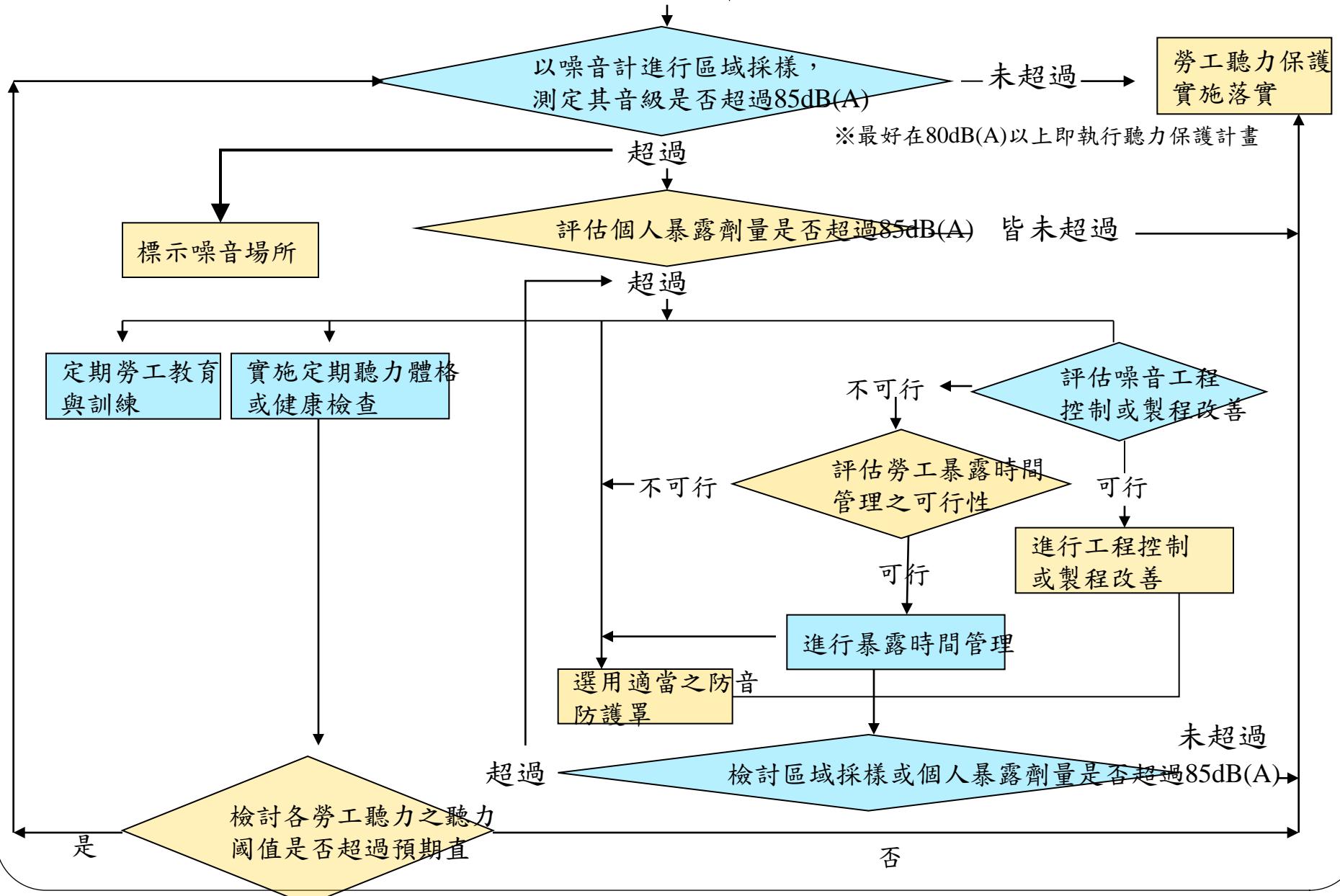


# 聽力保護與噪音改善技術介紹 及案例分享

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中山醫學大學  
107年11月22日

# 聽力保護計畫執行流程圖

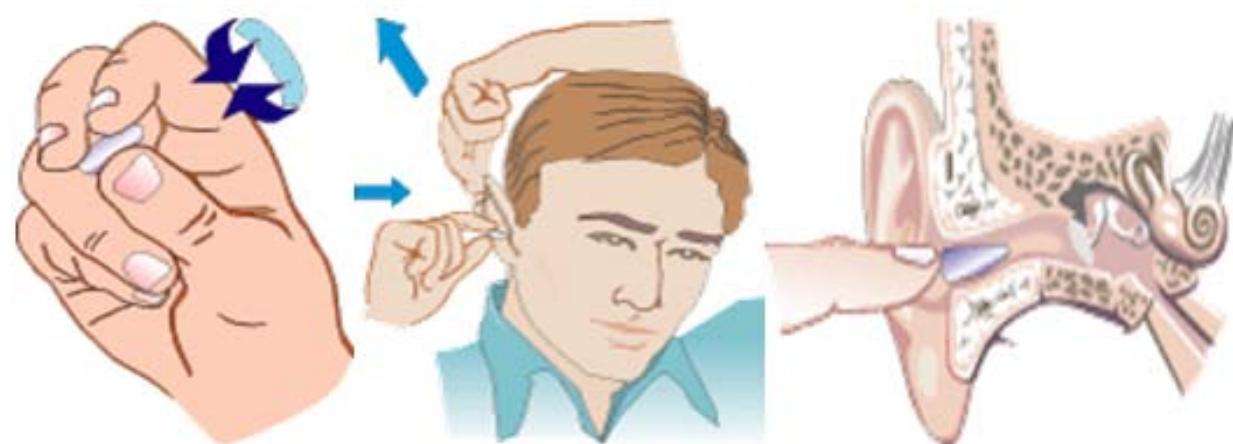
## 執行聽力保護計畫



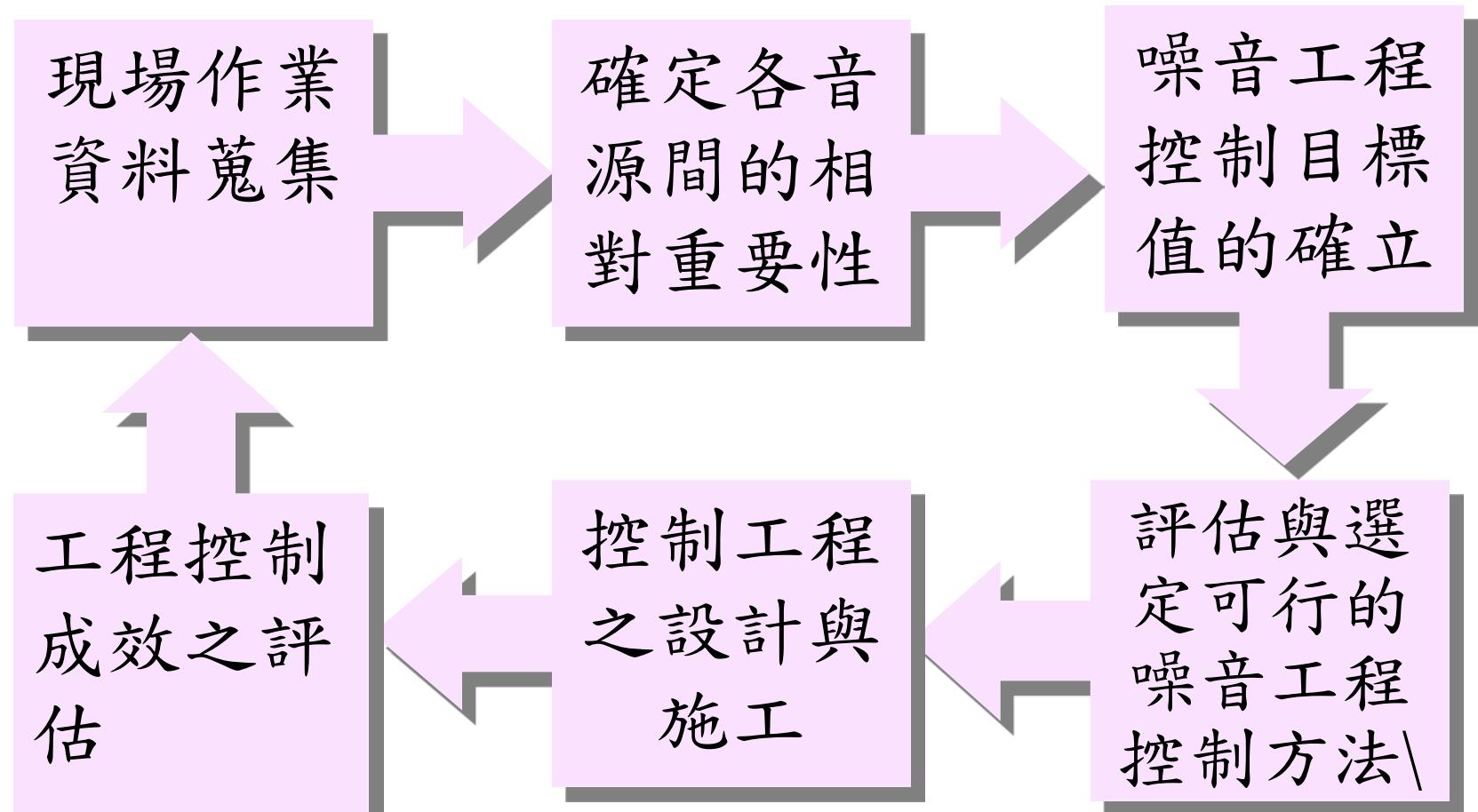
# 噪音暴露量降低

- 噪音強度降低
  - 噪音源之控制
  - 噪音傳播途徑之控制
  - 使用防音防護具
- 時間減少
  - 暴露時間管理

# 防音防護具



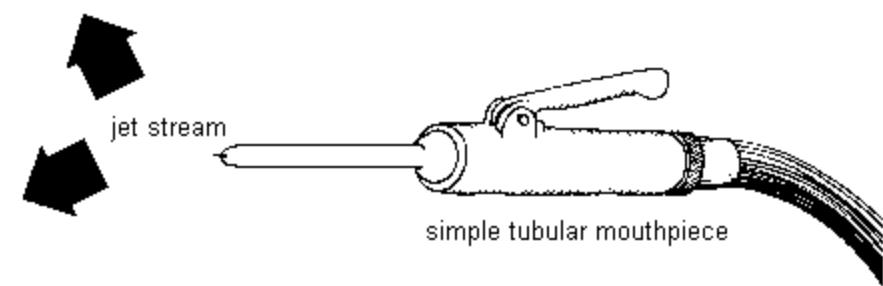
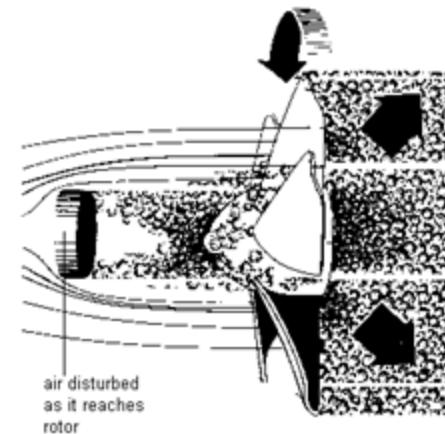
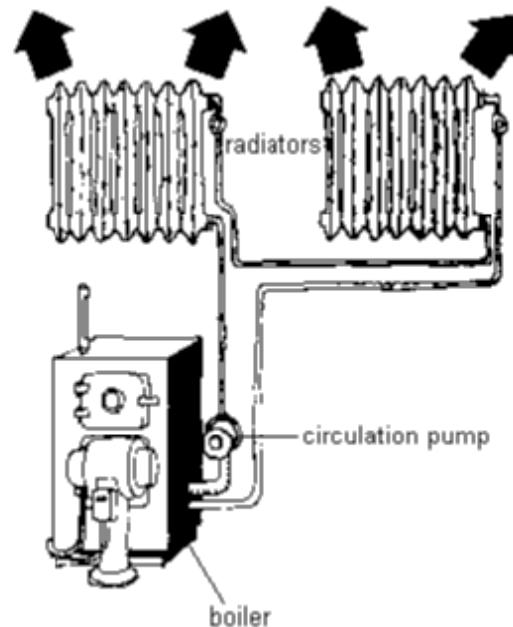
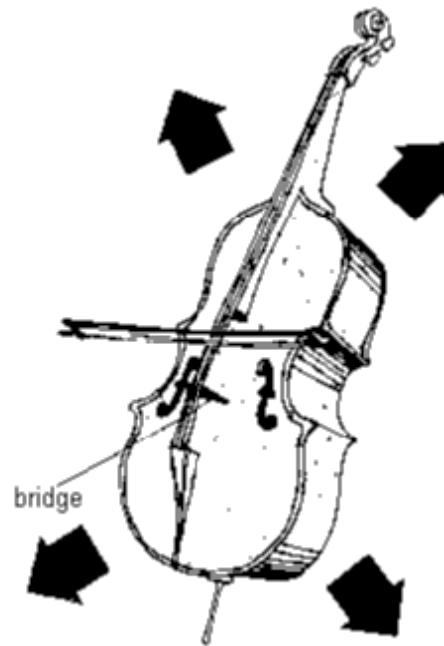
# 噪音控制進行步驟



