# INDUSTRIAL HYGIENE REVIEW MANUAL


## DEVELOPED BY

## UNIFORMED SERVICES UNIVERSITY of the HEALTH SCIENCES

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES ■ Public Health Service
Centers for Disease Control ■ National Institute for Occupational Safety and Health

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Division of Training and Manpower Development

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National Institute for Occupational Safety and Health
Cincinnati, Ohio 45226
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## Disclaimer

The material in this publication was collected from various sources in order to present as wide a range of information on the subject as possible; thus, the opinions and conclusions expressed are not necessarily those of the National Institute for Occupational Safety and Health.

## Preface

This publication is the result of a joint effort between the National Institute for Occupational Safety and Health (NIOSH) and the Uniformed Services University of the Health Sciences (USUHS). Its formulation was promoted by Mr. Frank Mackison, NIOSH Division of Standards Development and Technology Transfer, and Dr. Jack Berberick, NIOSH Curriculum Development Branch, in cooperation with the authors indicated below.

The manual was developed for industrial hygienists as a review guide for the multiple subjects encompassed by the career field. The study outlines detail those aspects of each subject with which industrial hygienists should be familiar. These outlines are supported by questions and answers representative of subject knowledge typically employed in the field. Questions and answers were collected from a wide variety of sources to provide a broad view of industrial hygiene. The material was initially gathered to support USUHS' Industrial Hygiene Review Course sponsored by the Department of Environmental Health and Occupational Safety and the Department of Preventive Medicine and Biometrics. Additional questions were prepared by course instructors to highlight certain learning points.

The final outlines, questions, and answers were reviewed by consultants and course lecturers. Reviewers are identified for each section of the manual. The content of the answer discussion should be viewed as the opinions of independent professionals rather than the official position of the authors' or reviewers' employers.

The goal of this manual is to provide a review compendium for practicing industrial hygienists. While many individuals will find the material useful in preparation for industrial hygiene certification examinations, its primary purpose is to serve as a much broader learning tool. It should not necessarily be regarded as representative of material likely to be encountered on certification examinations. The American Board of Industrial Hygiene has reviewed the USUHS material and concluded that their examination is not compromised. The Board agrees that its use will be helpful in examination preparation.

We would like to thank those professionals recognized in the manual whose expertise was offered in this endeavor. Further appreciation is extended to Ms. Melissa Leff for her effort in compiling this publication, and to Ms. Kathleen Patrone for editing the final copy.

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## Review Questions

1. In cyanide electroplating of brass, which of the following components of the plating bath may be released into the atmosphere?

   a. HCl, HBr, $H_2O$
   b. Zn salts, KOH, $H_2O$
   c. Cyanide salts, $NH_4OH$, $H_2O$
   d. MFL + NaOH + $H_2O$

2. Which of the following gases is least soluble in water?

   a. $NH_3$
   b. HCl
   c. HF
   d. $SO_2$
   e. $CF_4$

3. Which of the following would react with a strong oxidizing agent?

   a. $SiO_2$
   b. $H_2O$
   c. $O_2$
   d. Fe
   e. Asbestos

4. For the decomposition process defined by the following reaction, what volume hydrogen gas will be evolved if 17 grams of ammonia is decomposed?

$$2\ NH_3 \longrightarrow 2N_2 + 3\ H_2$$

5. Strong oxidizing agents:

   a. react quickly and violently with bases
   b. cause serious burns and damage to the respiratory tract
   c. are rarely encountered in the chemical process industries
   d. can be safely stored in steel cans

6. The chemical component of smoke tubes used for ventilation studies is:

   a. vanadium pentoxide
   b. titanium tetrachloride
   c. stannous chloride
   d. ammonium chloride
   e. dioctyl phthalate

7. The handling of ethyl ether involves severe explosive hazards because of its:

   a. high vapor pressure
   b. low flash point
   c. peroxide formation

d. more than one of the above
e. all of the above

8. Mercury vapor is best absorbed by:

a. activated charcoal
b. activated charcoal impregnated with iodine
c. activated charcoal impregnated with $CuSO_4$
d. calcium chloride
e. caustic soda solution

9. Which of the following has the lowest boiling points?

a. ethyl chloride
b. methyl chloride
c. methylene chloride
c. carbon tetrachloride
e. ethylene dichloride

10. Which of the following is an organophosphate?

a. phosphoric acid
b. TCP
c. ammonium phosphate
d. a and c above
e. none of the above

11. HCN and nitriles are members of which larger class?

a. simple salts of HCN
b. halogenated compounds
c. nitriles
d. all of the above
e. two of the above

12. Which of the following chemicals is not a solvent in the application identified?

a. alcohols used in paint clean-up
b. epoxy used in foundry coremaking
c. ketones used in paint spraying
d. hydrocarbons used in metal cleaning

13. A respirator filled with activated carbon should be effective in which of the following situations:

a. low concentrations of $NO_2$
b. low concentrations of CO
c. oxygen deficient atmospheres
d. zinc oxide fume
e. none of the above

14. How many ml of a liquid, specific gravity 0.83, M.W. 100, must be vaporized in a chamber 5 x 5 x 4 ft, to obtain a concentration of 100 ppm?

15. Given two spectrophotometer readings from two solutions and the known equivalent molar concentrations, how would you determine the molar concentration of an unknown solution from its spectrophotometer reading?

16. Glacial acetic acid should:

    a. be stored with concentrated nitric acid
    b. be kept refrigerated
    c. be stored with flammables
    d. be stored with acids and bases
    e. requires no special storage considerations

17. The pressure in a closed gas cylinder is doubled as a result of heating. If the original ambient temperature had been 25°C, what is the new temperature?

18. Complete the following table for a gas dispersed in another gas. Assume STP.

| Container Volume, $m^3$ | Total Mass Dispersed, mg | Mass conc. $mg/m^3$ | Dispersed Gas Molecular Wt. | ppm |
|---|---|---|---|---|
| 10 | 1 | -- | 100 | -- |
| 100 | -- | -- | 50 | 500 |
| -- | 100 | 100 | 100 | -- |
| 10 | -- | 0.1 | -- | 10 |

19. What property or properties of activated carbon make it a good medium for collecting samples?

20. Why does water pressure increase with depth and air pressure decrease with height?

21. What is the inverse square law?

22. A room temperature 3000 gallon surge tank used for line storage in a manufacturing process is located in a building separate from the manufacturing process. The tank breathes through a vent at the top and during a 200-min filling cycle fills at a rate of 15 gpm. The vapor pressure of the liquid is 75 mm Hg.

    a. What volume of air is necessary for dilution of each volume of gas which escapes upon filling if the concentration after dilution cannot exceed 200 ppm?

    b. Assuming good mixing, what minimum rate of general ventilation is required to avoid exceeding 200 ppm?

23. Room air at 70°F is exhausted at a rate of 100 cfm per enclosure for each of 10 enclosures where enamel frit is fused. What volume of 600°F exhaust air must the exhaust fan handle?

24. What is the molar volume at 300°C, 0.95 atmospheres (liters)?

25. You have determined that the concentration of a material is 100 $mg/m^3$ by using a pump calibrated to deliver 1.0 L./min. to an adsorption system. You later discover the pump actually delivered 1.5 L./min. What is the corrected concentration?

26. Chemical x with a molecular weight of 88 evaporates from a chemical process. Where would this material be most likely to accumulate?

    a. floor
    b. ceiling
    c. will mix uniformly
    d. insufficient information

27. Given a mercury in urine result of 0.14 mg/ml and a sample specific gravity of 1.016, what would the result be corrected to a sp. g. of 1.024?

28. How many liters of air must be collected to detect acrolein, $CH_2 = CHCHO$, at its OSHA exposure limit of 0.1 ppm if the lowest sensitivity of the measurement method is 1 mg?

29. The vapor pressure of mercury at 77°F is 0.0018 mm HG. What is the equilibrium concentration of mercury in a closed space containing a mercury pool?

30. Concentrations of gases and vapors are commonly expressed as:

    a. ppm by weight
    b. ppm by volume
    c. mppcf
    d. particles per million

31. 1 gram molecular weight of a gas at 25°C 760 mm Hg pressure occupies what volume in liters?

32. $(x-3)/2 = (y+4)/4$. If $x = 4$, $y = ?$

33. Convert 76°F to °R, °C, °K.

34. What is the volume in liters of 1 gal of liquid water when converted to vapor at 70°F, 1 atmosphere?

35. An m-xylene paint stripper tank has been found to contain 100 ppm benzene in the stripping liquid. Is the benzene TLV exceeded in the vapor above the tank? Assume saturation and that the tank and the below data all refer to 20°C.

| | Benzene | Xylene |
|---|---|---|
| Molecular Formula | $C_6H_6$ | $C_8H_{10}$ |
| Specific Gravity | 0.88 | 0.86 |
| Vapor Pressure, mm Hg | 75 | 8 |

a. no
b. yes
c. insufficient information

36. Which of the following is not an aliphatic hydrocarbon?

a. hexene
b. aniline
c. octane
d. pentene
e. methane

37. All of the following compounds have a basic benzene ring except:

a. phenol
b. toluene
c. xylene
d. acetylene

38. A suitable liquid phase for the gas chromatographic determination of benzene is:

a. carbowax
b. chromosorb W
c. poropak Q
d. alumina

39. Which of the following is not a suitable means of detection for high performance liquid chromatography?

a. fluorescence
b. absorbance of UV light
c. refractive index
d. x-ray diffraction

40. Which of the following would be most suitable for the desorption of toluene from activated charcoal?

a. isopropanol
b. hydrochloric acid
c. carbon disulfide
d. amyl alcohol

41. The most efficient instrumental technique for the qualitative determination of the elemental content (presence or absence of specific elements) of a dust sample is:

a. high performance liquid chromatography
b. gas chromatography
c. x-ray diffraction
d. UV spectrophotometry
e. atomic absorption spectrophotometry
f. emission spectoscopy

42. The x-ray diffraction method is used largely in occupational health:

    a. to determine trace quantities of metals in biological materials
    b. to establish the particle size distribution of an industrial dust
    c. to determine amorphous silica in dust
    d. to distinguish between quartz, cristobalite, and tridymite in dusts
    e. to separate airborne dusts into their respirable and non-respirable fraction

43. If 12.5 ml of a standard solution of 0.15N HCL is used titrating against NaOH using phenolphthalein, how many grams of NaOH were there in the sample?

    a. 0.037
    b. 0.074
    c. 0.0037
    d. 0.0074
    e. 0.00074

44. The detector most commonly used for the gas chromatographic determination of carbon-containing compounds is:

    a. flame photometric detector
    b. alkali flame detector
    c. flame ionization detector
    d. electron capture detector
    e. gas density meter

45. Convert 28.6 lb $NH_3$ per 1000 cubic feet to ppm. Atomic wt: N=14, H=1. 1 lb=453.6 g, 1 cubic foot=28.3 liters. (25°C, 760 mm Hg)

    a. 319, 380 ppm
    b. 320 ppm
    c. 657, 950 ppm
    d. 644, 220 ppm
    e. 658 ppm

