Representative noise levels

NOISE SOURCE	dB	Peak
Single musicians		
Violin/viola (near left ear)	85 - 105	116
Violin/viola	80 - 90 *	104
Cello	80 - 104 *	112
Acoustic bass	70 - 94 *	98
Clarinet	68 - 82 *	112
Oboe	74 - 102 *	116
Saxophone	75 - 110 *	113
Flute	92 - 105 *	109
Flute (near right ear)	98 - 114	118
Piccolo	96 - 112 *	120
Piccolo (near right ear)	102 - 118*	126
French horn	92 - 104 *	107
Trombone	90 - 106 *	109
Trumpet	88 - 108 *	113
Harp	90	111
Timpani and bass drum	74 - 94 *	106
Percussion (high-hat near left ear)	68 - 94	125
Percussion	90 - 105	123-134

Singer	70 - 85 *	94
Soprano	105 - 110	118
Choir	86	No data
Normal piano practice	60 - 90 *	105
Loud piano	70 - 105 *	110
Keyboards (electric)	60 - 110 *	118
Several musicians		
Chamber music (classical)	70 - 92 *	99
Symphonic music	86 - 102 *	120 - 137
* at 3 m		
Note: These representative noise levels are collated from a range of sources. They give an indication of the variety of noise levels and noise peaks that musicians and other workers can receive from the instruments concerned. This information can be helpful with estimating noise exposure and in identifying potential noise 'hot spots'. However, as shown, many of the instruments can exhibit a range of noise levels depending on how loudly they are **played**, for how long and under what circumstances (eg repertoire, venue, number of instruments concerned). Do not only use this information for a risk assessment but look at **Sound Advice Note 3 'Noise risk assessment and planning'** and the relevant sector guide(s).		

12.2 By carrying out a noise risk assessment based on noise measurements or other available information, the extent of the problem can be established and will allow the development of a plan for controlling the noise exposure.

12.3 Excitement in musical performance is not achieved by volume alone. Constant loud volume may become monotonous and is potentially damaging to both performer and listener. Drama is created by dynamic contrast, which can be achieved with a reduction in general volume levels that would not be noticed by the audience. This represents a culture change and may require greater effort to achieve the softer levels needed to maintain the range of dynamic contrast.

12.4 The table below aims to demonstrate how long it would take for a symphony orchestra player or singer to be exposed to the upper exposure action value of 85 dB if playing a typical repertoire, for example by composers such as Haydn, Schubert or Vaughan Williams.

Examples of how long it might take for a player to be exposed to the upper exposure action value of 85 dB if playing at the level of a typical symphony performance.

dB		
82	16 hours	eg violin
85	8 hours	eg harp
88	4 hours	eg trumpet
91	2 hours	eg trombone/French horn
94	1 hour	eg loud piano
97	30 minutes	eg loud soprano
100	15 minutes	
103	7.5 minutes	
137 dB (peak)	Maximum instantaneous peak noise when wearing hearing protection	Note that the peak noise from percussion, e.g. snare drum or cymbal clash, may exceed the 137 dB upper exposure action value.

12.5 Studies indicate that orchestral musicians can reach the upper exposure action value by playing for as little as 10-25 hours per week.

Noise risk assessments for orchestras

12.6 Assessment should begin when planning a season or concert, and continue right up to the moment when the music starts - when it switches to monitoring the effectiveness of the control measures. Some orchestras, where repertoire and venue(s) are consistent for a period, are able to base their noise risk assessments on previous noise measurements. Others may be able to use existing noise measurements as a point of reference, and may find it useful to take noise measurements as part of their monitoring. Additional material on noise measurement can be obtained from A sound ear II through the ABO and **Sound Advice Note 3 'Noise risk assessment and planning'**.

12.7 The starting point for a noise risk assessment may be based on the following:

- Knowledge of the venue - its acoustic, space, restrictions and resources.
- Knowledge of the various works to be played - peak volume, length and analysis of the scores for extreme changes in dynamics (change in volume, timbre, tempo),

instrumentation (numbers of each instrument required) and concentrations of energy.

- Layout of players - the number and configuration of musicians, for example how many brass or placement of percussion?
- Knowledge of the individuals involved - conductors (Do they like music loud? Do they rehearse a lot?), soloists (Are they noisy? Do they play loud instruments?) and composers (if available).
- The noise effects of specific instruments
- Is amplification involved?
- Are there any special effects or pyrotechnics - is the 1812 Overture to be performed?

