

M503

Noise - Measurement & Its Effects

Day 2

Today's Learning Outcomes

Ch 3 (Cont) MEASUREMENT AND ASSESSMENT OF WORKPLACE NOISE

- **To understand assessment of noise exposure levels**

Ch. 4 NOISE CONTROL ENGINEERING

- **To understand the causes of noise generation in common machinery**
- **To review noise control engineering possibilities**

Today's Learning Outcomes

PRACTICAL EXERCISES

- To measure a time varying source
- To calculate a daily noise exposure

Ch 3 Cont

Measurement and Assessment of Workplace Noise

Noise Exposure

To quantify the risk to workers it is necessary to determine their time-weighted average *noise exposure*.

Most regulations consider eight (8) hours to be a nominal workday. Therefore, the term “noise exposure normalized to a nominal 8-hour working day,” expressed as $L_{EX,8h}$, or $L_{Aeq,8h}$ is calculated.

Noise Exposure

$$L_{EX,8h} = L_{Aeq, T_e} + 10 \log \left[\frac{T_e}{T_o} \right]$$

T_e is the effective duration of the working day,
 T_o is the reference duration, $T_o = 8$ hours.

Exchange Rate

To estimate Dose response relationships it is necessary to determine how much increase in energy will result in an increased risk.

This is important because when time of exposure is used as a control measure or risk estimator the energy absorbed is related to the Sound Level AND the Time

Exchange Rate

In terms of acoustic power:

sound energy = sound power x time

Doubling of power or time ► 3 dB increase in SPL

Halving of power or time ► 3 dB decrease in SPL

**This relationship is called the Exchange Rate
and when it is formulated for 3 dB it is known as
the *equal-energy rule*.**

Double the Energy = Double the Risk

Exchange Rate

Not everyone agrees and there have been other proposals for various other exchange rates such as

6dB

5dB

Meters, particularly older dosimeters can have one of the other exchange rates set as 'factory defaults' so beware and always check the settings before commencing measurements.

Noise Dose

Some regulations use the concept of *noise dose, D*.

It was an attempt to simplify to laymen's terms to a simple number without subscripts in the hope of clearer understanding

If Dose = 100% was bad then

Dose = 25% would be OK

Also values of Partial Dose could be simply added

This approach has been largely superseded by the use of the $L_{Aeq,8hr}$

Daily Noise Exposure Determination

Rare for exposure to the same noise level for all the day so need to determine the noise level for each task and the time taken for that task.

Partial noise exposures used to determine the overall noise exposure $L_{Aeq,8h}$

$$L_{Aeq,8hr} = 10 \log \left(\frac{1}{8} \int_8 \frac{p_i^2(t)}{p_0^2} dt \right)$$

Where p^2 is the pressure², in Pa², for the noise level for each task during the work day

Daily Noise Exposure Determination (cont)

In essence the process is that:

- Each value of Pa^2 , is multiplied by the time, in hours, taken for that task to give a value of Pa^2h .
- All the values of Pa^2h are added for the total day.
- This is divided by 8 to normalise for 8 hours
- The resultant, in Pa, is then converted to dB

While the equation can be used in a spread sheet the following chart can be used, see Table 3.1 in the Manual

Daily Noise Exposure Determination (cont)

DECIBEL TO PASCAL-SQUARED CONVERSION									
dB	Pa ²	dB	Pa ²	dB	Pa ²	dB	Pa ²	dB	Pa ²
75	0.013	85	0.13	95	1.3	105	13	115	130
75.5	0.014	85.5	0.14	95.5	1.4	105.5	14	115.5	140
76	0.016	86	0.16	96	1.6	106	16	116	160
76.5	0.018	86.5	0.18	96.5	1.8	106.5	18	116.5	180
77	0.020	87	0.20	97	2.0	107	20	117	200
77.5	0.022	87.5	0.22	97.5	2.2	107.5	22	117.5	220
78	0.025	88	0.25	98	2.5	108	25	118	250
78.5	0.028	88.5	0.28	98.5	2.8	108.5	28	118.5	280
79	0.032	89	0.32	99	3.2	109	32	119	320
79.5	0.036	89.5	0.36	99.5	3.6	109.5	36	119.5	360
80	0.040	90	0.40	100	4.0	110	40	120	400
80.5	0.045	90.5	0.45	100.5	4.5	110.5	45	120.5	450
81	0.050	91	0.50	101	5.0	111	50	121	500
81.5	0.057	91.5	0.57	101.5	5.7	111.5	57	121.5	570
82	0.063	92	0.63	102	6.3	112	63	122	630
82.5	0.071	92.5	0.71	102.5	7.1	112.5	71	122.5	710
83	0.080	93	0.80	103	8.0	113	80	123	800
83.5	0.090	93.5	0.90	103.5	9.0	113.5	90	123.5	900
84	0.10	94	1.0	104	10	114	100	124	1000
84.5	0.11	94.5	1.1	104.5	11	114.5	110	124.5	1100

Daily Noise Exposure Determination (cont)

Consider an employee who undertakes the following tasks:

Use of planer with noise level at the ear of 102 dBA for 0.5 hours

Use of saw with noise level at the ear of 98 dBA for 4 hours

Use of drill with noise level at the ear of 89 dBA for 2.5 hours

Hammering with noise level at the ear of 92 dBA for 2 hours

Daily Noise Exposure Determination (cont)

Source	SPL,dBA	Pa ²	Time	Pa ² h
Planar	102	6.3	0.5	3.2
Saw	98	2.5	4	10
Drill	89	0.32	2.5	0.8
Hammer	92	0.63	2	1.3
			Total	15.3 Pa ² h
Normalise to 8 hour day - divide by 8				1.9 Pa ²
Find SPL from table that corresponds to this Pa ² $L_{Aeq,8h}$				97 dBA

Daily Noise Exposure Determination - Long Work Days

Basis of exposure criteria is that the worker has around 16 hours in relative quiet for the ear to recover but for long shifts the recovery time is much less.

Some standards (eg AS/NZS 1269) have an allowance

Shift length	Adjustment to $L_{Aeq,8}$
up to 10 hr	0
10 to 14 hr	+1
14 to 20 hr	+2
20 to 24 hr	+3

Daily Noise Exposure Determination - Long Work Days

The $L_{Aeq,8h}$ is determined in the usual manner

Then the adjustment from the table is added to the $L_{Aeq,8h}$ and the noise management plan developed based on this adjusted value

Example

If the $L_{Aeq,8h}$ is determined to be 89 dBA

And the actual work shift is 16 hours

then adjustment from the table is +1

So the noise management plan is developed on the basis of an exposure of $89+2 = 91$ dBA

Daily Noise Exposure Determination- Work Weeks

If worker has very different exposure from one day to another the averaged exposure over the week can be used

For each day the P_{a^2} values are added and the total divided by 5 , ie always normalized to a 5 day Week

The resultant $L_{Aeq,8h}$ determined.

Daily Noise Exposure Determination (cont)

Work Week Example

if the determinations of the Pa^2 values for each day

are Monday	0.06	Tuesday	0.63
Wednesday	0.06	Thursday	0.63
Friday	0.06		

Total Pa^2 for the 5 days = 1.44 Pa^2 week

divide by 5 = 0.29 Pa^2

From the table this gives $L_{\text{Aeq},8\text{h}}$ 88.5 dBA

So the noise management plan can be developed on the basis of noise exposure of 89 dBA.

Daily Noise Exposure Determination - Long Work Weeks

If worker regularly works for 6 or 7 days their hearing does not have the chance to recover during rest days. The total weekly exposure should be normalised to 5 days and the noise management plan developed on the basis of that exposure level

So for each day the Pa^2 values are added and the total divided by 5 and the resultant $L_{Aeq,8h}$ determined.

Always normalized to a 5 day week

Exposure Determination - Long Work Week

If the the Pa^2 values for each day are :

Monday	0.25	Tuesday	0.25
Wednesday	0.25	Thursday	0.25
Friday	0.25	Saturday	0.25

Total Pa^2 for the 6 days = 1.50 Pa^2week

Divide by 5 = 0.30 Pa^2

From the table $L_{\text{Aeq},8\text{h}} = 89 \text{ dBA}$

So the noise management plan can be developed on the basis of noise exposure of 89 dBA.

Daily Noise Exposure Determination

- Non Auditory Effects

Increasing evidence that non auditory factors can have an effect so that a greater hearing loss is experienced than would be expected from the noise levels alone

Difficult to quantify but allowance should be made

Daily Noise Exposure Determination

- Non Auditory Effects (cont)

Ototoxic products lead to hearing damage even without exposure to noise.

These include solvents such as toluene, styrene, trichloroethylene, carbon disulphide, hexane and butanol, and toxic metals including lead, mercury and trimethyltin, mixtures of solvents include xylene, heptane and ethylbenzene.

Daily Noise Exposure Determination

- Non Auditory Effects (cont)

Other contributors to hearing loss include smoking, vibration and stress.

On the other hand antioxidants and high temperatures may provide some protection from hearing damage.

Instrumentation Requirements for Surveys

- **If hazardous conditions, dust explosion, heat:
Must have intrinsic safety, hot working permits or protection for instrument.**
- **Appropriate Type for measurement**
 - SLM type 1 or 2**
 - Dosimeters type 2**
- **Calibrators comply to standards and appropriate for the SLM or dosimeter**

Instrumentation Requirements for Surveys (cont)

- **Check random incidence microphone, exchange rate, threshold level and operating procedures**
- **Refer to owners manual**

Instrumentation Requirements for Surveys (cont)

Frequency analysers, Sound Sources, statistical analyser's computer software and hardware should all be calibrated to the manufacturer's recommendations and used in accordance with the manufacturer's handbooks.

Field Check before and after each measurement session

Use the microphone's wind screen as a form of protection

Preliminary Survey

Purpose

The preliminary survey is a needs assessment. This survey identifies those areas, equipment items, and/or job classifications needing a more detailed sound survey

When to Conduct

- **After new equipment is installed, process changes occur, or in those areas where no previous sound level survey has been conducted.**
- **If the resultant sound level is 80 dBA or above, then a more detailed sound survey in those areas should be performed**

Method for Conducting a Preliminary Survey

- **The surveyor should conduct a walk-through survey in the area of concern.**
- **The surveyor should stop long enough at each piece of equipment, work station, or any desired location to make a clear determination as to whether or not the sound level equals or exceeds 80 dBA.**
- **If no SLM is available an estimate can be made if normal voice cannot be understood at an arm's length or approx 1m from the speaker**

Method for Conducting a Preliminary Survey

- **All portable and/or intermittent sources, such as pneumatic hand-held tools, air compressors, saws, etc., need to be measured as part of this survey.**
- **Presence of peak must be noted**
- **Clear identification of equipment and mode of operation required for later work or verification**

Reporting and Documentation

- **All areas less than 80 dBA should be documented as such. Documentation may take the form of a memo to the file indicating the date of the survey, the name of the surveyor, name of the area or department inspected, and the fact it has been identified as a low noise risk area.**

Reporting and Documentation

- **For those areas with sound levels at 80 dBA or above, a detailed sound survey should be scheduled and conducted as soon as possible.**
- **In addition, lower exposure limits exist for maritime and offshore personnel; and therefore, it is recommended the preliminary survey be bypassed and a detailed survey undertaken**

Detailed Sound Level Survey

Two main methods

- **Area or machinery noise survey - determination of the noise levels over a work area or around each particular machine.**
- **Personal noise exposure assessment - focuses on determination of the noise exposure for a person from data on the noise exposure for each of the tasks carried out during the day. Can also relate to the noise exposure of personnel undertaking that work pattern.**

Detailed Sound Level Survey

For any noise hazard risk assessment three crucial findings must be reported:

- **Operational L_{Aeq} for each noise source and for each worker in the area**
- **Peak L_{Cpeak} for each worker people in the area**
- **Estimation of $L_{Aeq,8h}$ based on the typical work pattern for the worker**

Detailed Sound Level Survey

Individual noise assessment - noise level for each activity and the time spent doing that activity used to estimate the individual noise exposure, $L_{Aeq,8h}$.

Area survey - data or map presents areas where noise levels are at a hazardous level. Used to prioritise noise control efforts.

Machinery noise survey - work areas where the noise levels are likely to be hazardous should be clearly identified. Used to prioritise noise control efforts.

Noise control survey - detailed noise level data on the sources used in the justification for the proposed noise control measures.

Area and/or Equipment Sound Level Survey

Purpose

- **Document all machines and components operating at 80 dBA or above,**
- **Identify required hearing protection areas, and create a priority list of noise sources suitable for noise control treatment.**
- **The survey should be repeated on a regular schedule, such as every two to five years, to validate or update existing data.**

Method for Conducting the Survey

- **Systematically measure sound levels at each machine**
- **Document the conditions at the time of survey,**
- **Preferably, measurements should be collected during typical operating conditions**

Method for Conducting the Survey

- **Measurements for machinery noise survey usually taken at 1m from each side of the machine**
- **Measurements for area noise survey usually taken at**
 - **0.1 to 0.2 m from operator ear when the operator is present.**
 - **if no person is present then 1.5 m above ground for a standing person or 0.8m above seat for a normally seated person**

Method for Conducting the Survey (cont)

- As worker not stationary good to scan a little around the position

The time, T , for each measurement location should be long enough to ensure that the value of $L_{Aeq,T}$ is representative

- If the source is essentially constant, a time of 30sec to 1 minute may be sufficient.

Method for Conducting the Survey (cont)

- If the noise level varies as the product is processed, the time T needs to be long enough to be representative of the entire task, tasks or worker exposure – typically three, four or more cycles of a process to allow for variance within the cycles.**

Using a Chain Saw as an example the time period may need to be long enough to include set up, idling between cuts, cutting and staking of the cut product

Example: Using a Chain Saw



Sound Contour Map

Map is just a snapshot in time of the sound levels on the day of the survey.

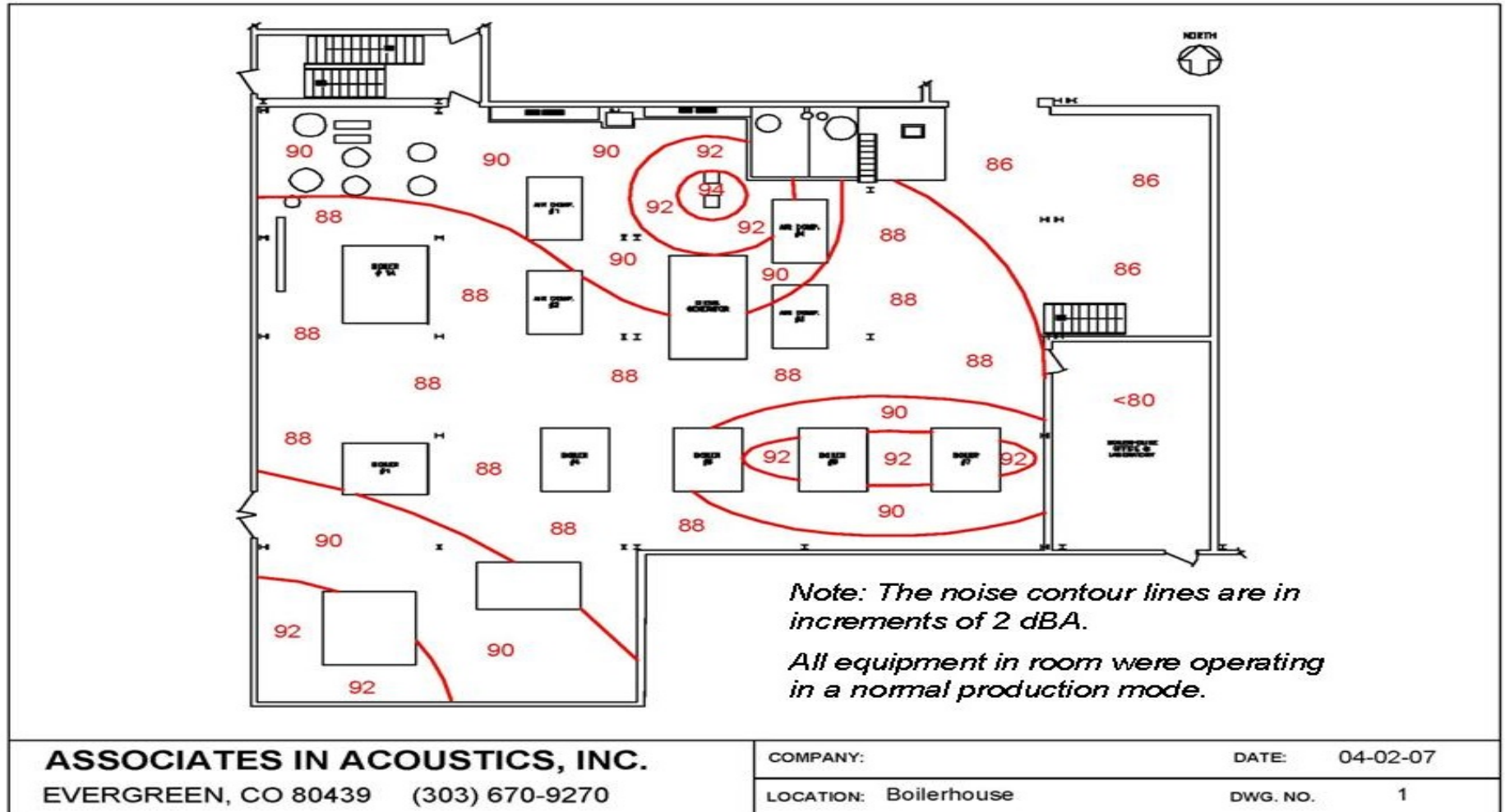
Actual levels will vary from day-to-day, depending upon the product, production rate, and equipment actually operating in the area.

So maps should not be used to delineate fine lines on the production floor for hearing protection zones

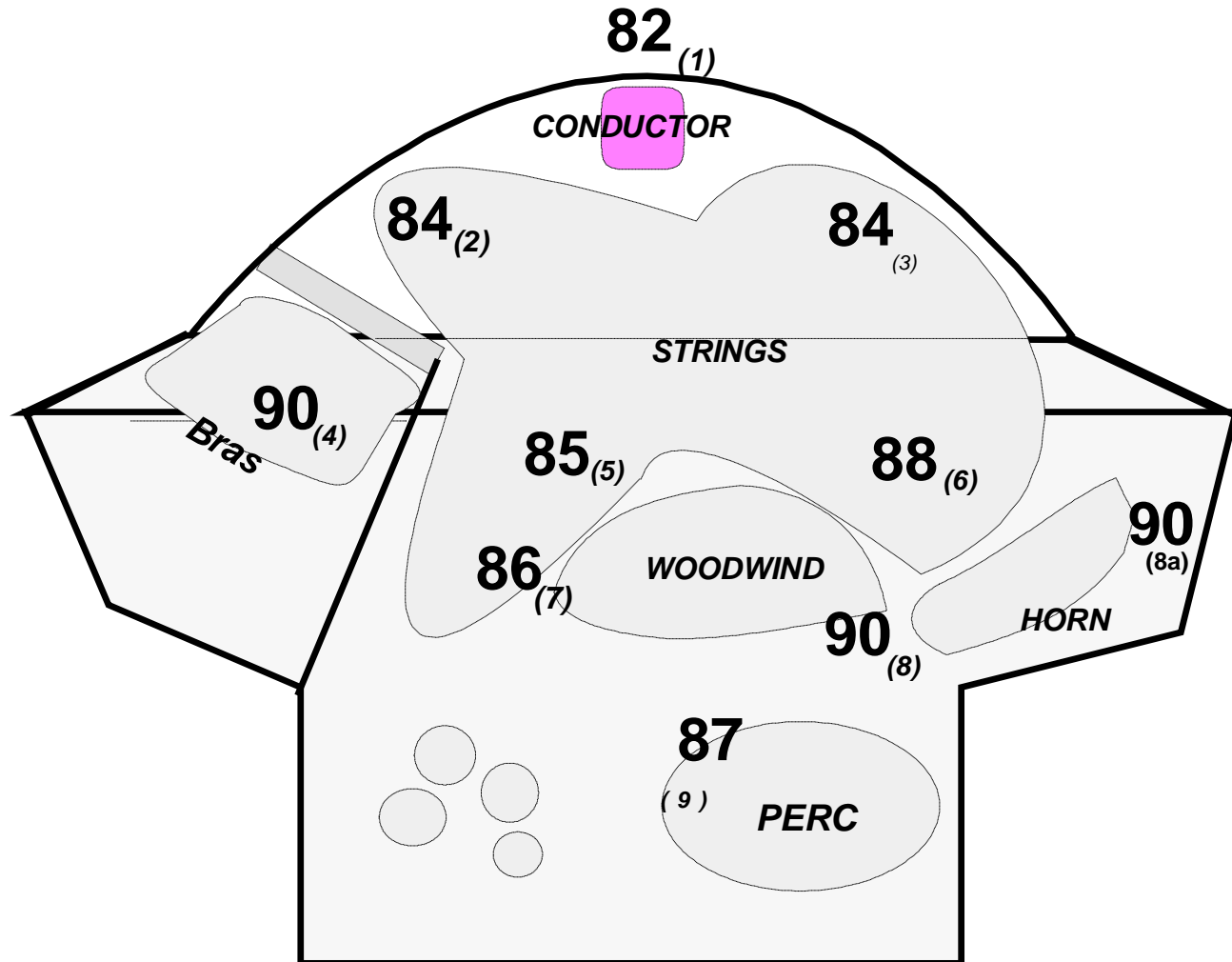
Sound Contour Map (cont)

It is common practice; however, that companies will designate the entire noise area, room, or department as a hearing protection area if it contains any sound levels above a specific threshold level, such as 85 dBA as this simplifies the management and supervision.