46. Convert 12 micrograms per cubic meter of phosgene gas to ppm. Formula: $COCl_2$, atomic wt: C=12, O=16, Cl=35.5. (25°C, 760 mm Hg)

    a. 0.003 ppm
    b. 3 ppm
    c. 30 ppm
    d. 0.05 ppm
    e. 5 ppm

47. Eighteen grams of pure methane gas (MW=16) will occupy how many cubic feet at 12°C and 28.0 inches Hg?

    a. 0.78 cu ft
    b. 0.87 cu ft
    c. 0.91 cu ft

d. 0.99 cu ft
e. 1.80 cu ft

48. What is the settling rate of vapor 3 inches below the emission point for a solvent at STP whose MW=79? The specific gravity of the air-vapor mixture is 1.0027.

a. 7.4 ft/sec
b. 0.74 ft/sec
c. 12.4 ft/min
d. 59.5 ft/sec
e. 7.4 ft/min

49. A room 50' x 20' x 10' contains 100 ppm $CCl_4$. How much time is required to lower the concentration to 25 ppm if a blower generating 300 CFM is used the clear the room?

a. 46 min
b. 11.1 min
c. 7.5 min
d. 54 min
e. 33.3 min

50. A vial containing 1 mg $CCl_4$ is broken in a carboy having a volume of 16 liters. The temperature is -2 C and pressure in the carboy is 540 mm Hg. What is the resultant air concentration?

a. 67.5 ppm
b. 12.6 ppm
c. 9.8 ppm
d. 6.4 ppm
e. none of the above

51. Methanol has a MW=32 and SG=0.792. What is the vapor volume generated by evaporation at a room temperature of 70 F at sea level (760 mm HG)?

a. 14.7 cu ft/gal
b. 27.4 cu ft/gal
c. 10.7 cu ft/gal
d. 17.4 liter/gm
e. 79.4 cu ft/gal

52. The partial pressure of oxygen in inspired air is approximately:

a. 100 mm Hg
b. 125 mm Hg
c. 158 mm Hg
d. 177 mm Hg
e. 203 mm Hg

53. All of the following are proteins except:

a. hemoglobin
b. fibrinogen
c. hydrocortisone
d. collagen
e. keratin

54. In the metabolism of carbohydrates, the starch macromolecule is hydrolyzed in:

a. the stomach
b. the intestine
c. the blood stream
d. the liver
e. none of the above

55. The direct waste product(s) of metabolism is (are):

a. water
b. carbon dioxide
c. ammonia
d. a and b only
e. all of the above

## Answers to Review Questions

1. c correct - Cyanide electroplating of brass → air containments

   a. HCL, HBr, $H_2O$: Never acid in contact with cynides or HCN gas evolved

   b. Zn salts, KOH, $H_2O$: Zinc, a normal component of brass, does not form ZnO in electroplating.
   KOH non-volatile except by aerosolization

   c. Cyanide salts, $NH_4OH$, $H_2O$

   d. MFL: incorrect formula

2. e correct - least soluable gas in $H_2O$:

   a. $NH_3$ 89.9g in 100cc $H_2O$ at $0^o$

   b. HCL 82.3g in 100cc $H_2O$ at $0^o$

   c. $NO_2$ soluble but decomposes in $H_2O$

   d. $SO_2$ 22.8g in 100cc $H_2O$ at $0^o$

   e. $CF_4$, carbon tetraflouride, soluble only in traces

   Note: This question has no best answer as written because of undefined solubility of $NO_2$. The message here is that some gases are much more soluble in water than others. Knowing this is useful in understanding sampling systems, potential for gas evolution from baths, i.e., a very soluble gas is less likely to be evolved, and potential for grab air samples to be reduced in concentration if containers are wet and gas is soluble. Containers can become wet unsuspectingly by condensation.

3. d correct - Reactive with strong oxidizing agents:

   a. $SiO_2$ no, Si+4 is highest oxidation state

   b. $H_2O$ no, H+1 is highest oxidation state

   c. $O_2$ no, it is an oxidizing agent

   d. FE yes: $Fe + O_2 \rightarrow FeO(Fe^{+2}) + Fe_2O_3\ (Fe^{+3})$

   e. asbestos no, a Mg silicate, $Si^{+4}$

4. 33.6L $H_2$ formed (STP)

find vol. of hydrogen gas if 17g of $NH_3$ is decomposed:

A volume → Weight Problem

| 17g | | | X liters |
|---|---|---|---|
| 2 $NH_3$ | ⟶ | 2$N_2$ + | 3 $H_2$ |
| 2 moles | | | 3 moles |
| 2 volumes | | | 3 volumes |
| 2 X 17(gmw) or 34g | | | 3 X 22.4L (mole volume) |

$$\frac{17g\,NH_3}{34g\,NH_3} = \frac{X \text{ liters Hydrogen}}{67.2 \text{ liters}} \quad \text{or} \quad 33.6L\ H_2 \text{ formed}$$

5. b correct - strong oxidizing agents:

   a. no, they are usually stable in bases

   b. yes, can cause serious harm to respiratory tract

   c. no, they are used extensively in chemical processes, e.g., disinfectants

   d. no, they can sometimes be stored in steel cans but can be very corrosive and this is probably not a good practice. A possible answer but not as good as b

6. b correct - chemical smoke tubes usually contain:

   a. $V_2O_5$ - no

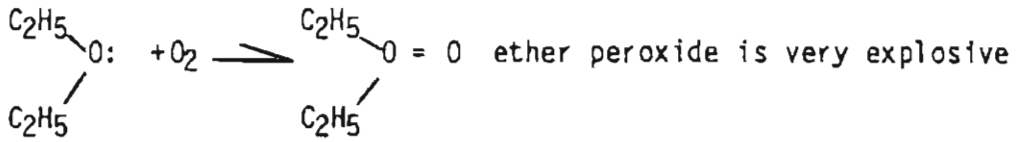
   b. $TiCl_4$ - yes + $H_2O$ in air ⟶ $TiO_2$ (fumes) + $HCl/H_2O$ fog/mist

   c. $SnCl_2$ - no + $H_2O$ in air ⟶ $SnO_1$ reacts slowly, fumes not heavy

   d. $NH_4CL$ - no stable in air

   e. Dioctyl Phthalate - used to determine respiration penetration as a test "smoke"

7. e correct - Ethyl ether is a potential severe explosion hazard




ether peroxide is very explosive

Peroxide formation usually occurs when air entrapped in ether undergoes peroxide formation, evaporation of the solvent leaves small residue of ether peroxide (solid), barely visible which easily detonates by heat or shock.

   a. high vapor pressure, yes BP. 34.6°C

b. low flash point, yes -49°C

c. peroxide formation, yes, see above

d. more than one above, yes

e. all of the above, yes

8. b correct - Hg vapor is best absorbed or adsorbed by:

a. Hg will revolatilize from charcoal and is not permanently adsorbed

b. activated charcoal impregnated with iodine:
$Hg + I_2$(on charcoal) $\rightarrow$ $Hg_2I_2$ or $HgI_2$(stable)

c. $CaSO_4$ has no effect on Hg

d. $CaCl_2$ will not absorb Hg

e. caustic solution will not effectively absorb Hg

9. b correct

| | | B.P. | |
|---|---|---|---|
| a. | ethyl chloride | 12.5°C | |
| b. | methyl chloride | -24°C | (lowest mol. weight) |
| c. | methylene chloride | 40°C | |
| d. | carbon tetrachloride | 77°C | |
| e. | ethylene dichloride | 83.5°C | |

10. b correct - organophosphate:

TCP = Tricreslphosphate $(CH_3C_6H_4O)_3P = O$

Used as additive in fuels, lubricants and hydraulic fluids, extremely toxic, similar to organophosphorous pesticides.

11. no correct answer - This question is poorly worded and has no correct answer. Cyanides and nitriles have in common the cyanide group - C N. This group may be ionically bonded to form simple salts such as NaCN which are all very toxic or covalently bonded to form nitriles, R - C N, where R is usually an alkyl group. The simplest nitrile is HCN. Alkyl nitriles with the exception of HCN are not particularly toxic, however, they are often contaminated with highly toxic and odorous isocyanides, N=C. Oxidation of isocyanides yields isocynates, N=C=O.

12. b correct - which is not a solvent application

a. alcohols in paint clean up = solvent action

b. Epoxy used in foundry coremaking - no solvent action (chemicals react to form polymer)

c. ketones in paint spray = solvent action

d. hydrocarbons in metal cleaning = degreasing solvent action

13. e correct - Respirator with activated charcoal should not be employed in an atmosphere containing $NO_2$ since the charcoal is an oxidizable material. NIOSH/OSHA Occupational Health Guidelines recommended only non-oxidizable materials be employed in a respirator protecting against $NO_2$. Respirators for CO contaminated environments usually use Hopcalite (Mn + Cu oxides) to catalyze CO to $CO_2$ (in the absence of moisture). Oxygen deficient atmospheres require an $O_2$ supply. The respirator with activated charcoal may be effective against zinc oxide fumes, but without some indication that the carbon bed is designed to filter aerosols, the respirator should not be used for this purpose.

14. volume of liquid = $5 \times 5 \times 4 ft^3 \times \frac{28.3 L}{ft^3} \times \frac{100 \text{ L contaminant}}{10^6 \text{ L container}} \times$

$$\frac{1 \text{g moles contaminant}}{24.45 \text{ L contaminant}} \times \frac{100 \text{ g contaminant}}{\text{g. mole contaminant}} \times \frac{1 \text{ mL contaminant}}{0.83 \text{ g. contaminant}} = 1.4 \text{ mL}$$

15. Absorbance vs. concentration is a linear (straight line) relationship (Beer's law), therefore use linear interpolation.

Beer's law: Absorbance = $\log \frac{Io}{I} = k\,c$

16. c correct - Glacial acetic acid should:

a. be stored with concentrated $HNO_3$ - No. Oxidizing agents, such as $HNO_3$, should not be stored with flammable acid

b. be refrigerated - No, freezes at 16.6°C

c. be stored with flammables - Yes, F.P. = 109 F, NFPA Class 2 Flammable. However, caution should be exercised in selecting the specific location because of its reactivity.

d. be stored with acids and bases - no, acids and bases should not be stored together

e. no

17. Basic Equation: Ideal Gas Law
$PV=nRT$

Given:

1. Volume of the gas cylinder does not change appreciably when heated, therefore $V_1=V_2$ where $V_1$ is the initial volume and $V_2$ is the final volume.

2. The temperature of the cylinder is 25°C, therefore $T_1$ (initial) = 25°C + 273 = 298°K

3. The final pressure is double the initial pressure, therefore $P_2=2P_1$

4. Note: the number of molecules in the cylinder does not change, therefore $n_1=n_2$ where n is the number of moles of gas. R is the gas constant.