12.8 Noise risk assessments help establish who is at risk and identify ways to prevent and protect people from hearing damage. Communication of the findings from noise risk assessments increases awareness among players, conductors and composers about possible noise-induced hearing damage and encourages everyone to moderate demands for ever-louder playing. Ensure that stage managers and orchestra porters are included in awareness training. Noise risk assessments will identify areas of greatest risk, which should be the priority for control.

Scheduling

12.9 Scheduling can help reduce noise exposure:

- Programme a quieter repertoire.
- Match the venue(s) with the programme.
- Programme concerts with a balanced quiet/loud repertoire.
- Schedule rehearsals with a balanced quiet/ loud repertoire.
- Allocate noisy instruments/passages into separate parts of rehearsals.
- Allow time for adjustments.
- Allow time for players' ears to recover from noise exposure.
- Match the programme with the venue

EXAMPLE - How a conductor can help

The conductor can play a vital part in helping to lower musicians' noise exposure in line with the Noise Regulations. It can be beneficial to understand the common rehearsal and performance practices that can greatly impact on a musician's noise exposure. Some of these control measures could include:

- Rather than rehearsing the full orchestra, a conductor may choose to undertake sectional rehearsals when they have detailed work with one or more sections of the orchestra.
- Exploring a greater range of dynamics within the orchestra to create excitement in the variance between a piano and forte marking rather than going for fortissimo could be of benefit.
- Performing with the orchestra in a number of varying layouts which will give sections occasional respite from traditional 'noisy' areas of the orchestra helps share the load.
- During rehearsals, once the desired effect has been achieved, allowing the orchestra to play under the marked dynamic.
- Avoiding unnecessarily rehearsing very loud sections of the score repeatedly.
- In a full orchestral rehearsal, while making corrections, only working with those particular players or sections who need to be playing at the time and avoid asking other instruments to play.

When programming a concert or a series, a conductor can also be aware that musicians' exposure is measured over a weekly average, so if they were able to programme larger, noisier works balanced out with smaller or quieter pieces, this could reduce noise exposure for their performers. It is also beneficial for an opera and ballet orchestra to rehearse in a space outside the orchestra pit, giving more ambient space to allow sound to escape. Generally the conductor has considerable control over the whole noise output of the orchestra and is able to improve conditions for musicians by being aware of what they are asking of their orchestra.

Venue

12.10 Modifications to the venue can help reduce noise exposure:

- Install specially-designed acoustic panelling and floor covering in frequently-used rehearsal and performance spaces; low and medium frequency acoustic absorption in pits or rehearsal rooms improves clarity and reduces exposures.
- Install adjustable acoustic panels, curtains and drapes in venues and use these to achieve lower noise levels.
- Make use of existing installed acoustic panels such as roof panels which may not be apparent.
- Consider extending the stage (use an apron) to increase the space available for performers.

- Try to keep a clear gap at the front of the platform - the floor surface may help reflect the higher frequencies towards the audience. This may allow players, particularly the strings, to play at a slightly lower level.
- Ensure that risers with more varied heights and widths are available.
- Improve projection - if you can reduce the amount of energy loss between the instrument and the audience/conductor, then you can reduce the power that a player needs to generate.
- Don't overdo special effects in performance. Select the quietest possible pyrotechnics to achieve the desired effect.
- Use earplugs as a last resort - see **Sound Advice Note 5 'Personal hearing protection'**.
- Remember, the solution in one venue may not work in another. Try to have a variety of noise-control measures available, as a collection of small adjustments may add up to a significant reduction in noise exposure. Each 3 dB of reduction in the noise level means half the noise exposure.
- Reduce volume/power output.
- Ensure conductors are aware of the house policy on noise control.

Layout

12.11 Plan the seating layout to minimise problems with noise exposure:

- If there is room, separate performers from one another. An average space of 1.7 m2 per person is adequate but 2 m2 space is better. Try to build upwards rather than out, as this helps to maintain contact between players and keeps the sides and back of the orchestra in closer contact with the conductor.
- Avoid putting players under an overhang as this is likely to increase noise exposure.
- Place brass and woodwind on risers to help them project their sound. They will not need to work so hard to produce their sound.
- Do not put one row of noisy instruments in front of another noisy row, unless the back row is high enough to play over the heads of the players in front.
- On flat stages try staggering seating so that a musician is not playing directly into the back of the player in front.
- It may be possible to rotate the seating positions within some sections of the orchestra and share the exposure of sitting near noisy neighbours.

