to the distance from the sounder. At that point a vertical line is drawn parallel to the "y" axis equal to the STC loss through the wall or door as appropriate. This can have as many iterations as necessary to account for the distance and barriers between the sound source and the recipient. The worked example is on page 9 and shown in Figure 5.

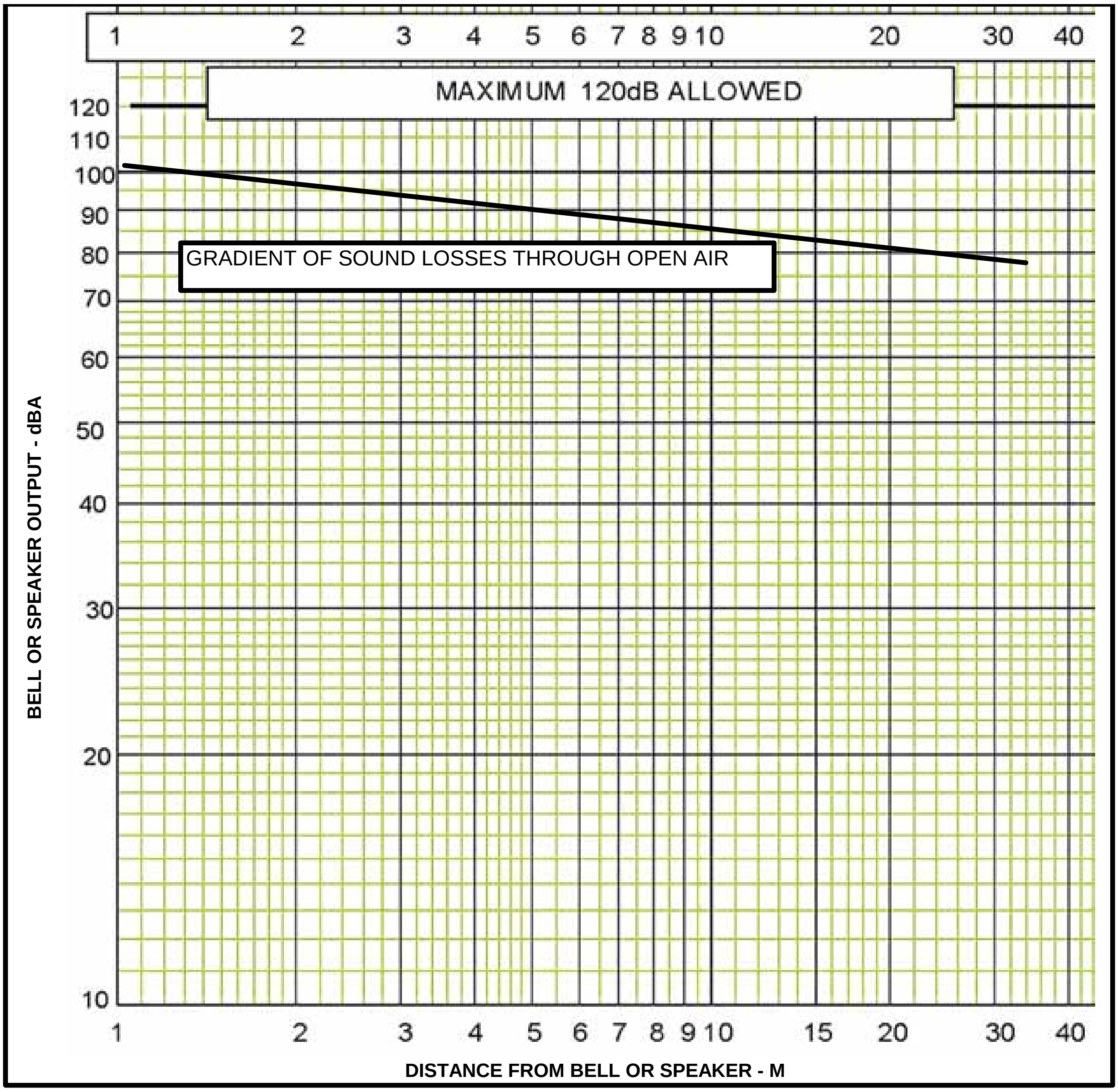

Figure 3 – Consolidated Sound losses due to distance – 100dBA Sources

Composite Elements

The composite STC of a composite wall and door assembly can be estimated by using the graphical procedure shown in Figure 4, based on the transmission losses through each of the elements dependant on the relative area of each.

