k. CALCULATING AXIAL BLADE SOUND FREQUENCIES

The formula below determines the dominant sound frequency from a rotating fan. Since the units for frequency are cycles per second, the formula is a simple calculation based on the number of "passes" each fan blade makes in one second. Fan motors and duct vibration also generate noise of a specific sound frequency.

FORMULA:

$$F = \frac{N \times RPM}{60}$$

where: F = sound frequency, cycles/sec (Hertz)
N = number of fan blades
RPM = revolutions per minute

PROBLEM:

A five-blade axial fan rotates at 1,800 revolutions per minute. What is the main sound frequency generated?

SOLUTION:

1. Substitute and solve:

$$F = \frac{5 \times 1800}{60}$$

2. Solution

$$F = \frac{9000}{60}$$

$$F = 150\ Hz$$

ANSWER:

A 5 blade fan rotating at 1,800 revolutions per minute will generate a noise having a frequency of 150 Hertz.

PROBLEM SET:

Noise Measurements

Note: Since measurement instruments are generally accurate to only 1 dB, or perhaps 0.5 dB, give your answers to the nearest whole decibel.

1. Given an rms sound power of 0.855 watts, calculate the sound pressure level in decibels.

2. Determine the sound power in watts for a 105 dB noise source (re. 10^{-12} watts).

3. How many watts of sound power is generated from a 97 dB source?

4. Given a pressure of 2,500 microbars, calculate the sound pressure level in decibels.

5. Calculate the sound pressure level corresponding to a pressure of 1 Newton per meter squared,

6. What is the sound pressure in microbars for a 105 dB noise source?

7. What is the sound pressure in Newtons per meter squared for a 105 dB noise source?

8. If the industrial hygienist wishes to reduce the sound pressure (measured in N/m^2) of a machine at 99 dB by half, what would the new sound pressure level.

9. Six compressors each generate 85 dBs each at a point equidistant from all of them. If all six are operating, what is the SPL?

10. A recent gathering of 465 industrial hygienists in a large reception hall with carpeting and sound absorbing walls generated a sound pressure level of 88 dB to an observer high above the ballroom floor. Calculate the average speaking volume of each participant assuming 1 out of every 3 was talking and all were equidistant from the observer.

11. The noise in a large printing facility which contains four operating printers measures 96 dB. If the four printers are the main source of noise and are equidistant from the measuring instrument, determine the dBA of each unit.

12. The SPL in a textile plant is 94 dBA. If an inspector sits equidistant from all the machines and each machine emits 84 dBA where he is sitting, how many machines are operating?

13. Using the table method, if an impact press generating 101 dBA is installed in the same room as a compressor at 102 dBA and a high pressure washer at 95 dBA, calculate the final SPL if each machine is operating at the same time.

14. Using the formula, determine the SPL when two machines in close proximity to each other are operating at 90 dBA and 100 dBA respectively.

15. Using the formula, determine the total SPL when 4 machines in close proximity to each other are individually operating at 91 dBA , 94 dBA, 98 dBA, and 100 dBA.

16. Using the tabular method, determine the total SPL when two machines in close proximity to each other are operating at 90 dBA noise and 100 dBA noise respectively.

17. If the SPL from a point noise source is 100 dB at 15 feet, what is the SPL at 10 feet?

18. The space shuttle generates 145 dB at 50 feet, how far must a person stand to stay within the OSHA 8 hour maximum allowable noise level (i.e., 90 dB) ?

19. If the SPL of a point source is 90 dBa at 6 inches, what is the SPL at 10 feet?

20. How far do you need to go from a point source to reduce a 105 dBA SPL at 6 in. to 84 dBA?

21. The manufacturer of a particular brand of ear muffs certifies a noise reduction rating of 19 dB. Calculate the field attenuation (with a 50% safety factor).

22. An employer needs to reduce noise exposure so that an employee can work on a machine generating 117 dBA for 1 hour. What noise reduction rating should the employer seek to stay within allowable limits and have a 50% safety factor?

23. Ear muff having a NRR of 10 are technically acceptable for 8 hour exposure of up to how many dB?

24. Calculate the permissible OSHA exposure period in hours for a constant 97 dBA sound source.

25. Calculate the permissible OSHA exposure period in hours for a constant 110 dBA sound source.

26. If a worker can be exposed to loud noise for only 2.5 hrs, what is the maximum dBA he may be exposed to during this period.

27. The dosimeter reading after an 8 hour noise exposure evaluation was 150. Determine the TWA equivalent SPL.

28. The dosimeter reading after an 8 hour noise exposure evaluation was 0.37. Determine the TWA equivalent SPL.

29. If a worker is exposed to 90 dBA for 6 hr, what is her maximum permissible noise exposure for the remaining 2 hours of the shift?