- If there is room, leave a couple of metres between the percussion section and other performers. Avoid having side-drum heads and suspended cymbals level with the ear of the players seated in front.
- Use fold-back speakers with caution.
- Meet with the conductor to explain the noise-control strategies.
- For some programmes it may be possible to have the noisiest instruments in one area of the stage. The rest of the performers can be remote from that group or be protected by the careful use of screens, minimising their exposure. However, noise measurements may be necessary to ensure that you are not placing the musicians in the noisy area at extreme risk.

Woodwind

12.12 Allow a clear path between the audience and the woodwind - this involves placing the woodwind players on risers and may require an even greater elevation for the brass.

Horns

12.13 Use adjustable baffles behind the horns - this improves the forward projection of their sound, so they don't have to play as loudly.

Brass

12.14 The use of risers to elevate brass sections may help to project their sound, which is highly directional, over the heads of the performers in front of them (see 'Risers' in **Sound Advice Note 4 'Noise-control measures and training'**)

Screens

12.15 If the above measures are insufficient, consider using screens (see **Acoustic screens**).

CASE STUDY - Symphony orchestra noise measurements

The orchestra management arranged for a noise assessment of individual members of the orchestra. Measurements were made during rehearsals. The musical repertoire being rehearsed at the time of this noise assessment was:

Vaughan Williams A London Symphony

Haydn Symphony No. 104 in D Major, 'London'

Schumann A Song of Orpheus

These were considered by members of the orchestra to be relatively quiet works.80% of the musicians wore individual dosemeters mounted on clothing as close to the ear as practical.

Other measurements were made by sound level meters (SLMs) positioned in strategic locations. These were:

- just behind and to the left of the conductor;
- at the centre front of the auditorium (balcony);
- where the double basses would normally sit (for this rehearsal they were in the centre of the rostra at the rear of the orchestra).

Each SLM was mounted on a tripod, with the microphone positioned at about head height (when seated) and pointing towards the middle of the orchestra.The key findings were:

Dosemeters results		
Total number of musicians with valid results	66	
Number for whom $L_{EP,d}$ exceeded upper exposure action value (85 dB)	26	
Highest recorded $L_{EP,d}$	93 dB	
Highest recorded L_{Aeq}	98 dB	
The highest recorded sound levels tended to centre on the brass and woodwind sections, followed by percussion and timpani.		
SLMs results over 6h 47m	**$L_{EP,d}$ dB**	**L_{Aeq} dB**
Auditorium	76	76
Conductor	79	80
Bass section	80	81

Conclusions

- A significant proportion (over 30%) of the musicians received a noise exposure in excess of the upper exposure action value of 85 dB during rehearsals of what were considered to be relatively 'quiet' works.
- Control measures should be implemented and hearing protection worn until the control measures are shown to be effective.

EXAMPLE - Planning concert layouts

The variation of layouts is one of the more effective control measures available, by providing the appropriate distance and height between players at different times. The input and co-operation of the conductor is essential as this enables the orchestra to address the issues as