# 噪音控制

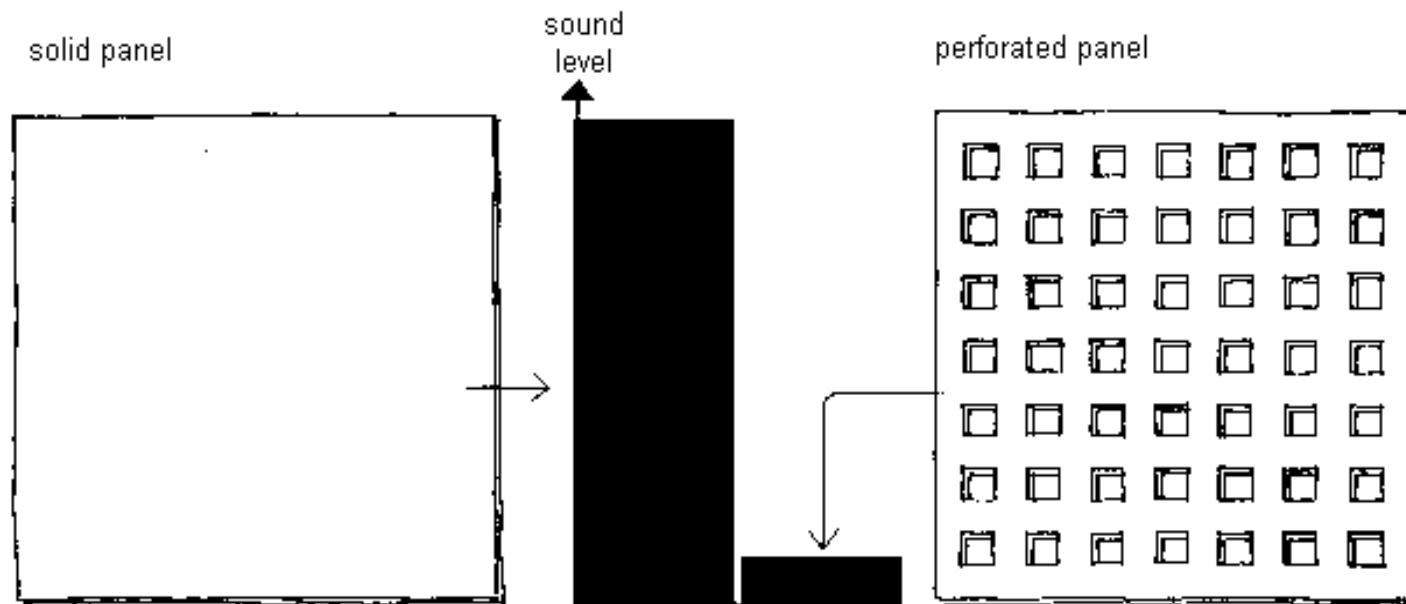
- 一個噪音問題可從噪音源、傳播途徑、受音者三方面考量控制措施，其中噪音源為問題主要部份，如果音源產生的聲音能降低，則環境中較無噪音的問題。
- 音源聲音的降低，主要仍在機台製造商的設計與製造階段。如從使用者進行改善，主要採取隔音、消音、隔振、阻尼、潤滑、平衡等措施。
- 噪音問題藉由將噪音源密閉、阻擋、與吸收，以減少空氣音傳播是常用的方法。

# 噪音的產生

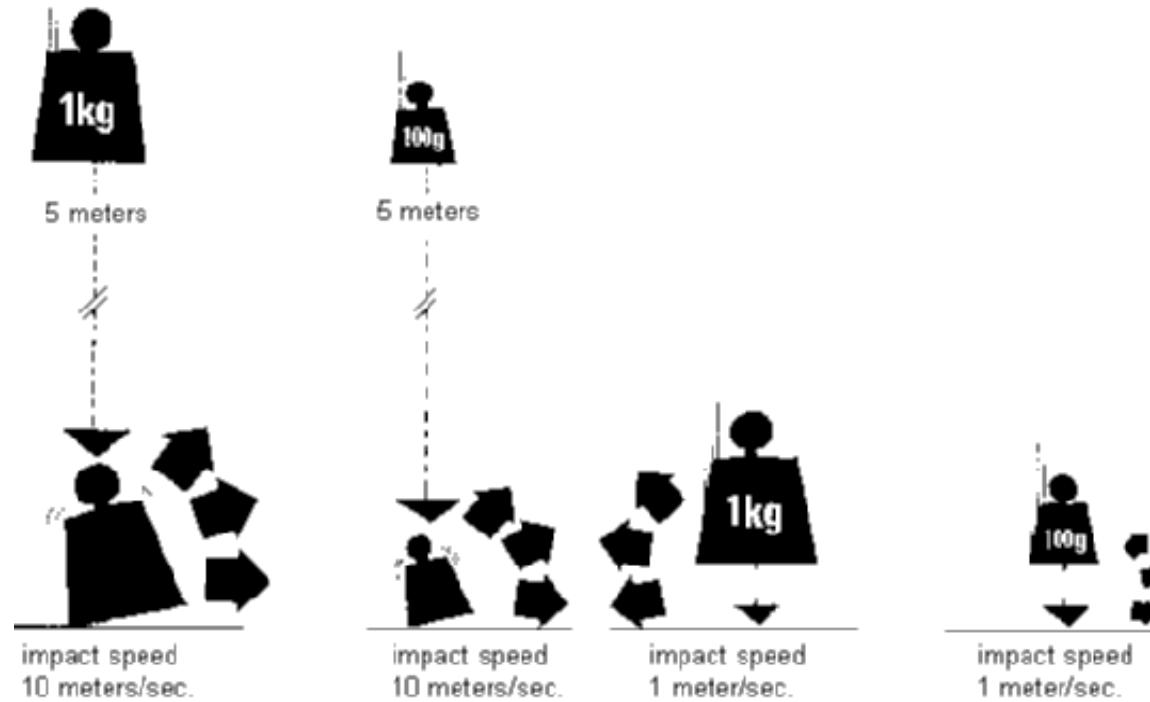


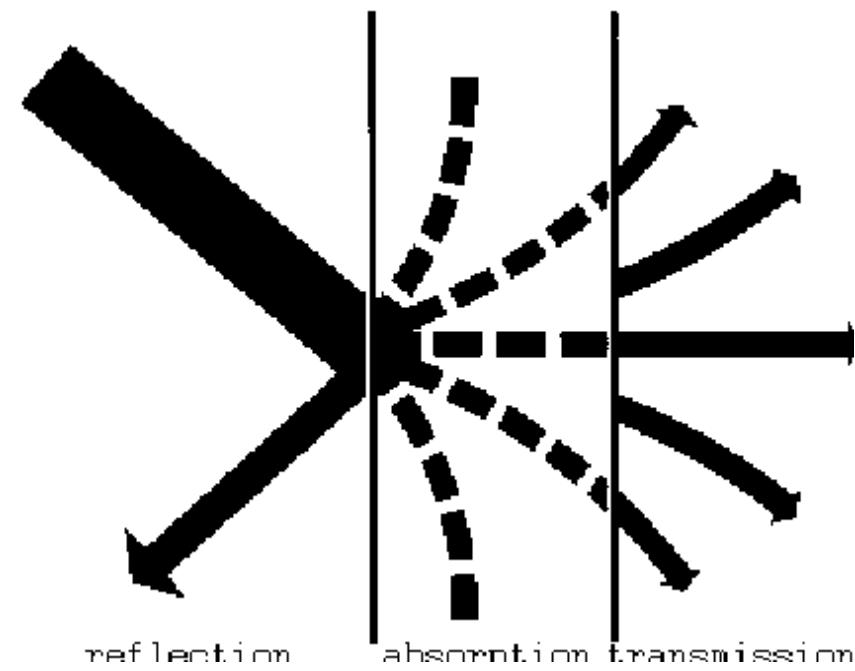
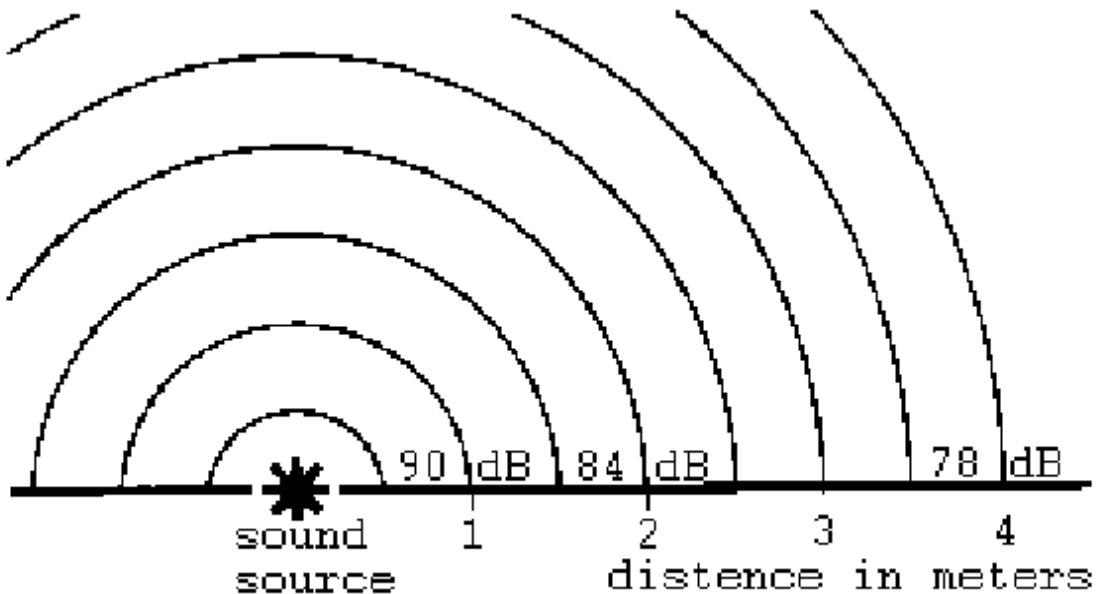
# 孔板產生較少噪音