- Calculate the difference between the STC of the two elements, the wall and the door.
- Calculate the area percentage of the lower STC element to that of the total area.

Using Figure 4 below, determine the adjustment to be subtracted from the higher STC value to give the composite STC of the two elements. This procedure can be reiterated if more than two elements are involved.

In this example, a wall with an STC of 50 has a door with in STC of 30. The door occupies 10% of the wall. The nomograph shows a deduction of 23 has to be made from the wall STC.

The result is a composite assembly with an STC of 34.

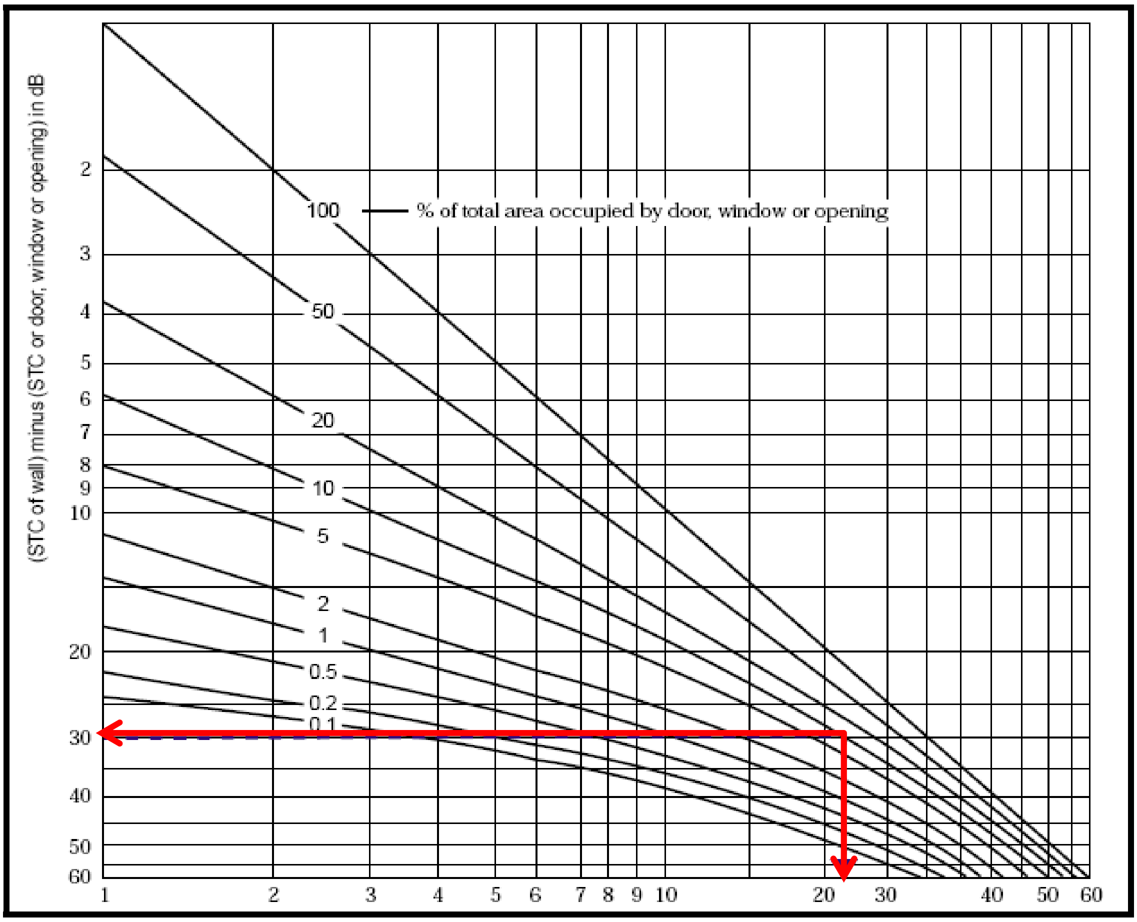

Figure 4 – Composite construction sound losses

Both Figures 3 and 4 are reproduced in blank form at the end of this paper so that practitioners can effect their own calculations.