Sound Contour Map



Sound Contour Map



Reporting and Documentation

- **Measurement results should be tabulated in descending order (loudest first) to prioritize noise control efforts**
- **Name of surveyor, survey date(s), equipment location, production rate, any abnormal or unusual conditions, and measurement positions should be noted**
- **The results may also be presented graphically as a sound contour map.**

Noise Exposure Survey

Purpose

Collect sufficient sound level and/or noise exposure data for personnel in the area to develop a conservation program

Noise Exposure Survey

- **A noise exposure determination should be made for all employees who work in areas having sound levels of 80 dBA or higher.**
- **After the initial determination, re-monitoring should be conducted at least every two years.**
- **And also whenever new equipment is added, old equipment removed or shut down, or process changes occur that alter the area noise environment.**

Individual Noise Assessment

Involves shadowing workers while they are carrying out their work or examples of their work.

Normally done by holding an integrating SLM at arms length in proximity of the workers ear and taking a sample for the duration of the task while observing the process and noise sources during the task.

The L_{Aeq} and the peak measurements are recorded and the next task is then undertaken.

Individual Noise Assessment

Data can be used in two main ways:

- **to gain an indication of the likelihood of each task to contribute to the persons daily exposure and allows all sources likely to lead to excess noise exposure to be identified for further investigation**
- **to estimate the daily noise exposure for each worker or groups of workers**

Job/Source Risk Assessment

No.	Work Process or Operation	L_{AeqT}	Peak	Complies with Regulatory Requirements
1	Cushman Truckster	75	103	YES
2	Cushman Spray Unit	76	102	YES
3	Quad Runner	72	101	YES
4	Honda Bike	67	-	YES
5	Mower Reelmaster 6700-D	83	102	YES
6	Mower Ransomes 213-D	83	102	YES
7	Mower John Deere 2653A	86	105	NO, if exposure exceeds 6 hrs 36 min
8	Mower John Deere F1145	90	115	NO, if exposure exceeds 2 hrs 32 min
9	Whipper Snipper Kawasaki	98	113	NO, if exposure exceeds 25 min
10	Blower Echo	94	108	NO, if exposure exceeds 1 hr 4 min

NOISE EXPOSURE ESTIMATION

This spreadsheet may be used to calculate the accumulated dose and $L_{Aeq,8}$ or $L_{EX,8h}$ based on area/equipment noise level data. Simply fill in the yellow shaded cells for the sound level in dBA and estimated exposure time (duration) in minutes for each job activity.

Note: This spreadsheet will normalize all data for non-eight hour workshifts to an 8-hr day.

JOB TITLE: Carpenter DEPARTMENT: Wood Shop SHIFT LENGTH: 8 hours					
ESTIMATED TOTAL DAILY NOISE DOSE AND $L_{Aeq,8}$ FROM EXPOSURE TO DIFFERENT SOUND LEVELS FOR DIFFERENT DURATIONS (3-dBA EXCHANGE RATE, 85-dBA CRITERION, NO THRESHOLD)					
SOURCE NUMBER	JOB ACTIVITY/LOCATION	SOUND LEVEL, dBA	REFERENCE DURATION, MINUTES	EXPOSURE TIME IN MINUTES	% DOSE PER SOURCE
1	Hammering	89.0	190	30	15.75
2	Band Saw	95.0	48	30	63.00
3	Planer	88.0	240	60	25.00
4	Jointer	93.0	76	60	79.37
5	Router	96.0	38	120	317.48
6	Lathe	89.0	190	90	47.25
7	Clean-up	82.0	960	30	3.13
8	Lunch/Breaks	65.0	48765	60	0.12
NOISE DOSE (%) AND $L_{Aeq,8}$ (dBA):					TOTAL ACCUMULATED DOSE: 551.1 %
CALCULATED $L_{Aeq,8}$:					92 dBA

Calculations are based on a 85-dBA Criterion, No Threshold Level, with a 3-dBA Exchange Rate

Reference Duration is the amount of time it takes to reach a 100% dose at a certain sound level.

$L_{Aeq,8}$ is the average daily noise exposure in dBA, which is normalized to an 8-hour workday.

Personal Noise Dosimetry

Points to especially note

- Field check and battery check
- Microphone position near ear
- Parameter settings- check exchange rate
- Explain process to worker
- Supervision
- Stay around to understand the workplace and likely sources observe work
- Results interpretation – check with other data sources



Personal Noise Dosimetry

Things that can go wrong include:

- **Failure to follow manufacturer instructions**
- **Failure to start and stop properly to avoid invalid data**
- **Microphone moved accidentally or intentionally**
- **Excessive bumps to microphone**
- **Non normal work day**
- **Wind effects**
- **Battery failure**

Representative Worst-Case Monitoring

Representative monitoring may be used to streamline the number of dosimetry samples needed.

Observations and interviews are used to identify

- similar exposure groups that have the**
- same job function or activity, and**
- are exposed to similar sound sources.**

From groups containing four or more employees, it is recommended at least three individuals be selected for monitoring with personal noise dosimeters.

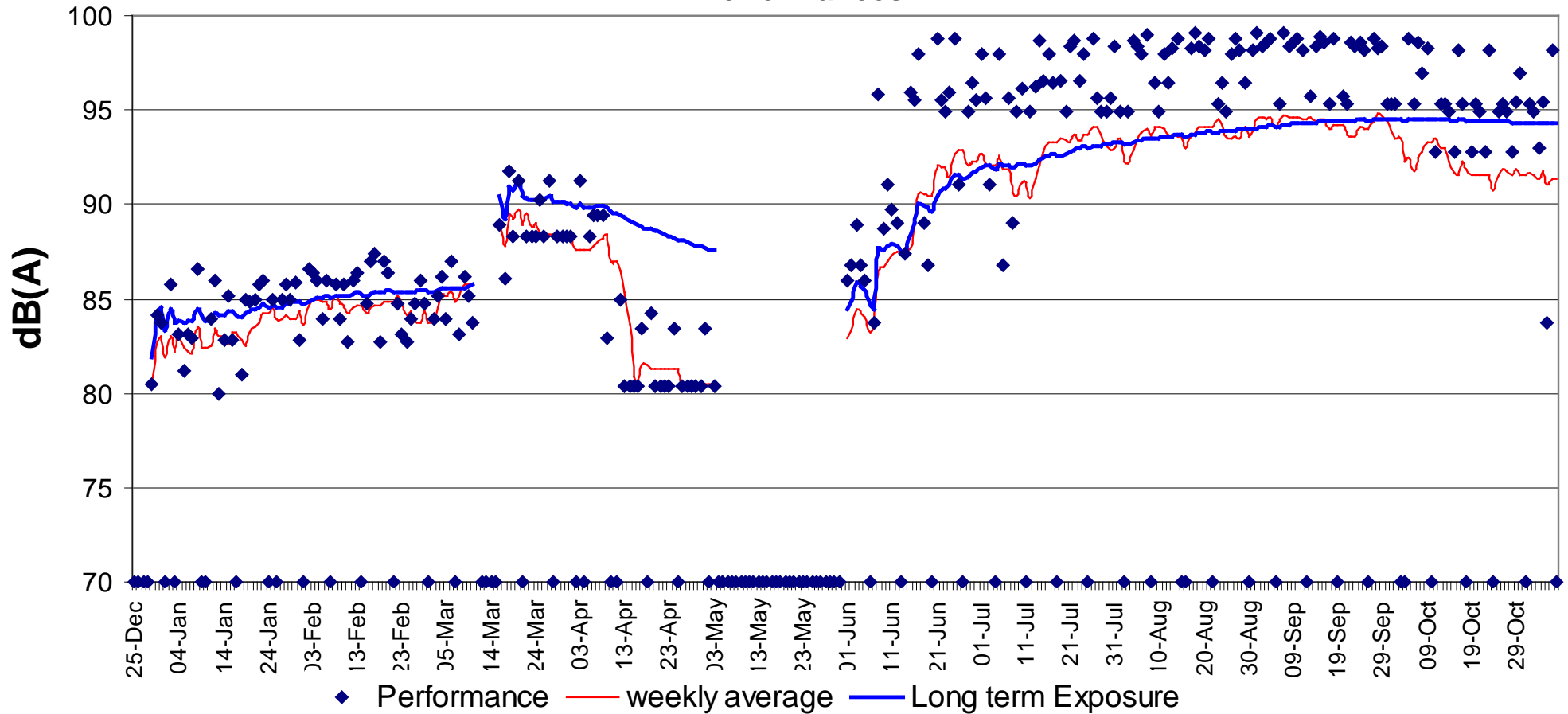
Statistical Monitoring

When having difficulty clearly defining a representative noise exposure statistical monitoring may be used.

In fact, statistical monitoring is preferred for individuals having job activities or classifications with highly variable work schedules, exposure to highly variable noise sources, and/or random mobility throughout the workday.

Statistical Monitoring

Predicted Noise Exposure Winter Schedule 1998 + Ballet
All Performances



Job / Source Risk Assessment

Measured Position		Performance LAeq,T dB 3h	1 performance gives LAeq,8 Daily	2 performances give LAeq,8 Daily
1	Conductor	82	78	81
2	Strings	84	80	83
3	Strings	84	80	83
4	Brass	90	86	89
5	Strings	85	81	84
6	Strings/ Harp	88	84	87
7	Bass	85	81	84
8	Wood	90	86	89
8a	Horn right	90	86	89
9	Percussion	87	83	86
		Requirement	85	85

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Data Analysis and Interpretation

All noise exposure data should be normalized to an 8-hour average for purposes of comparison with criteria.

The 8-hour average noise exposure should be referred to as the $L_{Aeq,8h}$, but may be termed the time-weighted average (TWA), especially in the United States.

Reporting and Documentation

- **Purpose of the survey,**
- **Who conducted the survey,**
- **Date(s) of the survey,**
- **Survey procedure(s),**
- **Instrumentation, including model and serial number,**
- **Instrument settings and record of field checks**
- **Department, areas, process units, and/or job activities surveyed,**
- **Any unusual conditions which would impact results,**

Reporting and Documentation

- All sound level data tables and/or maps,
- Noise dosimetry data for each employee sampled,
- Noise exposure assignments per job activity or classification,
- Names and identification numbers of all employees per affected job activity or classification,
- Recommendations, and
- Conclusions

Reporting and Documentation

The sound survey report and all data should be maintained for an appropriate period (depending on legislation) and could be forty (40) years or longer

Employee Notification

- All employees assigned a noise exposure, whether determined from an actual or representative sample should be
 - notified and
 - provided an explanation of the results.
- The notifications can be accomplished by posting the report and results in the workplace, or through individual notification, such as email or a written letter.
- Interpretation of the results should also be discussed at a future safety meeting.

Noise Control Survey

- **Purpose depends on the goals and objectives for the survey**
 - **Controlling noise at the source requires identification of the origin or source of noise, and definition of its acoustical properties (i.e. frequency spectrum, sound level versus time, etc.).**

Noise Control Survey

- **Treatment of the sound transmission path is easier if it does not require clear identification of the root cause of noise, but instead relies heavily on its frequency spectrum and room characteristics to provide the information needed to select the acoustical materials.**

Noise Control Survey

- **It is rare for a noise control effort to be a single solution**
- **The most dramatic and measurable noise reduction will result from successful implementation of control measures designed for the most dominant sources.**

Procedures, Data Analysis, and Interpretation of Results

- **Start with reference to preliminary survey or do your own**
- **Measure the overall A-weighted sound level, peak level and frequency spectrum, and graph the spectral data.**
- **For equipment with cyclic or fluctuating sound levels, measure the broadband sound level, in dBA, versus time, and log any peak levels.**

Procedures, Data Analysis, and Interpretation of Results

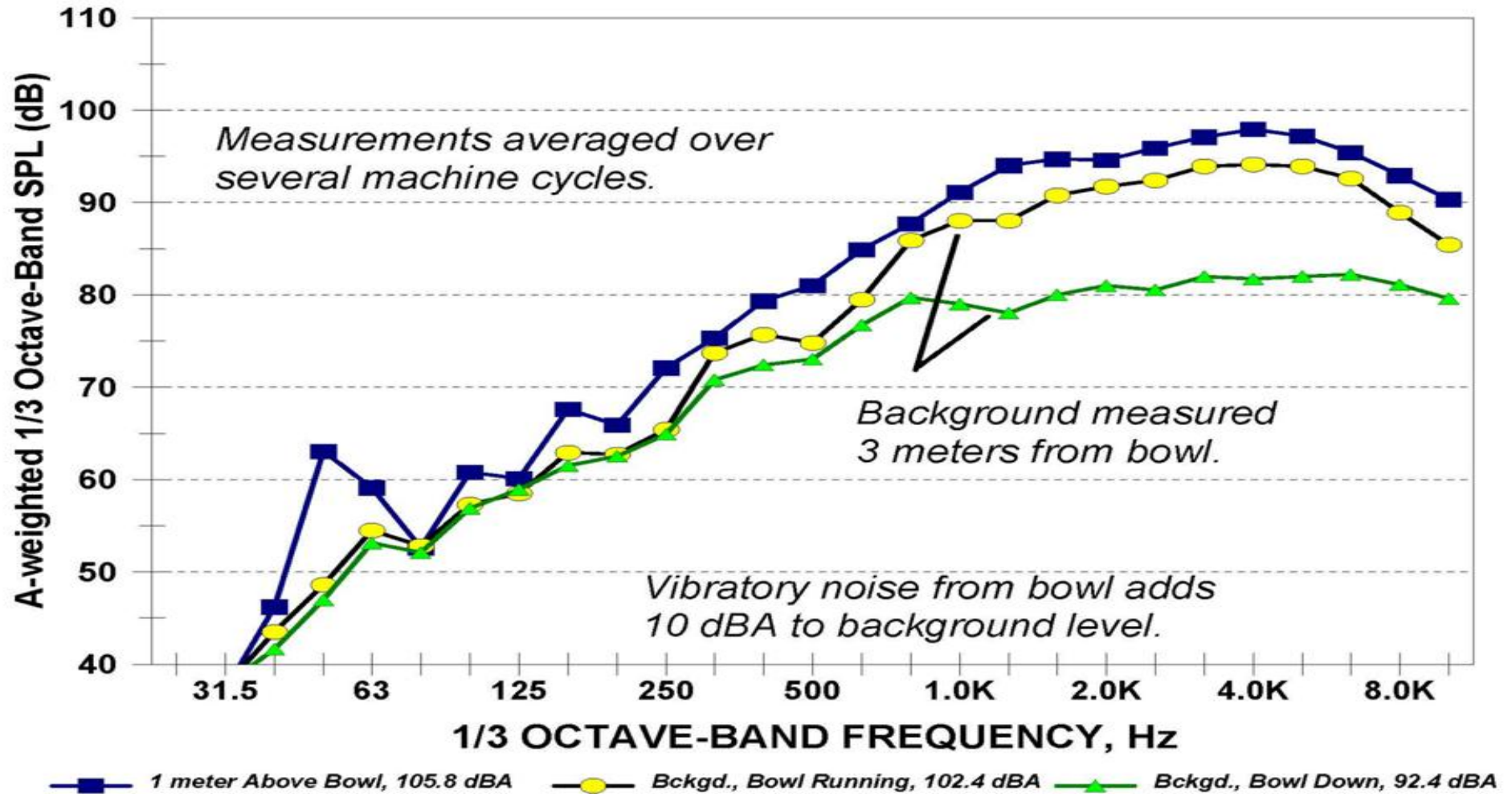
- **Compare frequency data from similar equipment, production lines, etc.**
- **Isolate components with temporary controls, or by turning on and off individual items whenever possible.**

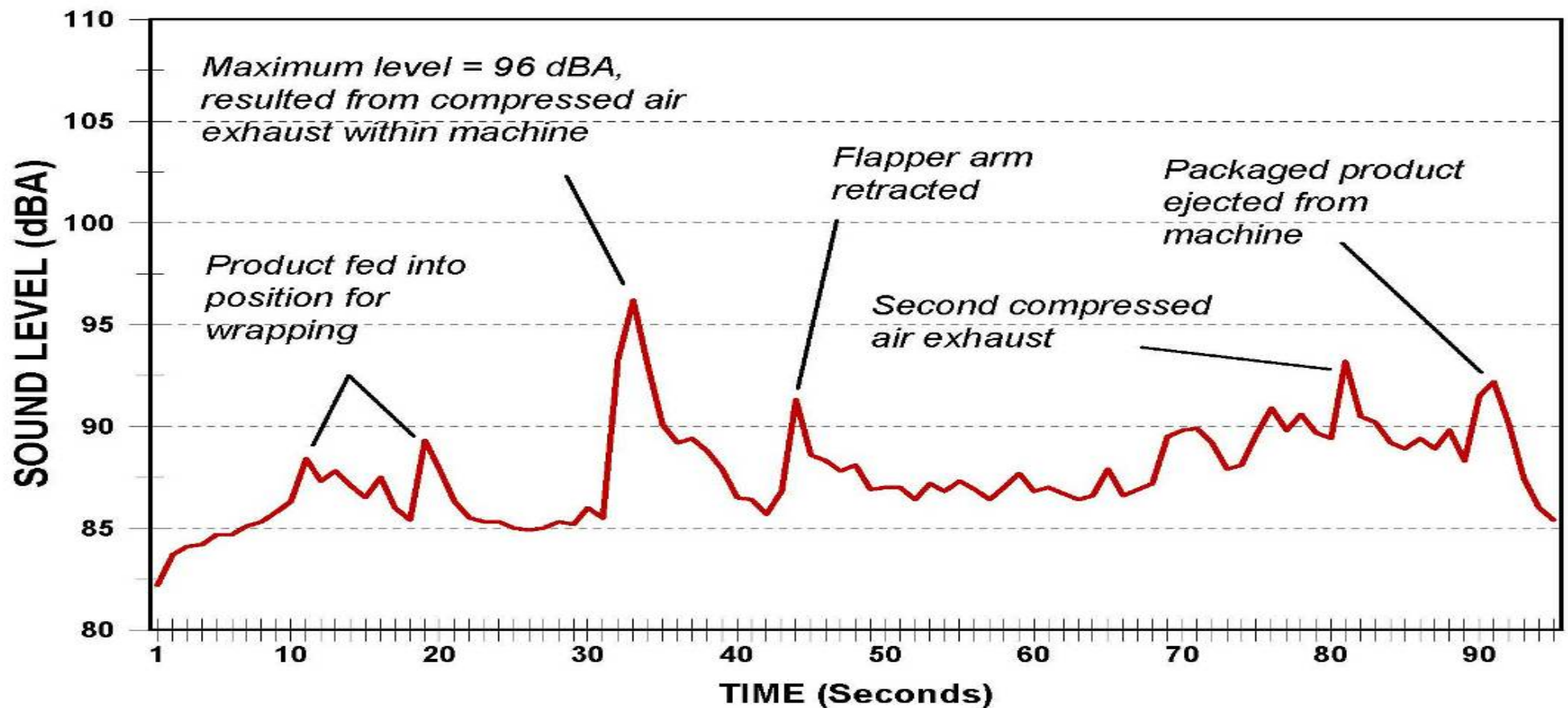
Procedures, Data Analysis, and Interpretation of Results (cont)

Consider the case of a vibratory bowl used to feed plastic parts into an injection molding machine.

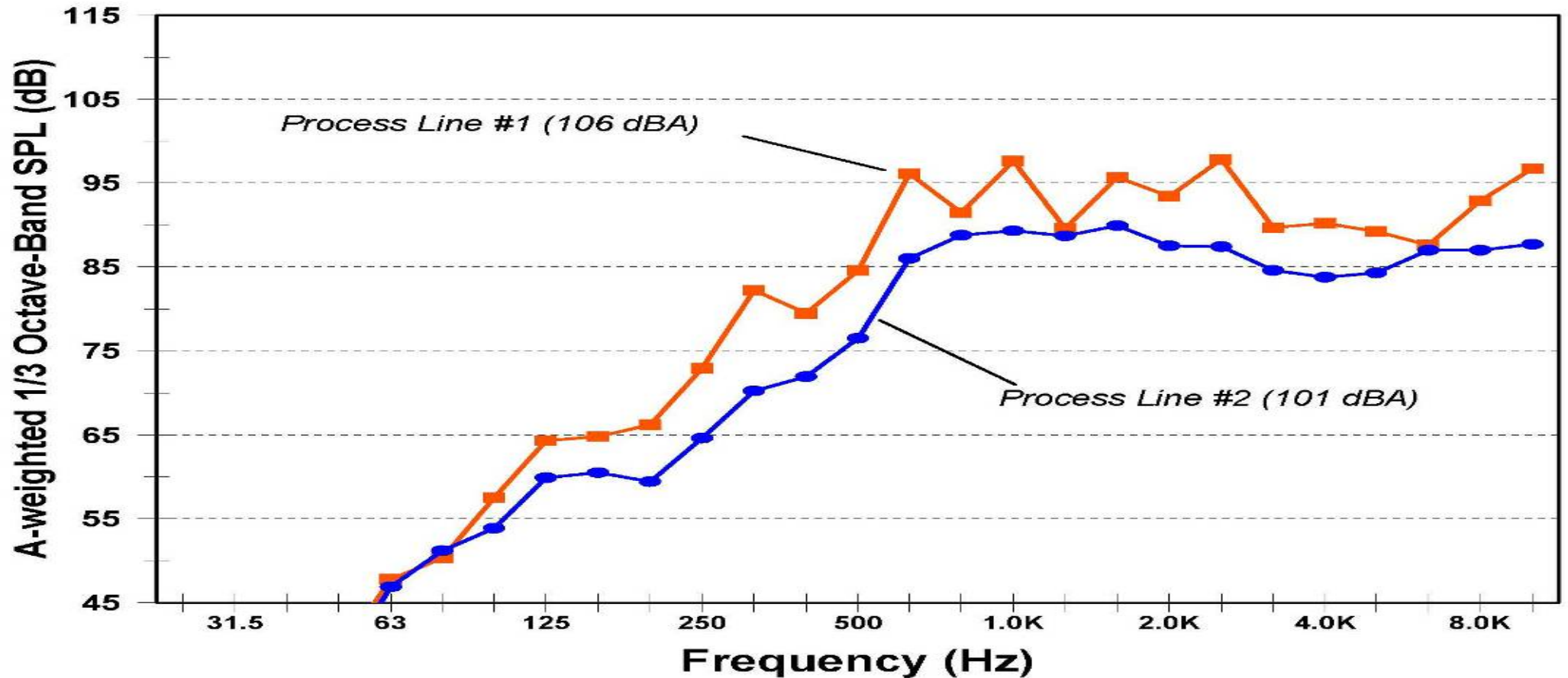
- What would you do?**
- What would you look for?**

COMPARISON OF SOUND LEVELS ABOVE VIBRATORY BOWL vs. BACKGROUND LEVEL





Sound level v time as measured over one full machine cycle at the workstation for packaging operator



Comparing sound levels of similar machines. Final punch operation for identical process lines operating at the same speed.