大面積的振動面在現場很難避免，平面振動如同幫浦來回推擠空氣，產生聲音。假如平面有孔洞則幫浦推擠效應變差，因此產生較小的聲音。

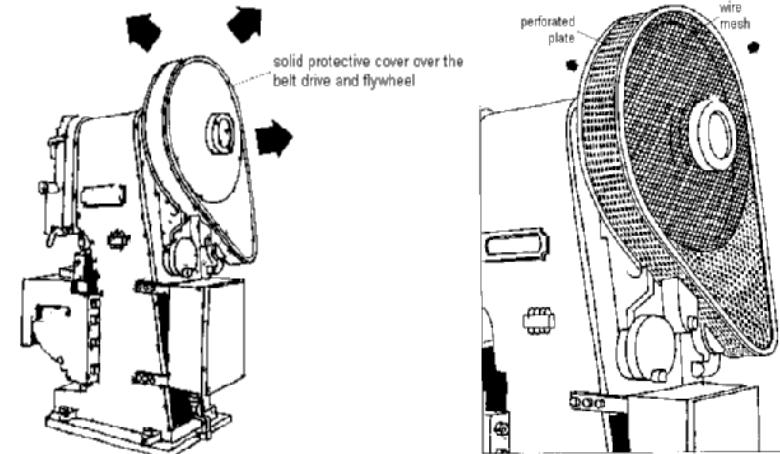
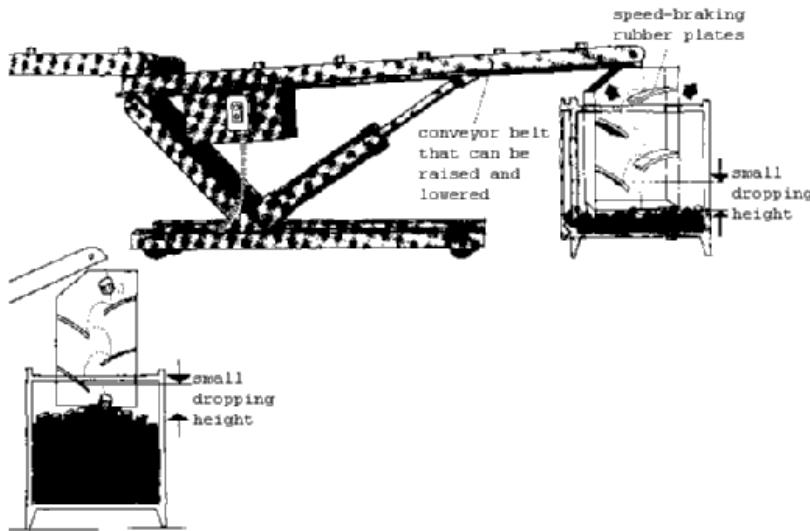
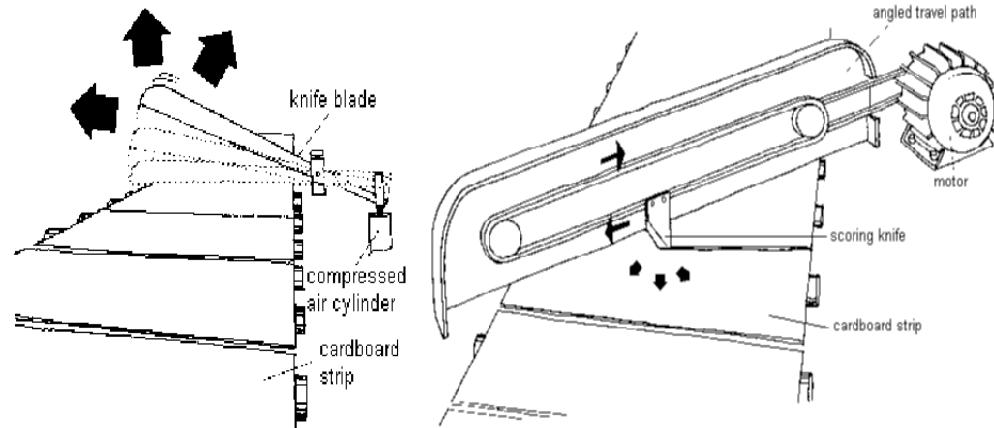
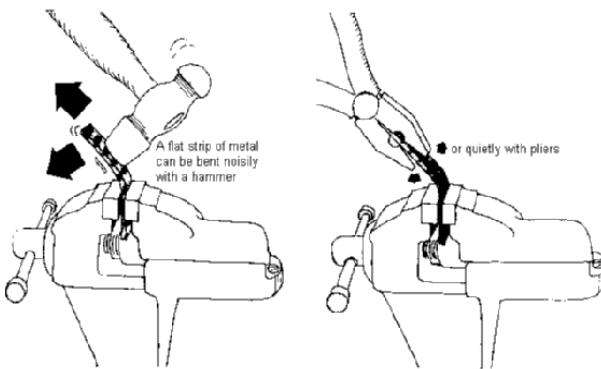


# 低速重量輕的物體產生最小的衝擊噪音

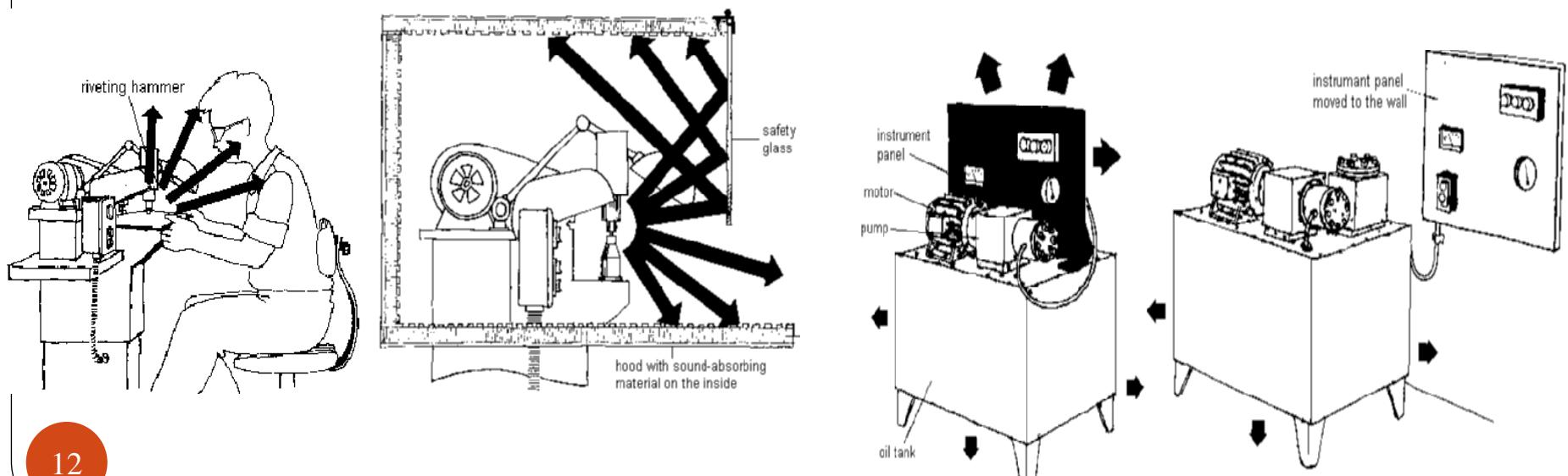
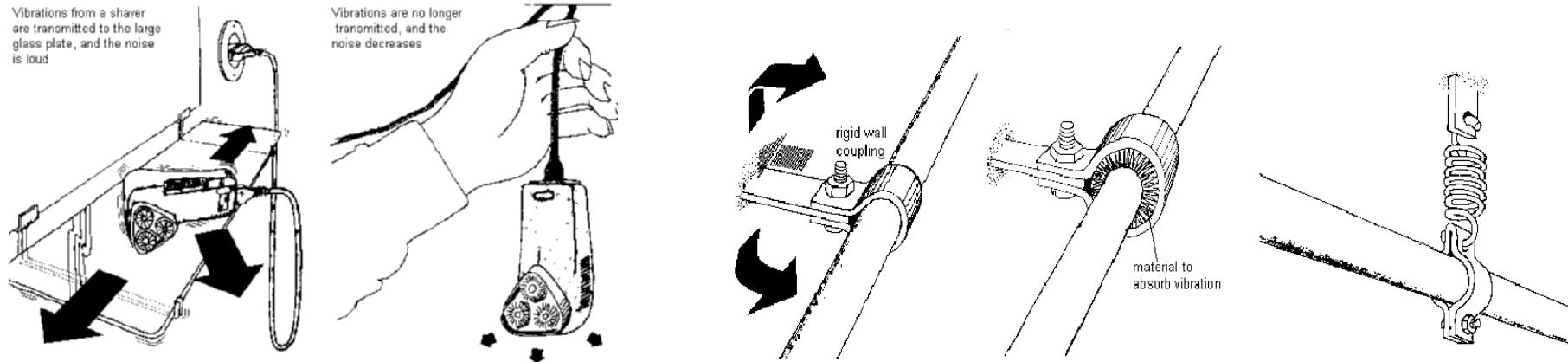




# 噪音源的改善



# 傳播途徑改善

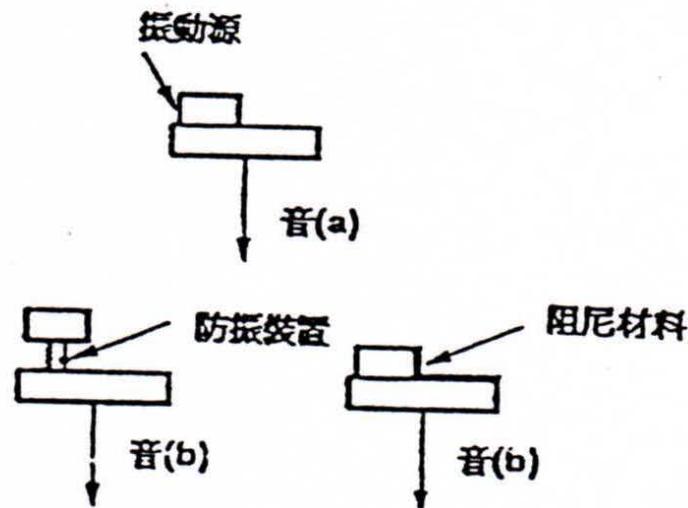
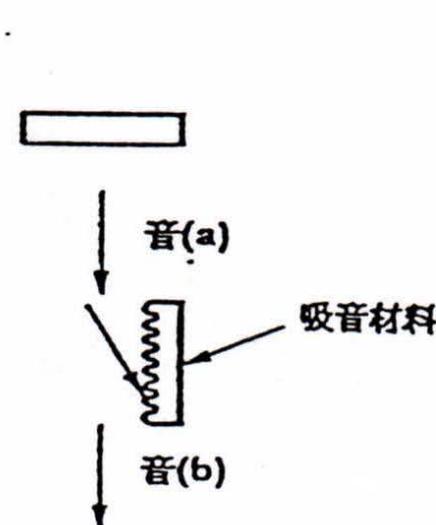
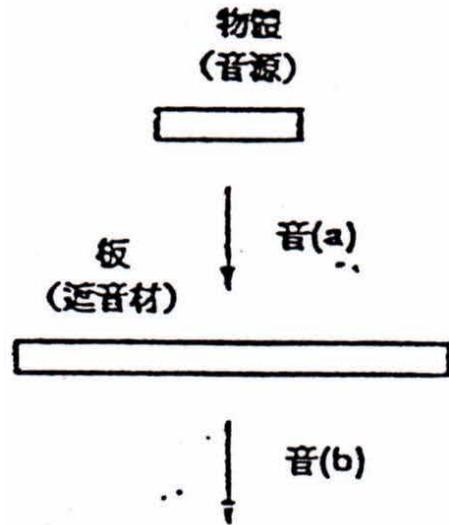


# 降低噪音暴露的方法

- 較不需更改機械設備的控制方法
  - 適當的維修與保養、改變勞工操作習慣、更換設備、振動零件的隔絕與減振、改變噪音設備的位置等
- 需增加裝置至機械設備上的控制方法
  - 裝設防音屏障、裝設包圍式隔音裝置(半包圍式與全包圍式)、鋪設包覆式隔音(風管與管路等)、加裝消音器、鋪設吸音材、增加房間的吸音力等
- 變更設計的控制方法
  - 物件墜落容器裝設軟性材質或減少墜落高度、以滑落代替墜落，減少撞擊發生、改變凸輪曲線減少產生衝擊狀況、使用軟性材料或緩衝裝置減少機械衝撞、更換金屬材質的輸送設備等
- 使用個人防護具

# 噪音工程控制對策

- 噪音源之物體藉由振動減少及將聲音的能量轉變成熱能消失，以達噪音降低的目的。
- 隔(遮)音(sound barrier)、吸音(sound absorption)、阻尼(damping)，振動隔絕(vibration isolation)