Solution:

$P_1V_1=n_1RT_1$ or $\frac{P_1V_1}{T_1} = n_1R$

$P_2V_2=n_2RT_2$ or $\frac{P_2V_2}{T_2} = n_2R$

from 4 above $n_1n_2$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \qquad (1)$$

from 1, 2 and 3 above, substitute into the above (1) equation

$$\frac{P_1V_1}{298} = \frac{(2P_1)V_1}{T_2} \quad \text{or} \quad T_2 = \frac{(2P_1)(V_1)(298)}{P_1V_1}$$

$$T_2 = 2(298) = 596^{o}K \text{ or } 323^{o}C$$

18. Basic Equation: Assuming STP, 0°c, 760mm Hg

$$ppm = Y \frac{mg}{m^3} \times \frac{g}{10^3 mg} \times \frac{m^3}{10^3 \text{ liters}} \times \frac{\text{g moles}}{Z\ g} \times \frac{22.4 \text{ liters}}{\text{g. mole}} \times \frac{10^6 \text{ liters}}{\text{million liters}}$$

or

$$ppm = \frac{Y \times 22.4}{Z}$$ where Y is concentration in $mg/m^3$
Z is g/g.mole (gram molecular wt of substance)

Solutions:

line 1. $Y = \frac{1mg}{10m^3} = \frac{.1mg}{m^3}$ $\qquad Z = 100$ g/g.mole

$$ppm = \frac{.1 \times 22.4}{100} = 2.25 \times 10^{-2}$$

line 2. ppm = 500 $\qquad Z = 50$

$$Y = \frac{ppm}{22.4} \times Z = \frac{500 \times 50}{22.4} = 1116. \frac{mg}{m^3}$$

$$mg = 1116. \frac{mg}{m^3} \times 100m^3 = 1.116 \times 10^5 mg$$

line 3. $Z = 100 \frac{g}{g.mole}$ $\quad Y = 100 \frac{mg}{m^3}$

$$ppm = \frac{100}{100} \times 22.4 = 22.4$$

$$m^3 = \frac{100mg}{100mg/m^3} = 1.0m^3$$

line 4. $Y = \frac{.1mg}{m^3}$ $\quad ppm = 1.0$

$$1ppm = \frac{.1}{Z} \times 22.4$$

$$Z = 2.24$$

$$\frac{.1mg}{m^3} \times 10m^3 = 1mg$$

19. Activated carbon is a good medium for collecting samples because of its property of high adsorptivity for gases, vapors, and colloidal solids and the ease in which these substances can be stripped from it for laboratory analysis. It also has a large surface available for adsorption per unit volume.

20. Pressure is an expression of the force exerted by a substance per unit area. In fluids such as water or air the pressure increases at a rate depending on the depth in water and decreases with altitude in the atmosphere because there is less air above as the altitude increases. The change in pressure with altitude is non-linear because of the compressibility of air.

21. The inverse-square law is a mathematical expression of the decrease in intensity of a physical quantity with the inverse of the square of the distance from the source. It applies to all radiant energy as long as the dimensions of the source are small compared to the distance from the source.

22. a. Concentration of gas in tank = $\frac{75 \text{ mm Hg}}{760 \text{ mm Hg}}$ = 0.0987 volume fraction

For dilution problems, the product of volume and concentrations, i.e., the amount of contaminant, is always constant. Therefore:

$$C_1V_1 = C_2V_2$$

$C_1$ = contaminant concentration in gas emitted from tank
= 0.0987 volume fraction

$V_1$ = volume of gas emitted from tank
= 15 gpm x 200 min = 3000 gal = 401 cu ft

$C_2$ = limiting contaminant concentration in room = 200 ppm

$V_2$ = total volume of dilution air plus air emitted from tank

$$= \frac{(0.0987)\ (401 \text{ cu ft})}{(200 \times 10^{-6})} = 198{,}000 \text{ cu ft}$$

(multiplying by $10^{-6}$ converts ppm to volume fraction)

The amount of dilution air that is necessary is 198,000 cu ft less the 401 cu ft that was emitted from the tank or, essentially, 198,000 cu ft.

b. Under steady state conditions, the 198,000 cu ft of air would have to be supplied continuously and uniformly over the 200 minute period fill cycle. Therefore, the supply rate would be:

$$\frac{198{,}000 \text{ cu ft}}{200 \text{ min}} = 990 \text{ cu ft/min}$$

23. $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ Charles' Law $\qquad V_2 = \frac{V_1 T_1}{T_2}$

$$= (1000)\frac{(460+600)}{(460+70)}$$

$$V_2 = 2000 \frac{ft^3}{min}$$

24. Use Charles' Law (see above)

$$\text{Molar volume} = 22.4\text{L} \times \frac{(273+300°)}{273°} \times \frac{1 \text{ atm}}{0.95 \text{atm}} = 49.5\text{L}$$

25. $$\text{Mg sample} \times \frac{1}{\text{rate}} \frac{\text{min}}{\text{L}} \times \frac{\text{L}}{m^3} \times \frac{1}{\text{min}} = \text{mg}/m^3$$

Since we have actually drawn more air than we initially assumed, our corrected answer must be more dilute than the original answer by an amount inversely proportional to the sampling rate.

$$\text{conc.} = 100 \frac{\text{mg}}{m^3} \times \frac{1.0 \frac{\text{L}}{\text{min}}}{1.5 \frac{\text{L}}{\text{min}}} = 66.7 \frac{\text{mg}}{m^3}$$

26. a correct MW air is $\sim 30 \frac{\text{gm}}{\text{mole}}$

i.e. 21% $O_2$ MW = 32 gm/mole
79% $N_2$ MW = 28 gm/mole

Density of gases is directly proportional to MW. So Mw 88gm/mole gas will sink.

27. Given a mercury in urine result of 0.14 mg/ml and a sample specific gravity of 1.016, what would the result be corrected to a sp. g. of 1.024?

To correct urine concentrations to a standard specific gravity requires adjusting for the volume of water to be added or removed from the solution to achieve the desired specific gravity. For example, if a solution with a specific gravity of 1.1 were to be adjusted to a specific gravity of 1.05, the volume would approximately be doubled. This is because the same amount of solute (approximately 0.1 $g/cm^3$ in the original solution) must be diluted with approximately one $cm^3$ of water additional to bring the specific gravity down to 1.05 (0.1 g solute in 2 $cm^3$ of water 0.05 grams solute in 1 $cm^3$ $H_2O$, 1.05 grams (solute and water) per $cm^3$).

To solve the problem rigorously, one uses the following mass balances and a table of specific gravities vs. concentrations for the specific solute involved.

$$\underset{\text{(specific gravity)}}{\frac{\text{total g}}{cm^3}} = \underset{\text{(toxin concentration)}}{\frac{\text{g solute}}{cm^3}} + \frac{\text{g } H_2O}{cm^3}$$

$$\text{Adjusted Concentration} = \text{Original Concentration} \times \frac{\text{Reference Sp. g.} - \frac{gH_2O}{cm^3}\ ref}{\text{Test Solution Sp.g.} - \frac{\text{g } H_2O}{cm^3}\ test}$$

If one assumes that there is exactly one gram of water per cubic centimeter of solution, the equation reduces to

$$C_A = C_O \times \frac{\text{Ref. Sp. g.} - 1}{\text{Test Sp. g.} - 1}$$

There is an error of up to 25% inherent in the latter assumption. NIOSH recommends adjusting to a reference specific gravity of 1.024 using the latter approximate formula. Other sources sometimes recommend 1.016, hence the source of this problem. Substituting these values in the NIOSH formula

$$C_A = 0.14 \frac{mg}{ml} \frac{1.024 - 1}{1.016 - 1} = 0.21 \frac{mg}{ml}$$

It is worthwhile to note that the largest possible correction given a "normal" specific gravity range of 1.003 to 1.030 would be 8X, a rather large and generally overlooked figure. (Reference, Patty, Vol. III, p. 273-276.)

28. MW = 56

at STP One (1) gram molecular weight occupies 22.4 L. (STP).

Volume Sample = $10^6$L air $\times \frac{22.4 \text{ L Acr}}{0.1 \text{ L Acr}} \times \frac{0.001 \text{ g.Acr}}{56 \text{ g.Acr}}$ = 4000L

for correction to 25° and 760 mmHg Pressure (usual sampling conditions)
the volume sampled = 4000 L $\frac{24.45}{22.41}$ = 1.09 X 4000 = 4360L

29. Vapor pressure of mercury at 77°F is 0.0018mmHg.
The equilibrium concentration Hg in a closed space is

$$PPM = \frac{\text{Partial vapor pressure of Hg}}{\text{Total barometric pressure}} \times 10^6$$

$$= \frac{0.0018\text{mm}}{760\text{mm}} \times 10^6 = \frac{1.8\times10^{-3} \times 10^{-6}}{760} = \frac{1.8 \times 10^3}{7.6 \times 10^2} = \frac{1800}{760} = 2.37 \text{ PPM}$$

30. b correct - use ppm by weight for liquids
mppcf = million particles per cubic foot

31. Charles' Law

$$\frac{V}{T} = \frac{V^1}{T^1}$$

$$V^1 = V\frac{T^1}{T}$$

$$= (22.414)\frac{(273+25)}{(273)}$$

$V^1$ = 24.46 liters

32. $\frac{(x-3)}{2} = \frac{(y+4)}{4}$ if x=4, y=?

$$\frac{(4-3)}{2} = \frac{(y+4)}{4}$$

$4\,(1/2) = y+4$

$2-4 = y$

$y = -2$

check

$$\frac{(4-3)}{2} = \frac{(-2+4)}{4}$$

$$1/2 = \frac{2}{4}$$

33. Convert 76°F to °R, °C, °K

°R = °F+460
76+460 + 536°R

$$°C = \frac{(°F-32)}{1.8}$$

$$= \frac{(76-32)}{1.8} = \frac{44}{1.8} = 24.4 = 24°C \text{ (2 sig. figs.)}$$

°K = °C+273
76+273 = 279°K

34. Volume (STP) = 1 gal $H_2O$ X 8.34 $\frac{\#}{gal}$ X $\frac{1}{18}$ $\frac{\#mole}{\#H_2O}$ X 359 $\frac{ft^3}{\#mole}$

= 166 $ft^3$

or = 1 gal X 3.8 $\frac{L}{gal}$ X 1000 $\frac{g}{L}$ X $\frac{1\ g\ mole}{18g}$ X 22.4 $\frac{L}{g\ mole}$

= 4729 L

35. Assume 1 g solution
MW Benzene = 78
MW Xylene = 106
Raoult's Law:

partial pressure = vapor pressure X mole fraction

mole fraction benzene = $\frac{\text{moles benzene}}{\text{moles benzene + moles xylene}}$

(must use an arbitrary volume or mass of solution, choose one gram)

$$= \frac{\frac{\text{mass Bz}}{\text{g solution}}}{\frac{\text{mass Bz}}{\text{g solution}} + \frac{\text{mass Xy}}{\text{g solution}}}$$

$$\frac{\text{mass Bz}}{\text{g solution}} = \frac{100\ \text{g Bz}}{10^6\ \text{g sol.}} = 10^{-4}\ \frac{\text{g Bz}}{\text{g sol}}$$

$$\frac{\text{mass Xy}}{\text{g solution}} = \frac{10^6\text{-}100\ \text{g Xy}}{10^6\ \text{g sol}} = 0.9999\ \frac{\text{g Xy}}{\text{g sol}}$$

$$\text{mole fraction Bz} = \frac{\frac{10^{-4}}{78}}{\frac{10^{-4}}{78} + \frac{0.9999}{106}} = 9.54 \times 10^{-5}\ \frac{\text{moles Bz}}{\text{mole sol}}$$

$$\text{partial pressure Bz} = \frac{9.54 \times 10^{-5} \times 75\ \text{mmHg}}{7.16 \times 10^{-3}\ \text{mmHg}}$$

$$\text{ppm Bz} = \frac{\text{partial pressure}}{\text{total pressure}} \times 10^6$$

$$= \frac{.00716 \times 10^6}{760} = 9.4\ \text{ppm}$$

36. b correct. Aniline is an aromatic compound consisting of a benzene ring with an attached $NH_2$ radical. The compounds hexene, octane, and pentene are straight-chain aliphatic hydrocarbons, while methane

consists of a single carbon atom making it the simplest compound in the aliphatic family. (Ref. 1, p. 237.)