Fundamental Measures Reported

For any noise hazard risk assessment there are three crucial noise measurements which must be reported. These are:

- **Operational L_{Aeq} or SPL**
- **Peak SPL**
- **Estimation of $L_{Aeq,8h}$**

4 Engineering Noise Control

Engineering Noise Control

- **Treatment at source is most effective way to prevent NIHL**
- **Hearing protectors should only be used as interim measure or when there are no feasible engineering noise controls**
- **Engineering control often requires multiple steps**
- **Requires patience and persistence**

Understanding Required of:

- **How sound is generated,**
- **How to identify the source(s) of noise,**
- **Options for treating the source, path, and/or receiver,**
- **Benefits and costs of noise control,**
- **Products and resources available**
- **Other methods available to reduce worker noise exposure.**

Developing Noise Control

- **If straightforward can be done in-house**
- **Normally consultant required to**
 - **conduct the detailed survey**
 - **identify the sources**
 - **design the engineering controls, and**
 - **develop a plan of action**

Machinery Noise

Machinery noise is created mainly by

- mechanical impacts,**
- high-velocity air,**
- high-velocity fluid flow,**
- vibrating surface areas of a machine,**
and
- vibrations of the product being**
manufactured.

Machinery Noise

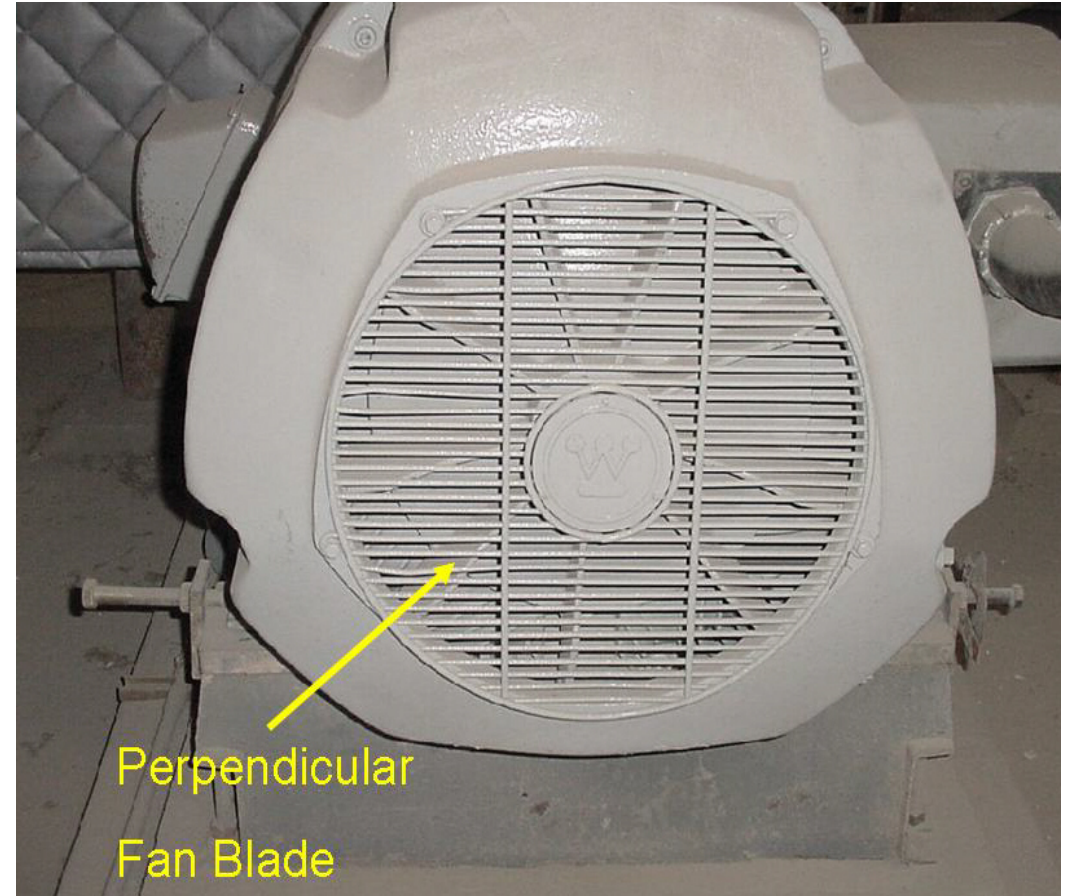
Solutions to Machinery noise require

- A need to understand how noise is created before attempting to minimize it.**
- An early design stage prioritisation of noise as an issue improves the probability of success.**
- A recognition that machinery noise control is a system challenge - each component in the system needs to be considered individually.**

Electric Motors

Noise sources

- **Aerodynamic – fan blade**
 - **Non directional**
 - **Directional**



Electric Motors



Noise sources

- **Aerodynamic – fan blade**
- **Mechanical – forces on rotor/shaft**
- **Magnetic. – gap between rotor and stator**

Electric Motors

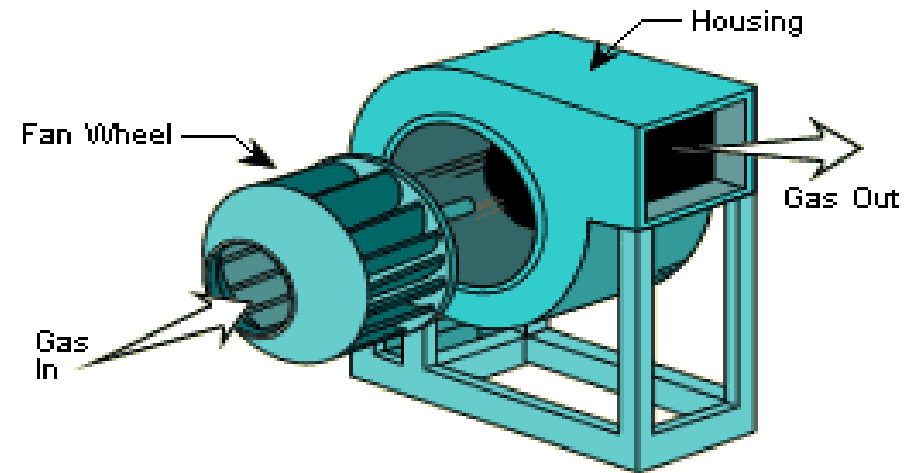
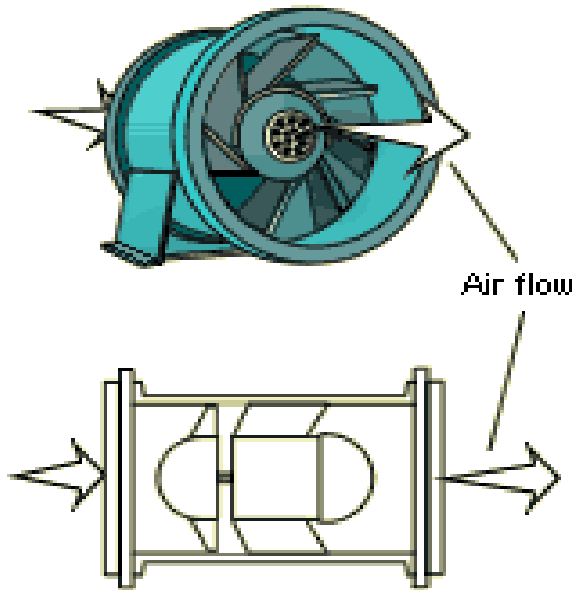
Low noise motors

- Are Available New
- Retrofit of
 - Fan silencers
 - Motor mounts
- Enclosures



Is possible but buy quiet is better.

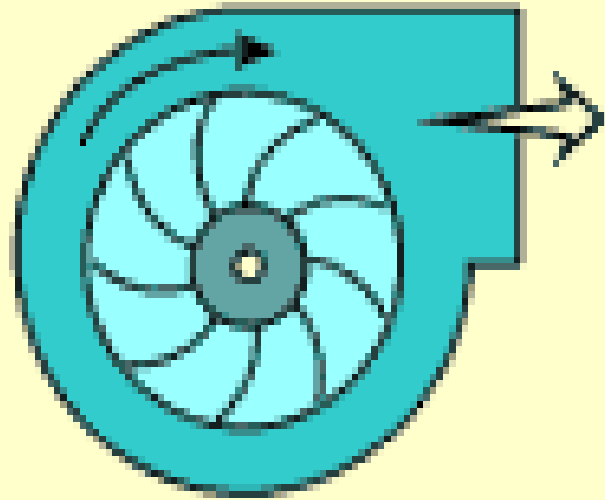
Fans



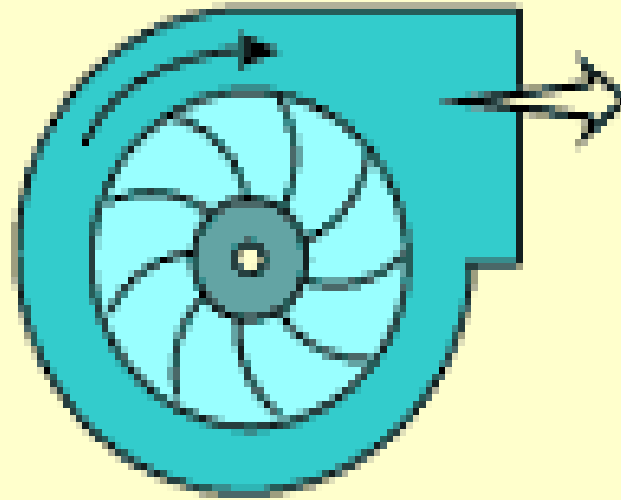
**Axial and Centrifugal
Control best at design stage**

Minimise Fan Noise

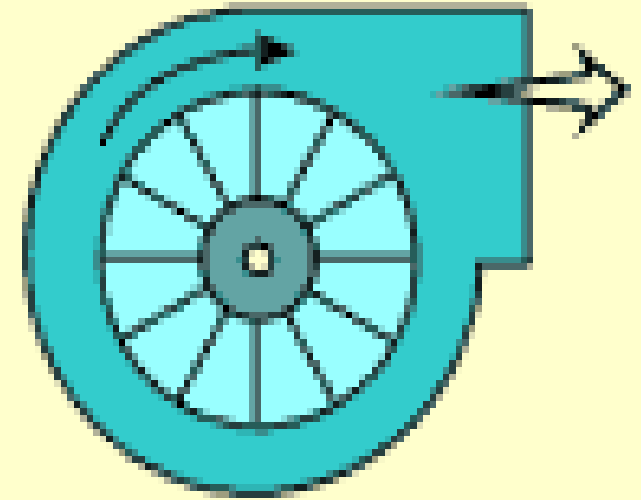
- Buy quiet



(a) Forward Curved

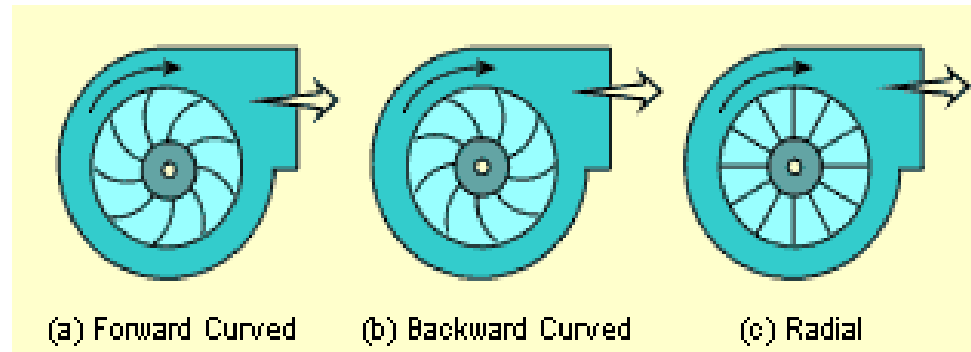


(b) Backward Curved



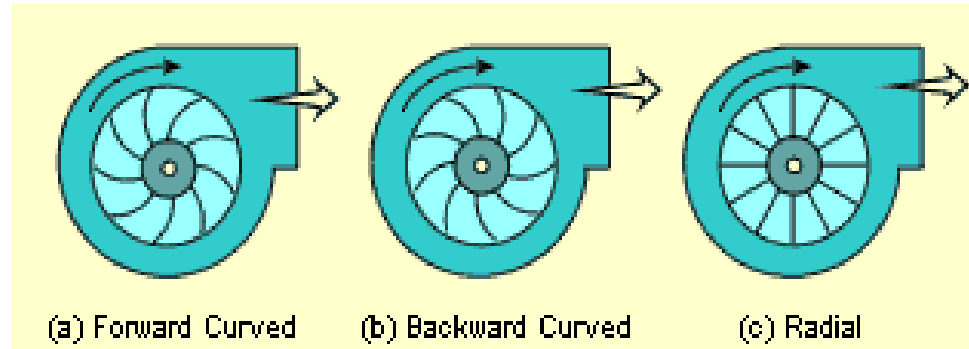
(c) Radial

Minimise Fan Noise



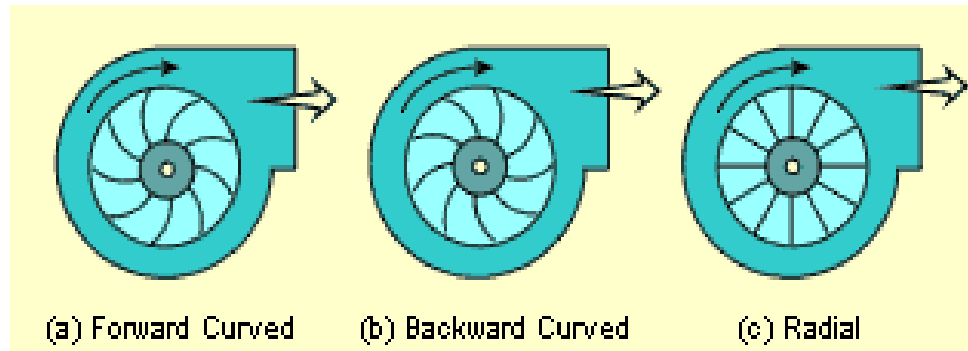
Forward-curved fans used primarily for heating, ventilation, and air-conditioning systems. These are especially sensitive to particulate and are not used extensively in air pollution control systems. This type of fan is usually noisier than backward-inclined bladed fans.

Minimise Fan Noise



Backward-curved fan blades handle gas streams with relatively low particulate loadings because they are prone to solids build-up. Backward-curved fans are more energy efficient than radial blade fans.

Minimise Fan Noise



Radial blades often used on particulate-laden gas streams because it is the least sensitive to solids build-up on the blades. These are heavy-duty industrial fans, commonly used to move material, such as trim scrap, wood chips, and even product. They are amongst the loudest fan type with very strong and dominant tonal components

Minimise Fan Noise

- **Efficient and low discharge velocity**
- **Use large and slow moving fans not of smaller, faster units.**
- **Fan to operate away from the stall region.**
- **Clearance of > 1 fan wheel diameter at all unducted inlets and 1.5 wheel diameters at all unducted outlets.**

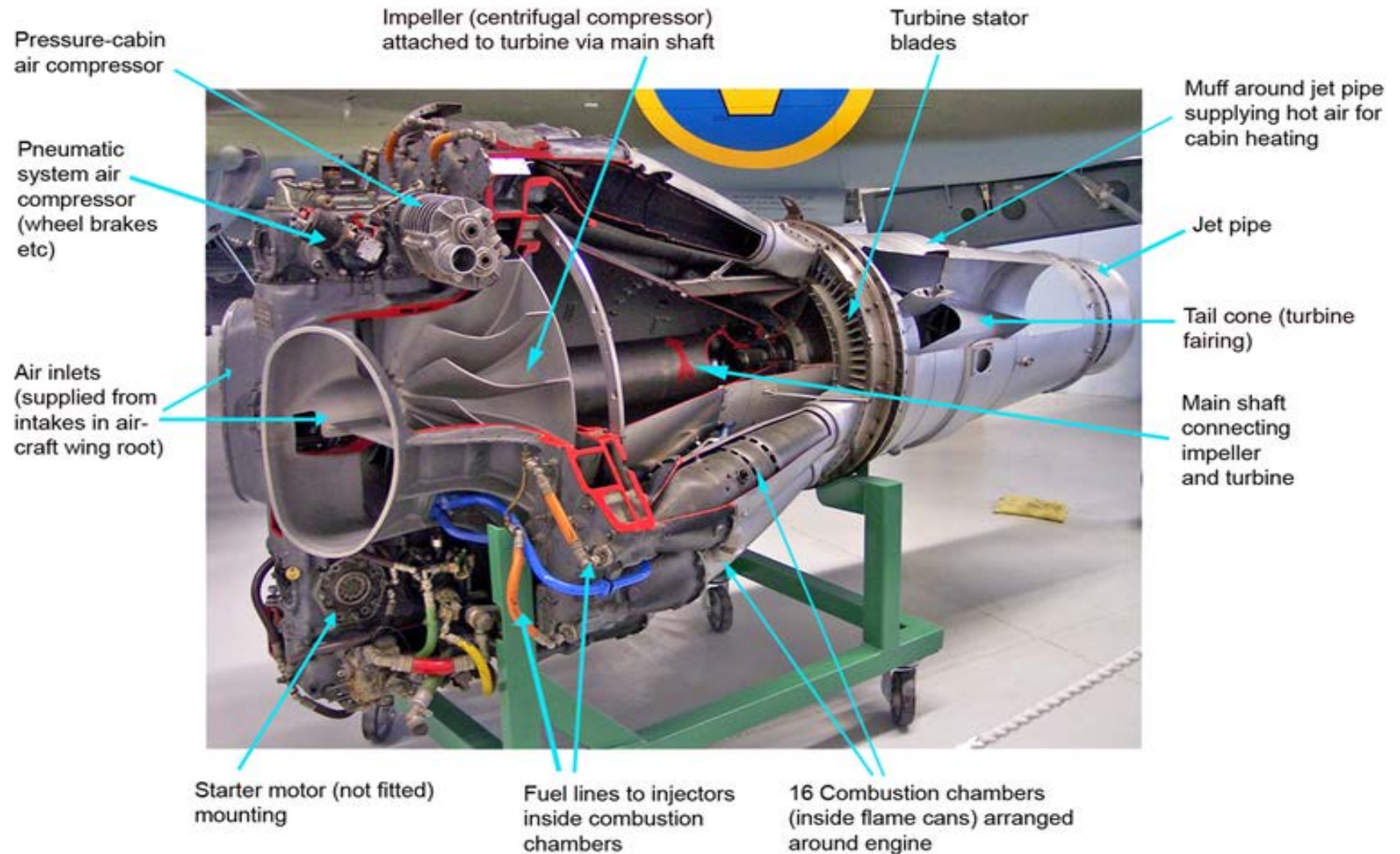
Minimise Fan Noise (cont)

- **Vibration isolation mounts or hangers**
- **Flexible connectors for ductwork**
- **Gradual inlet and discharge transitions**
- **Ducted installations, silencer, sound trap, elbow, offset, transition etc at least 3 equivalent duct diameters from fan.**

Minimise Fan Noise (cont)

- **All duct fittings designed for low pressure drop.**
- **As noise travels upstream and downstream from a fan, silencers and/or duct liners may be required in both the inlet and discharge paths.**

Compressors



Compressor Noise

Types of compressors:

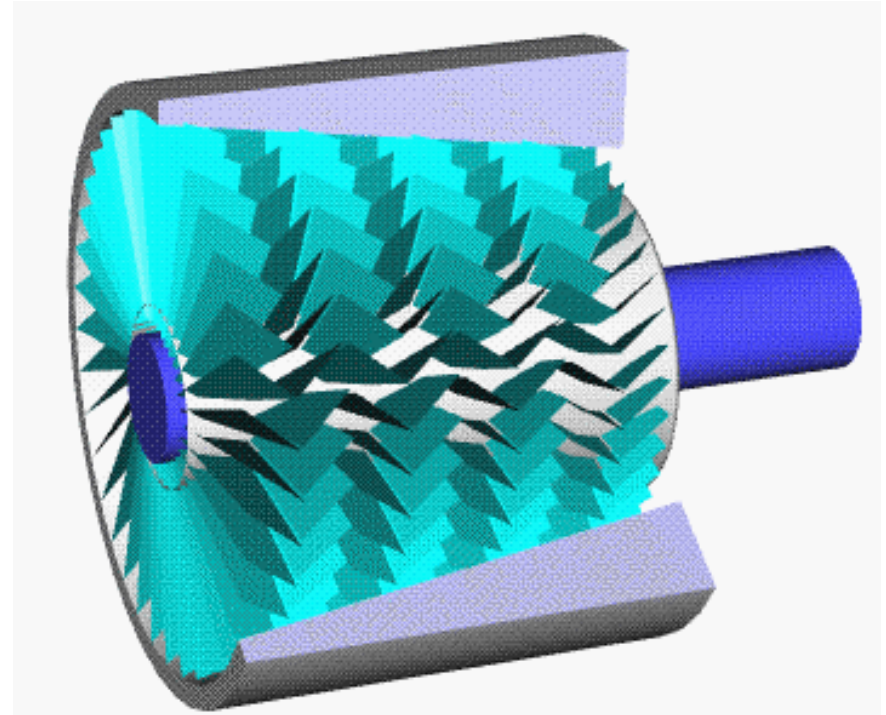
- Centrifugal
- Rotary screw
- Reciprocating

Control blade passing frequency as tones occur at multiples of that frequency

Use in line silencers

Compressor Noise

**Cutaway view of an axial compressor.
High flow such as gas turbine high noise via the connected piping system.**



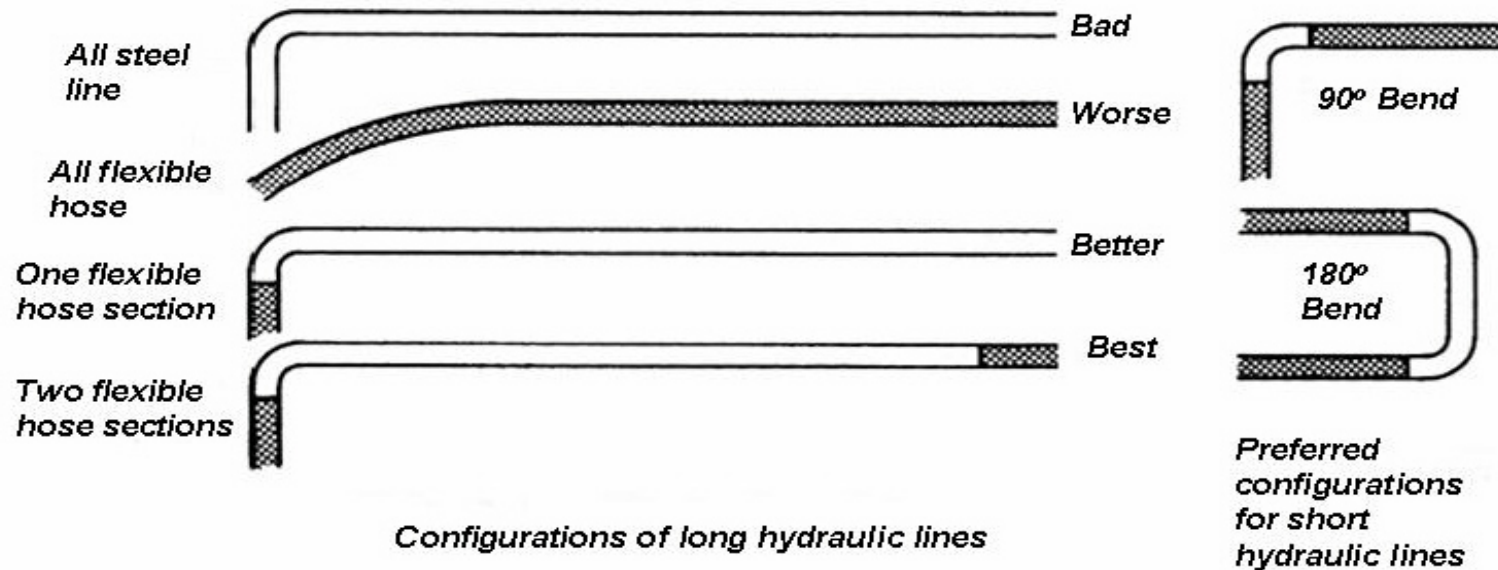
Pumps

Types of pumps:

- Roto dynamic pumps
 - positive displacement pumps
-
- Operate close to design conditions
 - Avoid resonances in piping
 - Lagging
 - Vibration isolation

Hydraulic Noise

Hydraulic pumps usually small and low noise:
Tonal noise can come from coupling between pump and motor



Mechanical Impacts

Common e.g. solenoids, punch press

Control by:

- **proper maintenance,**
- **using minimum driving force,**
- **damp radiated noise**

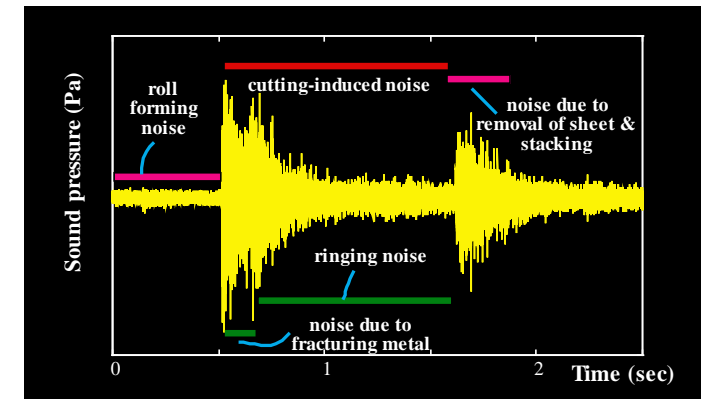
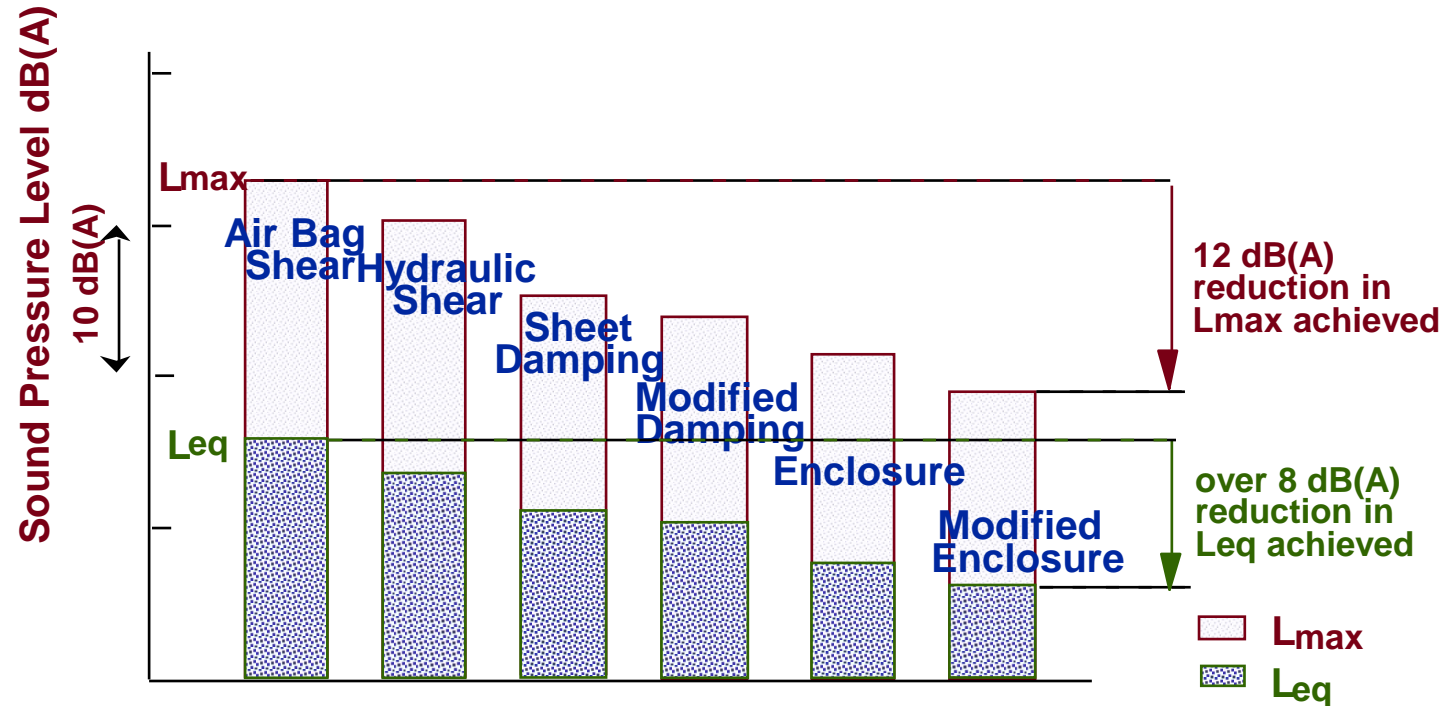
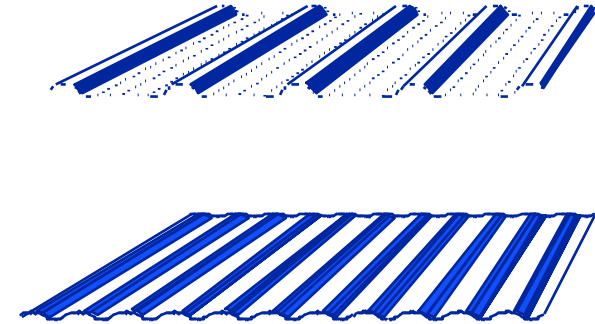
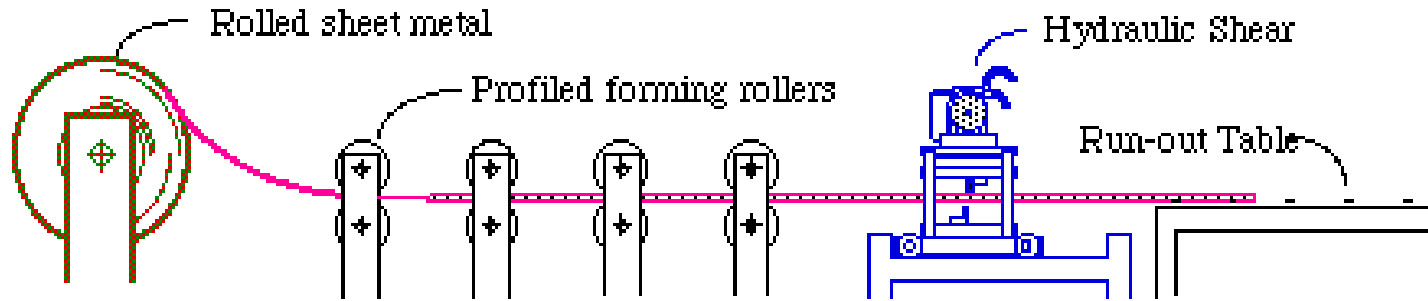
Radiated Noise

Avoid panels becoming ‘sounding boards’ and radiating the sound

Control options:

- **Divide large sections of a machine casing into smaller sub-sections**
- **Add**
 - **mass,**
 - **damping and**
 - **stiffness**
- **Vibration isolation at attachment points.**

Noise from Roll Forming Machines



Source: UNSW at ADFA

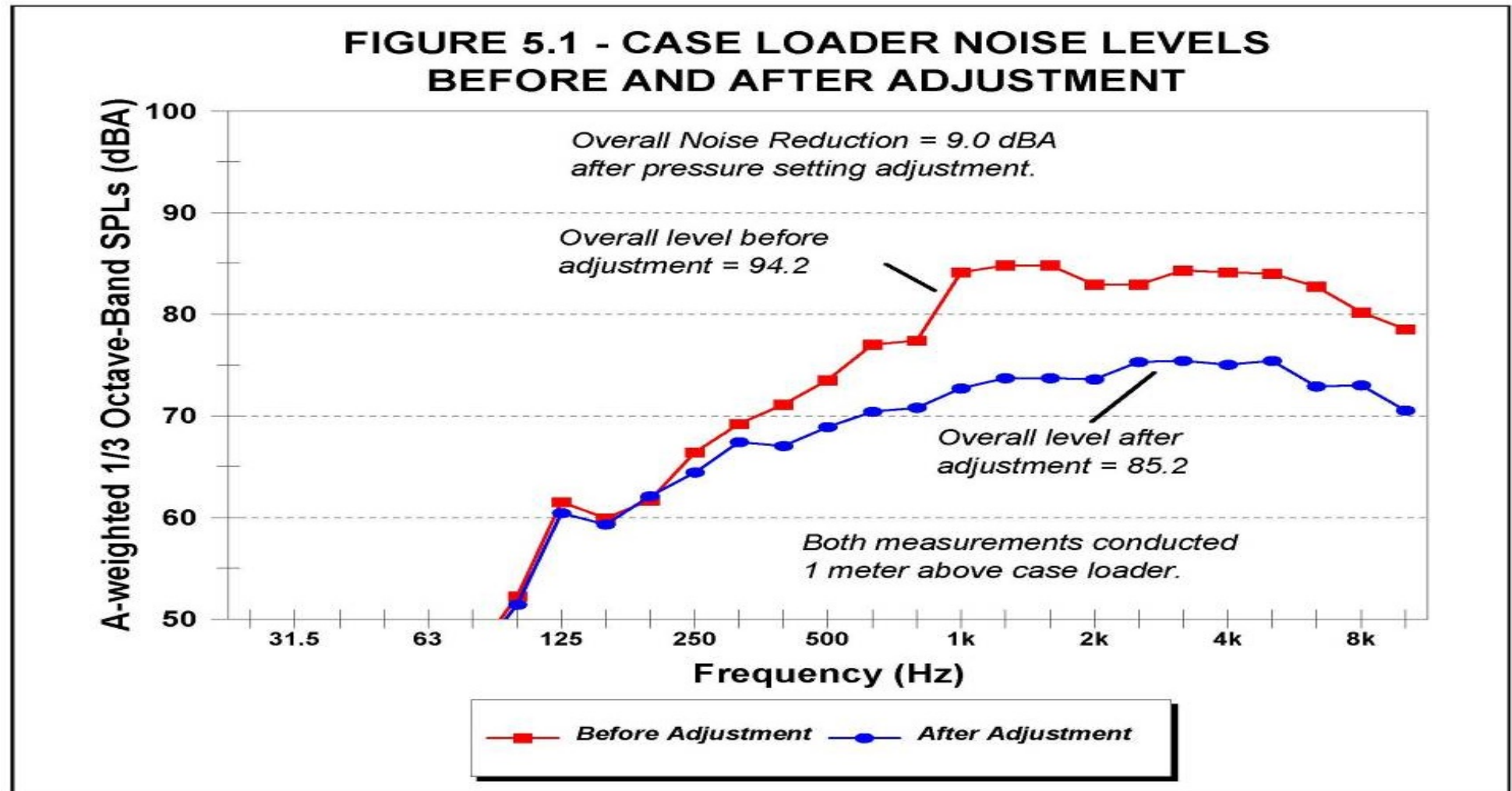
Engineering Control

Hierarchy :