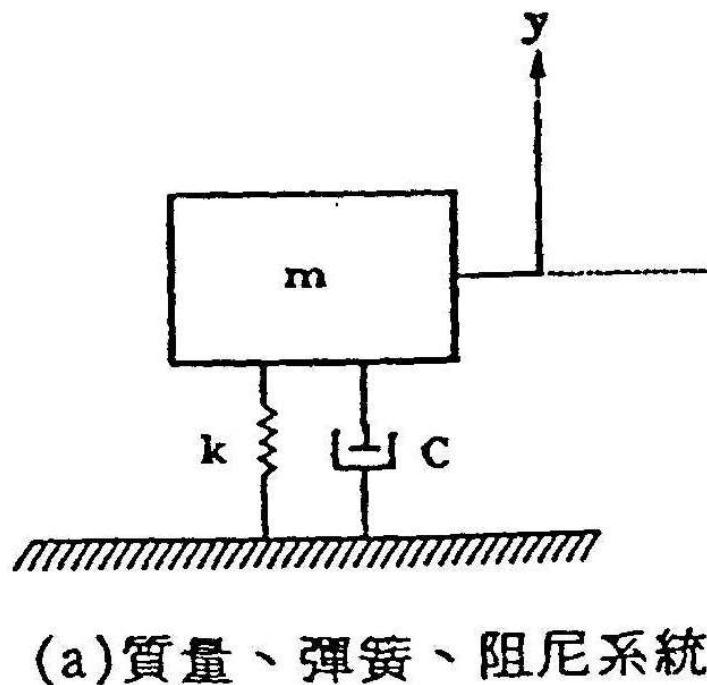
(A)遮音

(B)吸音

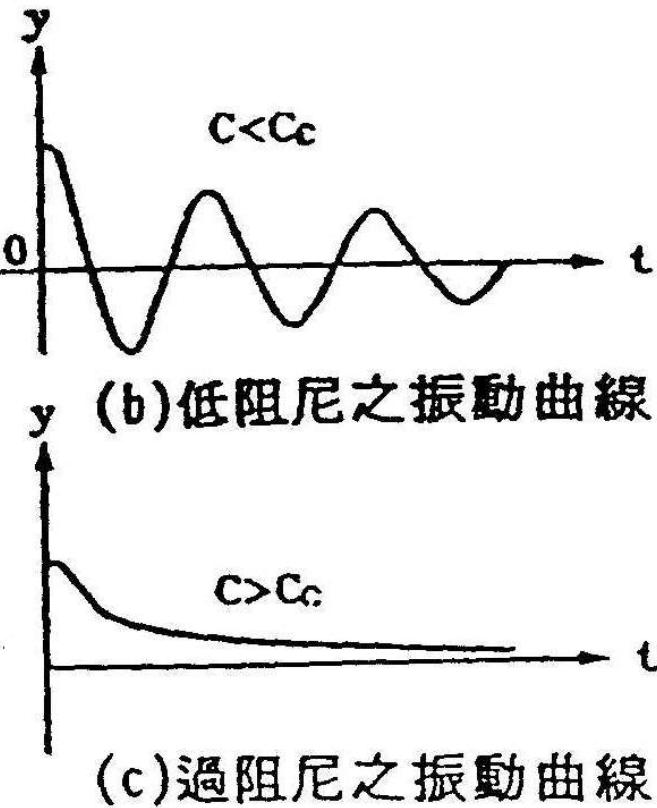
(C)振動絕緣

(D)阻尼處理

# 阻尼概念



(a)質量、彈簧、阻尼系統



(b)低阻尼之振動曲線

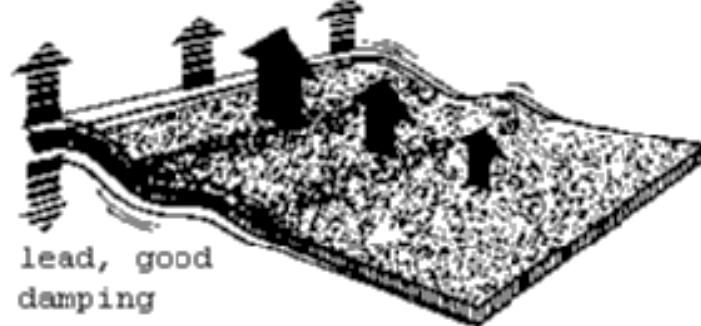
(c)過阻尼之振動曲線

# 阻尼面產生較小聲響

example of vibration movement in a plate

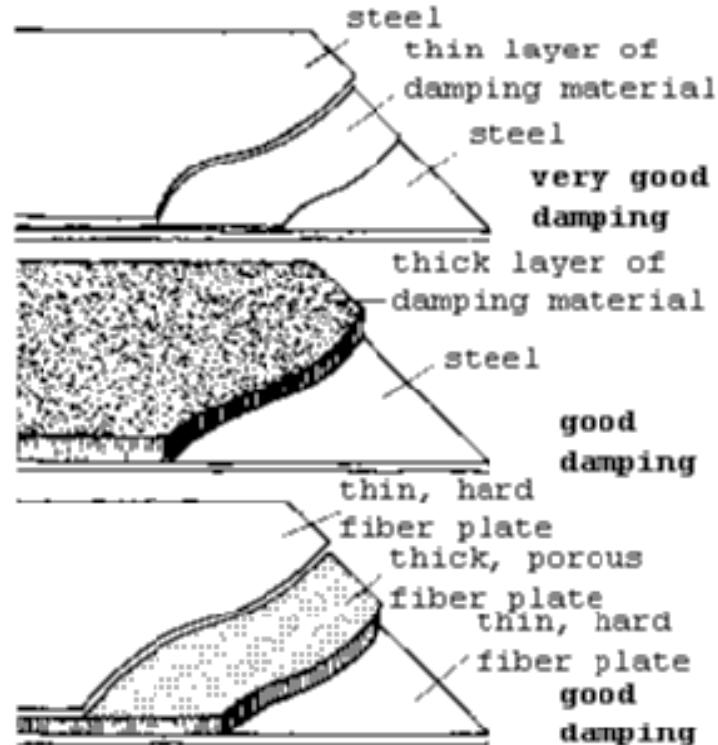


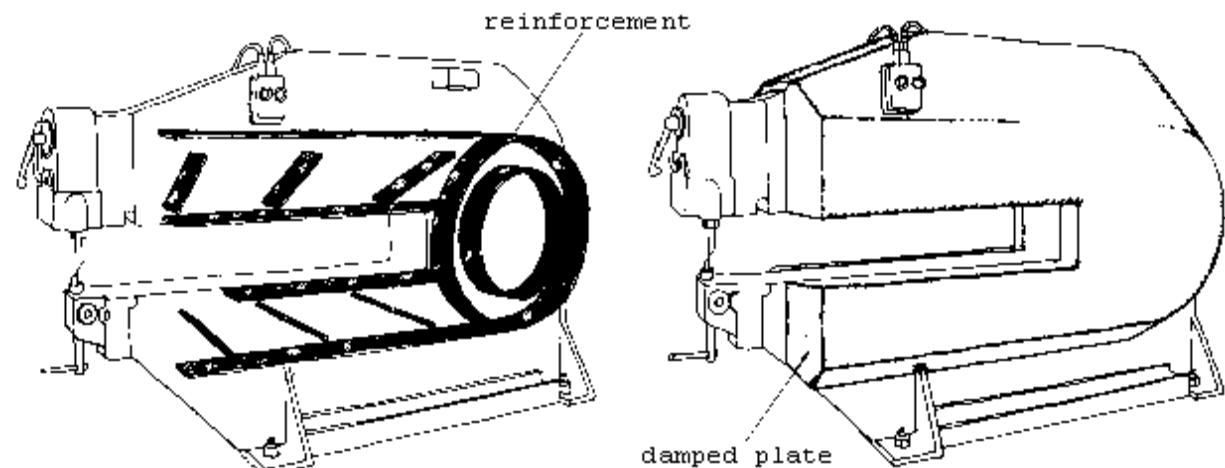
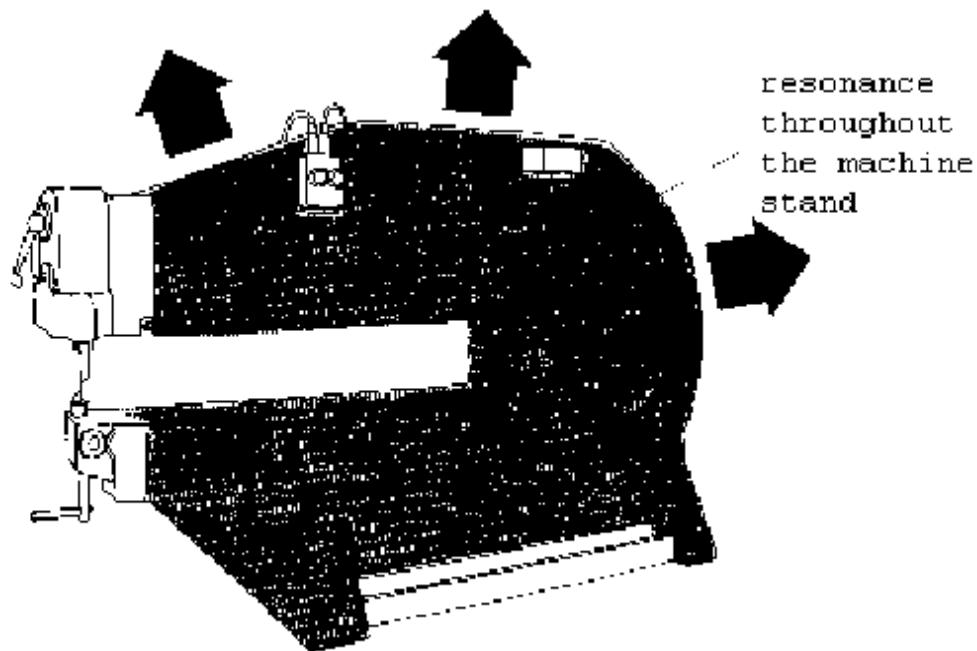
steel, no damping



lead, good damping

example of "artificial" damping



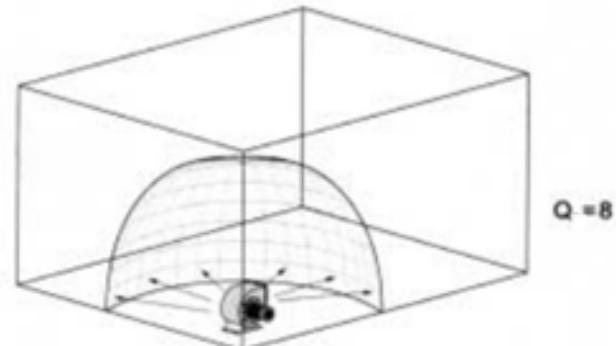
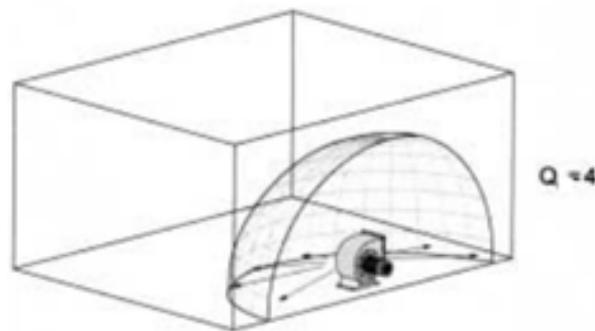
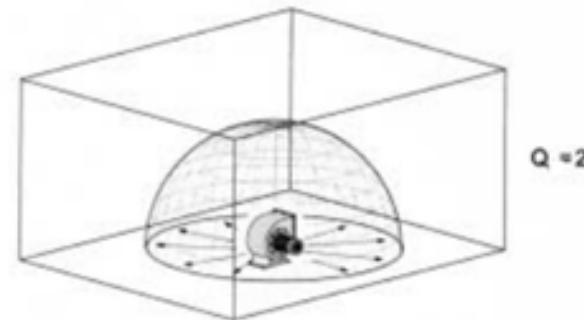
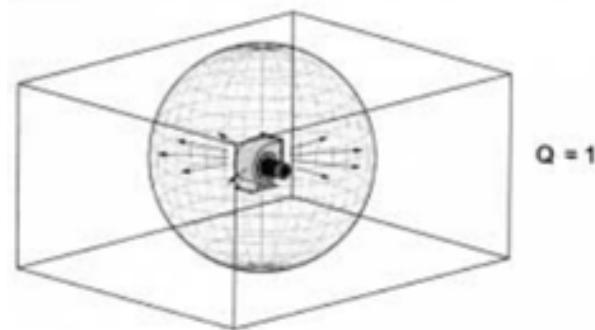