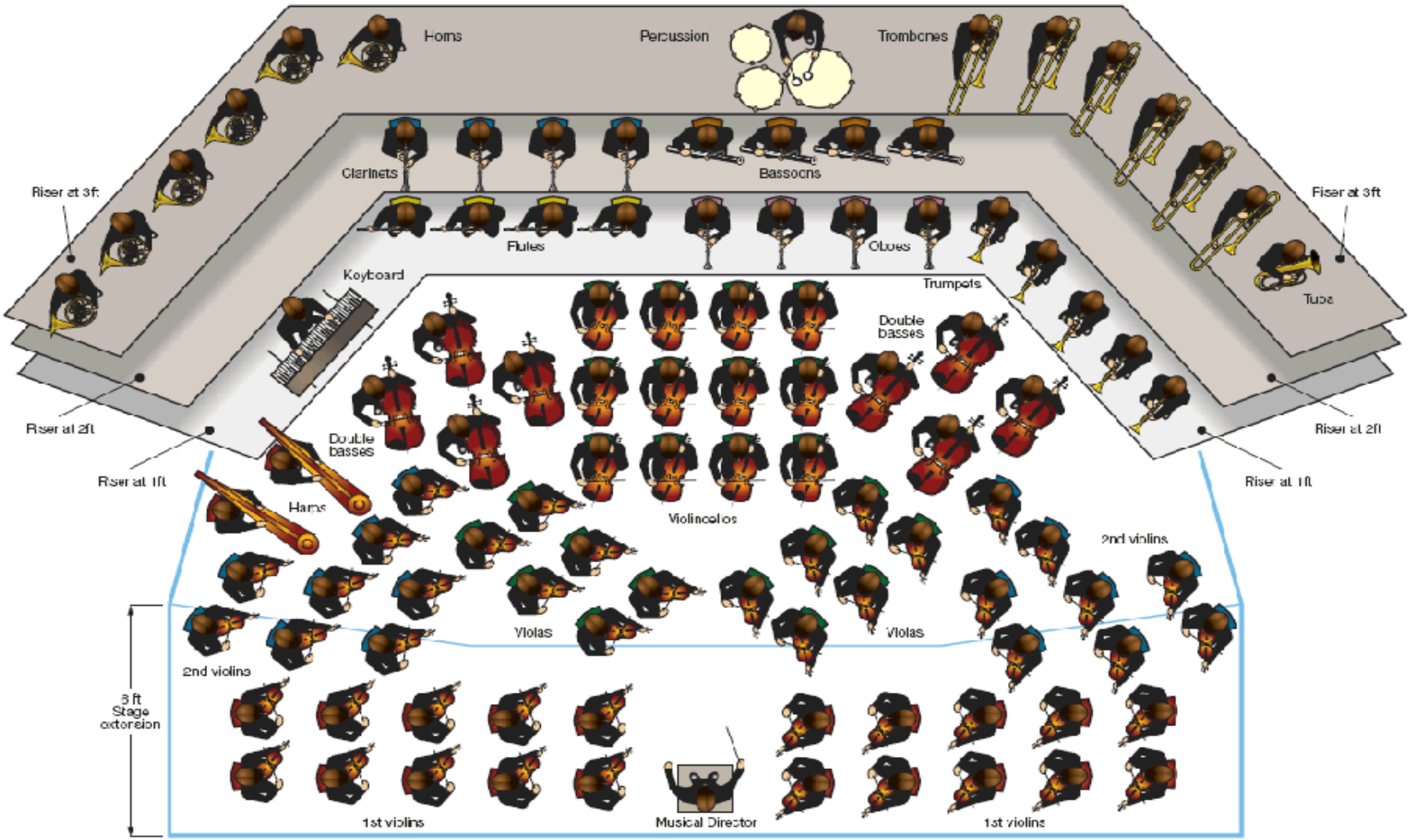
they develop and, with monitoring, vary the layouts of the orchestra. This has the added bonus of providing opportunities for artistic experimentation.

It would be relatively straightforward to vary layouts between concerts were the orchestra to perform only in its home venue. However it is important to consider the idiosyncrasies and unsuitability of some of the stages where the orchestra is repeating all or part of a programme. These engagements are crucial and repeating programmes happen frequently. It would be unfair on conductors and the musicians to change the layout after significant preparation at the home venue and, for this reason, the knowledge and experience of the players of these smaller venues is crucial. Reaching a balance, therefore, usually requires compromise on all fronts.