SAMPLE CALCULATION

Based on the above, it is possible to determine the sound transmission losses through an open area and through a wall and / or door.

The example below is a simple calculation for a smoke alarm in an apartment. A copy of Figure 3 is used to plot the locations and distances as follows:-

- 85Dba Smoke alarm located 2.0m from a closed hollow core door into a bedroom.
- 17dB loss through the hollow core door.
- Bedhead is located 1.5m from the closed door.

The resultant sound pressure level is 62 dBa which although is less than the 75dBA that is often assumed to be the requirement, is still >10dBA above the ~40dBa ambient sound level specified in Clause 3.22 in AS1670.1 and therefore would comply.

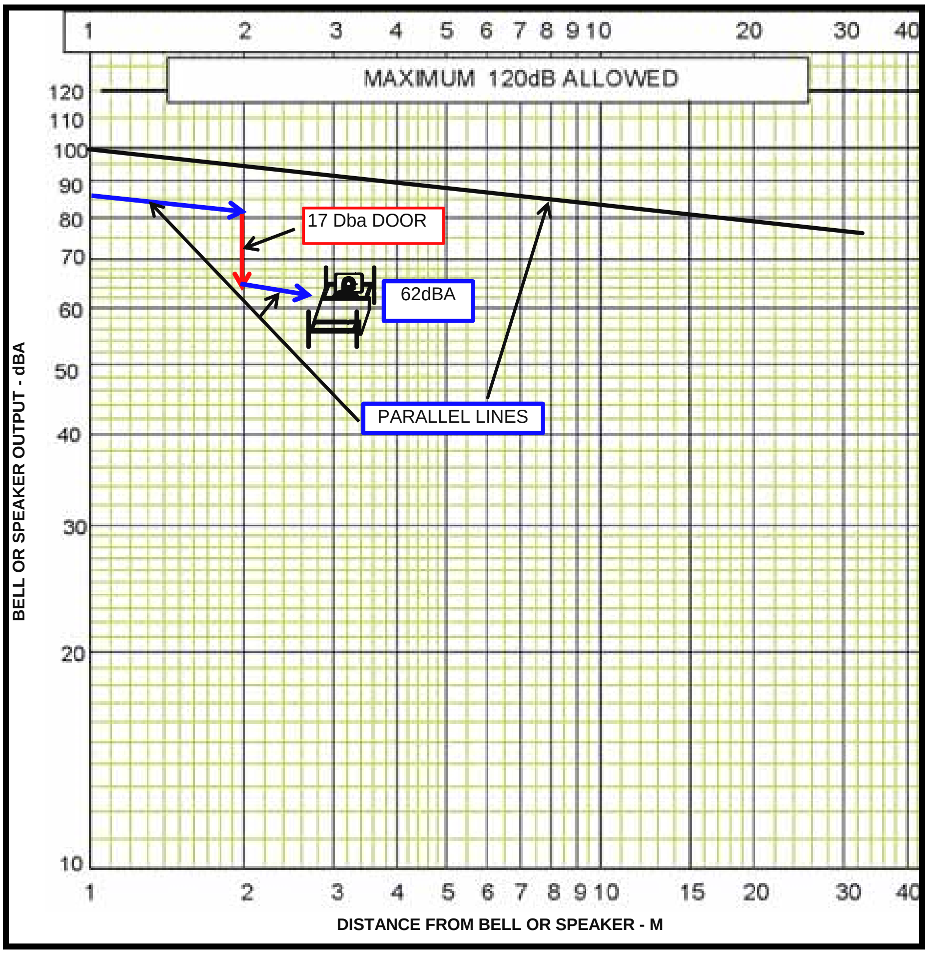

Figure 5 - Example Calculation

References

[1] Building Code of Australia – 2014 – Volume one, Class 2 to 9 Buildings

[2] Standards Australia, *AS1670.1 – Fire detection, warning, control and intercom systems – System design, installation and commissioning. Part 1: Fire*,

[3] Standards Australia, *AS1670.4 – Fire detection, warning, control and intercom systems – System design, installation and commissioning. Part 4: Sound systems and intercom systems for emergency purposes*

[4] Standards Australia AS3786 – *Smoke Alarms.*

[5] BS EN ISO 140-3: 1995 (formerly BS 2750 Part 3)

[6] NFPA 72 – *National Fire Alarm and Signaling Code* – USA

I trust that this paper provides appropriate advice regarding occupant warning system design.