- **At source**
- **Between source and receiver**
- **At receiver**

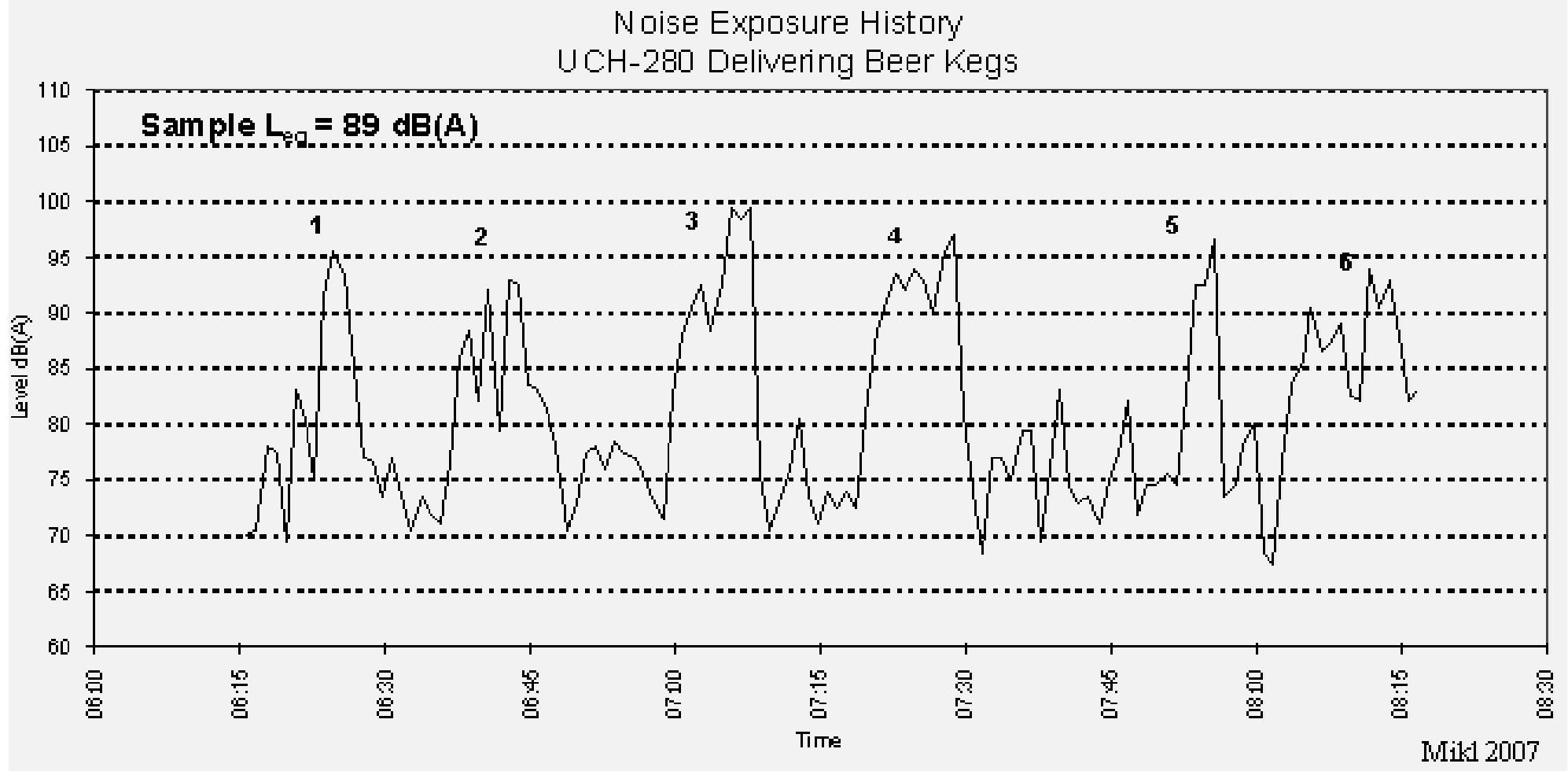
Source Treatments

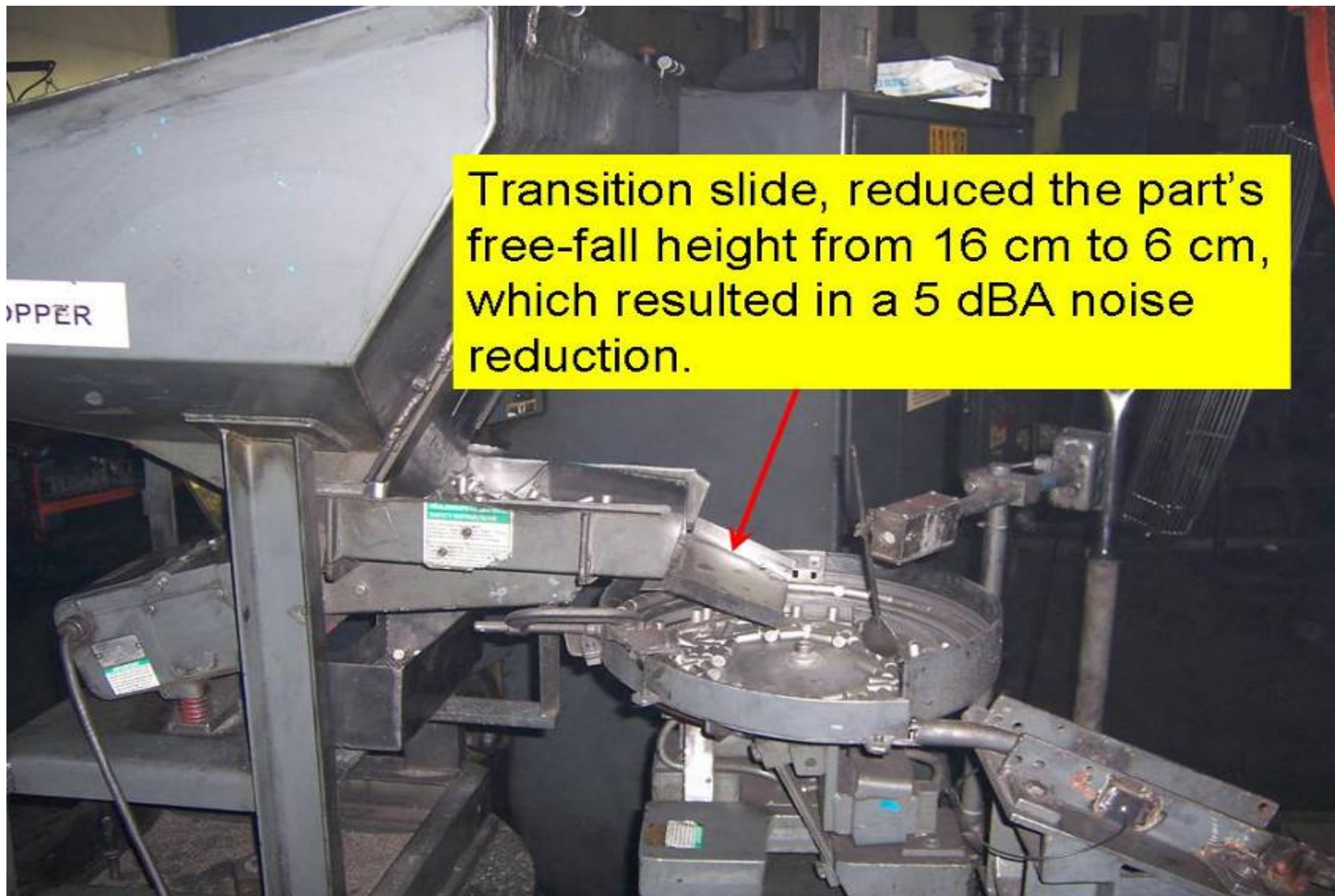
Avoid or Minimise Impacts



Source Treatments

Avoid or Minimise Impacts

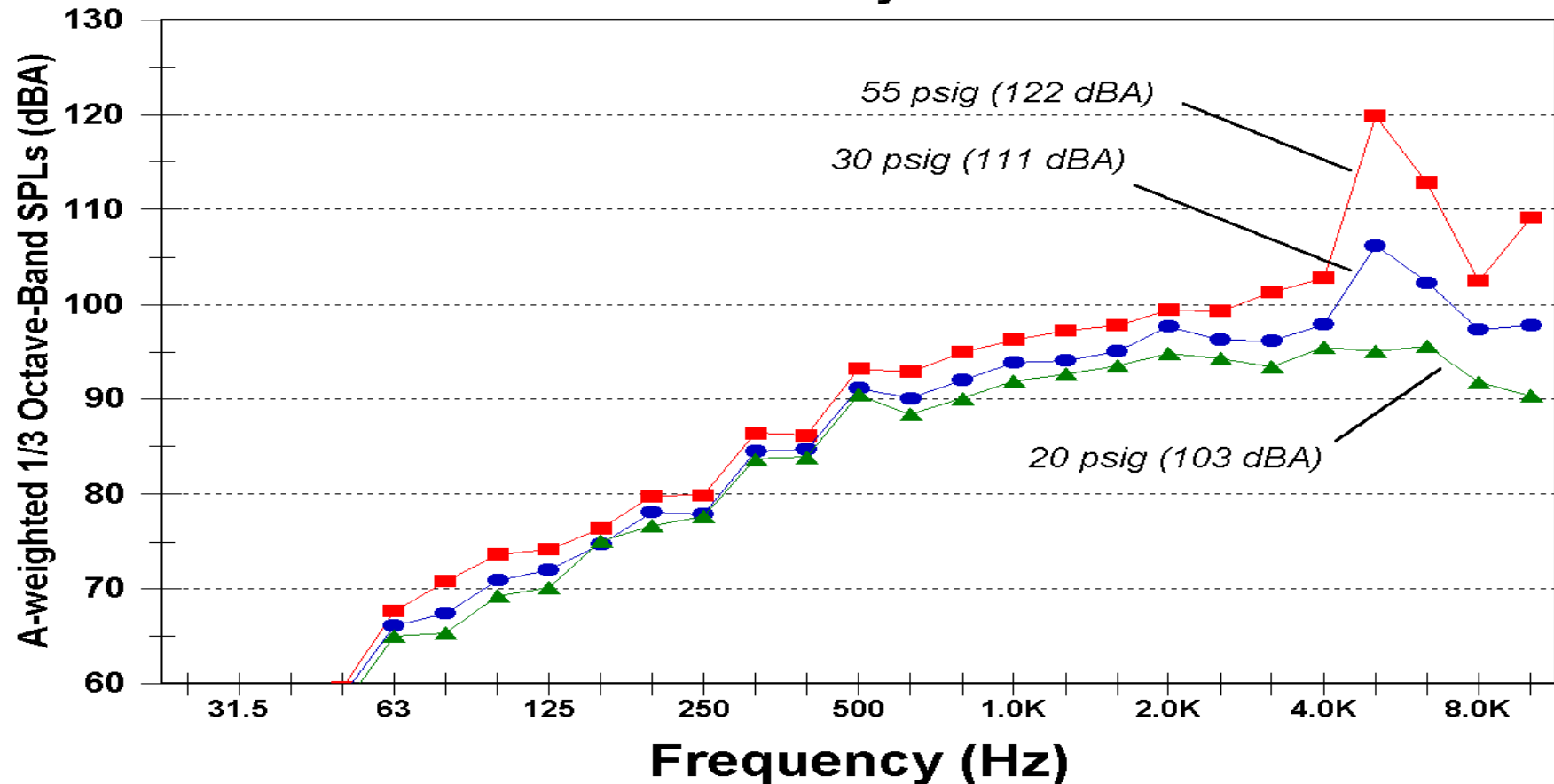




Source Treatments

Pneumatic or Compressed Air Systems

**Noise Reduction Resulting from
Air Pressure Adjustments**



Source Treatments

- **Control valves in straight runs of pipe**
- **Bends and tees at least 10 pipe diameters downstream of a valve**
- **Pipe cross section reducers and expanders at an included angle of 15-20 degrees**
- **Insulation and/or an in-line silencer when choke valves in the line**

Source Treatments

- **Eliminate sudden changes of direction**
- **Limit fluid-flow velocity to a maximum of 9.15 meters per second**
- **Design the system such that the flow velocity (in feet/seconds) does not exceed 100 times the square root of the specific volume (in cubic feet/lb.) for gases and vapors.**

Source Treatments

- **Maintain laminar flow for liquids (keep the Reynolds Number less than 1,200)**
- **Use flex connectors and/or vibration isolation for the piping system**
- **In-line silencer – when the best achieved from the other treatments**

Source Treatments – Radiated Noise

- **Divide vibrating surface areas into smaller sections**
- **Add stiffeners to large unsupported metal panels**
- **Add small openings or perforations in large solid surfaces**
- **Use expanded metal**
- **Add vibration damping material**

Source Treatments – Vibration Damping

- **Hopper bins and product chutes**
- **Thin metal machine casings or panels**
- **Metal enclosure walls**
- **Fan housings, and**
- **Gearbox casings**

Source Treatments – Vibration Isolation

- **Pipe hangers**
- **HVAC equipment**
- **Flex connectors for piping systems**
- **Rotating machinery mounts and bases**
- **Enclosure isolation.**

Source Treatments – Silencers

- **High-pressure pressure regulators, air vents, and blow downs**
- **Internal combustion engines**
- **Reciprocating compressors**
- **Centrifugal compressors**

Source Treatments – Silencers

- **Screw compressors**
- **Turbines**
- **Rotary positive displacement blowers**
- **Rotary vacuum pumps and separators**
- **Industrial fans or blowers**

Source Substitution

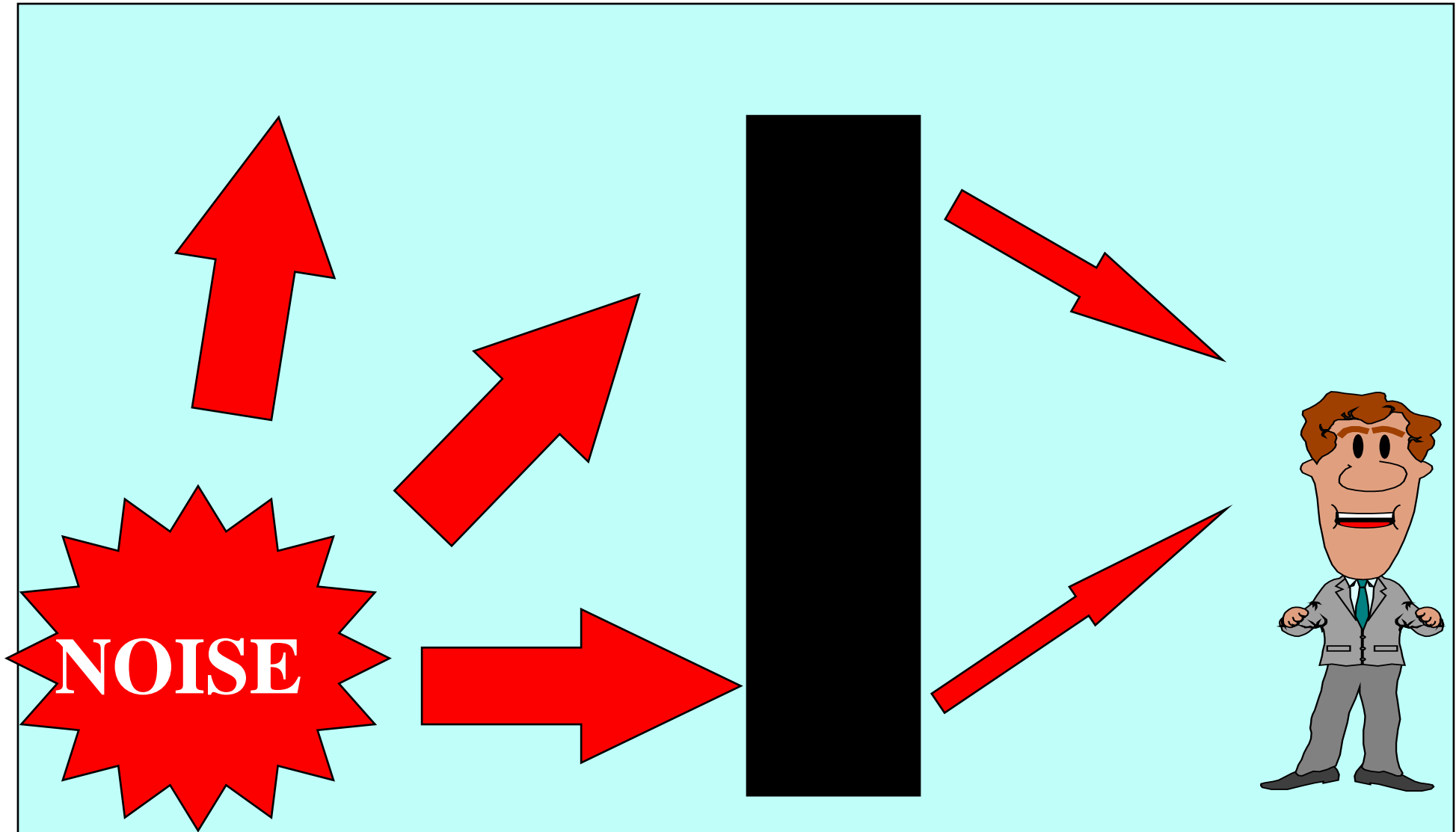
Focus on alternatives for

- **Gears, Bearings,**
- **Fans or Blowers,**
- **Control valves, Trim valves,**
- **Air compressors,**
- **Pneumatic tools, Air guns and nozzles,**
- **Electric motors, and**
- **Pumps.**

Source

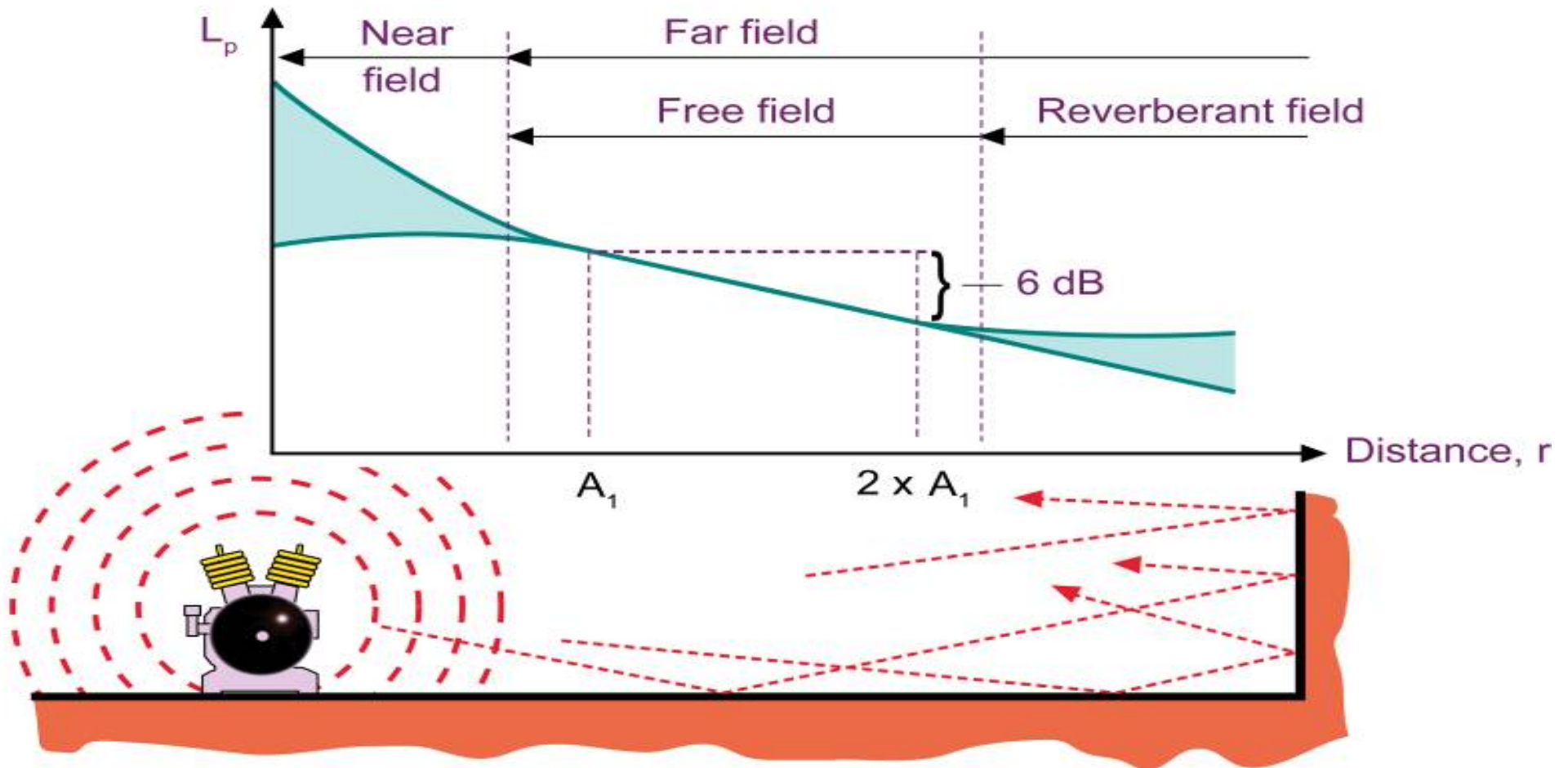
Transmission Path

Receiver

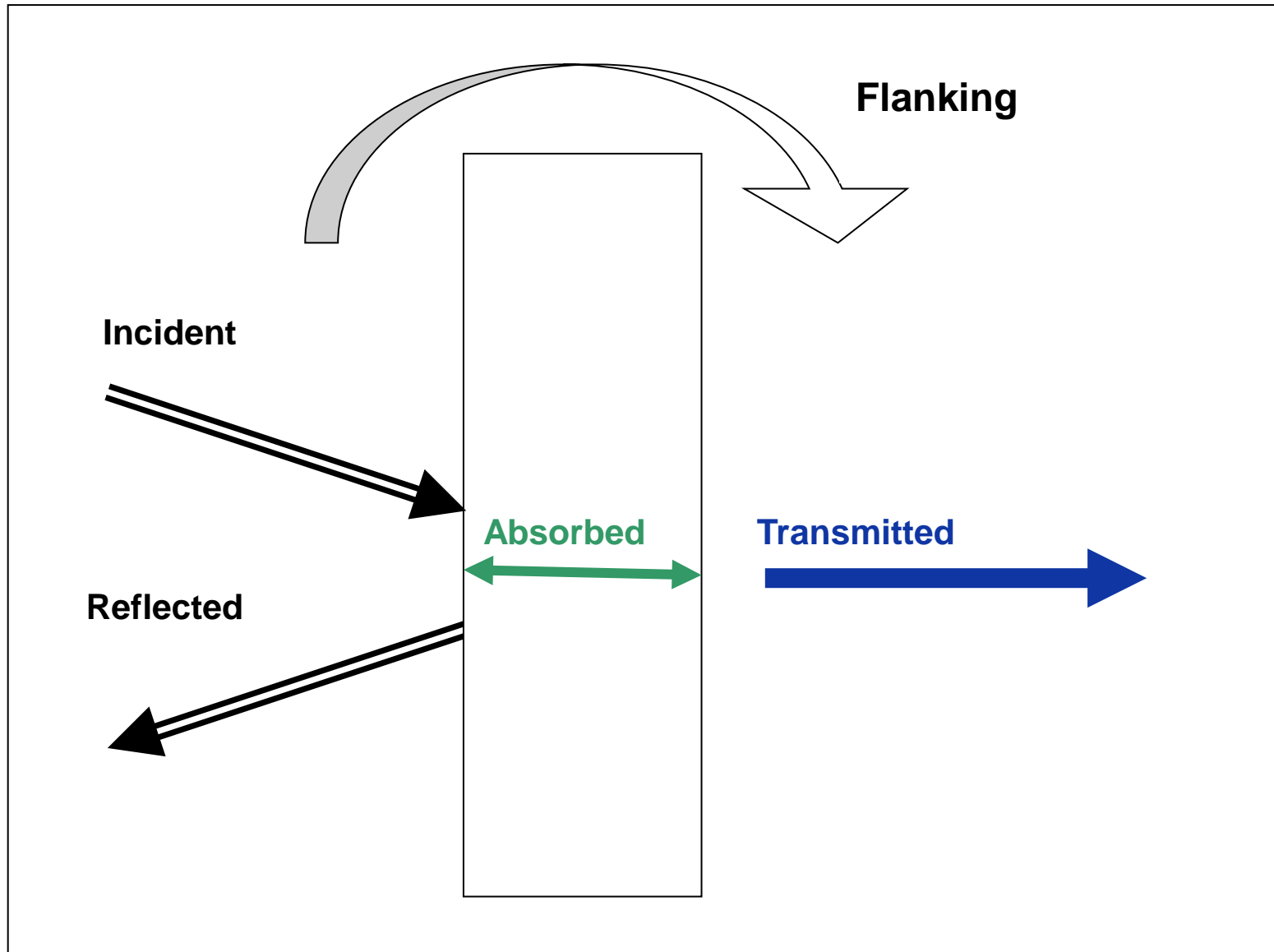


Transmission Path

Sound Fields



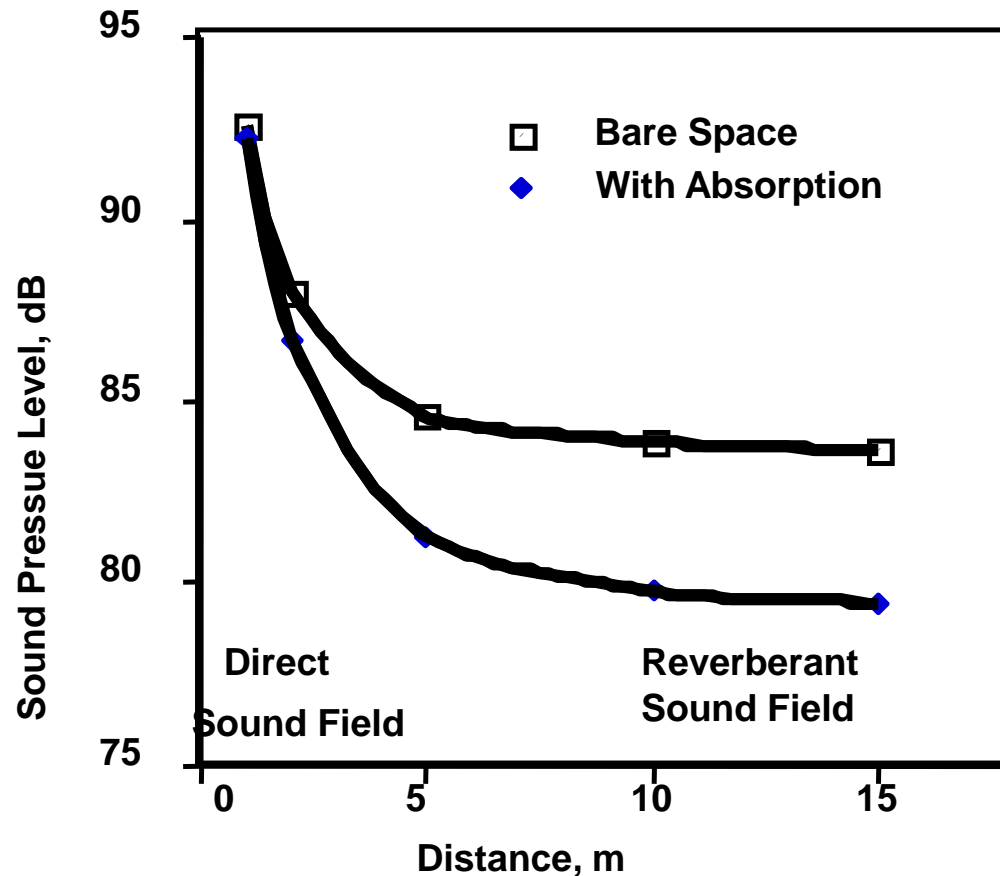
Transmission Path



Sound Absorption

Reduces reflected/reverberant sound

Does little for direct sound to operator



Sound Absorption Materials

Sound absorption materials are used to reduce the build up of sound in the reverberant field.