37. d correct. Acetylene, alkyne, consists of two carbon atoms connected with a triple bond. The other compounds are aromatics comprised of a benzene ring with the following attached radicals: phenol - OH, toluene - $CH_3$, xylene - 2 $CH_3$'s. (Ref 1, p. 268, 270.)

38. a correct. In chromatographic analysis, Carbowax is employed as a liquid phase for specific hydrocarbons including benzene. Poropak Q and Alumina are utilized as adsorbants. Chromosorb W is employed as a solid support. (Ref. 2, p. 264-265.)

39. d correct. Detectors for high performance liquid chromatography use various principles including sample fluorescence, refractive index, and absorption of UV light. Also included as detectors are conductivity, polarography, and radioactivity. X-ray diffraction is a method normally employed for identification of inorganic, crystalline materials.

40. c correct. As is outlined in numerous instrumental analysis instructions, a standard desorption chemical for aromatic hydrocarbons absorbed on activited charcoal is carbon disulfide. The resultant solution is then introduced into the gas chromatograph for both qualitiative and quantitative analysis.

41. f correct. Inorganic powders, such as dust, can be directly analyzed utilizing emission spectroscopy without extensive sample preparation. This fact, coupled with its extremely high sensitivity when sample size is not limiting, makes emission spectroscopy the method of choice for qualitative analysis of a dust sample. (Ref. 2, p. 247.)

42. d correct. X-ray diffraction is employed extensively for identification and quantification of inorganic crystalline materials. It is specifically advantageous because of its ability to analyze chemical compounds rather than elements. Therefore, it is ideal to distinguish between quartz, cristobalite, and tridymite. (Ref. 2, p. 28.)

43. b correct. To determine the weight of NaOH in the sample, the number of moles in the sample must be calculated for the neutralization equation:

$$NaOH + HCl \longrightarrow NaCl + H_2O$$

One mole of HCl will neutralize one mole of NaOH. The number of moles of NaOH in the sample is equivalent to the volume times the moles per liter or normality of the titrating agent.

$$0.0125 \text{ liters} \times 0.15 \text{ N} = 0.001875 \text{ moles}$$

For weight, 1 mole of NaOH = 40 grams. Therefore,

$$\text{wt} = 0.001875 \text{ moles} \times \frac{40 \text{ grams}}{\text{gram-mole}} = 0.074 \text{ grams}$$

44. c correct. The flame ionization detector is the method of choice for carbon-containing compounds. Flame photometric detectors are employed for sulfur and phosphorus-containing compounds, while the alkali flame detector is normally utilized for nitrogen and phosphorus-containing molecules. Electron capture detectors are used for halogenated compounds and pesticides. (Ref. 2, p. 265-267.)

45. c correct. One gram-mole of a gas will occupy 24.4 liters at 25 C, 760 mm Hg. The relationship between ppm and $mg/m^3$ is therefore:

$$(MW)(ppm) = (mg/M^3)(24.4) \qquad \text{(see question 18)}$$

For the given conditions, conversion to ppm will be:

$$(17)(ppm) = \frac{28.6\ lb \times 453.6\ gm/lb \times 1000\ mg/gm}{1000\ ft^3 \times 28.3\ lt/ft^3 \times M^3/1000\ lt} \times 24.4\ lt/gm\text{-}ml$$

$$ppm = 657{,}950 \qquad \text{(Ref. 2, p. 17.)}$$

46. a correct. Employing the same principle as given in problem #18;

$$(MW)(ppm) = (mg/M^3)(24.4)$$

$$(99)(ppm) = (12\ microgram/M^3 \times 1\ mg/1000\ microgram)(24.4)$$

$$ppm = 0.003 \qquad \text{(Ref. 2, p. 17.)}$$

47. d correct. The volume occupied by the methane gas is based on the fact that one gram-mole of the gas will occupy 22.4 liters at STP. Therefore, the weight of the gas is converted to moles, the volume calculated and subsequently corrected to the given conditions.

$$Vol = \frac{18\ grams}{16\ gm/gm\text{-}mole} \times \frac{22.4\ Lt}{gm\text{-}mole} \times \frac{ft^3}{28.3\ lt} \times \frac{285°K}{273°K} \times \frac{29.92\ in\ Hg}{28.00\ in\ Hg}$$

$$Vol = 0.99\ ft^3$$

48. c correct. The settling rate of a vapor from a point source can be calculated if factors such as mixing and stack height are considered inconsequential in air pollution and falling material equations. When the distance evaluated is one foot or less from the vapor generating source, the resultant relationship is given as:

$$v_s = \sqrt{\frac{2\ g\ (SG - 1)\ (h)}{SG}}$$

where g is gravitational acceleration in $ft/sec^2$, h is the distance in ft from the source of vapor generation, and SG is the specific gravity of the vapor-air mixture. For the conditions given:

$$v_s = \sqrt{\frac{2\ (32\ ft/sec^2)\ (0.0027)(0.25\ ft)}{1{,}0027}}$$

$$v_s = 0.208\ ft/sec \times 60\ sec/min = 12.4\ ft/min$$

49. a correct. The time required to decrease the concentration of a contaminant after the generation process is interrupted is given by the relationship:

$$t = \log_{10} \frac{C}{C_0} \; (-2.303) \; \frac{P}{Q}$$

where t is the time, C and $C_0$ are the final and initial concentrations of the contaminant respectively, P is the room volume, and Q is the ventilation rate. For the given conditions:

$$t = \log_{10} \frac{25 \text{ ppm}}{100 \text{ ppm}} \; (-2.303) \; \frac{10{,}000 \text{ ft}^3}{3000 \text{ ft}^3/\text{min}}$$

$$t = 46 \text{ min} \qquad \text{(Ref. 2, p. 580.)}$$

50. b correct. The volume occupied by one gram-mole of a gas at 0°C and 760 mm Hg is 22.4 liters. Under the conditions given, this volume must be corrected for temperature and pressure. Therefore:

$$\text{Volume/gm-mole} = 22.4 \text{ liters} \times \frac{760 \text{ mm Hg}}{540 \text{ mm Hg}} \times \frac{271°\text{K}}{273°\text{K}}$$

$$\text{Volume/gm-mole} = 31.3 \text{ liters}$$

The calculation for concentration in ppm is based on the ratio of gas volume to container volume times $10^6$. Therefore:

$$\text{ppm} = \frac{0.001 \text{ gm } CCl_4}{154 \text{ gm } CCl_4/\text{gm mole}} \times \frac{31.3 \text{ liters}}{16 \text{ liters}} \times 10^6$$

$$\text{ppm} = 12.6 \qquad \text{(Ref. 2, p. 17.)}$$

51. e correct. To determine vapor volume generated, the pounds per gallon of methanol must be calculated and equated to volume per pound-mole. Since there are 8.31 pounds per gallon of water, weight of methanol is:

$$\text{wt} = 8.31 \text{ lb} \times 0.792$$

$$\text{wt} = 6.58 \text{ lb}$$

At 70°F, one pound-mole of a gas occupies 386 $ft^3$. Therefore, the volume of vapor generated by methanol per gallon at the given conditions is:

$$\text{Vol vap} = \frac{6.58 \text{ lb/gal} \times 386 \text{ ft}^3/\text{lb-mole}}{323 \text{ lb meth/lb-mole}}$$

$$\text{Vol vap} = 79.4 \text{ ft}^3/\text{gal} \qquad \text{(Ref. 2, p. 17.)}$$

52. c correct. At sea level, the total pressure of atmospheric air is 760 mm Hg. Since oxygen makes up approximately 20.8% of this air and partial pressure is directly proportional to the air component concentration, the partial pressure of inspired oxygen is approximately 158 mm Hg. (Ref. 2, p. 32.)

53. c correct. Hydrocortisone is the only compound listed that is not a protein. It is a major hormone generated by the adrenal cortex. (Ref. 2, p. 39.)

54. b correct. Carbohydrates, provided mostly by dietary sugars and starches, are metabolized in the intestine by amylase, an enzyme generated in the pancreas. (Ref. 2, p. 42.)

55. e correct. Water, carbon dioxide, and nitrogen in the form of ammonia are direct waste products of metabolism. (Ref. 2, p. 45.)

References

1. Helmprecht, H. L., Freidman, L. T., Basic Chemistry for the Life Sciences, State University of New York, McGraw-Hill, 1977.