30. If a worker is exposed to 2 hr at 85 dBA, 1 hr at 90 dBA, 4 hr at 88 dBA and 1 hr at 100 dBA, has the OSHA noise exposure standard been exceeded?

31. Given an exposure profile of; 1 hr at 90 dBA, 1 hr at 95 dBA, 4 hr at 88 dBA and 2 hr at 100 dBA, has the OSHA noise exposure standard been exceeded?

32. If a worker has been exposed for 2 hr at 95 dBA at the beginning of the workshift, for how many hours can the person be exposed to 100 dBA that same day?

33. A 4 blade aircraft propeller rotates at 26,000 revolutions per minute, what is the sound frequency?

34. What is the fan speed in RPM, if a 16 blade fan generates 1,015 Hertz?

35. ACGIH guidelines for 120 dB impact noise is not more than 10,000 impacts per day. Assuming a 8 hour workday with 0.5 hr lunch break and a constant impact rate, what is the average time interval, in seconds, between impacts during the working hours?

ANSWERS TO PROBLEMS

Noise Measurement

1. **119 dB** – Substitute values in either form of the sound power formula and solve. [10 Log (0.855 ÷ 10^{-12})]. Answer: 119 dB.

2. **0.0316 Watts** – Substitute values in the short form of sound power formula, rearrange. [(105 - 120) ÷ 10 = Log w]. Take the antilog of both sides and solve $10^{(105-120)\div10}$ Answer: 0.316 watts.

3. **0.00501 Watts** – Substitute values in the short form of sound power formula, rearrange. [(97-120) ÷ 10 = Log w] Take the antilog of both sides and solve $10^{(97-120)\div10}$ Answer: 0.00501 watts.

4. **142 dB** – Since the pressure is given in microbars, use 0.0002 microbars as the reference value. Substitute values in either form of the sound pressure level formula and solve. Using the standard formula, 20 Log (2,500 ÷ 0.0002). Answer: 142 dB.

5. **94 dB** – Since the pressure is given in N/m^2, use 0.00002 N/m^2 as the reference value. Substitute values in either form of the SPL formula and solve. Using the standard formula, 20 Log (1÷ 0.00002). Answer 94 dB.

6. **35.5 microbars** – Either formula can be used. Substituting the values in the simplified (microbars) formula yields: 105 = 20 Log *p* + 74 or after rearranging: $10^{(105-74)\div20}$. Answer: 35.5 microbars.

7. **3.55 N/m^2** - Either formula can be used. Substituting the values in the simplified (Newtons/m^2) formula yields: 105 = 20 Log *p* + 94 or after rearranging: $10^{(105-94)\div20}$. Answer: 3.55 N/m^2.

8. **93 dB** – Long method: Determine the pressure a 99-dB noise produces in N/m^2 and divide this value by 2. Take this pressure and calculate the new SPL. Step 1: ($10^{(99-94)\div20}$) ÷ 2 = 0.8891. Step 2: SPL = Log 0.8891 + 94.

Answer: 93.0. Short method: Pressure doubles, add 6 dB or pressure halved, subtract 6 dB. [99 - 6]. Answer: 93 dB

9. **93 dB** – Substitute in formula and solve. [85 + 10 Log 6] Answer: 92.8 dB

10. **66 dB** – (Many assumptions must be made if this problem is to be solved using the multiple identical source formula. Lets make them all.) First determine how many people are talking, 465 ÷ 3 = 155. Substitute values, rearrange formula and solve. [88 = SPL_i + 10 Log 155] or [88 - 21.9] Answer: 66.1 dB

11. **90 dB** – Substitute values, rearrange formula and solve. 96 = SPL_i + 10 Log 4 or 96 - 6.02 = SPL_i. Answer: 90.0 dB

12. **10 machines** – Substitute value, rearrange formula and solve. 94 = 84 + 10 Log x or $10^{(94-84)\div 10}$. Answer: 10 machines.

13. **105 dB** – Start with the 2 highest SPL's. Subtract them and determine the amount added to the higher SPL using the table. 102 - 101 = 1, at a difference of 1 dB, add 3 dB's to higher value. Intermediate answer, 102 + 3 = 105. Using 105 dB, evaluate the incorporation of a 95 dB noise using the same approach [105 - 95 = 10]; at a difference of 10 add 0 to higher value. Answer: 105 dB.

14. **100 dB** – Substitute values in formula and solve. 10 Log ($10^{90\div 10}$ + $10^{100\div 10}$) or 10 Log (1.1×10^{10}) or 10 × 10.04. Answer: 100.4 or 100 dB.

15. **103 dB** – Substitute values in formula and solve. 10 Log ($10^{91\div 10}$ + $10^{94\div 10}$ + $10^{98\div 10}$ + $10^{100\div 10}$) or 10 Log (2.008×10^{10}) or 10 × 10.30. Answer: 103 dB.