# 音功率級與音壓級

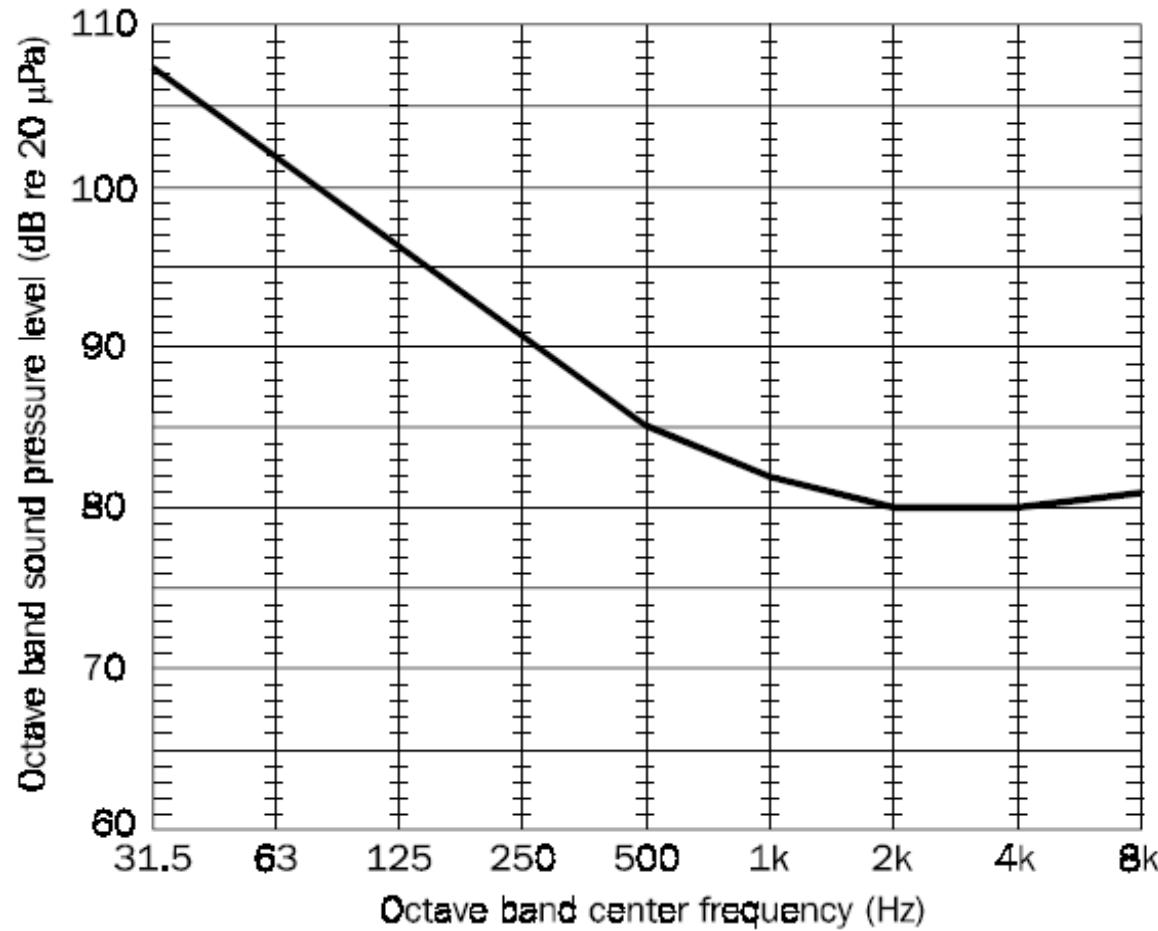
$$L_p = L_w + 10 \log \left[ \frac{Q}{4\pi r^2} + \frac{4}{R} \right]$$

- $L_p$ ：音壓級 (dB)，參考值 =  $2 \times 10^{-5}$  Pa；
- $L_w$ ：音功率級 (dB)，參考值 =  $10^{-12}$  W；
- Q：音源方向因子；
- r：音源距離 (m)；
- R：室常數 =  $\frac{S\alpha_{av}}{1 - \alpha_{av}}$ ；
- S：室內總面積( $m^2$ )；
- $\alpha_{av}$ ：室內平均吸音係數。

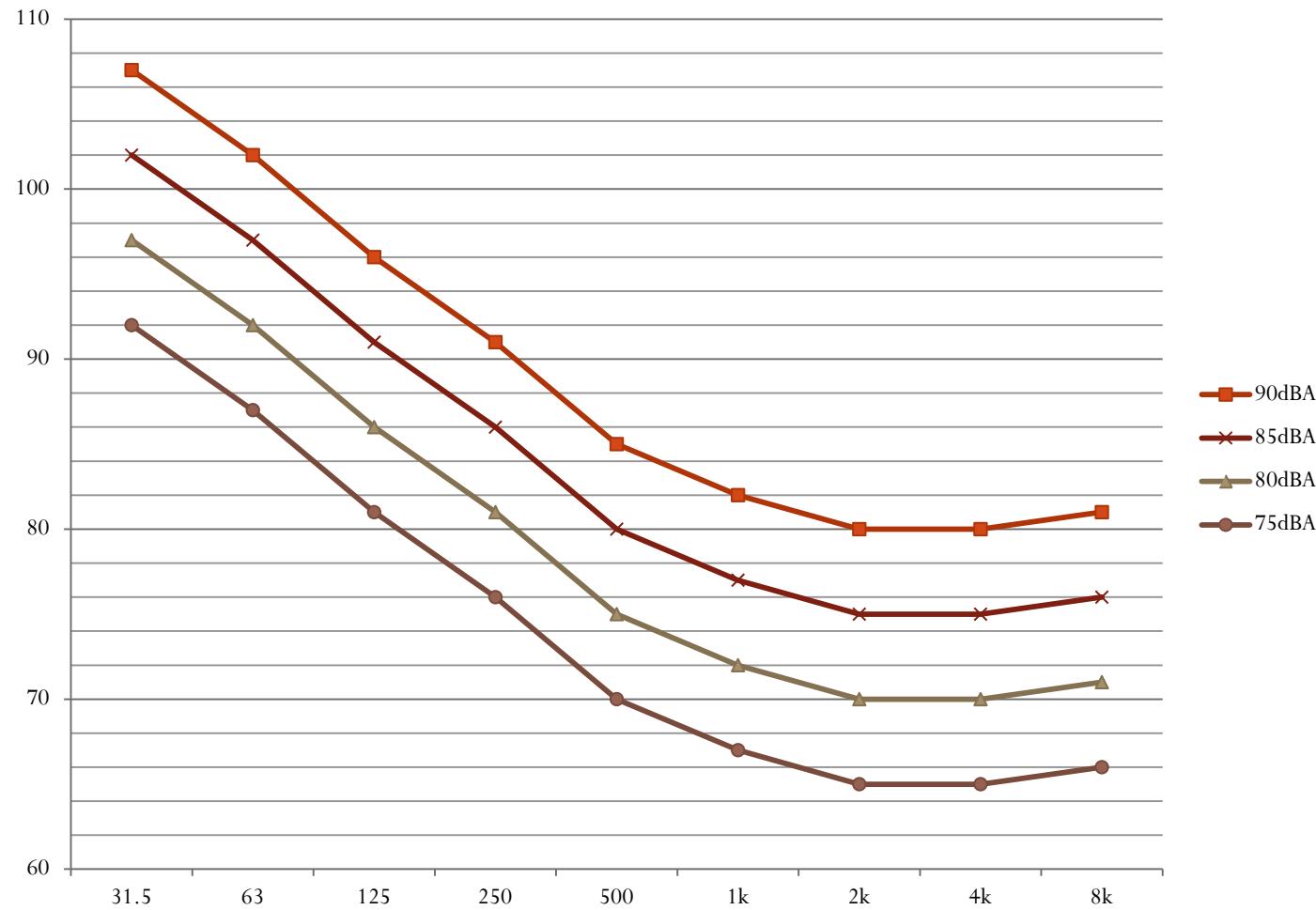
# 音源方向因子



# OSHA的目標線圖(90dBA)



# 目標頻譜圖



# 隔音箱選材計算

		31.5	63	125	250	500	1k	2k	4k	8k	備註
1	距離音源0.5米	80	82	84	87	86	93	88	80	81	
2	目標值	107	102	96	91	85	82	80	80	81	查圖表
3	降低量					1	11	8			
4	變動容許量					3	3	3			安全係數
5	迴響效應					15	15	15			計算所得
6	隔音箱TL值					19	29	26			

$$L_p = L_w + 10 \log \left[ \frac{Q}{4\pi r^2} + \frac{4}{R} \right] \quad R = \frac{S\alpha}{1 - \alpha}$$

改善前 R1與改善後 R2

$$L_p = L_w + 10 \log \left[ \frac{2}{4\pi(0.5)^2} + \frac{4}{R_1} \right] = L_w + 1$$

$$L_p = L_w + 10 \log \left[ \frac{2}{4\pi(0.5)^2} + \frac{4}{R_2} \right] = L_w + 16$$

迴響效應增加15分貝

某機械裝置在50x30x10m室內，房屋地板/天花板為混凝土且牆為磚造構成，運轉噪音達93dB，如使用鋼板建造3x3x3m之隔音箱將機械噪音隔離，使室內噪音降至85dB，請問如何選擇隔音材？

- 決定所需材料的TL

1.先算屋內 $L_{p1}$

$$\bar{\alpha} = \frac{(50 \times 30 \times 2 \times 0.02) + (30 \times 10 \times 2 \times 0.04) + (50 \times 10 \times 2 \times 0.04)}{3000 + 600 + 1000} = 0.027$$

$$R = \frac{4600 \times 0.027}{1 - 0.027} = 128m^2$$

$$L_{p1} = L_w + 10 \log \left[ \frac{2}{4\pi(1.5)^2} + \frac{4}{128} \right] = L_w - 9.9dB$$

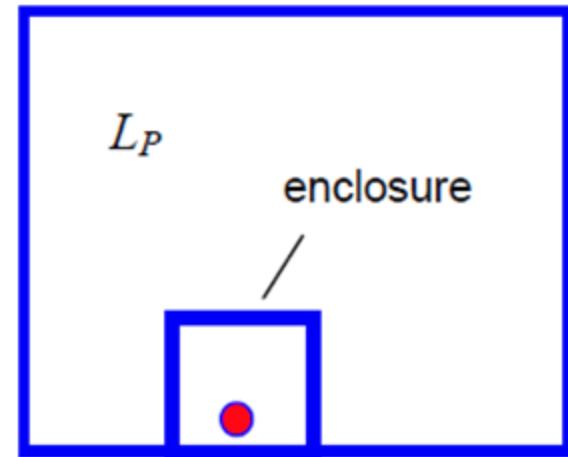
2.再算箱內 $L_{p2}$

$$R = \frac{54 \times 0.02}{1 - 0.02} = 1.1m^2$$

$$L_{p2} = L_w + 10 \log \left[ \frac{2}{4\pi(1.5)^2} + \frac{4}{1.1} \right] = L_w + 5.7dB$$