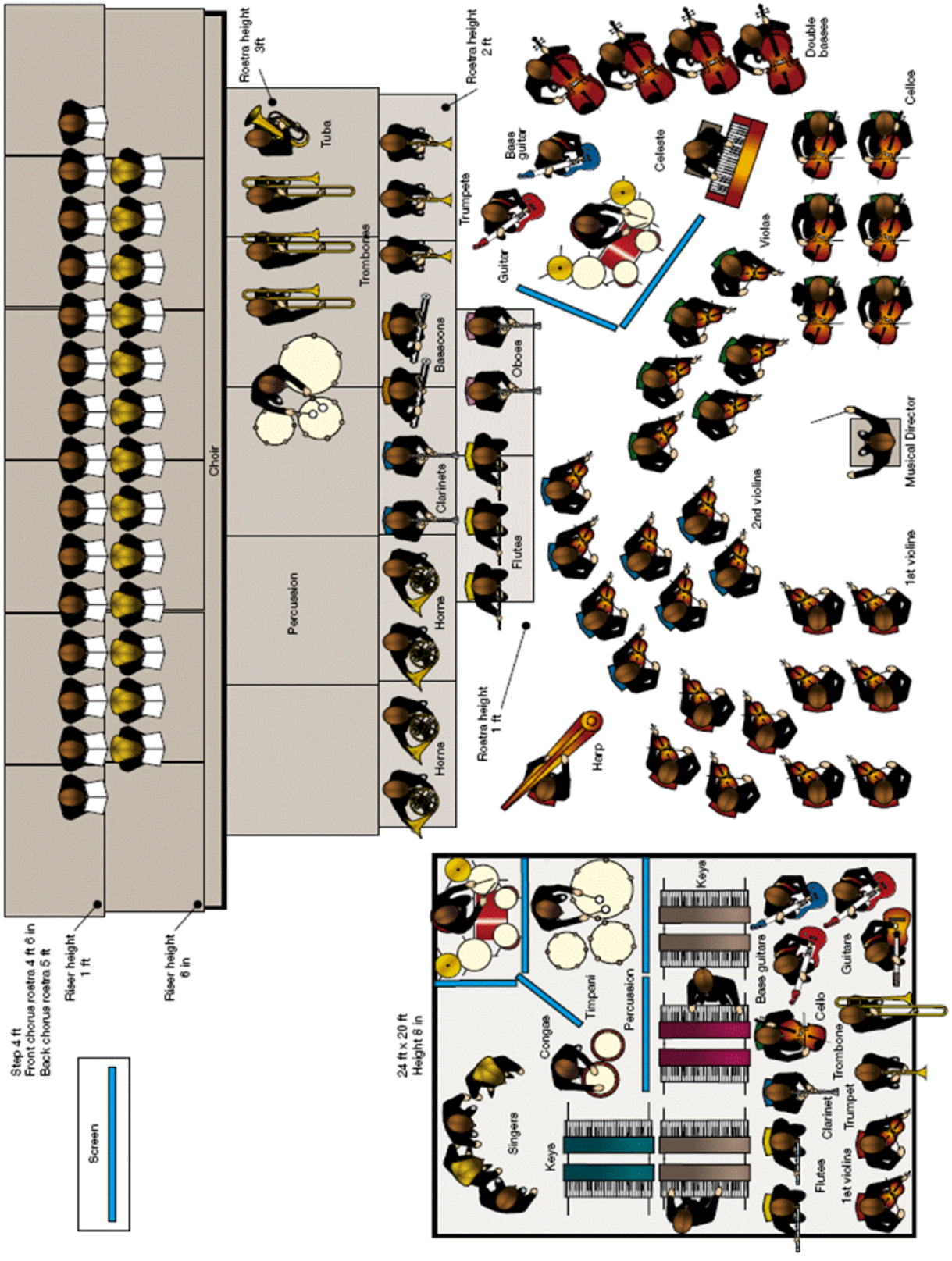
Two examples are shown below. Note risers are provided with their heights marked.

Another layout for an orchestra/pop group during a recording session is in **Sound Advice Note 15 'Studios'**.

Example orchestra layout from Royal Festival Hall, pre-2007


Horns
Percussion
Trombones
Clarinets
Bassoons
Riser at 3ft
Riser at 3ft
Flutes
Oboes
Keyboard
Trumpets
Double basses
Tuba
Riser at 2ft
Riser at 2ft
Riser at 1ft
Riser at 1ft
Double basses
Harps
Violincellos
2nd violins
Violas
Violas
2nd violins
3 ft Stage extension
1st violins
Musical Director
1st violins

Note: To be more effective the riser heights for the trumpets should be at least 2ft
Example layout from 'MusicLab', an educational programme involving professional and amateur musicians