2. Amdur, Mary, O et al, The Industrial Environment--Its Evaluation and Control, NIOSH, 1973.

# Chapter 2: TOXICOLOGY

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I. Physiological Background
- A. Nervous System
  - 1. central
    - a. includes brain and spinal cord
    - b. controls voluntary and involuntary (automatic) responses
  - 2. peripheral - involuntary responses
    - a. somatic, controls nonvisceral (non-abdominal) motion, (skin, eye, ear)
    - b. automatic (cardiac, smooth muscle, glands)
      - 1. sympathetic
      - 2. parasympathetic
- B. Endocrine
  - 1. includes kidney, pancreas, pituitary, thyroid
  - 2. controls many body process rates (e.g., sweat rate)
  - 3. source of hormones
- C. Respiratory System (see Respiratory Disease Chapter)
  - 1. a key route of entry in industrial poisonings
  - 2. affected by numerous common hazardous materials - particles and gases
  - 3. chemical ($CO_2$) and neurological control
  - 4. performance monitoring valuable in industrial hygiene surveillance (see Medical Monitoring Chapter)
  - 5. hyperventilation (too much breathing) and hypoxia (too little oxygen)
- D. Circulatory System
  - 1. includes heart, veins, arteries, and capillaries
  - 2. elasticity helps maintain hemostasis
  - 3. heart rate and blood pressure (systolic and diostolic) primary functional indicators
- E. Defense Mechanisms
  - 1. barriers - skin, mucous membranes
  - 2. immune system
  - 3. temperature control
- F. Detoxification - primarily by liver
- G. Interactions between toxins
  - 1. synergism
  - 2. antagonism

II. Important Industrial Toxin Classes and Examples
- A. Simple Irritants
  - 1. ammonia
  - 2. most acids
  - 3. ethylene oxide
- B. Asphyxiants
  - 1. simple - toxic effect due primarily to oxygen exclusion
    - a. nitrogen

b. methane
c. see TLV book for additional items

2. chemical - reduce oxygen handling capacity of blood
   a. carbon monoxide
   b. cyanides
3. carbon dioxide

C. Hepatotoxins
1. chlorinated hydrocarbons
2. carbon disulfide

D. Nephrotoxins (kidney)
1. heavy metals and their components
   a. uranium
   b. lead
   c. mercury
   d. chromium
2. carbon disulfide
3. chlorinated hydrocarbons
4. antibiotics

E. Hematopoietics (pertaining to or affecting blood forming system)
1. nitrites
2. aniline
3. lead
4. carbon disulfide
5. methylene chloride

F. Lung damaging agents
1. asbestos
2. silicon dioxide
3. metal fumes (iron, cadmium, zinc oxides)
4. nitrogen dioxide
5. beryllium
6. cotton dust
7. coal dust

G. Hemotoxins and CNS actions
1. mercury (organic and inorganic)
2. organophosphorous insecticides
3. lead
4. hydrogen sulfide
5. phosgene
6. carbon disulfide
7. nitrous oxide ($N_2O$)
8. benzene
9. ketones (MBK)
10. boranes

H. Immune System effects
1. toluene diisocyanate (sensitization)
2. fungi (sensitization)

I. Carcinogens
1. benzene
2. benzidine
3. nickel carbonyl
4. vinyl chloride
5. asbestos
6. ionizing radiation
7. see OSHA list (29 CFR 1000-100) and TLV Booklet

J. Skin irritants
    1. fibrous glass
    2. chromic acid (nasal mucus)
    3. hydrocarbons

## Review Questions

1. A patient with headaches, nausea, vomiting, fatigue, jaundice, and oliguria may have an occupational disease caused by:

   a. lead
   b. mercury
   c. benzol
   d. carbon tetrachloride
   e. hydrogen sulfide

2. Which of the following bacterial diseases may be classified as an occupational hazard?

   a. anthrax
   b. brucellosis
   c. glanders
   d. none of the above
   e. all of the above

3-7. Match the following occupational diseases with the appropriate descriptive paragraph:

   3. _____ benzol poisoning
   4. _____ lead poisoning
   5. _____ aniline poisoning
   6. _____ cadmium poisoning
   7. _____ carbon monoxide poisoning

   a. cough, substernal pain, dyspnea, pulmonary emphysema, tachycardia, tachypnea, respiratory system primarily affected, check for lymphocytosis

   b. headache, dizziness, anorexia, muscle cramps, purpura and bleeding gums, tests indicated are complete blood count and urine sulfide ratio

   c. headache, dizziness, nausea, blurred vision, weakness, thready pulse, tachycardia, and cherry-red discoloration of mucous membrane

   d. headache, vertigo, weakness, unsteady gait, cyanosis, tremors, and brown discoloration of urine occur, check blood cell count and methemoglobin

   e. metallic taste, anorexia, constipation, and irritability, pallor, tremors, abdominal tenderness are noted, check reticulocytes and look for porphyrins

8. It is currently claimed that primary pulmonary cancer is:

   1. caused by heavy cigarette smoking over a period of years

2. decreasing in incidence
3. related etiologically to air pollution
4. predictable on the basis of genetics

correct answer(s):

_____ a. 1, 2, 3, only
_____ b. 1 and 3 only
_____ c. 2 and 4 only
_____ d. 4 only
_____ e. all are correct

9. Exposure to which of the following irritant gases has been claimed to be a cause of bronchial asthma?

a. chlorine
b. sulfur dioxides
c. ammonia
d. phosgene
e. all of the above
f. two of the above

10. A 53-year old farmer was admitted to the hospital with complaints of anorexia, loss of weight, hyperirritability and fine tremors. These symptoms were gradual in onset and of at least three weeks' duration. A tentative diagnosis of peripheral neuritis was made.

There was a history of the use of the same insecticide on numerous occasions over the past three years. Diagnostic tests demonstrated the presence of insecticide in fatty tissues only and also liver dysfunction.

The most likely diagnosis is:

a. malathion intoxication
b. hepatitis
c. DDT-poisoning
d. kerosene intoxication
e. gasoline intoxication

11. The most potentially dangerous formulation of an insecticide is:

a. wettable powder
b. aerosol
c. dust
d. emulsifiable liquid
e. solution

12-13. A 29-year old pest control operator was hospitalized in cyanotic condition. Shortly thereafter it was determined that previous signs and symptoms experienced by the patient included headache, giddiness, blurred vision, weakness, nausea, cramps, diarrhea, discomfort in the chest, sweating, miosis, tearing, salivation, and pulmonary edema. Uncontrollable muscle twitches were also present. The patient gave a history of having sprayed a large apartment building

with a "new type of insecticide". He reported that he got some of the concentrated material on his hands and arms during the course of diluting it for use and that he had not used a respirator during the three hours of spraying.

12. The most likely diagnosis is:

a. carbon monoxide intoxication
b. chlordane poisoning
c. kwashiorkor
d. intoxication due to an organophosphorous insecticide
e. chromorhinorrhea

13. The most important diagnostic aid is:

a. fat biopsy
b. red blood cell count
c. cholinesterase determination
d. liver function test
e. electrocardiogram

14-16. For each of the following phrases, select the one heading which is most closely related to it and put the appropriate letter into the assigned blank.

14. _____ granulomatous pulmonary lesions

15. _____ a primary cutaneous irritant, but also seemingly associated with an increased risk of bronchogenic carcinoma

16. _____ fumes inhaled may induce febrile illnesses with symptoms like those of an acute respiratory disorder.

a. chromates
b. hydrogen sulfide
c. zinc oxide
d. beryllium
e. formaldehyde
f. mercury

17. The most common mode of entry for parathion is:

a. eyes
b. skin
c. ingestion
d. respiratory
e. b and d above

18. In phosgene or ammonia exposure, which is the most likely physiological syndrome?

a. irritation of mucous membranes, skin, lungs, cornea
b. liver and kidney damage
c. narcotic effects
d. allergic responses

19. Carbon dioxide is best considered:

    a. an irritant
    b. a systemic poison
    c. a simple asphyxiant
    d. a chemical asphyxiant
    e. none of the above

20. Which of the following is not a simple asphyxiant?

    a. $CH_4$

    b. $N_2$

    c. AR

    d. $C_2H_4$

    e. $C_2H_2$

21. Which of the following is least likely to be associated with chronic overexposure to fluorides?

    a. anorexia
    b. nausea
    c. osteosclerosis
    d. ulcers of the skin

22. Which is the most likely set of symptoms associated with acute nitrogen dioxide exposure?

    a. pulmonary edema, reduced olfactory sense, dyspnea
    b. vertigo, vomiting, cyanosis
    c. dizziness, giddiness, feeling of well being
    d. shortness of breath, euphoria, hallucinations

23. Which of the following is more likely to be associated with inorganic lead toxicity vs. organic lead?

    a. insomnia
    b. irritability
    c. muscular pain
    d. loss of appetite
    e. punctate basophils and cholic

24. Which of the following is not a heavy metal toxin?

    a. beryllium
    b. mercury
    c. silver
    d. cadmium
    e. bismuth

25. Which of the following is a known carcinogen according to the ACGIH?

a. benzidine
b. $Cr_2O_3$
c. cigarette smoke
d. perchloric acid
e. sodium fluoride

26. Which of the following chemicals is associated with "garlic breath?"

a. antimony
b. cadmium
c. selenium
d. arsenic
e. c and d above

27. Tellurium and selenium are of most toxic importance as:

a. metal oxide fume
b. elemental metal vapor
c. salt solutions
d. acid solutions
e. solid elemental metal

28. Which of the following is a sensitizing agent?

a. DDT
b. toluene diisocyanate
c. trinitrotoluene
d. vinyl chloride
e. polyurethane

29. Beta-naphthylamine is an important cause of:

a. heart disease
b. hepatitis
c. renal failure
d. bladder tumors
e. ulceration of the nasal septum

30. Organophosphorous insecticides act by:

a. cholinesterase inhibition
b. acetycholine inhibition
c. blood chemistry imbalance
d. clotting action inhibition
e. general central nervous system disruption

31. Chlorinated hydrocarbon insecticides act by:

a. clotting action inhibition
b. blood chemistry imbalance
c. cholinesterase inhibition
d. acetylcholine inhibition
e. central nervous system interference

32. A patient complains of headache, nausea, vomiting, fatigue, jaundice, and oliguria. He is a likely victim of poisoning by:

    a. lead
    b. mercury
    c. benzol
    d. carbon tetrachloride
    e. hydrogen sulfide

33. A dry cleaning plant operator has used Stoddard solvent, trichloroethylene, and perchloroethylene for many years. The body systems most likely to reflect overexposure are:

    a. kidneys and liver
    b. lungs
    c. skin
    d. nervous system
    e. gastrointestinal tract

34. Which of the following forms of mercury is most toxic if ingested?

    a. alkyl
    b. aryl
    c. elemental
    d. salts
    e. c and d above

35. Bladder cancer is best associated with:

    a. benzo(a) pyrene
    b. chromic acid
    c. peroxyacetyl nitrate
    d. chloramines
    e. vinyl chloride

36. Pentaborane combines which of the following properties?

    a. high volatility, high combustibility, central nervous system toxin
    b. TLV much greater than odor threshold, chronic gastrointestinal irritant
    c. TLV much less than odor threshold, central nervous system toxin, low reactivity
    d. pyrophoric, odorless, central nervous system toxin
    e. both a and b above

37. The TLVs of the various forms of mercury, in descending order, are (least toxic to most toxic):

    a. dimethyl Hg, ethyl mercuric phosphate, inorganic vapors, inorganic dusts
    b. inorganic mercury (all forms), alkyl compounds
    c. dust, vapors, salts, liquid
    d. alkyl compounds, inorganic mercury

38. Why is mercury a water pollutant?

    a. mercuric ions can be biologically methylated to alkyl compounds
    b. the amount of mercury in water has increased ten-fold in the last ten years
    c. the amount of alkyl compounds entering water has increased ten-fold during the last five years
    d. mercuric ions are very poisonous

39. The result of an acute exposure to beryllium (inhalation) is:

    a. renal failure
    b. chemical pneumonitis
    c. lung collapse
    d. myocardial granulomatosis