Advantages:

- **Can provide a reduction (3 dB) in the reverberant sound build up, especially in pre-existing hard spaces,**
- **Works best in relatively small volume rooms or spaces (less than 300 m³),**
- **Can be purchased and installed at a reasonable cost, and**
- **Works best on middle-to-high frequency noise.**

Sound Absorption Materials

Disadvantages:

- Room treatment does nothing to address the root cause of the noise problem,
- Can interfere with facility lighting, ventilation, and/or sprinkler patterns,
- Does not reduce any noise due to direct sound propagation,
- Will have no measurable benefit to employees working primarily in the direct field,
- Cleaning and maintenance of porous sound absorbing materials can be problematic,

Sound Absorption Materials

Disadvantages (cont)

- **Cleaning and maintenance of porous sound absorbing materials can be problematic,**
- **The materials can deteriorate over several years, and may need periodic replacement (perhaps every 7-10 years), and**
- **Rarely does this form of treatment eliminate the need for hearing protection.**

Sound Transmission Loss

- **Sound transmission loss materials are used to block or attenuate noise propagating through a structure, such as walls of an enclosure or room.**
- **Materials must be heavy and dense, with poor sound transmission properties.**
- **Common applications include barriers, enclosure panels, windows, doors, and building materials for room construction.**

Sound Transmission Loss

- Depends on frequency it is harder to reduce low frequency sound
- High STL for *single leaf constructions*
 - High mass Low stiffness High damping;
- Higher STL may be achieved with *double leaf constructions*
 - Minimise direct connections
 - Cavity width as large as possible
 - Sound absorbing material in the cavity

Sound Transmission Loss

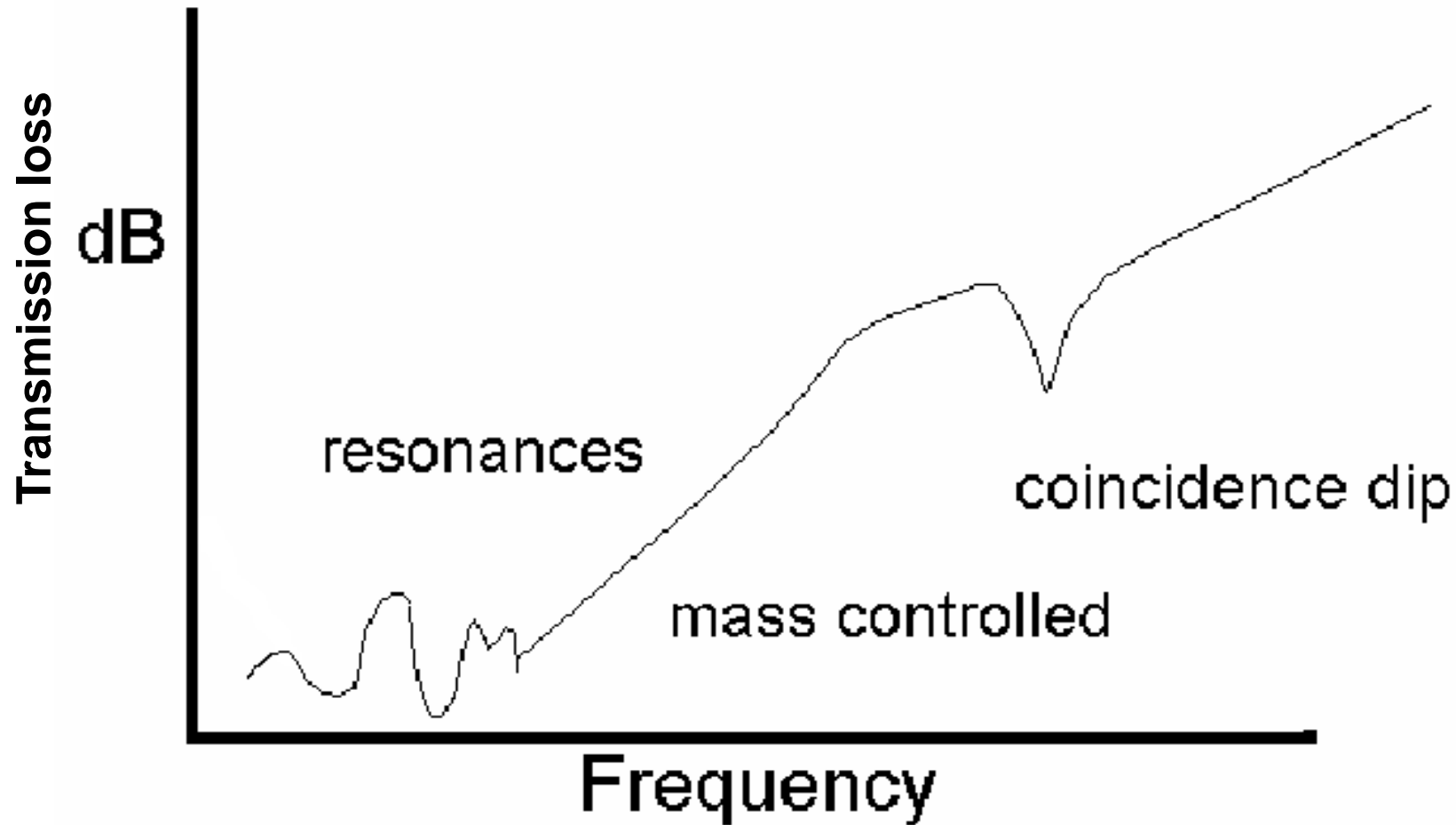
- **TL of materials is frequency dependant and TL curves should be used when designing enclosures to match the sound spectrum being controlled**
- **Single number ratings give less information but are often referred to for general noise such as buildings**
- **ISO 717, Acoustics Ratings of Sound Insulation in Buildings and of Building Elements, or regional or national variants on this standard define the Weighted Sound Reduction Index (Rw).**

Sound Transmission Loss

- **ISO 717, Acoustics Ratings of Sound Insulation in Buildings and of Building Elements, or regional or national variants on this standard define the Weighted Sound Reduction Index (R_w).**
- **United States, ASTM 90, Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions, define the Sound Transmission Class (STC).**
- **Both methods produce comparable, but not identical results.**

Sound Transmission Loss

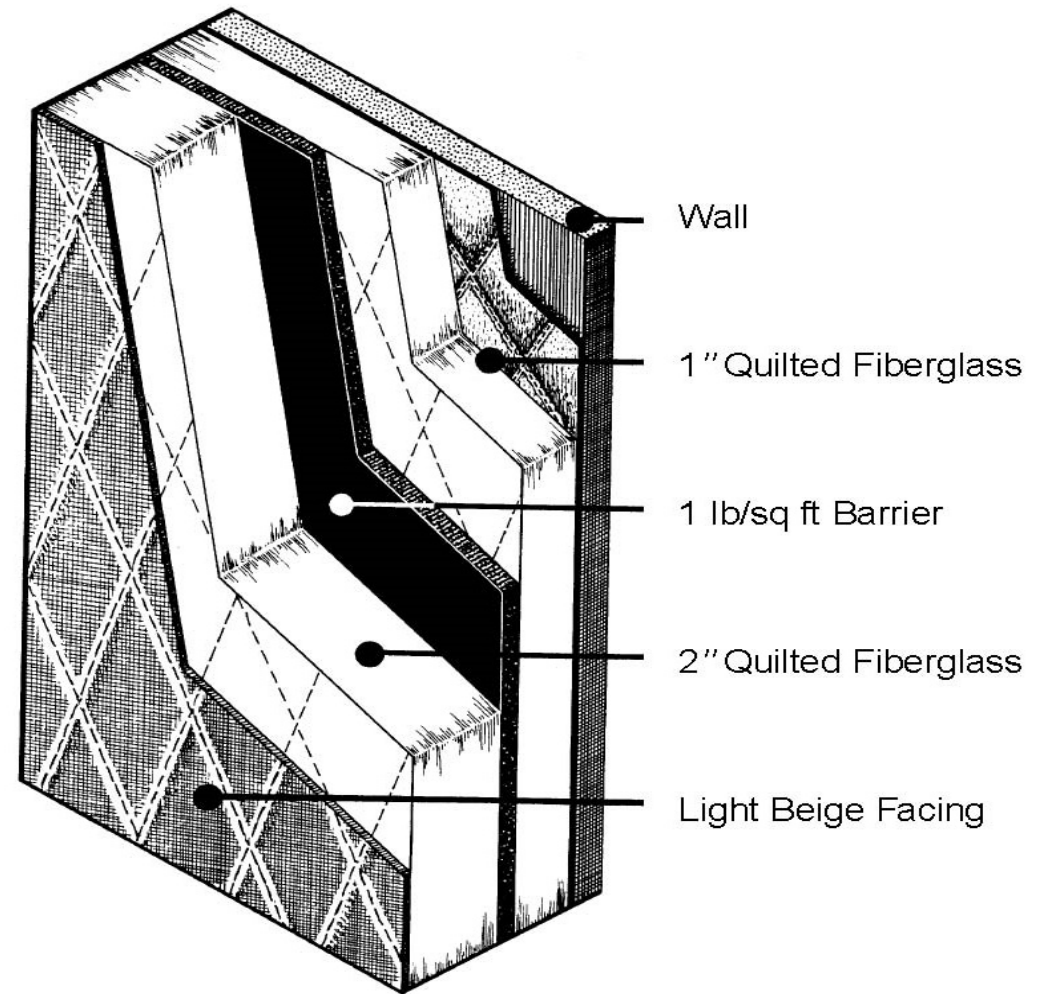
Variation of transmission loss with frequency



Sound Transmission Loss

Multiple Layer Panels combine a sound absorption material with a high transmission loss material to form a composite system.

Can be sound absorbing material on one side or a complex 'sandwich' panel with a number of layers

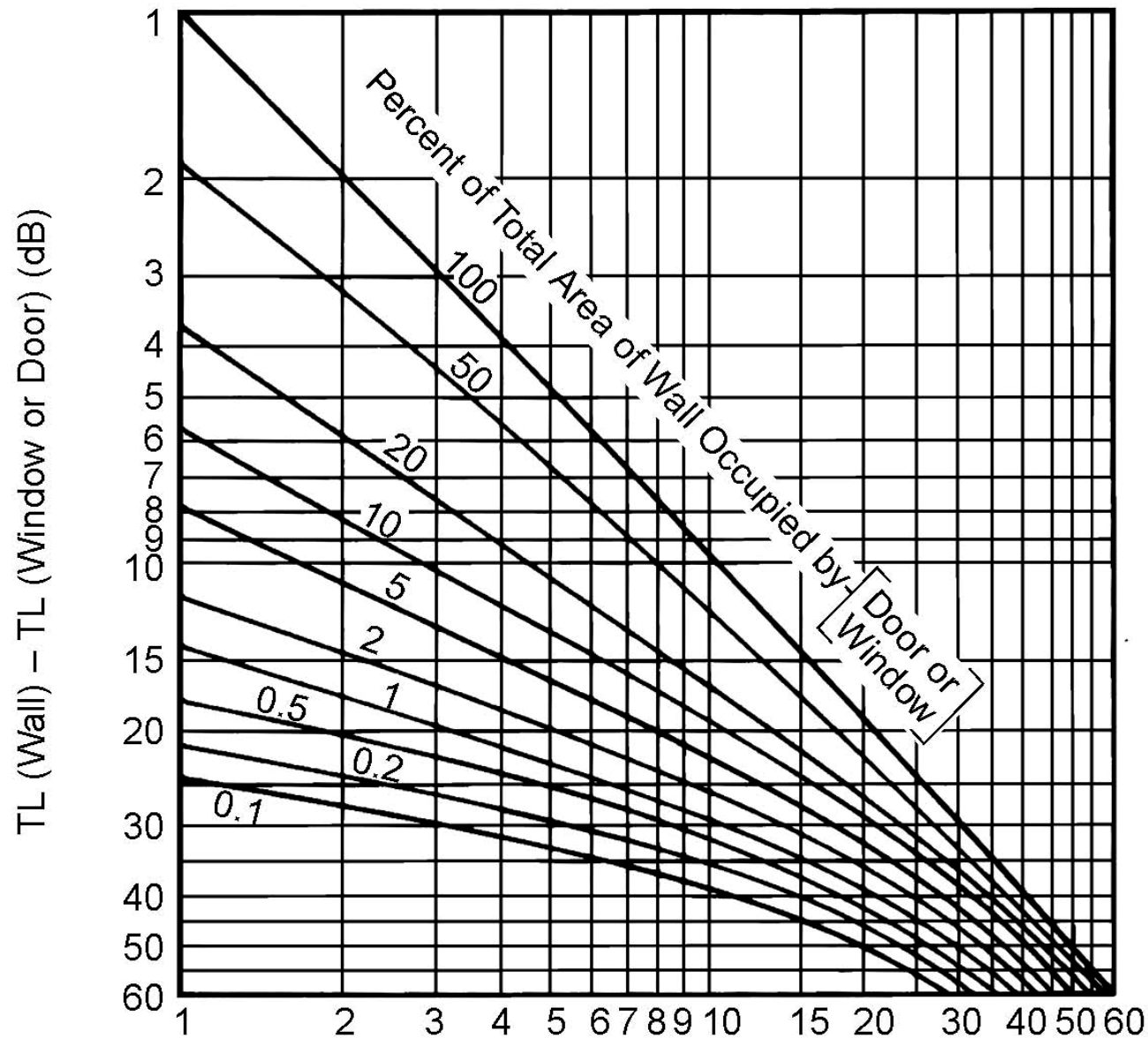


Doors, Windows and Access Panels in Walls

To put an openable element in a wall and achieve the same TL of the original panel, need to select door and window systems having at least the same TL as the panel.

This is often difficult to achieve and usually the overall TL values of the wall with the openable element will be less than the original wall.

The following Figure may be used to estimate the new TL of the combined structure.



Decibels to be Subtracted from TL of Wall for Effective TL of Composite Barrier

Doors, Windows and Access Panels in Walls

Example:

A window is inserted into an enclosure wall. The TLs of the wall and window are 33 dB and 18 dB, respectively. The window occupies 10% of the total surface area of the wall. What is the composite TL?

Doors, Windows and Access Panels in Walls

Step 1. Determine the difference between the TL's of the wall and window.

$$\text{TL (wall)} - \text{TL (window)} = 33 - 18 = 15 \text{ dB}$$

Step 2. Use Figure and locate 15 dB along the vertical axis.

Step 3. Draw a horizontal line until it intersects with the 10% total area occupied curve.

Doors, Windows and Access Panels in Walls

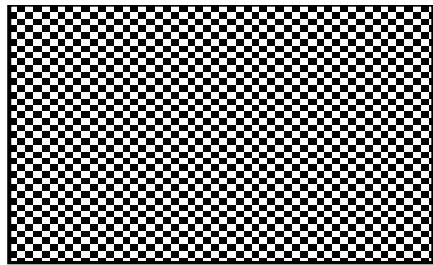
Step 4. Extend a vertical line down until it meets the horizontal axis, which is at a point slightly above 6 dB.

Step 5. Subtract the approximate 6 dB resultant from the TL of the wall to obtain the effective TL of the composite wall.

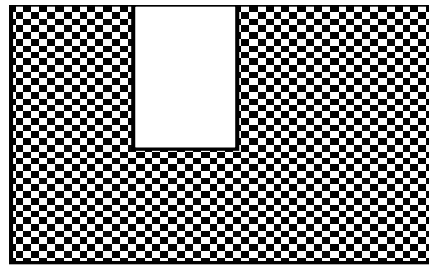
$$\begin{aligned}\text{TL (composite wall)} &= \text{TL (wall)} - 6 \text{ dB} \\ &= 33 - 6 \\ &= 27 \text{ dB}\end{aligned}$$

Sound Transmission Loss

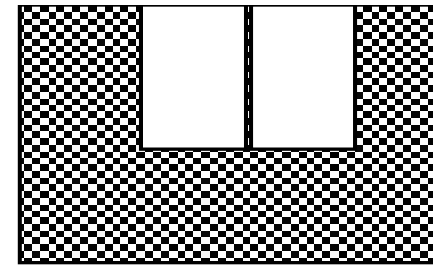
- **Weakest link limits overall performance**