3.決定TL

$$TL = 8 + 5 + 15.6 = 28.6dB$$



承上例:如在隔音室內鋪設吸音材，有何差異？

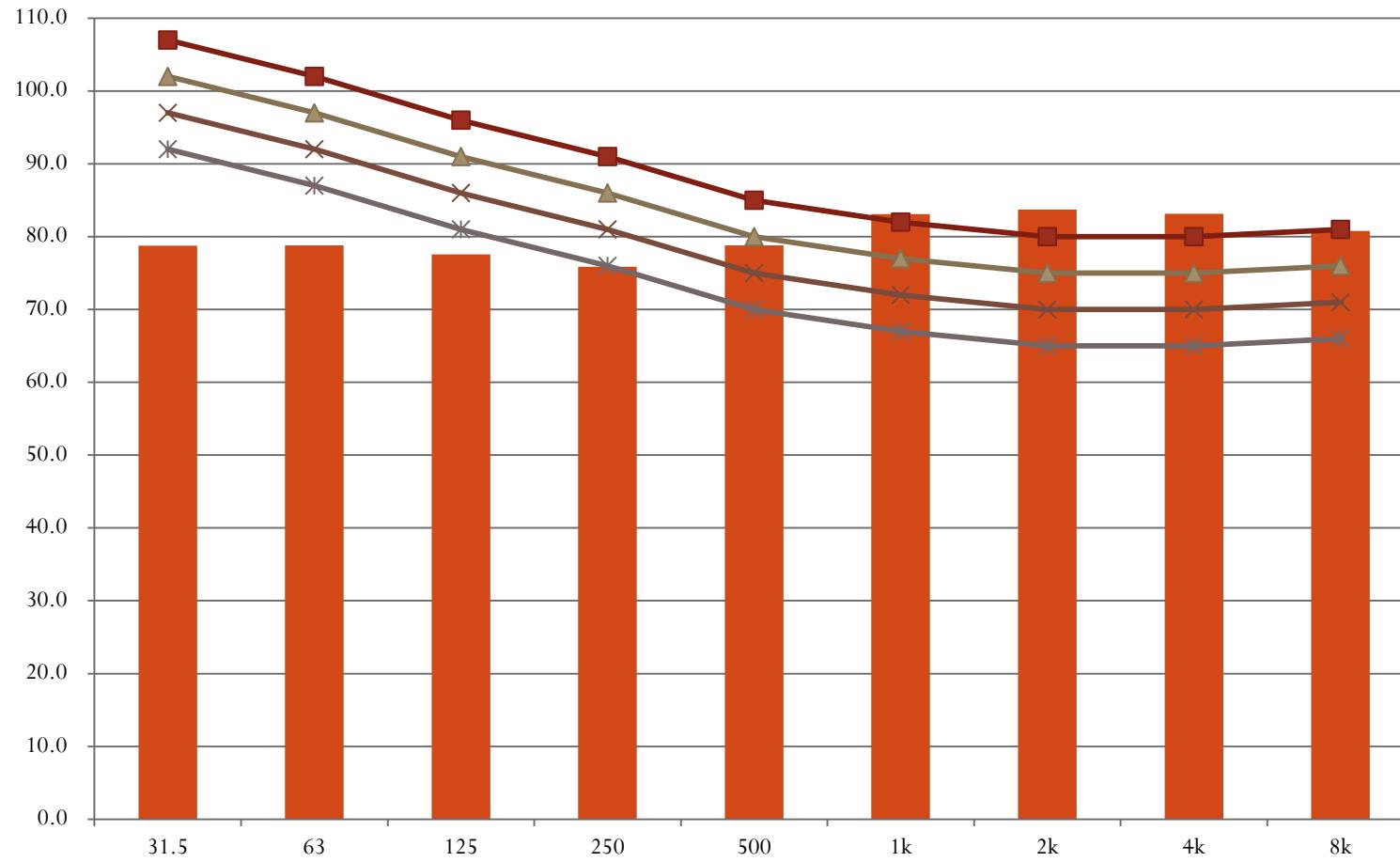
假設選用吸音係數為0.9的吸音材料，  
則隔音室內平均吸音係數變為

$$R = \frac{54 \times 0.9}{1 - 0.9} = 486m^2$$

$$L_{p2} = L_w + 10 \log \left[ \frac{2}{4\pi(1.5)^2} + \frac{4}{486} \right] = L_w - 11dB$$

$$TL = 8 + 5 - 1 = 12dB$$

# 噪音頻譜與目標值曲線



# 噪音與80dBA目標曲線之差值

	31.5	63	125	250	500	1k	2k	4k	8k
改善前	78.8	78.8	77.6	75.9	78.8	83.1	83.7	83.1	80.8
目標值	97	92	86	81	75	72	70	70	71
降低量	-	-	-	-	3.8	11.1	13.7	13.1	11.8
變動允許量					3	3	3	3	3
反射增強量							8.8		
所需TL量							25.5		

# 使用吸音材降低環境噪音

- 在反射效應較強的聲場環境，如以吸音材料改善，理論上達到的降噪效果，可以以下式估算：

$$NR = 10 \log \left( \frac{A_2}{A_1} \right)$$

式中  $A_1$  為改善前室內總吸音力(米沙賓)

$A_2$  為改善後室內總吸音力(米沙賓)

$NR$  為噪音降低量( $dB$ )

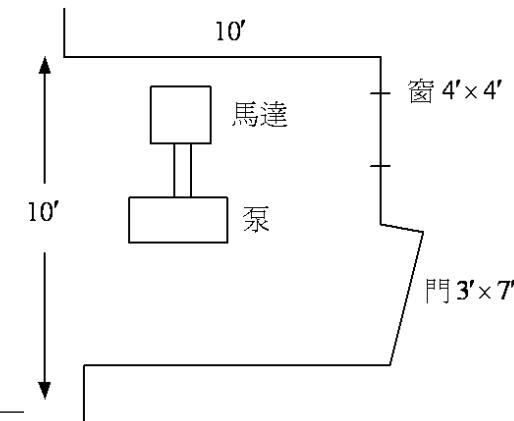
# 室內之聲音總吸收(吸音值)

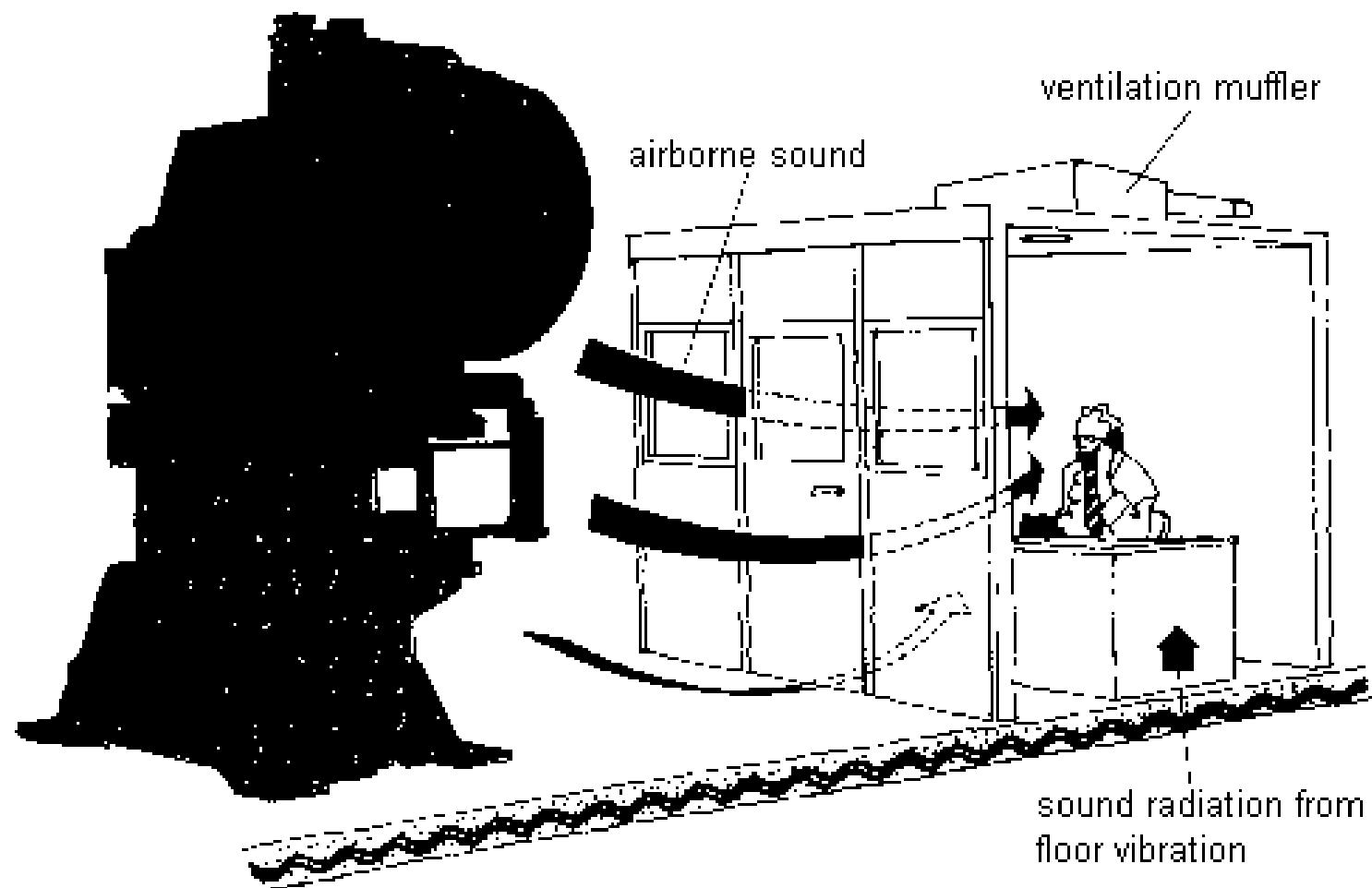
$$\begin{aligned} A &= \sum_{i=1}^n \alpha_i S_i \\ &= \alpha_1 S_1 + \alpha_2 S_2 + \dots + \alpha_n S_n \\ &= \bar{\alpha} S \end{aligned}$$

$$S = \sum_{i=1}^n S_i$$

# 吸音材改善案例

- 有一  $10' \times 10' \times 8'$  混凝土與磚牆構造小屋，內有馬達與抽水泵。小屋有一面牆為對外開放，另一面有玻璃窗與鐵門，如圖示。
- 在兩牆與天花板加鋪1'厚  $3\text{lb}/\text{ft}^3$  玻璃纖維板改善
- 改善前
  - 81(125Hz)、88(250Hz)、92(500Hz)、95(1kHz)、92(2kHz)、91(4kHz) dBA
- 改善後
  - 81(125Hz)、86(250Hz)、88(500Hz)、90(1kHz)、87(2kHz)、86(4kHz) dBA
- 噪音減少
  - 0、2、4、5、5、5 dBA





# 隔音室(Enclosure)

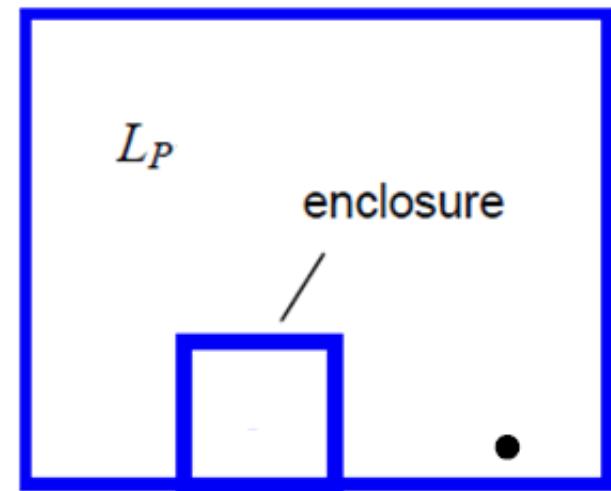
$$NR = TL - 10 \log \left( \frac{S_w}{R} + \frac{1}{4} \right)$$

式中  $NR$ 為隔音室內外的音壓級差( $dB$ )

$TL$ 為隔音室傳送損失( $dB$ )