40. What is the hazard to vegetation from fluoride, $NO_2$, $SO_2$?

    s. root damage
    b. visible leaf damage
    c. stem damage
    d. all of the above

41. What is the danger in using ethylene oxide?

    a. toxicity
    b. fire hazard
    c. carcinogen
    d. all of the above
    e. two of the above

42. Formaldehyde is classified as a(n):

    a. simple asphyxiant
    b. irritant
    c. chemical asphyxiant
    d. chlorinated hydrocarbon

43. Methane is classified as a(n):

    a. irritant
    b. simple asphyxiant
    c. chemical asphyxiant
    d. organic phosphate

44. What is the primary organ damaged by benzene?

    a. kidney
    b. liver
    c. hematopoietic system
    d. brain

45. Exposure over a long period of time to carbon tetrachloride, perchloroethylene, Stoddard solvent damages the:

    a. kidney
    b. CNS
    c. liver
    d. lung

46. What are the effects of MEK?

    a. dermatitis and narcosis
    b. liver and kidney damage
    c. hematopoietic system damage
    d. tachycardia

47. What are the effects of TDI?

    a. irritation of skin, eyes, respiratory tract and pulmonary edema
    b. headache, blood changes, chromosomal aberrations
    c. skin ulceration, changes in structure of cornea, bladder cancer
    d. liver damage, irritation of respiratory tract, headache

48. What are the effects of pentaborane?

    a. liver, kidney damage and CNS depressant
    b. tachycardia
    c. blood changes
    d. cancer

49. Formaldehyde is primarily a:

    a. systemic poison
    b. simple asphyxiant
    c. primary irritant
    d. contact dermatitis causative

50. A cholinesterase test is used on workers exposed to:

    a. trichloroethylene
    b. parathion
    c. carbon monoxide
    d. mercury
    e. none of the above

51. What effect does CO have on blood?

    a. replaces oxygen in hemoglobin and reduces transportation of oxygen
    b. replaces oxygen in hemoglobin and reduces white blood cells
    c. sensitizes respiratory tract and restricts flow of blood
    d. reduces oxygen in lungs and causes edema

52. A chemical asphyxiant may cause death by:

a. excluding oxygen from the lungs
b. depressing the action of the heart
c. interfering with the utilization of oxygen taken into the lungs
d. stimulating the metabolism so the available oxygen is inadequate
e. latent action through the mucous membrane

## Answers to Review Questions

1. d correct, carbon tetrachloride. Key is jaundice as it is the most likely substance on the list to exhibit this symptom. However, heavy intoxication by lead may also cause jaundice so other symptoms confirm carbon tetrachloride. (Ref. 1, p. 194-5.)

2. e correct, all are occupational hazards.
   Anthrax - A bacterial disease, primarily of hoofed animals, transmitted to anyone working with infected animals or their remains, including hides. Spores may remain viable for years. Disease usually characterized by skin lesions. (Ref. 2, p. 12.)
   Brucellosis - A bacterial disease characterized by irregular fever, headache, chills and aching. Transmitted to man primarily by animal tissues and fluids of swine and cattle. (Ref. 2, p. 57-8.)
   Glanders - A bacterial disease of equines transmitted to man by contact with infected animal tissues or fluids, e.g. mucous, often through abraded skin. Disease manifest in a variety of systemic infective forms. Often fatal. Generally eradicated except in the Far East. (Ref. 2, p. 201.)

3. b correct for benzol poisoning. Key is urinary phenol, the best test for benzene exposure. (Ref. 1, p. 237-8.)

4. e correct for lead poisoning. Key is metallic taste and porphyrins exam.

5. d correct for aniline poisoning. Key is urine discoloration due to methemoglobin formation.

6. a correct for cadmium poisoning. Key is substernal pain although many metal fumes will produce this symptom.

7. c correct for carbon monoxide poisoning. Key is cherry red color although this is not always an easily observed symptom.

8. b correct.

9. e correct. Asthma is long term damage to the respiratory system limiting pulmonary function. Chlorine and phosgene are equally capable of producing bronchial asthma from chronic exposure. Phosgene has been reported to produce an emphysema from low level exposures which has been activated by paroxymal spasms. Chlorine exposure has also been accused of producing asthma though it has not been proven (The question is open.). Phosgene and chlorine are more likely to get to the bronchioles than is $SO_2$ or ammonia. The latter two are usually absorbed in the upper respiratory passages because of their high water solubility. Therefore, phosgene and chlorine are more likely to produce lung damage while ammonia and $SO_2$ are more likely to produce upper respiratory effects. The answer could be "all" of the substances listed or "none" depending how one defined bronchial asthma. (Ref. 2.)

10. c correct. Key is presence in fatty tissues and liver dysfunction. Malathion presents few if any chronic effects.

11. b correct. The most important route of entry for industrial toxins is the respiratory tract. To enter the respiratory tract, toxins must be either gases or aerosols (including dusts). Thus b is correct. It should be noted, however, that in terms of actual experience, most industrial insecticide poisonings occur as a result of skin absorption. For non-occupational poisoning, ingestion (by children) is the most important route. It is also important to note that for a worker exposed to pesticide sprays, absorption through the skin may be, in reality, the most important entry route, that is to say that the worker receives the largest fraction of this actual dose as a result of droplets that have landed on his skin. (Ref. 3, p. 63; Ref. 4, p. 931, 2, 8, 9.)

12. d correct. CNS effects and muscle twitching key to identification of organophosphorous pesticide intoxication. (Ref. 1, p. 455.)

13. c correct. Organophosphorous pesticides are anticholinesterase agents. (Ref. 1, p. 45.)

14. d correct. Symptomatic of chronic berylliosis. (Ref. 5, p. 626.)

15. a correct. In severe cases of chromate exposure, cutaneous irritation may cause perforation of the nasal septum. (Ref. 1, p. 354, 355.)

16. c correct. Statement refers to metal fume fever commonly associated with ZnO fumes generated when welding on galvanized steel or brass founding. (Ref. 1, p. 409.)

17. b correct. Parathion has an extremely low vapor pressure, so volatilization is unlikely. Workers applying insecticide may easily be intoxicated by inhaling vapors, but a more frequent cause of poisoning is skin absorption by agriculture workers and others who may come in contact with pesticide residues.

18. a correct. This set of symptoms is typical of all irritant gases, e.g., $NO_2$, $Cl_2$, HCl.

19. c correct. Some experts may regard e as the best answer because of the efects of $CO_2$ on respiratory rate. In addition, $CO_2$ problems confronted by divers include unconsciousness at levels as low as 10% by volume. However, classic industrial hygiene problems are normally associated with $CO_2$ and oxygen deficiency which renders it a simple asphyxiant. (Ref. 7.)

20. e correct. This question poses a difficult problem because a - d are listed in the 1979 TLV booklet as simple asphyxiants and nitrogen, while not listed, is generally considered to be one except in the case of nitrogen narcosis experienced by divers. The question then reduces to one of which of the possible choices is most likely to exhibit toxic effects. Zenz, Occupational Medicine (Ref. 5), classifies acetylene as "practically non-toxic." Patty, Industrial Hygiene and Toxicology (Ref. 11), says at 10% it is "slightly intoxicating," at

20% "marked intoxication occurs" and "unconsciousness occurs in 5 minutes" at 35%. These are affects clearly above and beyond simple asphyxiation and more severe than those of any other available answer. It is noteworthy that both ethylene and acetylene have been used as anesthetics, the former at 80% with oxygen and the latter at 30-35%.

21. d correct. a, b and c are all symptoms of chronic fluoride poisoning. Only d is an acute affect. (Ref. 1, p. 319-321.)

22. a correct. $NO_2$ is an irritant gas and does not produce systemic symptoms.

23. c correct. a - d are symptoms typical of both inorganic and organic lead intoxication, although the acute muscle and joint pair associated with inorganic lead is often uniquely identifiable. Symptoms in "e" are unequivocably inorganic lead. (Ref. 8, p. 293.)

24. a correct. Heavy metals are sometimes defined as those with atomic weights greater than 70 or a density greater than 5.

25. a correct. (Ref. 10.)

26. c correct. Garlic breath also caused by tellurium. (Ref. 1, p. 387.) It is believed that tellurium impurities in selenium cause the garlicy breath, not the selenium itself. (Ref. 11.)

27. a correct. Mostly a problem in iron foundry workers and copper refining. Elemental "e" is relatively nonirritating.

28. e correct. A reactant in forming polyurethane foams.

29. d correct. Benzidine is used in azo dye manufacture. (Ref. 1, p. 273.)

30. a correct. Anticoagulants are used primarily as rodenticides, e.g., Warfarin. (Ref. 1, p. 453-454.)

31. e correct. a is true for anticoagulants like Warfarin. c is true for organophosphorous insecticides.

32. d correct. Carbon tetrachloride poisoning symptoms. Jaundice is key. Typical of all chlorinated hydrocarbon intoxication.

33. c correct. a applies only to chlorinated hydrocarbons, b applies to acute Stoddard solvent exposures, d applies to both in acute exposure and trichloroethylene in chronic exposures. All are defatting agents and cause frequent dermatitis. According to the AIHA Stoddard Solvent Hygienic Guide, dermatitis is the most common occupational problem associated with its use.

34. a correct. Sax, Dangerous Properties of Hazardous Materials, rates both organic and inorganic mercury 3 on an ingestion toxicity scale of 5 (most toxic) but states specifically that aryl mercury compounds are much less toxic than alkyl mercuries. Sax states that elemental mercury is "not absorbed through the G.I. tract," therefore it is

essentially non-toxic by ingestion. Taken as a class, alkyl mercury compounds must be considered more toxic than mercury salts because of the many extremely toxic members of the group such as chloromethyl mercury, LD(Lo)(human)=5mg/kg vs. mercuric chloride, LD(Lo)(human)= 29mg/kg. Therefore the increasing order of toxicity is elemental - aryl - salts - alkyl.

35. a correct. b. Inorganic chromium compounds are suspected carcinogens.
c. Peroxyacetyl nitrate, irritant, photochemical air pollutant.
d. Chloramines, suspected carcinogens in water supplies formed by reactions of chlorine with amines.
e. Vinyl chloride causes angiosarcoma (liver cancer).

36. a correct. Note the following: Formula $B_5H_9$ B.P. 48°C
Flash Pt. 36°C
Lower flammable limit 1.3%
Pentaborane is highly reactive and has a strong odor. However the TLV is only 0.005 ppm.

37. b correct. Alkyl mercurials have very high toxicity. They have an affinity for lipid-containing organs, resulting in CNS disturbances. They can be absorbed through the skin.
TLV, all forms except alkyl=0.05mg/$m^3$ TLV alkyl mercury=0.01mg/$m^3$

38. a correct. Mercuric ions can be biologically methylated to alkyl compounds. Bacteria protect themselves against mercury metal dumped into lakes and streams by converting it to methyl mercury ions ($CH_3Hg^+$) and to gaseous dimethylmercury ($(CH_3)_2Hg$). These organic compounds are passed up the food chain to man.