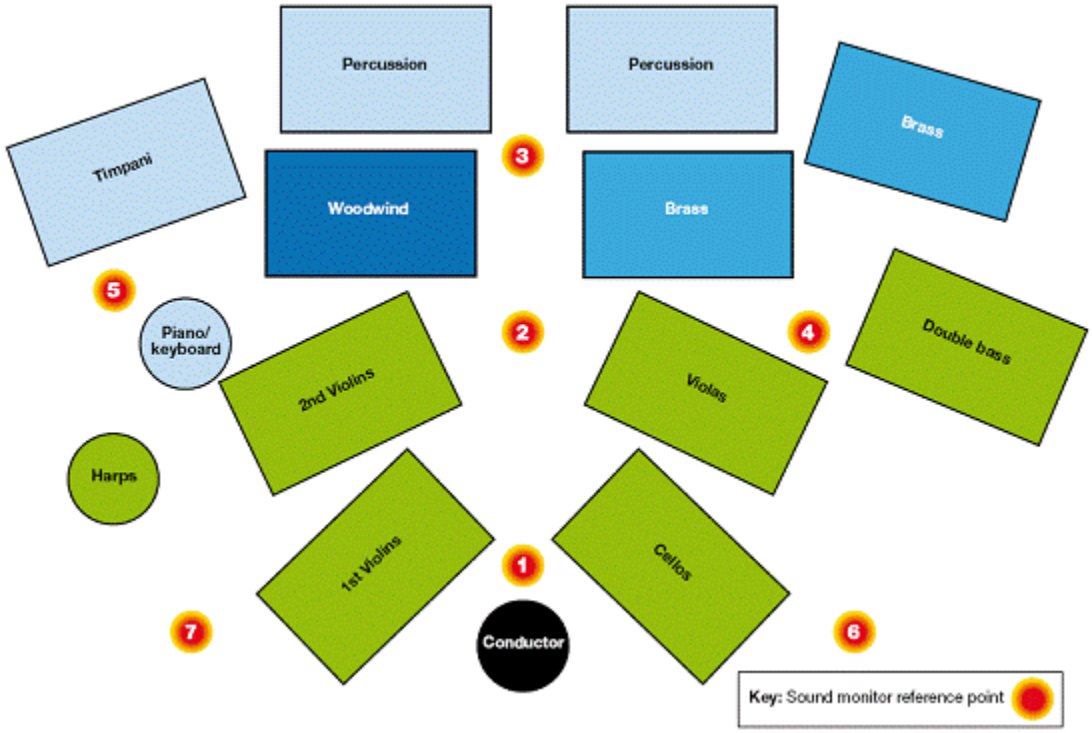
Personal hearing protection

12.16 If, after putting in place all the appropriate control measures, the exposure is likely to be at or greater than the upper exposure action value, personal hearing protection must be used. In other situations its use may be recommended. See **Sound Advice Note 5 'Personal hearing protection'**.

12.17 Some woodwind players may think they have natural protection by using the Valsalva manoeuvre (the creation of a slight positive middle-ear pressure when blowing a woodwind or brass instrument), however, this cannot be considered as an alternative to using hearing protection.