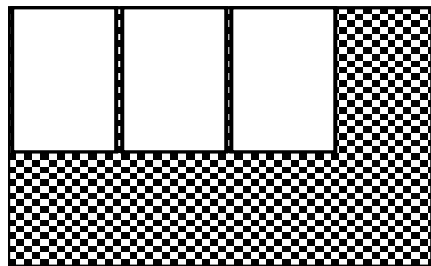
Sound reduction 50 dB



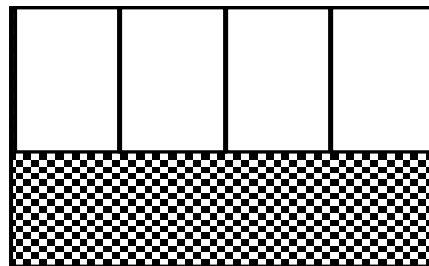
Sound reduction 29 dB



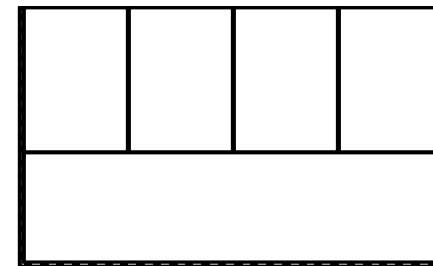
Sound reduction 25 dB



Sound reduction 23 dB

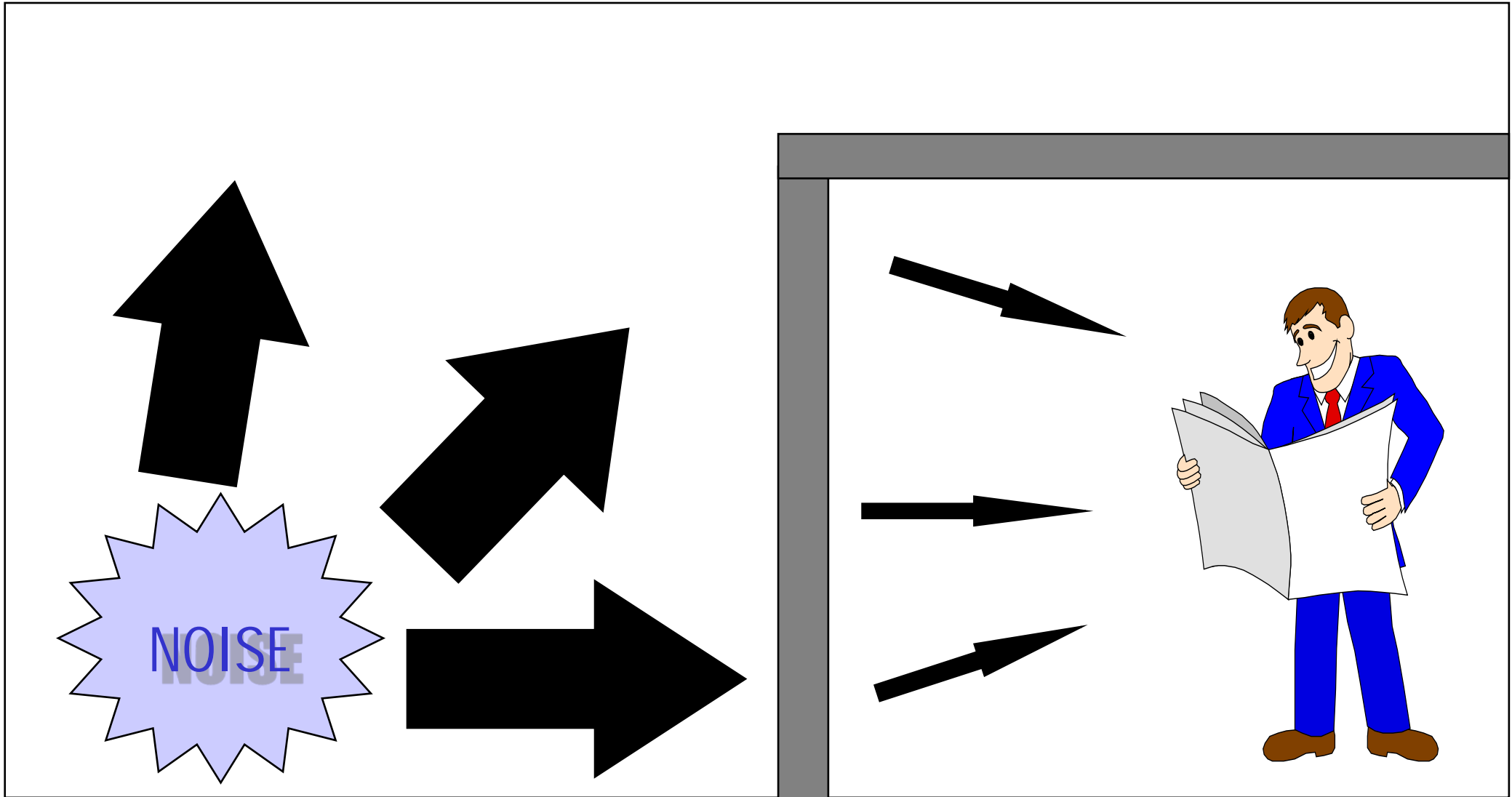


Sound reduction 22 dB

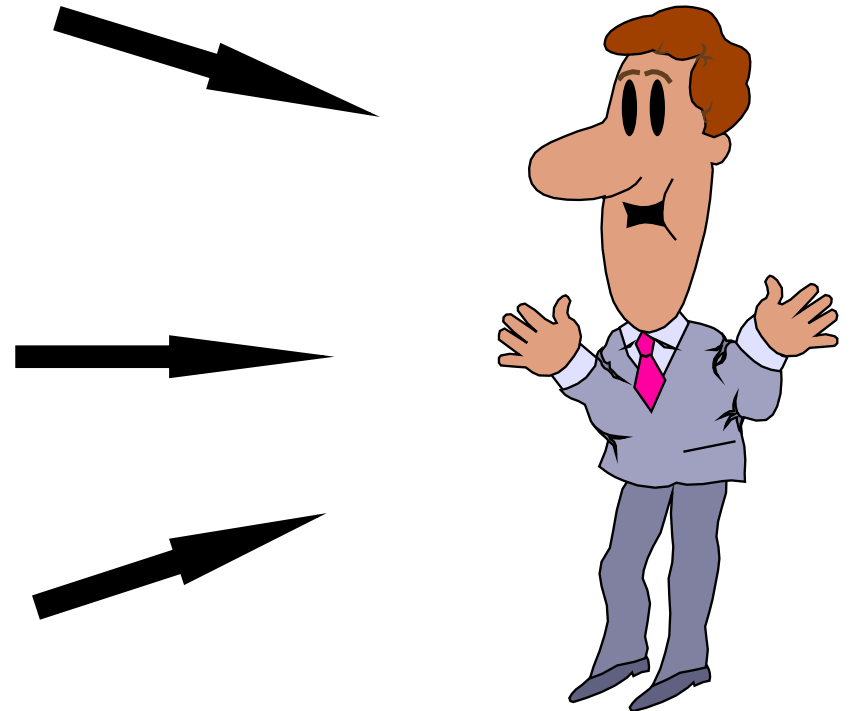
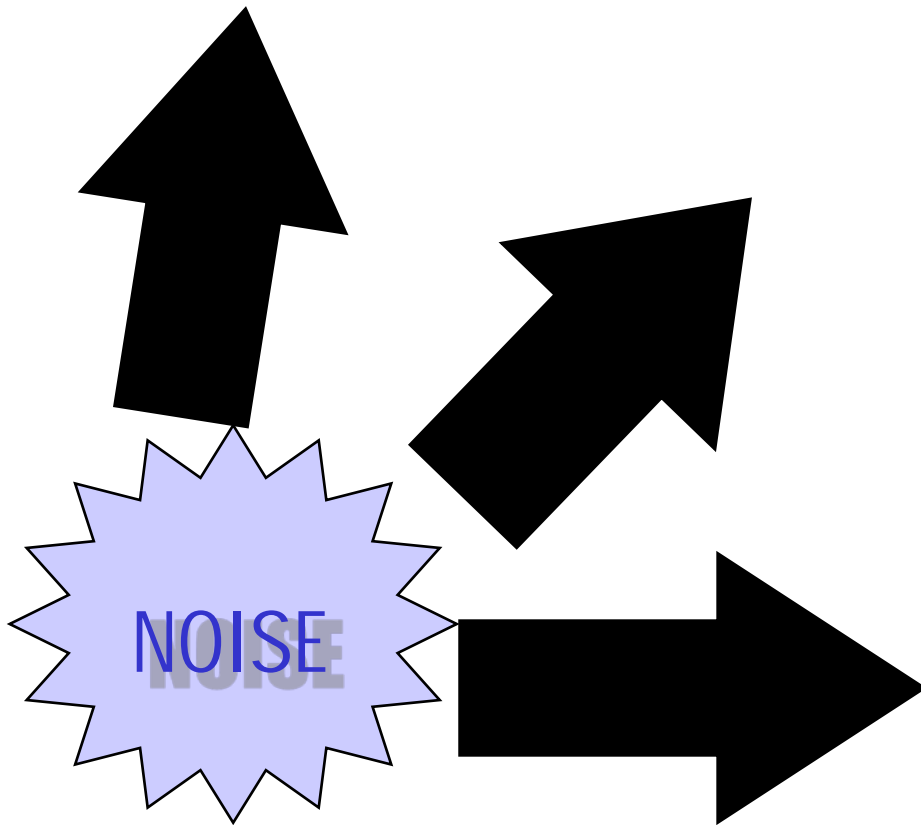


Sound reduction 20 dB

Control Booth or Machine Enclosure



Enclosure



Booths/Enclosures

Advantages:

- Don't have to identify the source
- *Well constructed* enclosures can provide 20-40 dB reduction,
- Can be installed relatively quickly and at a reasonable cost,
- Provides significant noise reduction across a wide range of frequencies.

Booths/Enclosures

Disadvantages:

Access to equipment are restricted,

- **Difficult to acoustic seal around openings**
- **Disassembly/reassembly leads to gaps at panel joints,**
- **Heat build up inside the enclosure**
- **May need internal lighting, gas detection, fire suppression etc**
- **Can create a confined space**

Booths/Enclosures

Disadvantages (cont)

- **Potential for internal surface contamination**
- **Panels can be damaged/deteriorate**
- **Need periodic maintenance for acoustical integrity**
- **Employee acceptance can be difficult**

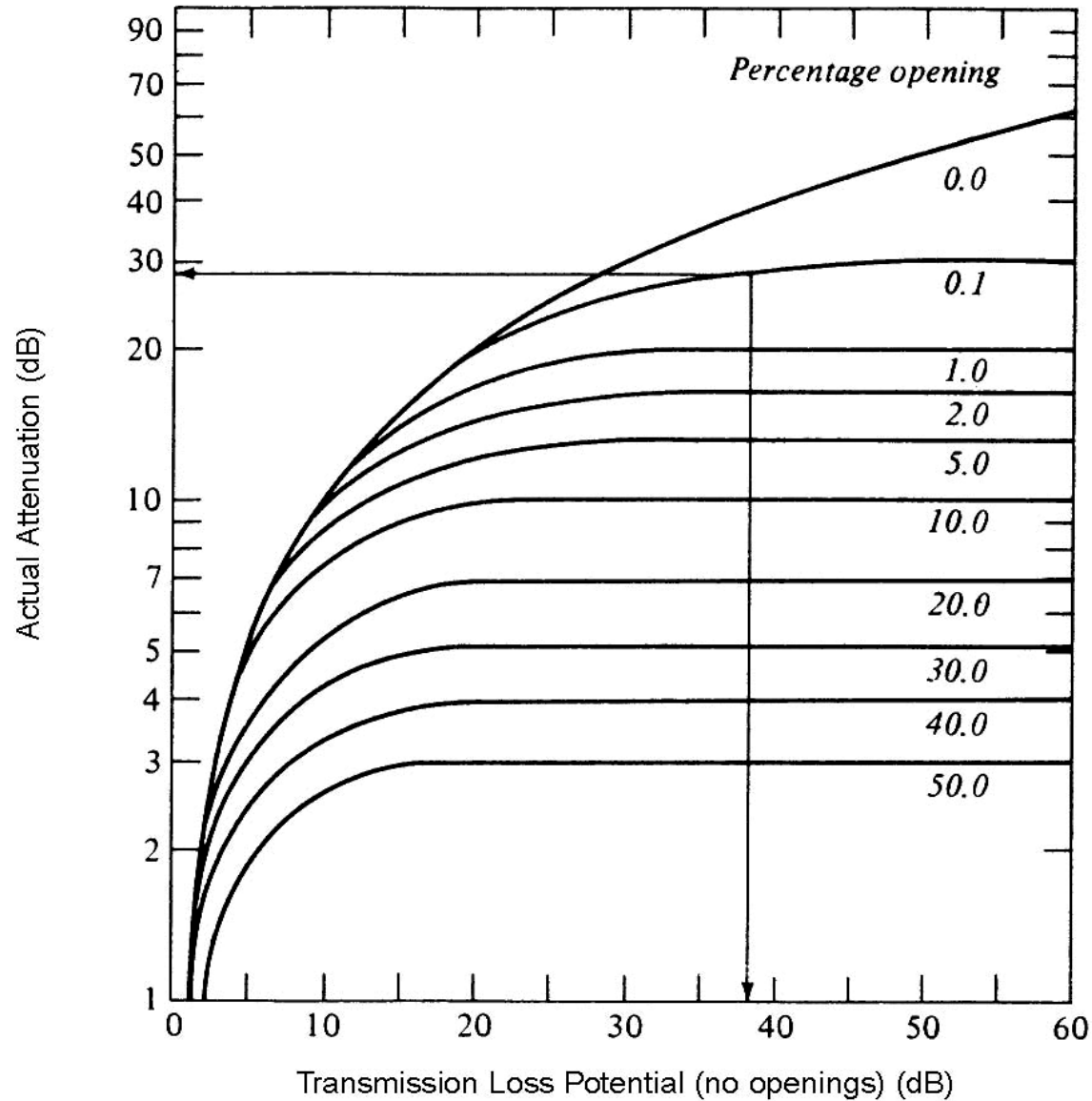
Enclosure Design

- **Bigger the better**
- **Panels must have good noise reduction**
- **Sealing vital**
- **Absorptive lining**
- **Protection of lining**

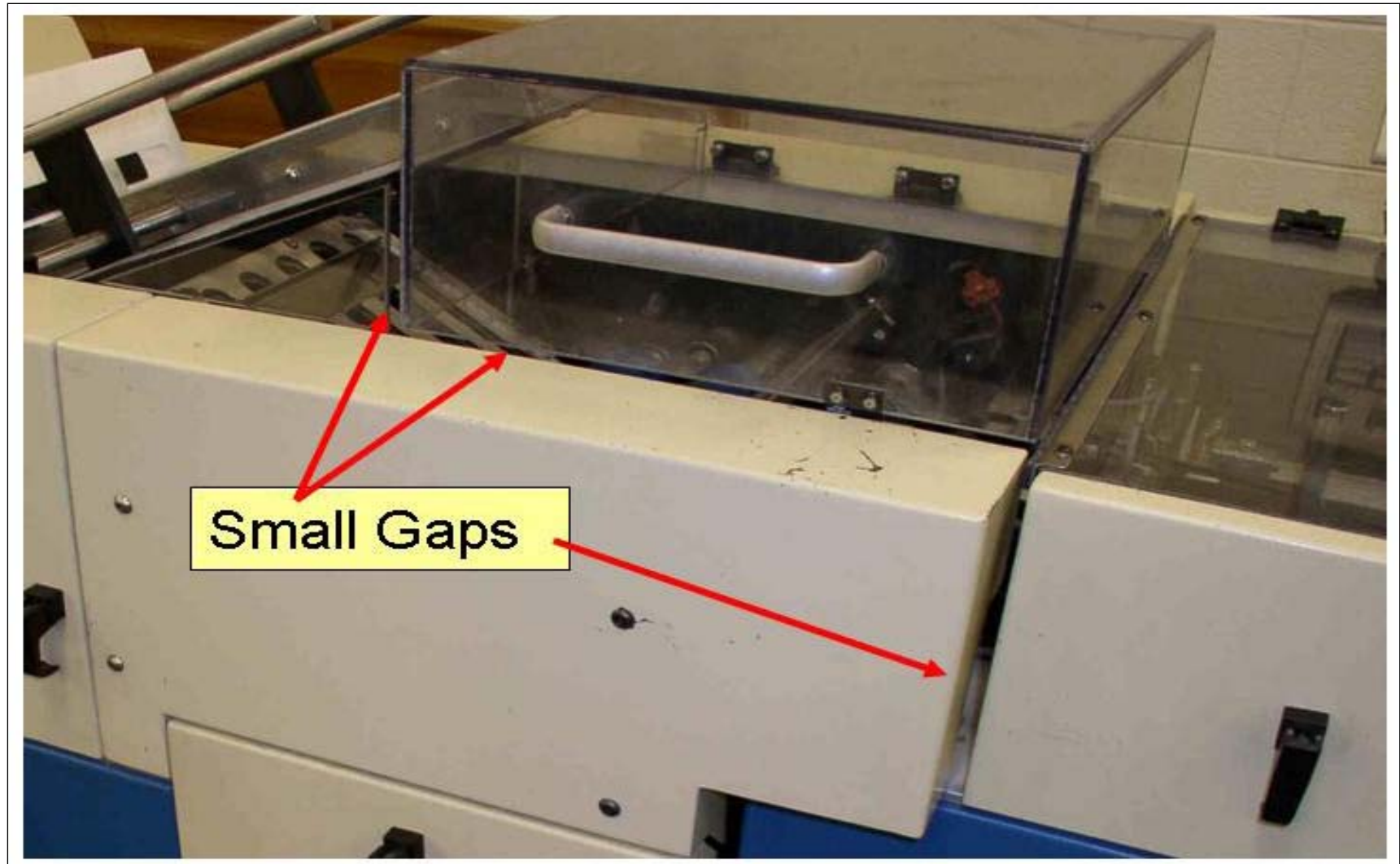
Enclosure Design (cont)

- **Isolation – vibration**
- **Product flow**
- **Worker access**
- **Ventilation**
- **Fire prevention**