39. b correct. Beryllium is a primary irritant involving the respiratory tract. An intense exposure causes severe chemical pneumonitis with pulmonary edema.

40. b correct. These gases (including fluoride as HF) enter the leaf through the stomata and cause damage, usually by plasmolysis. $SO_2$ and $NO_2$ cause chlorosis. Fluoride produces necrotic or "burned" leaf tips and/or edges. Because of the characteristic leaf damage, sensitive plant types can be good indications of air pollutants and useful in monitoring programs.

Although photosynthesis is affected, it is not enough to significantly alter the growth of the plant, therefore a) root damage c) stem damage are incorrect except in the long run, in which the plant dies. See Stern's Air Pollution, vol. I, 2nd ed.

41. e correct. a. toxicity - yes, nausea, vomiting, irritation to nose, throat, lungs, pulmonary edema, unconsciousness caused by inhalation of the gas, which also irritates the eyes and produces dermatitis.
b. fire hazard - yes, very dangerous when exposed to heat or flame, can react with acids and bases, alcohols, aluminum chloride, aluminum oxide, ammonia, copper, iron chloride, etc.

c. carcinogen, an indefinite, human carcinogen; causes cancer in female mice exposed to it for a prolonged period. Current exposure standards do not consider carcinogenic properties, therefore this is probably not a good answer as of today.

42. b correct. HCHO is a colorless pungent gas which causes severe irritation to mucous membranes of the respiratory tract and eyes. It is also a suspect carcinogen.

43. b correct. $HC_4$ displaces $O_2$ which leads to shortness of breath, unconsciousness and death from hypoxemia.

44. c correct. Benzene affects the hematopoietic system, causing anemia and leukopenia. Signs and symptoms of poisoning include headache, dizziness, fatigue, loss of appetite, irritability, nervousness, nosebleed and other hemorrhagic manifestations.

45. b correct. (Ref. 1.) Perchloroethylene causes long term CNS as well as liver and kidney affects (Ref. 11.) Trichloroethylene is notable in its failure to significantly affect the liver (Ref. 5) but does present long term CNS effects (Ref. 1.) Stoddard solvent should present symptomology similar to petroleum naphtha which may affect CNS on long term exposure, e.g., peripheral neuropathy may result from the hexane component. Therefore CNS damage is the only common effect.

46. a correct. MEK, methyl ethyl ketone, is also an irritant.

47. a correct. It is also known for its ability to cause sensitization, manifesting an asthmatic-like reaction.

48. a correct.

49. c correct.

50. b correct. Reduced cholinesterase activity is an indicator of parathion intersection. Parathion is a cholinesterase inhibitor insecticide. Carbon monoxide is tested by carboxyhemoglobin, mercury by urinary mercury, trichloroethylene by urinary trichloroacetate.

51. a correct. CO has approximately 250 times the affinity of oxygen for hemoglobin and therefore greatly reduces transportation of oxygen.

52. c correct. Chemical asphyxiants, such as carbon monoxide and nitrites which form carboxyhemoglobin and methemoglobin, inhibit oxygen uptake by hemoglobin though adequate $O_2$ is present in the inspired air. A chemical which depresses the heart causes ischemia anoxia. A gas which causes anoxia by displacing oxygen and thereby excluding it from the lungs is a simple asphyxiant and causes anoxia as do chemical asphyxiants. Chemicals which interfere with cell metabolism and cause hypoglycemia, such as excess insulin, or which inhibit metabolism, such as cyanide, azide, and dinitrophenol, cause cytotoxic anoxia.

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Chapter 3: RESPIRATORY DISEASE

Reviewer: Thomas Hodus, MD, NIOSH

I. Anatomy
   A. Nasopharynx - separates particles greater than 10 um diameter
   B. Trachea and bronchus
      1. narrowed by asthma-causing agents
      2. bronchitis - inflammation usually accompanied by excess secretion
   C. Bronchioles
   D. Alveoli
      1. site of oxygen - carbon dioxide exchange
      2. site of most allergic, pneumoconiosis and emphasema attacks

II. Airway Deposition of Particles
   A. Clearance mechanisms
      1. sneeze
      2. cough
      3. mucocilliary action
      4. marcophage action
   B. Deposition dependence
      1. particle physical parameters (most disease associated with particles between 1 and 5 um diameter)
      2. respiratory rate
      3. breathing mode (oral, nasal)

III. Disease identification
   A. Relation to non-occupational disease
   B. Smoking influence
   C. Spirometry as diagnostic tool
   D. Symptomology

IV. Important Specific Diseases
   A. Pneumoconiosis
      1. coal workers
      2. silicosis
      3. shaver's disease
      4. berylliosis
      5. siderosis
      6. stannosis
      7. asbestosis
   B. Industrial Bronchitis
   C. Occupational Asthma
      1. usually an allergic response
      2. important causes
         a. castor and soy beans
         b. dander
         c. diisocyanates
         d. grain and wood dust
         e. organic anhydrides
      3. delayed responses not unusual
      4. symptoms

D. Byssinosis and Mill Fever
E. Hypersensitivity Pneumonitis
    1. caused by fungi
    2. bagassosis most important

V. Soluble Irritants
    A. Acids and nitrogen dioxide
    B. Ammonia

VI. Lung Cancer
    A. Source difficult to identify
    B. Some important agents
        1. asbestos
        2. coke
        3. radionuclides
        4. chrome VI (suspect)
        5. nickel carbonyl
        6. OSHA and ACGIH lists of known and suspect carcinogens

## Review Questions

1. Name six (6) specific pneumoconioses and the causitive agent.

   1. _____
   2. _____
   3. _____
   4. _____
   5. _____
   6. _____

2. Silicosis is a disease caused by inhaling dust which contains small particles of:

   a. glass
   b. crystalline $SiO_2$
   c. amorphous silica
   d. aluminum silicate

3. Inhaled dust particles over ten microns in diameter:

   a. often penetrate to the lung alveoli
   b. are filtered out by the upper respirator tract
   c. clog the terminal bronchioles
   d. are highly toxic

4. Fibrosis of the lung, if extensive, is disabling because:

   a. the ability to expand the chest is lost
   b. scarring causes a mismatch between lung ventilation and perfusion (bathing with blood)
   c. the lining of the alveoli is thickened
   d. the x-ray picture shows nodulation

5. The size particle which as the greatest retention in the alveoli is:

   a. 0.5 - 1 μ
   b. .0 - .74 μ
   c. 1 - 5 μ
   d. 5 - 10 μ

6. Most U.S. asbestos work involves which type?

   a. chrysotile
   b. amosite
   c. crocidolite
   d. cristobalite
   e. anthophyllite and actinolite

7. Which asbestos form is considered most dangerous from an occupational disease standpoint?

   a. chrysotile
   b. amosite

c. crocidolite
d. cristobalite
e. anthophyllite and actinolite

8. Which form of silica has the lowest TLV?

a. crocidolite
b. cristobalite
c. chrysotile
d. tridymite
e. crystaline quartz
f. fused
g. two or more of the above have the same lowest value

9. Which of the following silicates is not a mineral fiber?

a. asbestos
b. asbestiform talc
c. mica
d. nonasbestiform talc
e. more than one of the above

10. Which of the following does not belong in the group?

a. siderosis
b. metal fume fever
c. ZnO
d. welding
e. mesothelioma

11. Which of the following does not belong in the group?

a. Farmers' Lung
b. nitrogen dioxide
c. welding
d. air pollution
e. pulmonary irritant

12. For particles to gain access to the alveolar regions of the lungs, they must have diameters less than:

a. 10 microns
b. 5 microns
c. 0.5 microns
d. 0.1 microns
e. 20 microns

13. Acute beryllium poisoning causes what symptoms?

a. contact dermatitis and ulcers

b. mild respiratory inflammation
c. pneumonitis with pulmonary edema
d. all of the above

14. What are the three most common types of crystalline silica?

a. quartz, cristobalite, tridymite
b. quartz, asbestos, tridymite
c. quartz, chrysotile, tridymite
d. chrysotile, cristobalite, quartz

15. Which has the highest incidence of lung cancer?

a. asbestos insulation installers
b. asbestos miners
c. chromate miners
d. coke oven workers

16. Byssinosis comes from exposure to:

a. cotton ifbers
b. asbestos fibers
c. wool fibers
d. ferric oxide
e. none of the above

17. Formaldehyde is primarily a:

a. systemic poison
b. simple asphyxiant
c. primary irritant
d. carcinogen
e. CNS toxin

18. A gas which exercises its toxic effect mainly by irritation of the respiratory tract is:

a. carbon monoxide
b. carbon dioxide
c. nitrogen dioxide
d. hydrogen cyanide
e. two of the above

19. An occupational disease which often leads to increased susceptibility to tuberculosis is:

a. asbestosis
b. silicosis
c. siderosis
d. metal fume fever
e. byssinosis

20. Among the following, which one does not play an important part in removing dust particles from the inspired air before it reaches the lung alveoli?

    a. nasal turbinates
    b. nasopharyngeal mucous
    c. cilia of mucous membranes
    d. tonsil
    e. all play an important part

21. Shaver's disease is a:

    a. lung disease attributed to inhalation of fumes from manufacture of aluminum oxide abrasive
    b. skin infection caused by shaving brushes contaminated by anthrax spores
    c. communicable disease of children
    d. skin disorder encountered in workers who prepare hides for tanning
    e. none of these

22. Coal Workers' pneumoconiosis and chronic silicosis usually take how long to show up on an x-ray?

    a. 3 - 6 months
    b. 1 - 5 years
    c. 10 - 12 years
    d. 20 - 25 years

23. Which of the following causes silicosis?

    a. silicates
    b. $Ca\ CO_3$
    c. $SiO_2$

24. The factor which is most responsible for dust gaining entrance to the terminal air sacs of the lung is:

    a. composition of dust
    b. concentration
    c. particle size
    d. condition of the lungs

25. Pneumoconiosis may be defined best as a disease of the lungs produced by inhalation of:

    a. biological contaminants
    b. chemical components of the environment
    c. dusts
    d. organic insecticides

26. Coal workers' pneumoconiosis can be stated to be:

    a. explainable due to silica content
    b. disposition of coal dust in the alveoli

c. due to hydrocarbons carried to lungs on coal aerosol
d. none of the above

27. Dyspnea is:

a. difficult breathing
b. reduced ability to maintain equilibrium
c. a form of lung fibrosis
d. lack of appetite
e. vertigo

28. Regarding metal fume fever select the incorrect statement.

a. several metallic oxides are responsible
b. sodium and potassium are chiefly responsible
c. the condition usually appears several hours after exposure
d. it occurs most commonly in welding, foundry, and galvanizing operations
e. clinical manifestations resemble the typical sensitization reaction to foreign protein.