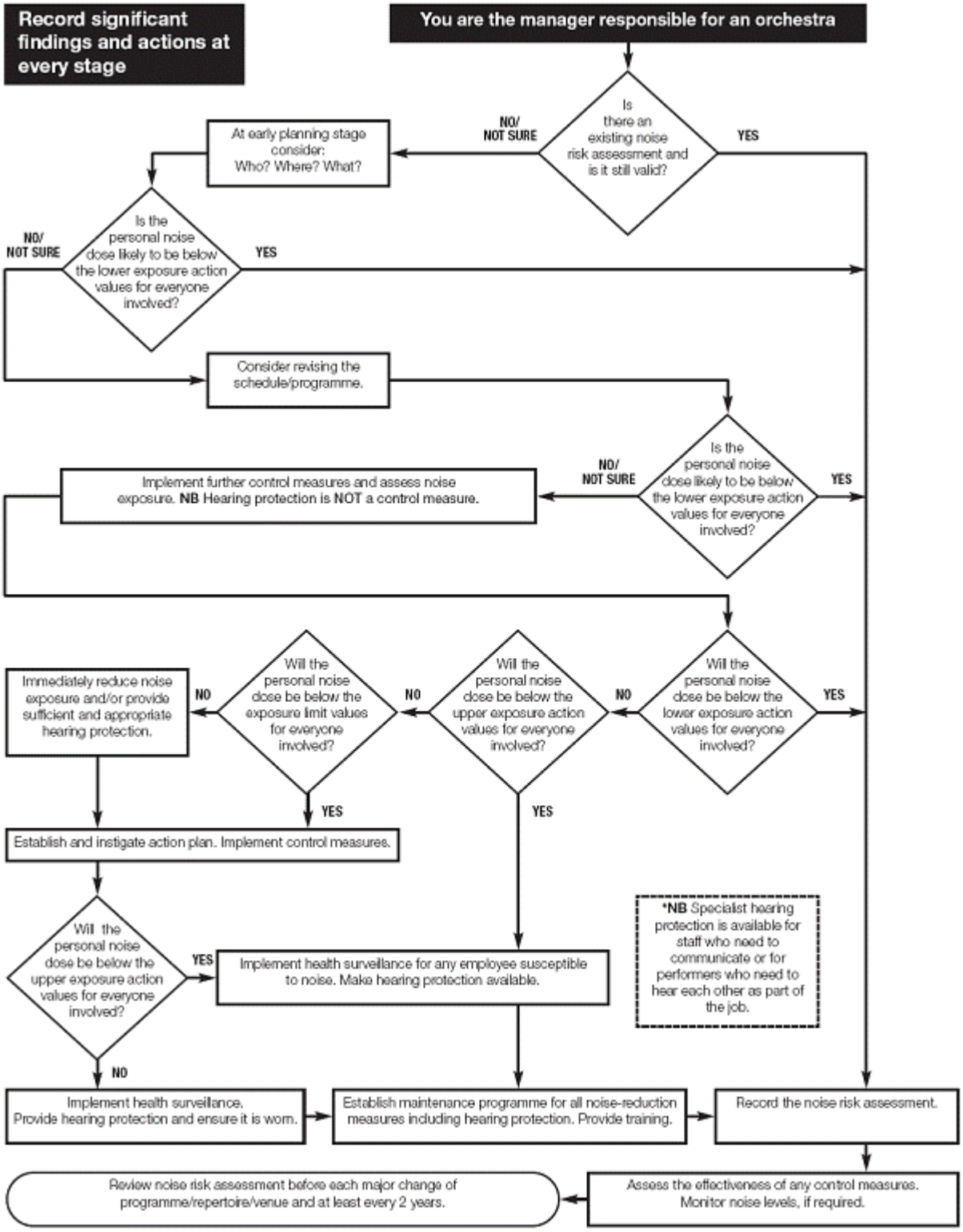
Reference positions

12.18 Reference positions for taking noise measurements can be useful for orchestras, especially when touring, to help assess whether sound levels are under control (see figure below).



Example of an orchestral layout showing reference positions for noise measurement

Noise risk assessment for orchestras



12 A1 Acoustic screens

Use of screens

1 Acoustic screens should only be used in accordance with the risk assessment and on a collective basis as determined by a person who is competent. It is essential that screens are

carefully sited to ensure that they do not create a secondary problem of reflected sound for players close by. Screens should be as large as possible, and extend vertically as far as possible. The application of absorption to them helps control sound levels.

2 Proper training is essential on the choice and use of acoustic screens. Extreme care is needed in positioning screens. Experimenting is usually necessary to achieve the best result.

3 Large screens may help to isolate percussion sections, other noisy instruments and loudspeakers from other performers. However they need enough room to be effective and can reflect sound back at performers seated behind them unless arranged so as not to increase the sound levels for these performers. Large screens may produce distortion and make it difficult for the performer to hear other instruments. In most environments, it may be necessary to include vision panels in screens unless the screens themselves are transparent.

4 Screens should not be regarded as personal protective equipment as they can double the noise exposure of the player to the rear, as well as increasing the risk of an over-playing injury. The protection afforded to the player in front may prove to be more psychological than acoustic although this may be worthwhile where the risks of hyperacusis or stress are significant.

5 Acoustic screens can provide some protection to individual players from noisy sections in orchestral layouts. However screens are not useful to all sections of an orchestra, for example horns, and can sometimes cause sound to reflect back to the performer.

6 In amplified music environments, the strategic positioning of appropriate absorbent screens can provide significant protection. Where the sound is amplified and performers are using monitors, drum kits should be mic'd and located in booths where possible. Alternatively place a large screen in front or behind the drum kit (where vision is required, this could be transparent) to help isolate the drummer's sound from the rest of the performers.

7 In film-set environments, the use of appropriate absorbent screens positioned out of shot can be used as protection during loud activities.