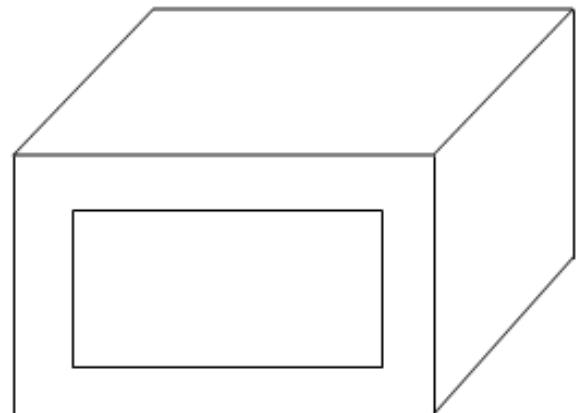
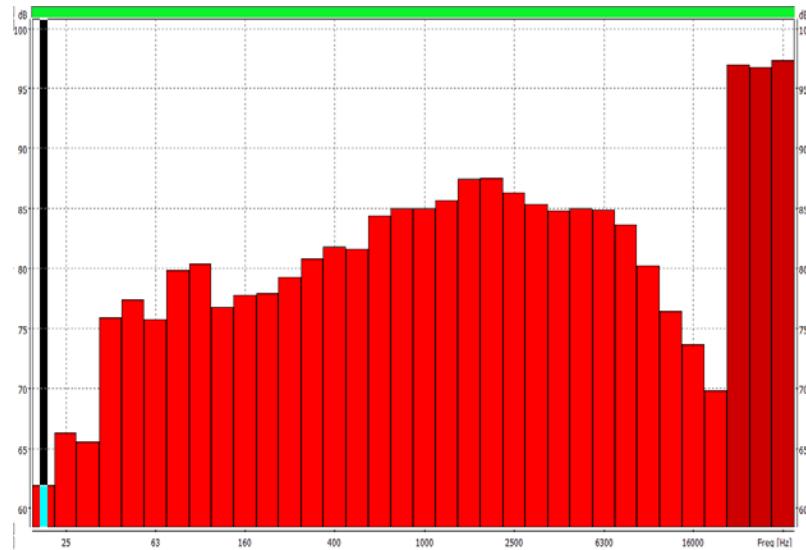
$S_w$ 為隔音室外部的暴露面積( $m^2$ )

$R$ 為隔音室內部的室常數( $m^2$ )



# 隔音室改善案例

- 某作業場所噪音高達97dBA，在該區域內建造隔音室( $15' \times 10' \times 8'$ )做為中控室或休息室，並使室內噪音在75dBA以下，以改善作業人員噪音暴露劑量。



- 中控室在500Hz之平均吸音係數(假如水泥地板 $\alpha=0.02$ 、泡棉天花板 $\alpha=0.60$ 、合板牆壁 $\alpha=0.17$ 、玻璃窗 $\alpha=0.04$ ) 計算如下：
  - 平均 $\alpha = [(15 \times 10 \times 0.02) + (15 \times 10 \times 0.60) + (10 \times 8 \times 2 \times 0.17) + (15 \times 8 \times 0.17) + (10 \times 4 \times 0.04) + (80 \times 0.17)] / (240 + 160 + 300) = 0.22$
  - $R = (700 \times 0.22) / (1 - 0.22) = 197$
  - $22 = TL - 10 \log(1/4 + 550/197) = TL - 4.8$
  - $TL = 26.8 \text{ dB}$

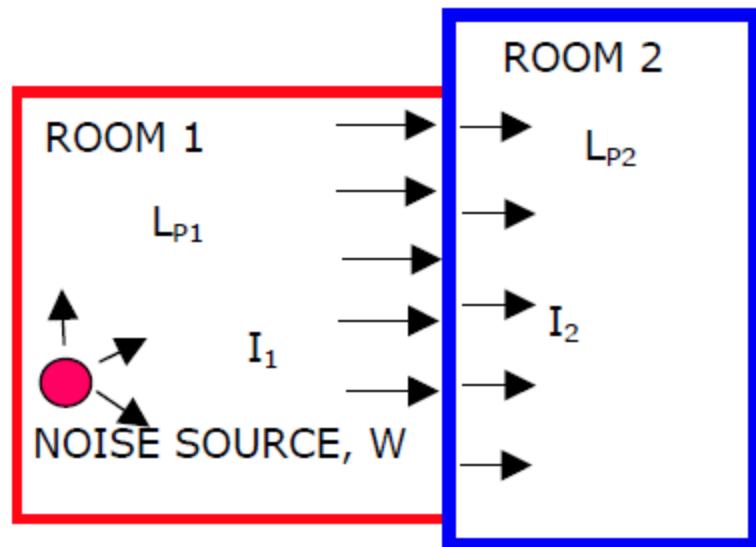
		125	250	500	1k	2k	4k	8k
1	目前噪音頻譜	83	83	87	89	90	90	88
2	改善目標(75dBA)	81	76	70	67	65	65	66
3	降噪分貝數	2	7	17	22	25	25	22
4	噪音變動量	5	5	5	5	5	5	5
5	NR需求值	7	12	22	27	30	30	27
6	中控室內反射增加量 (計算過程如下)		4.6	4.8	4			
7	TL需求值		16.6	26.8	31			

# 傳送損失(TL)與噪音減少值(NR)

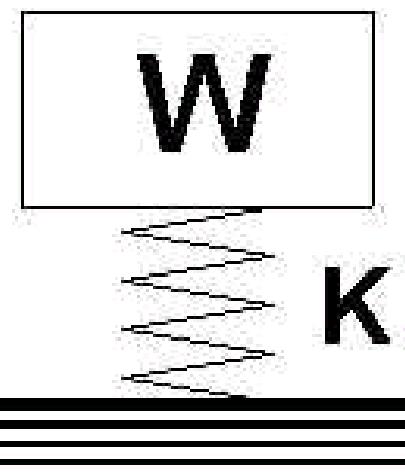
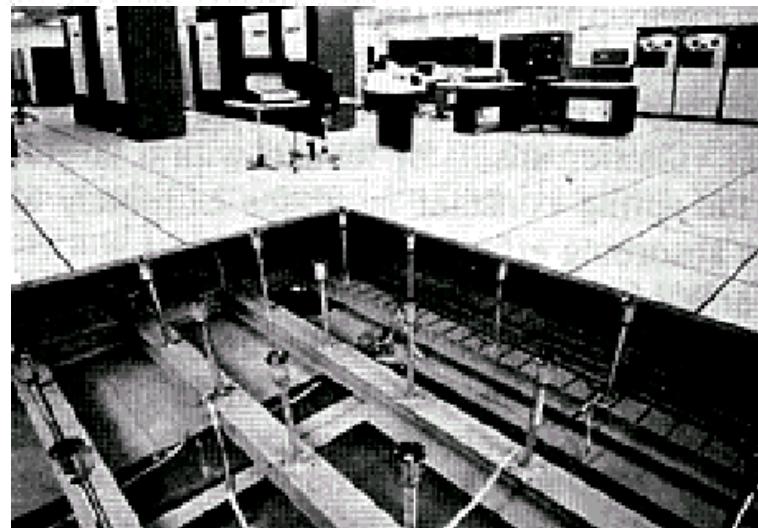
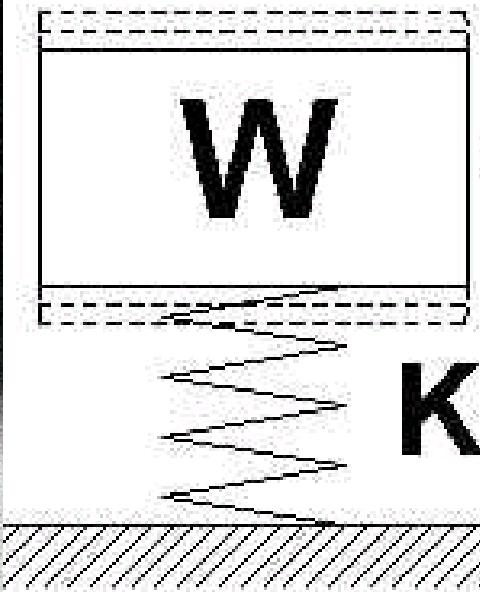
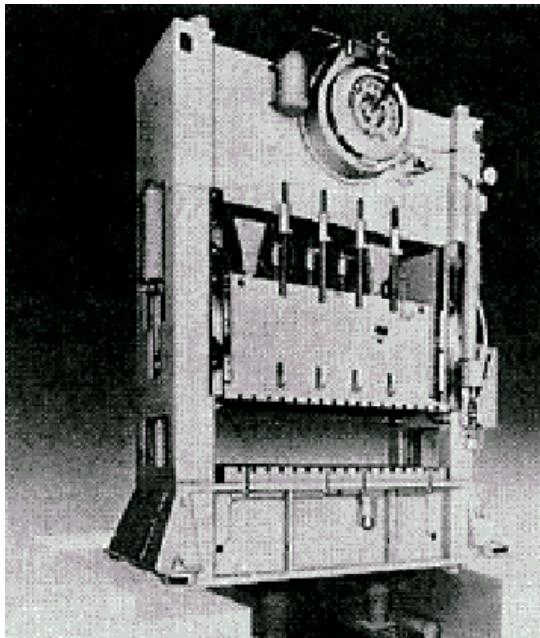
$$NR = TL + 10 \log \frac{A}{S}$$

A: 接收室的吸音力( $m^2$ )

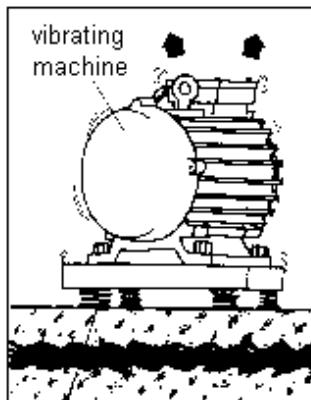
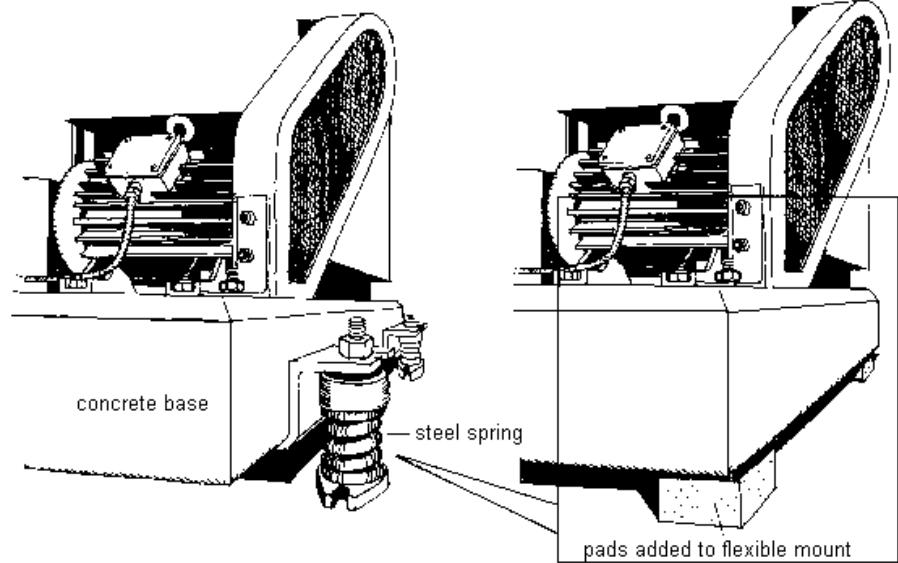
S: 牆面積( $m^2$ )