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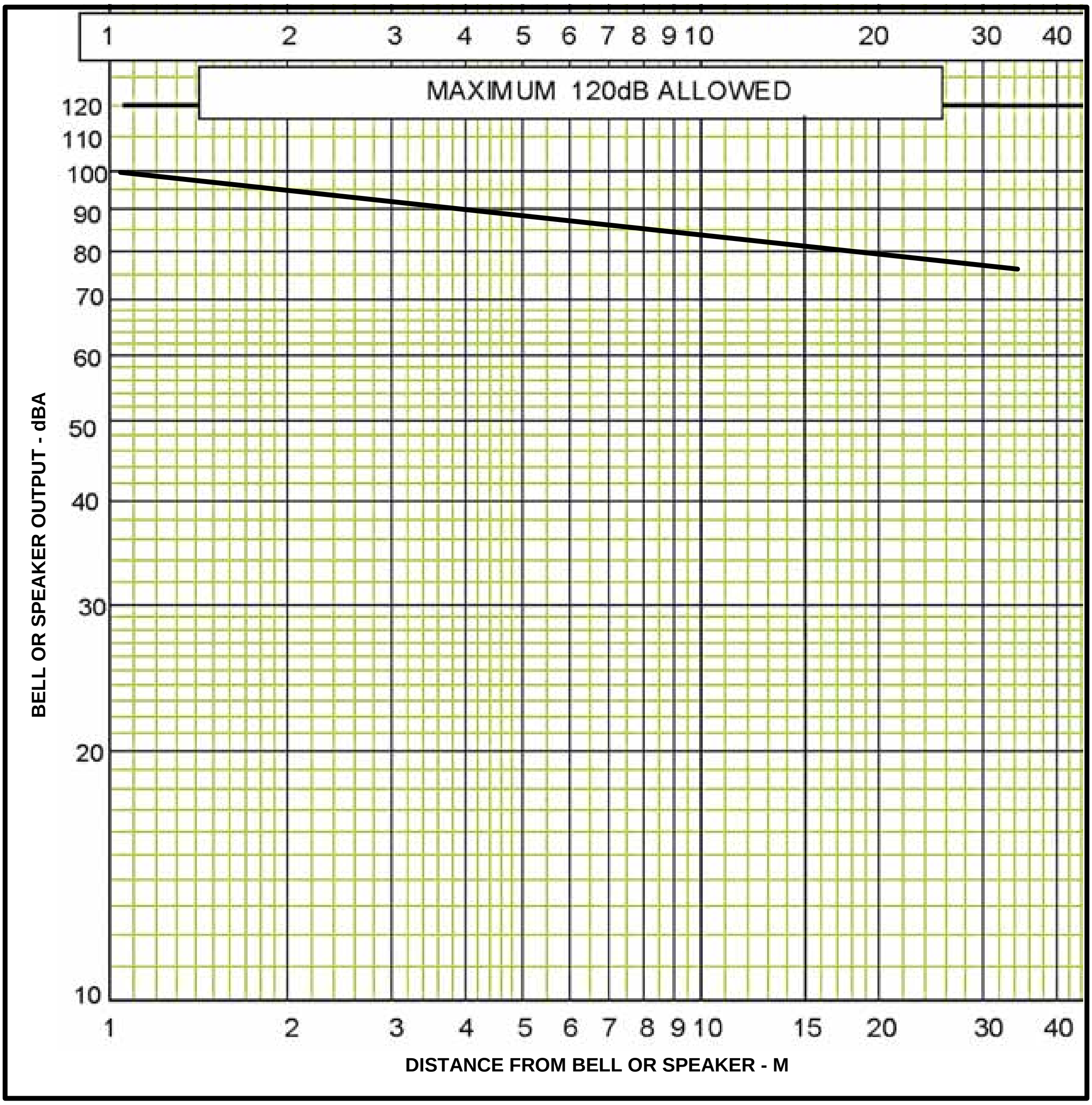
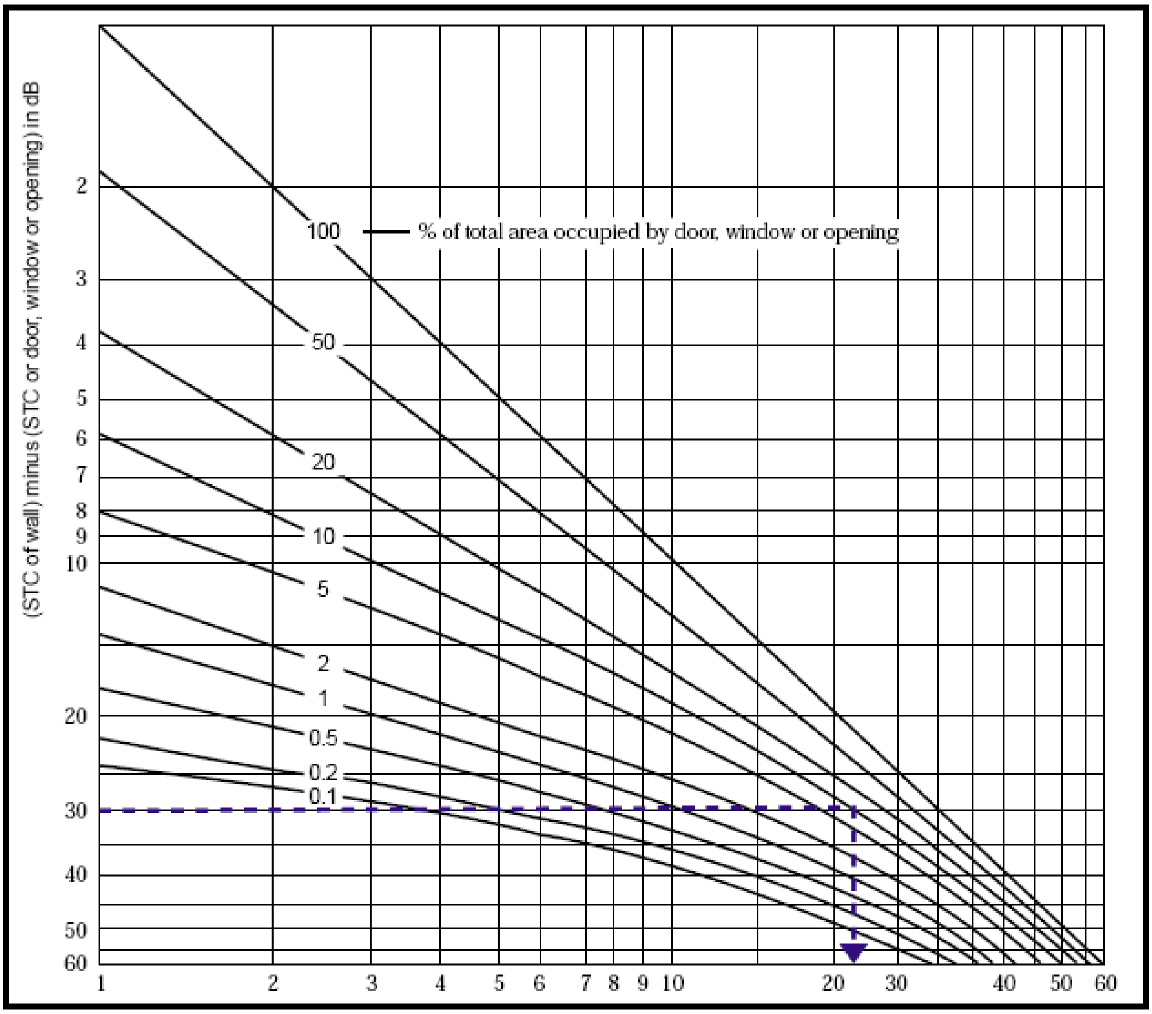


MAXIMUM 120dB ALLOWED
BELL OR SPEAKER OUTPUT - dBA
120
110
100
90
80
70
60
50
40
30
20
10
1 2 3 4 5 6 7 8 9 10 15 20 30 40
DISTANCE FROM BELL OR SPEAKER - M


(STC of wall) minus (STC or door, window or opening) in dB
100 — % of total area occupied by door, window or opening
50
20
10
5
2
1
0.5
0.2
0.1
2
3
4
5
6
7
8
9
10
20
30
40
50
60
1
2
3
4
5
6
7
8
9
10
20
30
40
50
60