Personal screens

8 Individual acoustic screens can be located around players to help protect them from high sound levels produced nearby. Individual acoustic screens are most effective if placed near to a performer's head and used in accordance with the manufacturer's instructions. The indiscriminate use of personal screens can actually increase the noise exposure for others so screens should be introduced in a considered manner. It is not acceptable to slightly reduce a medium risk (for example, to the performer in front of a screen) by doubling a high risk to the musician playing into the screen (which reflects sound back at the musician).

Potential problems

9 Employers need to take into account potential problems if they are considering installing screens, for example:

- Lack of room.
- Screens can reflect sound back at the performers seated behind nearby.
- Screens may produce distortion.
- Screens may make it difficult for performers to hear other instruments.

Types

10 There are two main screen constructions: these are hard (acoustically reflective) and soft (acoustically absorbent). There is a hybrid third type that combines the hard and soft types.

11 Hard screens are commonly made from plastic or similar transparent material to maintain visual contact.

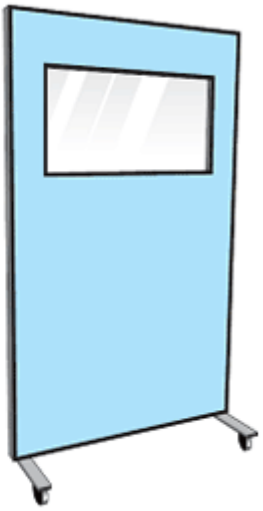
12 Soft screens comprise an acoustically absorbent material (mineral fibre, foam, foils etc) mounted on a panel and covered in a decorative finish.

13Screens can be relatively small and discretely placed to deal with localised specific issues. Studio screens are usually 2 m or so high, and can be used to form enclosures. These are normally absorbent and can include transparent vision panels.

Local reflective screen

Small stand screen

Perspex drum screens



Absorbent 2 m high screen

Glossary

For a more detailed explanation of terms see **Useful information and glossary**.

Fold-back monitors Loudspeakers sited near performers to allow them to hear specific sounds which would otherwise be too quiet, for example a singer on stage to hear a pit orchestra. Includes on-stage monitors and side fills.

Noise exposure: 'The noise dose', which can be calculated, takes account of the actual volume of sound and how long it continues. Noise exposure is not the same as sound level, which is the level of noise measured at a particular moment.

Noise measurements Decibels (dB) are used for measuring noise. A-weighting is used to approximate to the frequency responses of the human ear. C-weighting is used to measure peak, impact or explosive noise.

Orchestra pit In a theatre, an area in which the orchestra performs at a lower level in front of, and usually partially under, the stage.

Reference position Standard location, usually static, selected to enable monitoring of noise levels to be conducted by measurements.

RisersRostra or platforms.

Seating rotation The amount of exposure to noise depends on where the musician sits and plays within the orchestra. The noise exposure of musicians may be varied by moving them.

Upper exposure action values see Exposure action values in **Useful information and glossary**

Bibliography

- *A sound ear II: The Control of Noise at Work Regulations 2005 and their impact on orchestras* Association of British Orchestras 2008. Download from **www.abo.org.uk**
- *Control of noise in the music entertainment industry. Code of practice* Worksafe Western Australia Commission 2003 **www.docep.wa.gov.au/worksafe**
- *The Control of Noise at Work Regulations 2005*SI 2005 No 1643 The Stationery Office 2005 ISBN 978 0 11 072984 8 (also available from **www.opsi.gov.uk**)
- *Controlling noise at work. The Control of Noise at Work Regulations 2005. Guidance on Regulations* L108 (Second edition) HSE Books 2005 ISBN 978 0 7176 6164 0
- *Listen while you work: Hearing conservation for the arts for performers and other workers in art and entertainment* Safety & Health in Arts Production & Entertainment (SHAPE), Canada 2001 ISBN 978 0 7726 4643 9 **www.shape.bc.ca/resources/pdf/listen.pdf**
- *Noise at work: Guidance for employers on the Control of Noise at Work Regulations 2005.* Leaflet INDG362(rev1) HSE Books 2005 (single copy free or priced packs of 10 ISBN 978 0 7176 6165 7) **www.hse.gov.uk/pubns/indg362.pdf**
- *Protect your hearing or lose it!* Pocket card INDG363(rev1) HSE Books 2005 (single copy free or priced packs of 25 ISBN 978 0 7176 6166 4) **www.hse.gov.uk/pubns/indg363.pdf**