# 振動隔絕



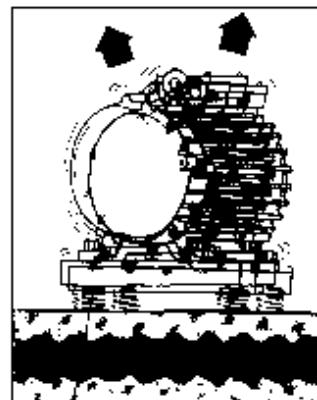
# 錯誤的選擇 將擴大振動



springs without  
internal damping

vibration frequencies  
lower than fundamental  
frequency

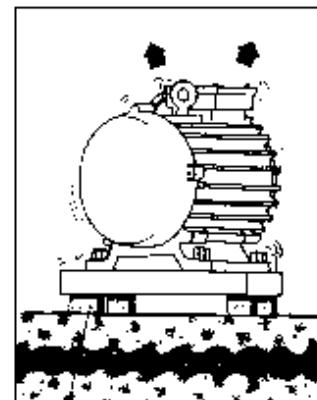
no isolation



springs without  
internal damping

vibration frequency close  
to fundamental frequency

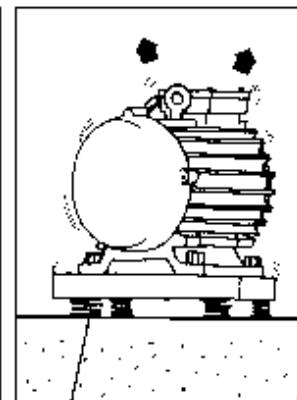
dangerous reinforcement  
of vibrations



springs with good  
internal damping

vibration frequency close  
to fundamental frequency

no isolation

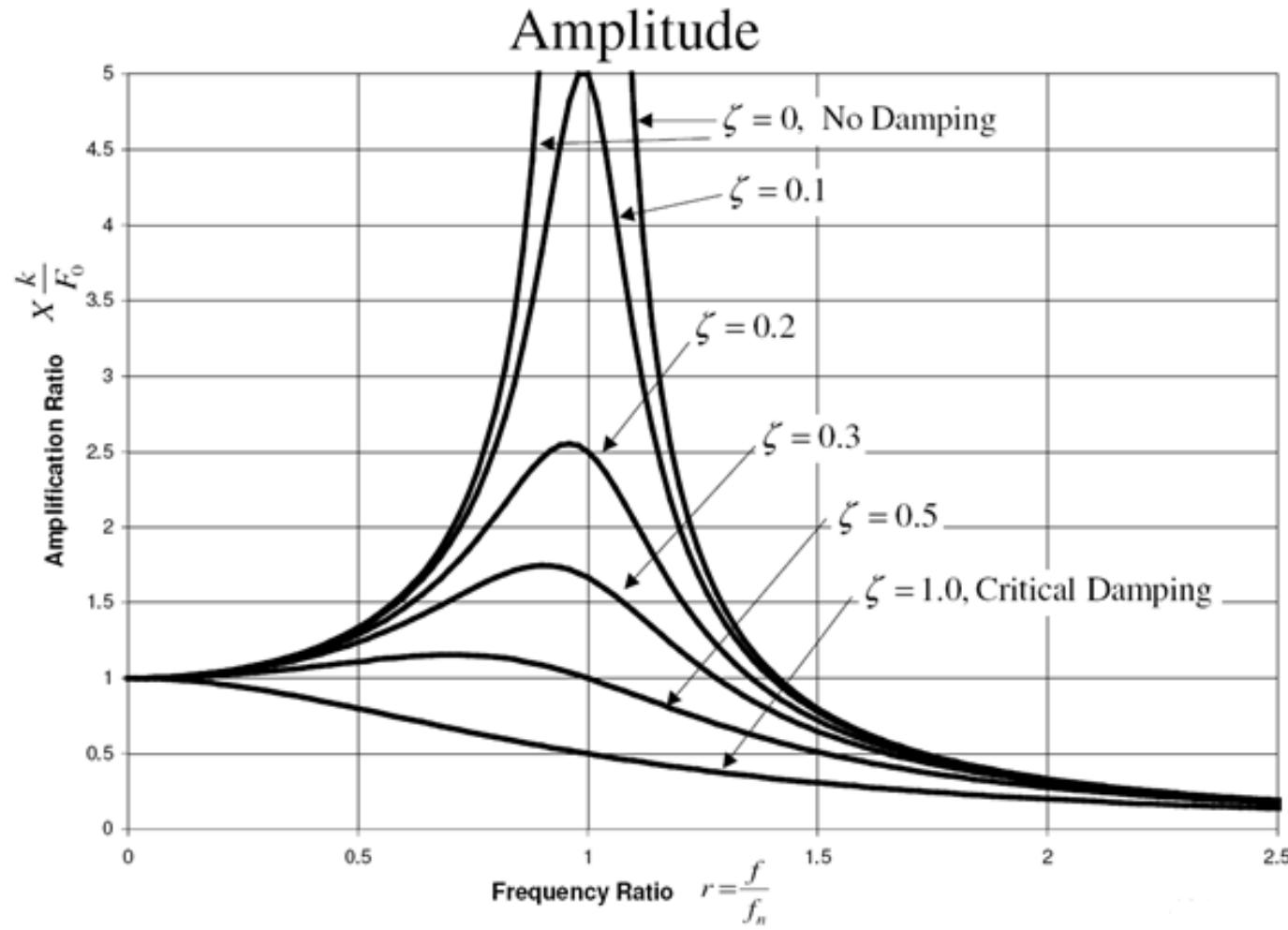


springs without  
internal damping

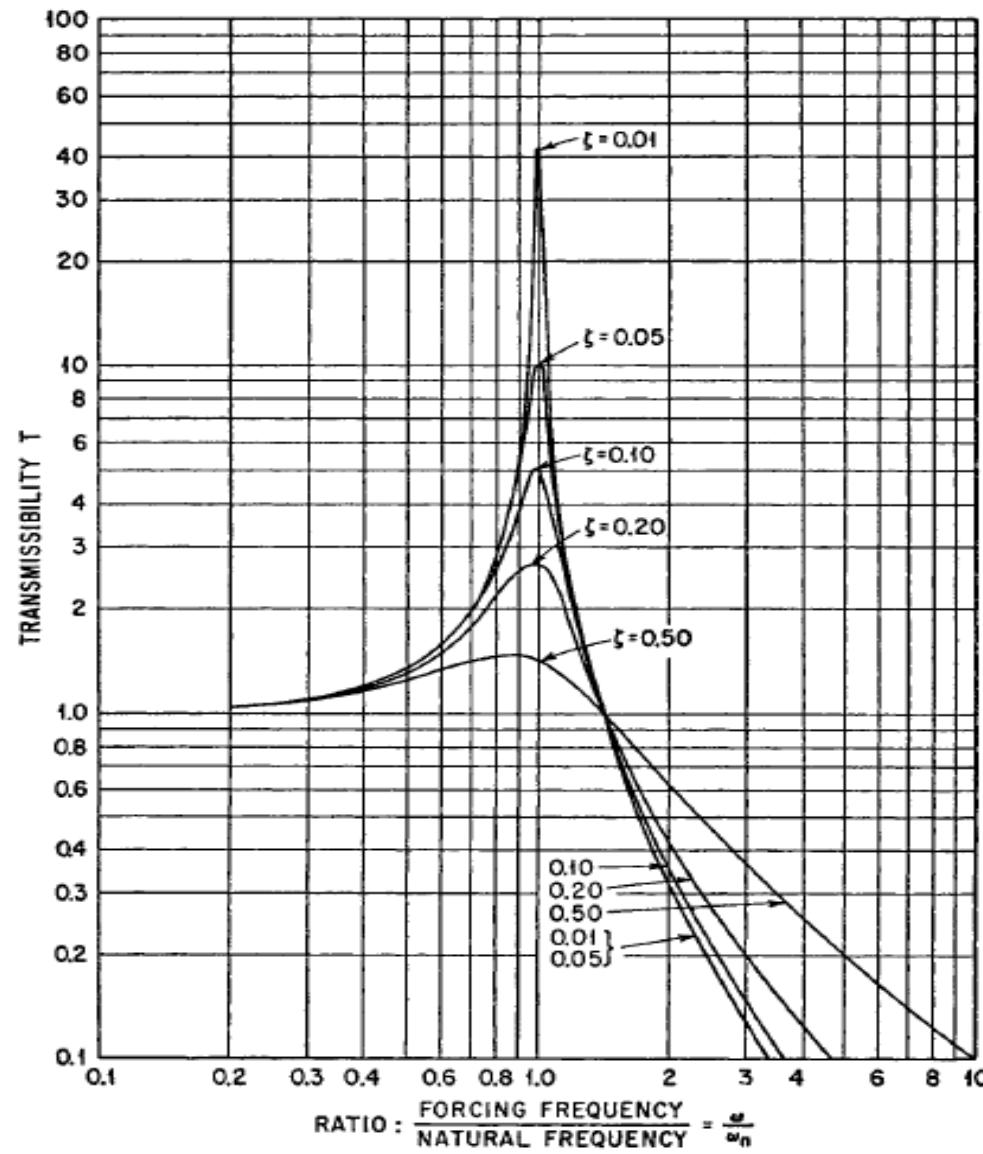
vibration frequency  
higher than fundamental  
frequency

good isolation

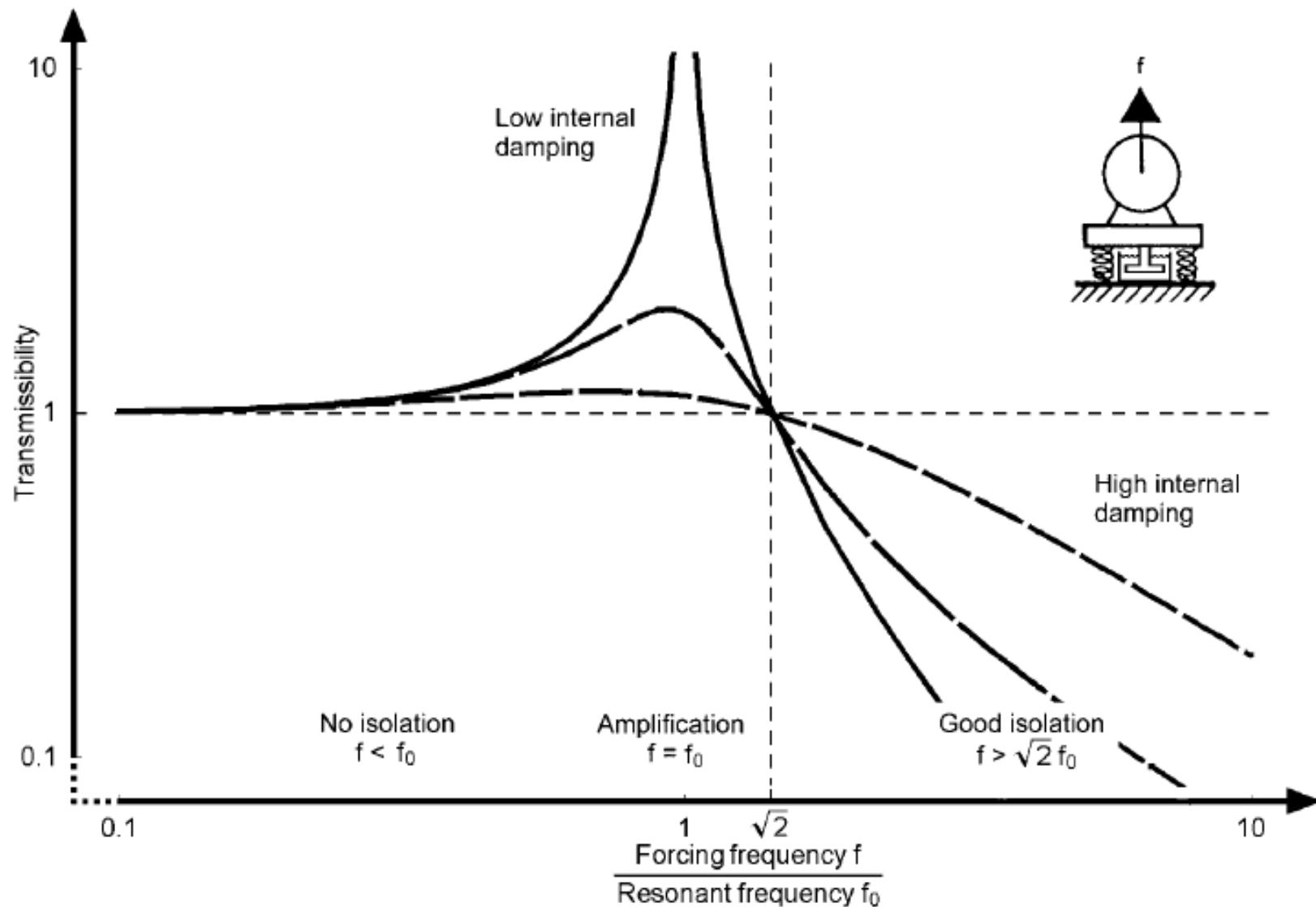
# 阻尼強迫振動系統的反應



# Transmissibility Curves



# 隔振設計



感謝聆聽  
敬請指教

Thank you for your attention!