16. **100 dB** – Subtract and evaluate the difference using the table. In this case, 100 – 90 = 10. At a difference of 10, nothing is added to higher value. Therefore the sound pressure level, practically speaking, remains unchanged. Answer: 100 dB.

17. **104 dB** – Substitute in distance formula and solve. 100 + 20 Log (15 ÷ 10), Answer: 103.5 or 104.

18. **28,120 feet** – Substitute in distance formula, rearrange and solve. $90 = 145 + 20 \text{ Log } (50 \div x)$, or $x = 50 \div (10^{(90-145)/20})$ Answer: 28,117 or 28,120 ft.

19. **64 dBA** – Substitute in distance formula and solve. 90 + 20 Log (0.5 ÷ 10), Answer: 63.9 or 64 dB

20. **5.61 feet** – Substitute in distance formula, rearrange and solve. $84 = 105 + 20 \text{ Log } (0.5 \div x)$, or $x = 0.5 \div (10^{(84-105)/20})$. Answer: 5.61 ft.

21. **6 dB** – Substitute values in field attenuation formula and solve; (19 - 7) ÷ 2 Answer: 6 dB.

22. **31 dB** – Look up or calculate the OSHA noise standard for a 1 hour exposure period. Answer: 105 dB. Determine the reduction necessary; 117 db - 105 db equals 12 dB. Substitute this value in formula and rearrange to determine the approximate field attenuation. 12 = (NRR - 7) ÷ 2. Solving for NRR the Answer: 31 dB.

23. **93 db** – The use of the phase "minimally acceptable by law" implies not using the recommended safety factor. Therefore simply subtract 7 db from the NNR to achieve the attenuation factor (10 - 7 = 3). Add this number to the 8 hour OSHA maximum (90 db + 3 dB). Answer: 93 dB.

24. **Approximately 3 hours** - Substitute the values in the formula and solve. $8 \div 2^{(97 - 90)/5}$. Answer: 3.03 hours.

25. **0.5 hour** - Substitute the values in the formula and solve. $8 \div 2^{(110 - 90)/5}$. Answer: 0.5 hour.

26. **98 dB** - Substitute the values in the formula and solve. $2.5 = 8 \div 2^{(x - 90)/5}$ Hint: take the log of both sides of the equation to remove the exponent. (Log 2)(x – 90 / 5) = Log 8 / 2.5). Answer: 98.39 or 98 dB.

27. **93 dB** – Substitute values in TWA equivalent formula and solve. [90 + (16.16 × Log (150/100))]. Answer: 92.9 or 93 dB.

28. **83 dB** – Since the value is already in decimal form, substitute in simplified formula and solve. [90 + (16.61 × Log 0.37)]. Answer: 82.8 or 83 dB.

29. **90 dBA** – This can be logically deduced or solved by using the equation. Logically, it can be seen that 6 hours at 90 dB is close to the maximum. Another 2 hours at 90 dB will reach the maximum exposure limit. Using the equation, simply substitute and solve. Use a DND value of 1, since you are evaluating exposure up to the maximum. 1 = (6/8) + (2/x), x = 8. Therefore the dB whose exposure time equals 8 hours is 90 dB.

30. **No, DND = 0.625** – First eliminate assessing the exposure at 85 and 88 dB. There are no exposure limits for these dBs. Next, substitute values into formula and solve. The denominator for the 90 dB sound is 8 and for the 100 dB sound it is 2. Therefore, the problem becomes DND = (1/8) + (1/2). Answer: 0.625.

31. **Yes, DND=1.375** – The answer should be obvious given that at 100 dB the maximum exposure has been reached. However if you wish to solve it using the formula proceed by eliminating from consideration the exposure at 88 dB. Next, substitute values into formula and solve. The denominator for the 90 dB sound is 8, the 95 dB is 4 and the 100 dB sound it is 2. Therefore, the problem becomes; (1/8) + (1/4) + (2/2). Answer: 1.375.

32. **1 hour** – Using the equation, simply substitute and solve. Use a DND value of 1, since you are evaluating exposure up to the maximum allowable. 1 = (2/4) + (x/2). Answer: 1.

33. **1,730 Hertz** – Substitute values in formula and solve. Answer: 1,733 or 1,730 cycles per second or Hertz

34. **3,800 revolutions per minute** – Substitute values, rearrange formula and solve. (1,015 × 60) ÷ 16. Answer: 3,798 or 3,800 RPM

35. **2.70 seconds** – Assess only 7.5 hours. Convert 7.5 hours into seconds. Answer 27,000 seconds. If 10,000 impacts occur in 27,000 seconds, how many seconds are there between each (1) impact. Answer: 2.70. Note: this does not mean each impact will last 2.70 seconds; the frequency of the impact noise is 1 per 2.70 seconds.