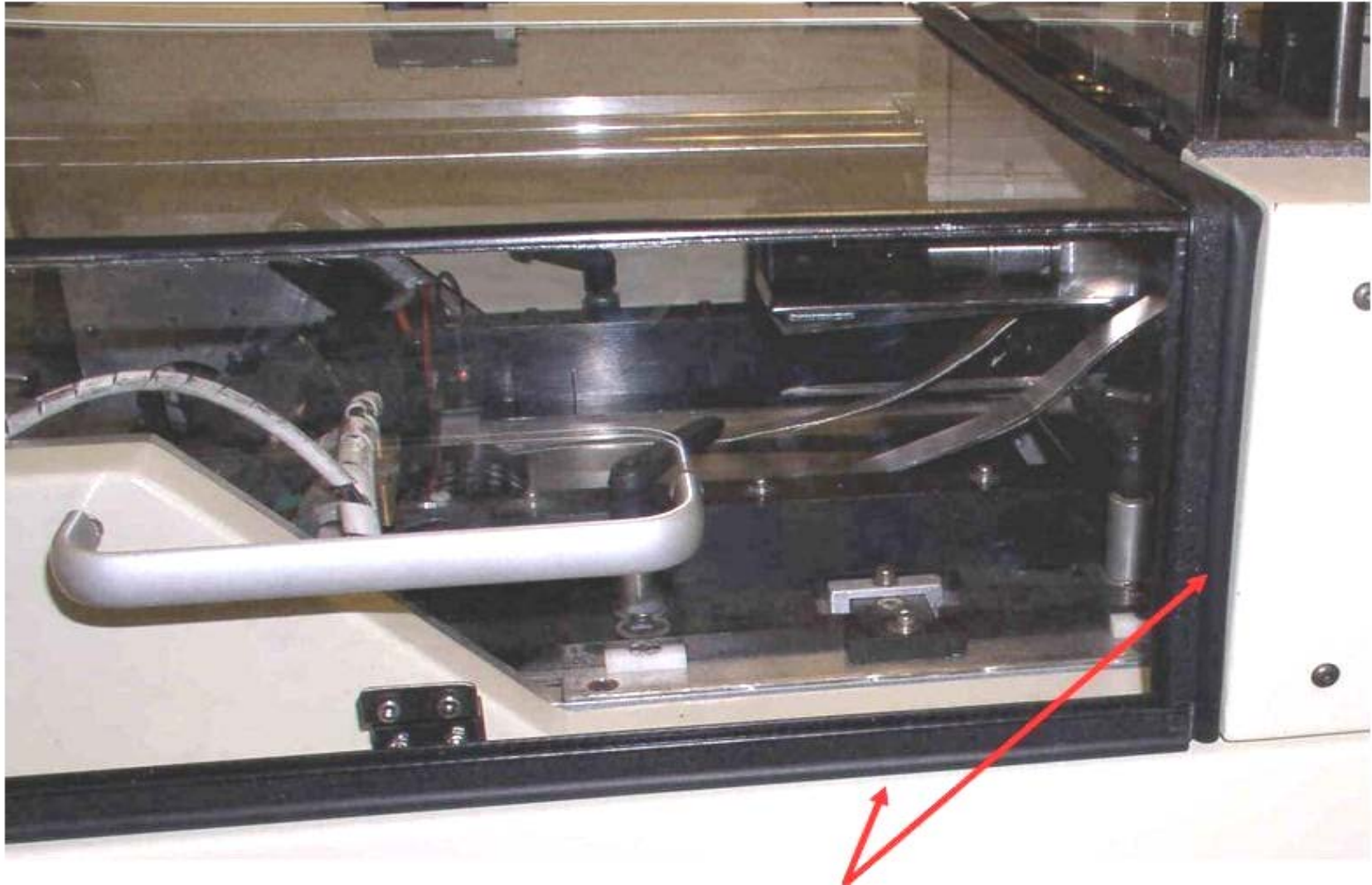
Effect of Opening



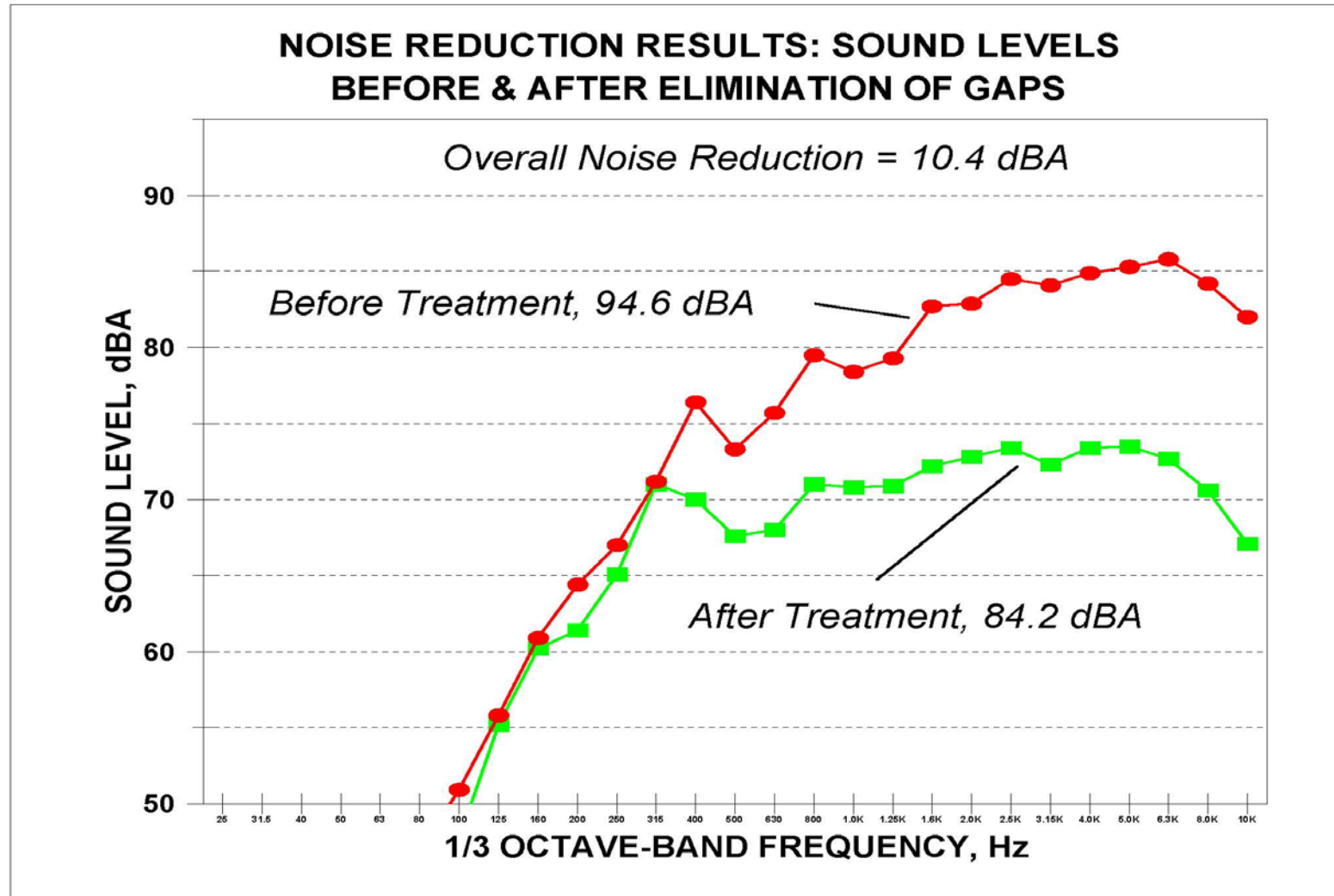
Enclosures



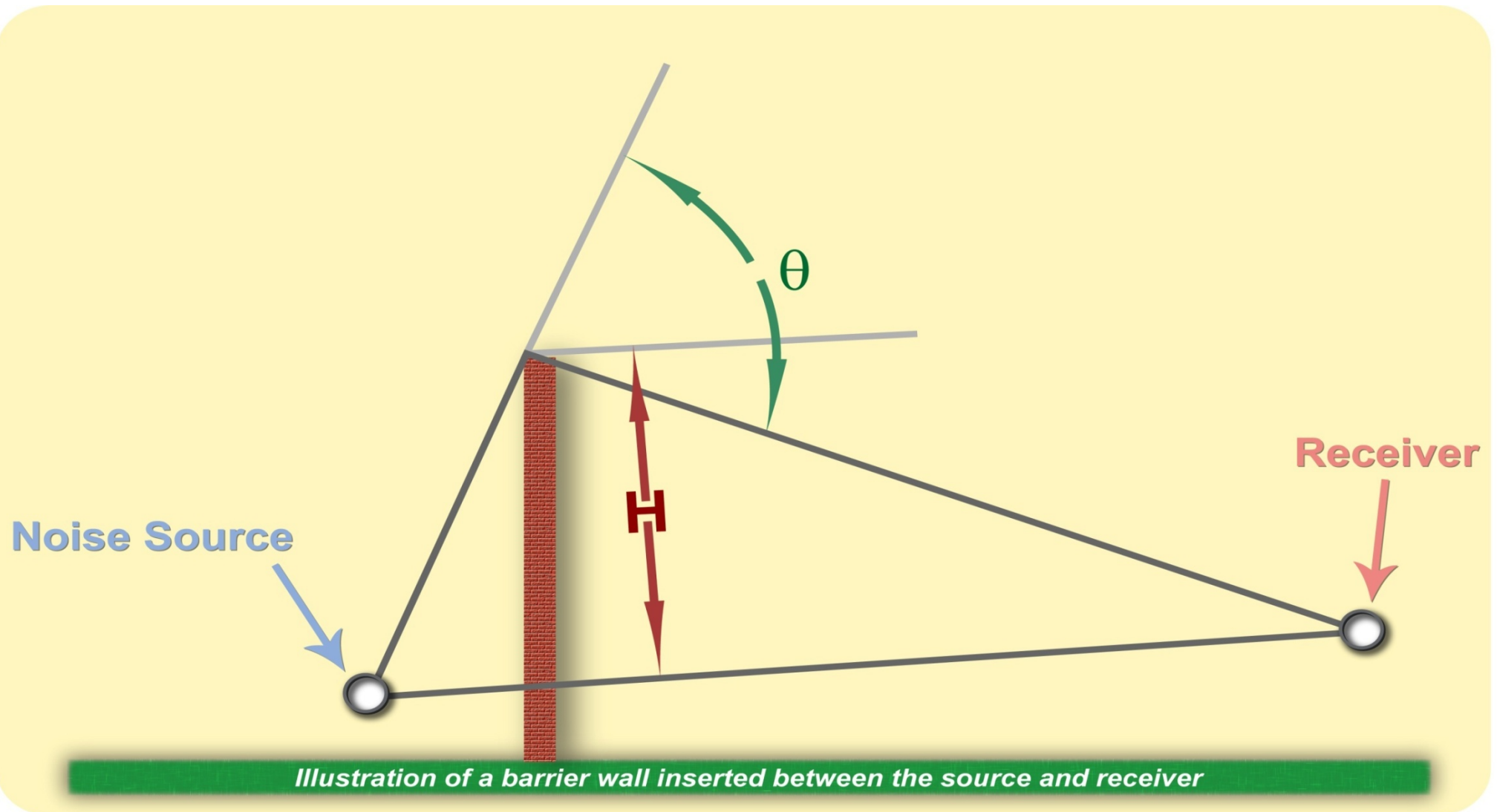
Enclosures



Enclosures



Barrier Walls

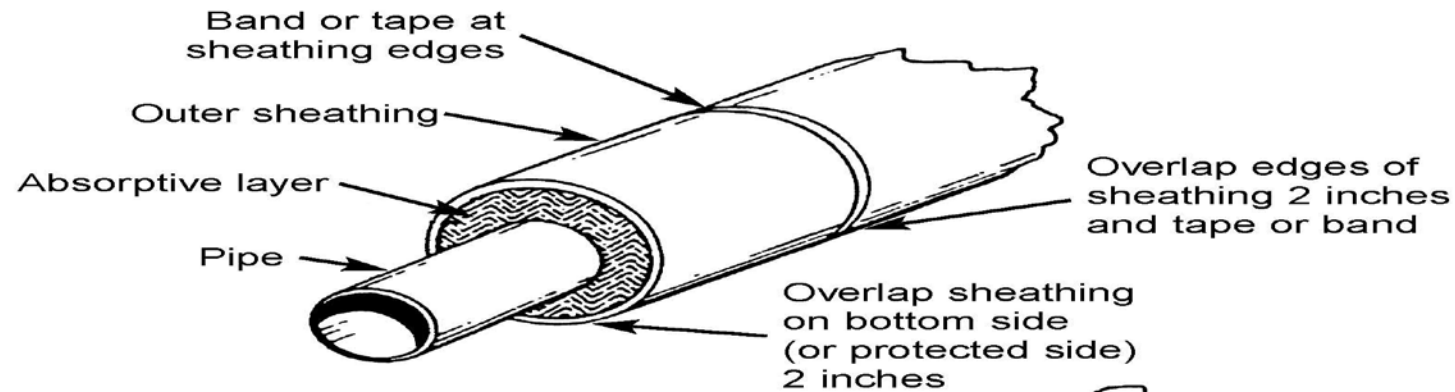


Barriers

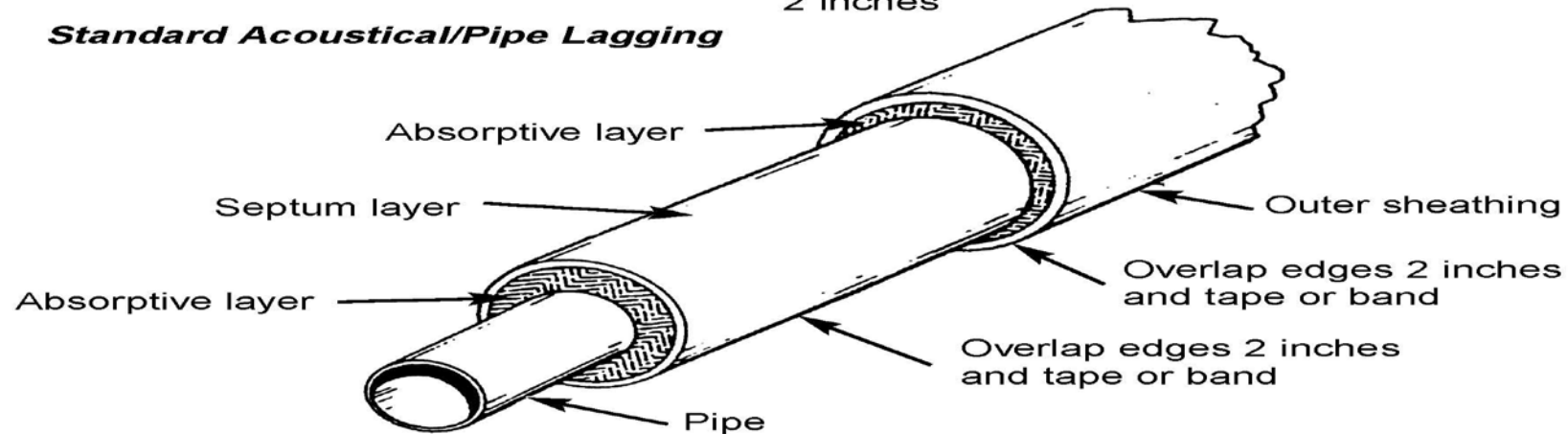
- **Either close to source or receiver**
- **Wide enough to screen source**
- **Tall as practical**
- **Reasonable noise reduction for material**
- **Solid and no gaps**
- **Window with good noise reduction**

Lagging

- Wrapping of exterior surface



Standard Acoustical/Pipe Lagging



***Pipe Lagging Using
Sandwiched Septum Layer for High Noise Level Reductions***

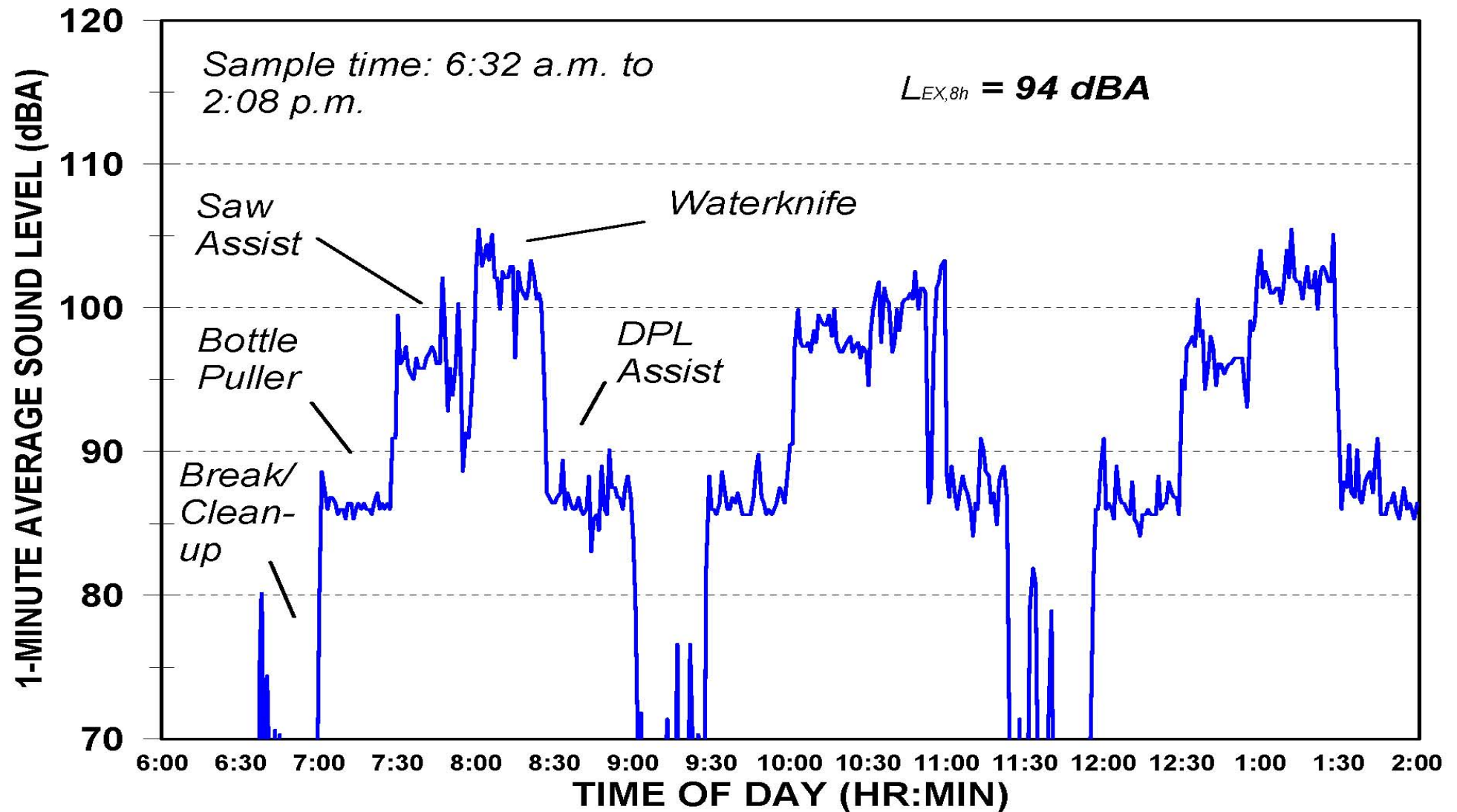
Lagging

- **Resilient absorptive material**
- **Avoid any coupling**
- **Seal all edges, joints**
- **Special materials for high temperatures**
- **Thick layer for low frequency absorption**
- **Means to avoid condensation**

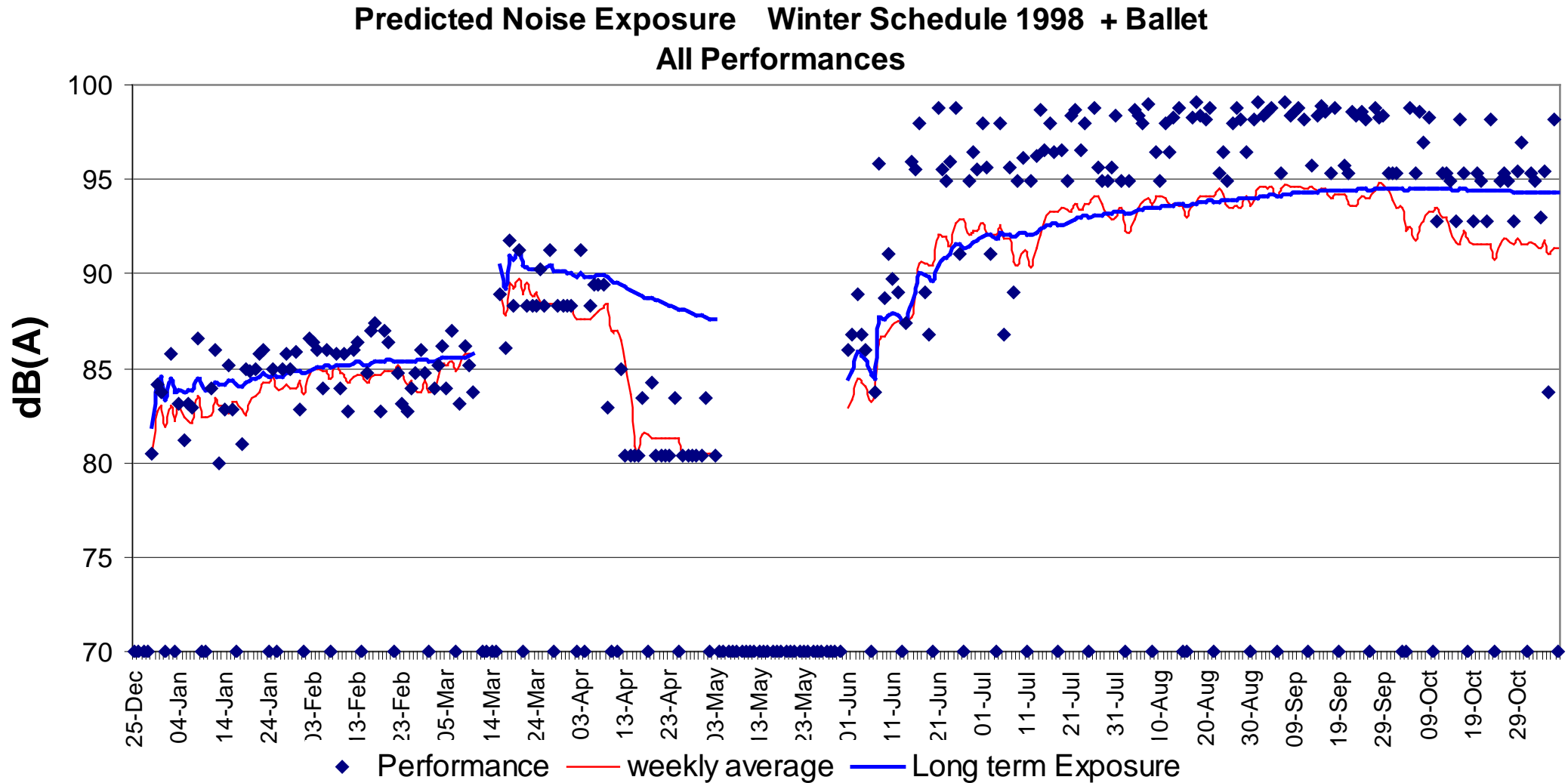
Administrative Controls

- **Scheduling of shifts**
- **noisy tasks in controlled areas**
- **quiet tasks away from noisy tasks**
- **noise refuge areas or control rooms,**
- **Remote control and remote monitoring,**
- **Maintenance and servicing schedules**
- **Specifications for limiting noise levels.**
- **Workers away from noisy areas whenever possible**

Administrative Controls



Administrative Controls



Planning Layout

Noise control by location of the source should be considered for the design and equipment layout of new plant areas and for reconfiguration of existing production areas.

Simple rule is to keep machines, processes, and work areas of approximately equal noise level Together.

Planning Layout (cont)

Separate particularly noisy and particularly quiet areas by buffer zones having intermediate noise levels.

In addition, a single noisy machine should not be placed in a relatively quiet, populated area.

Noise Refuges

Provide relief from noise in “quiet” areas for breaks, meals, complete their paperwork, etc.

Control rooms or noise isolation booths, also provide relief from noise, as well as hot or cold thermal environments.

Remote control, monitoring and automation can increase the time workers can effectively spend inside the quiet control room.

Administrative Controls



Acoustical control room and noise refuge in a paper manufacturing facility

Regular Maintenance

Maintaining all equipment at its optimum performance condition should be the first step in any noise control programme.

When a noise-producing problem is identified during a visual and auditory inspection, the problem should be corrected immediately

Regular Maintenance

Successful implementation of an acoustical maintenance programme will ensure the correction of simple and often overlooked noise problems and \ will yield significant benefits in both the long-term life of the equipment and minimizing the noise exposure risk to employees.

Noise Limits in Specifications

A buy-quiet programme has the first step to establish acceptable noise criteria for construction of a new plant, expansion of an existing facility, and purchase of new equipment.

Specified noise limits should be included at the design and/or procurement stage.

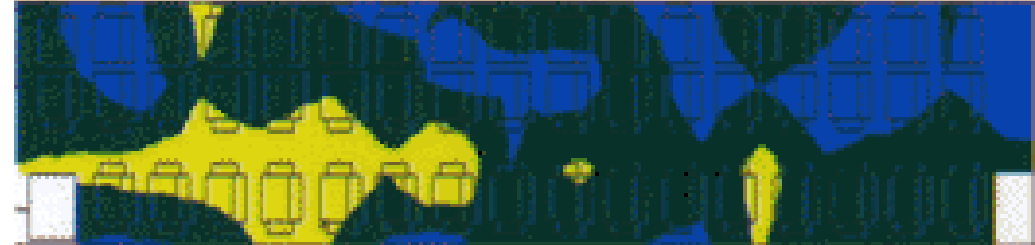
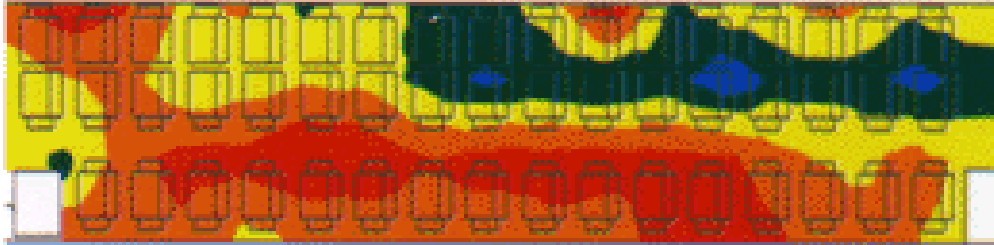
Besides selection of the equipment, consideration of noise early in the equipment layout design is essential.

Noise Limits in Specifications

Validation of noise criteria requires a cooperative effort from all involved through to commissioning

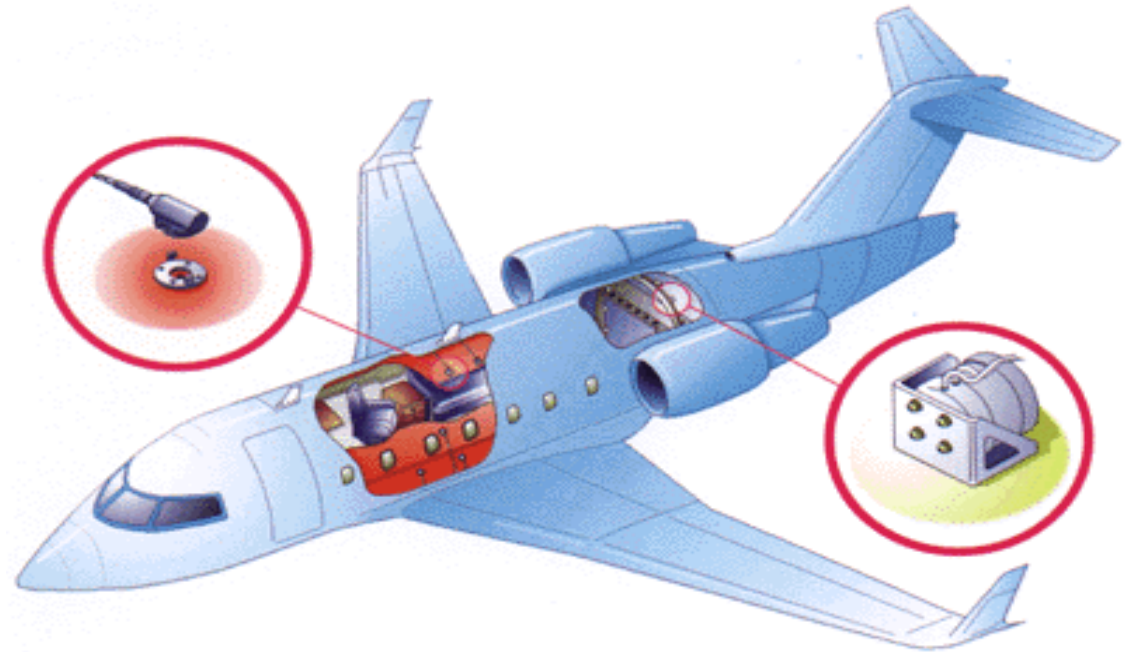
Even the most thorough and concise specification document is of little value unless the onus of compliance is placed on the supplier or manufacturer.

Active Control



Active noise and vibration system in an aircraft

**Elements of the system –
microphones and
loudspeakers**



Conclusion

Control of noise at the source is the goal

Other options are control between source and receiver and control at receiver

Limiting noise in the specification and design stage reduces the need for remedial work in the future

Today's Learning Outcomes

- **To understand assessment of noise exposure levels**
- **To understand the causes of noise generation in common machinery**
- **To review noise control engineering possibilities**
- **To measure a time varying source**
- **To calculate a daily noise exposure**