29. Alveoli are found in:

a. the respiratory system
b. polluted water
c. wine fermentation
d. the digestive tract
e. a and d above

30. A spirometer is used to measure:

a. duct velocities
b. cable lay parameters
c. respiratory air moisture content
d. heart output volume
e. lung respiratory volumes

31. Which statement is incorrect?

a. rock dusting is used in coal mines even though prolonged work exposure to any dust might cause industrial bronchitis
b. the main threat to life for a coal miner is coal workers' pneumoconiosis
c. coal workers may develop silicosis as well as coal workers' pneumoconiosis
d. the size of dust particles is an important factor in determining what part of the lung is affected

32. Which statement is incorrect?

a. silicosis increases the risk of developing active tuberculosis
b. smoking kills and disables more Americans than does coal workers' pneumoconiosis

c. major advances in the treatment and possible cure of coal workers' pneumoconiosis have been made in the last 10 years
d. the more advanced form of coal workers' pneumoconiosis, called complicated CWP (or progressive massive fibrosis), can cause significant symptoms and shorten life

## Answers to Review Questions

1. Silicosis - crystalline silica
   Asbestosis - asbestos fibers
   Siderosis - iron oxide fume
   Coal workers' pneumoconiosis - coal dust
   Berylliosis - beryllium
   Shaver's Disease - combination of aluminim oxide, aluminum and other contaminants from aluminum smelting possibly including silica
   Stannosis - tin

2. b correct. Glass is amorphous $SiO_2$.

3. b correct. See discussion under question 5.

4. b correct. Thickening of the alveolar wall is characteristic of interstitial lung disease which results from beryllium, moldy hay (Farmer's lung) and bagasse. (Ref. 1, p. 500.)

5. c correct. Assuming retention in the lung means retention in the alveoli, there is a maximum in the curve between 1 and 5 aerodynamic diameter and a minimum at about 0.5 um. Particles larger than 5 μm would be retained at a very high rate if they reached the alveoli, but they are removed in the upper passages by impaction and interception.

6. a correct. Chrysotile accounts for 95% of world's production, most of which comes from Quebec and is imported by the U.S. (Ref. 2, p. 121.)

7. c correct. Crocidolite is associated with mesothelioma, a normally fatal cancer of the pleura (lining of the lung). Incidence is especially high among smokers exposed to asbestos. (Ref. 2, p. 121-122.) Cristobalite is a form of quartz.

8. g correct. Crocidolite and chrysotile are asbestos not quartz. The TLVs for tridymite and cristobalite are one-half that of quartz. (Ref. 3, 1979, p. 32.)

9. e correct. Both talc and asbestos are silicates. Asbestiform talc receives its name because of its fibrous nature. Neither non-asbestiform talc nor mica are fibrous.

10. e correct. a - d are all associated with metal fume fever. Mesothelioma is associated with asbestos.

11. a correct. b - e are all associated with nitrogen dioxide. Farmer's lung, a hypersensitivity pneumonitis, is caused by fungal spores in hay. Nitrogen dioxide is a pulmonary irritant produced in welding operations and the principal component of the "oxides of nitrogen" air pollution group. Silo Fillers' disease, caused by nitrogen dioxide from a fermentation side reaction, is not to be confused with Farmer's lung. (Ref. 1, p. 499-500.)

12. b correct. See discussion under question 5.

13. d correct. All of the listed symptoms may reflect acute beryllium poisoning. (Ref. 4 p. 123.)

14. a correct. Asbestos is not quartz and chrysotile is the most common asbestos form.

15. a correct. Historically, lung cancer has been most frequent among asbestos installers and commercial processors. However the population (40,000 in the U.S.) involved in installation is about four times larger than that involved in processing. Therefore the incidence (the total number of cases reported over a given time period) is much higher. The populations involved in chromate mining and coke oven work are relatively small and therefore incidence is relatively low. ("Proceeding of Workshop on Asbestos", OSHA, 1977, p. 59-60.) Note: "incidence" is the total number of cases in the subject population, "incidence rate" is the number of cases divided by the size of the population area usually multiplied by some standard population size.

16. a correct. See question 1. Wool (animal) fibers are not known to cause disease.

17. c correct. Formaldehyde is primarily a pulmonary and cutaneous irritant causing overt irritation to eyes and nose at 2 - 3 ppm and known to be a dermal sensitizer. One might suspect systemic poisoning and CNS effects, but irritation, to the extent of death by pulmonary edema, and pneumonitis at concentrations as low as 100 ppm (30 min.) render these effects unobservable. As of today it is suspected of being a carcinogen but this is not established and the National Cancer Institute is now investigating the issue. (Ref. 4 ,p. 272-273; Ref. 5, p. 587.)

18. c correct. CO is a chemical asphyxiant, $CO_2$ a simple asphyxiant, HCN combines with hemoglobin and interferes with cellular metabolism at virtually all levels.

19. b correct. (Ref. 2, p. 130.)

20. d correct. (Ref. 1, p. 494-498.)

21. a correct. See question 1. (Ref 1, p. 135.)

22. c correct. Silicosis may develop in as little as two years but most cases takes more than 10 to 12 years and some cases taking over 40 years. (Ref. 6, p. 900.)

23. c correct.

24. c correct. Penetration into the lung is primarily an aerodynamic phenomena dependent primarily on particle size and uninfluenced by concentration or chemical composition. Chemical composition may have an indirect effect if particles are hygroscopic since absorption of water will alter particle size. Condition of the

lungs can also affect penetration to the alveoli since certain lung conditions alter the size of alveoli, bronchioles and bronchi. These effects are secondary to particle size.

25. c correct. (Ref. 7, p. 112.)

26. b correct. (Ref. 7, p. 115.)

27. a correct. (Ref. 8, p. 486.)

28. b correct. Sodium and potassium oxides are unstable, picking up water from any available source and forming strong bases. Both are extremely irritating and even small amounts would produce severe respiratory irritation.

29. a correct. Alveoli are the small air sacs in the lungs. They are the site of oxygen - $CO_2$ exchange.

30. e correct. A spiromter is a clinical diagnostic device used to measure lung expiratory volumes. It is also used as a primary standard for volume in calibration of air sampling equipment.

31. b correct. Rock falls and other accidents are the main problem. (Ref. Unpublished consultation, Appalachian Laboratory for Occupational Safety and Health, NIOSH.)

32. c correct. None of the chronic pneumoconioses have effective treatment. (Ref. 1, p. 500.)

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# Chapter 4: OCCUPATIONAL DERMATOSES

Reviewer: Edward Emmett, M.D., Johns Hopkins University

I. Significance
   A. Most often reported occupational disease (40%)
   B. Population very conscious of skin problems

II. Disease Classifications
   A. Irritant contact dermatitis - most common
      1. solvents
      2. soaps and detergents
      3. coolants
   B. Allergic contact dermatitis
      1. nickel and its salts
      2. chromium salts
      3. mercurials
      4. rubber and plastic additives
      5. poison ivy and oak
   C. Folliculitis - results from inflammation of hair follicles
   D. Chloracne - from some chlorinated solvents
   E. Physical irritants - fibrous glass
   F. Skin cancer
      1. important causes
         a. arsenic and its compounds
         b. sunshine, ultraviolet radiation
         c. ionizing radiation
         d. coal tar pitch
         e. polycyclic aromatic hydrocarbons
      2. most serious type - melanoma - rate increasing
   G. Miliaria - prickliheat
   H. Ulceration - chrome salts and other materials

III. Structure and function of the skin
   A. Principal components
      1. epidermis and stratum corneum
      2. dermis - contains blood vessels and lymph glands
      3. hypodermis
      4. sweat glands and hair follicles
   B. Functions
      1. barrier
      2. antibacterial and antifungal
      3. sensation
      4. temperature regulation
      5. vitamin D production
      6. emotional expression

IV. Percutaneous Absorption
   A. Controlling factors
      1. region of body - skin thickens
      2. nature of substance
      3. nature of vehicle
      4. skin condition

B. Water Solubles
   1. better absorbed by wet skin
   2. absorption increased for covered skin

V. Prevention
   A. Substitution
   B. Engineering
   C. Education
   D. Protective Clothing
   E. Administrative exclusion of sensitive workers through preplacement exams
   F. Personal hygiene

## Review Questions

1. Among the following, the most frequent occupational disease is:

   a. due to radioactive exposure
   b. chemical poisoning
   c. dermatosis
   d. pulmonary infection
   e. systemic infection

2. Which of the following methods would be most effective in reducing dermatisis in electroplaters?

   a. barrier creams
   b. gloves
   c. local exhaust ventilation
   d. general air purification
   e. frequent hand washing

3. Which of the following is least likely to involve problems of occupational dermatoses?

   a. leather tanning
   b. lumbering
   c. asbestos processing
   d. fish packing
   e. farm labor

4. Which industry has the highest number of lost man-days annually due to occupational dermatitis?

   a. leather tanning
   b. meat packing
   c. electrical components
   d. paint
   e. abrasive products

5. Dermatitis tends to be most severe in which of the following industries?

   a. silver
   b. meat packing
   c. lead battery
   d. paint
   e. concrete products

6. The overall "highest risk" industry, as defined by OSHA, for occupational dermatitis is:

   a. poultry dressing
   b. nonferrous foundries
   c. leather tanning
   d. small arms
   e. paint

7. Which of the following carries a TLV "skin" notation?

   a. xylene
   b. benzidine
   c. epichlorohydrin
   d. two of the above
   e. all of the above

8. The skin notation next to a chemical in the TLV bookelt means that:

   a. the chemical causes dermatitis
   b. there is an overall exposure contribution by skin absorption
   c. material should not be permitted to touch the skin at any time
   d. material is of toxicological importance only if skin is involved
   e. two of the above

9. Of all occupational deseases occurring in industry, the most prevalent is:

   a. lead poisoning
   b. silicosis
   c. mercurialism
   d. dermatitis

10. The most frequent cause of occupational dermatoses is exposure to:

   a. soap and detergents
   b. solvents
   c. fibrous glass
   d. strong acids and alkalis

11. A frequent cause of aggravation and prolongation of occupational dermatoses is:

   a. the use of protective hand cream
   b. irritants present in improperly cured rubber gloves
   c. application of strong medication to the lesions
   d. exposure to x-rays

12. In surveying a plant using epoxy resins, you found a number of workmen with dermatitis. Which one of the following control measures would be <u>least</u> effective in controlling the hazard?

   a. local exhaust ventilation
   b. frequent washing of hands, face or other exposed skin surfaces with soap and water
   c. frequent washing of hands and face with an organic solvent followed by soap and water
   d. good housekeeping
   e. use of protective clothing, i.e., gloves, aprons, coveralls, etc.

13. Match the following columns (which concern hazards which enter through the skin).

| | |
|---|---|
| 1. Deep "punched out" ulcer | a. Curing agents like phenols |
| 2. Blocking of sweat ducts | b. Chromium |
| 3. Destruction of dermis | c. Grease |
| 4. Hardening reactions | d. Base used for cleaning aluminum |

1._____ 2._____ 3._____ 4._____

14. Barrier creams:

a. are effective because they neutralize potential irritants
b. reduce contact of irritants with the skin
c. are preferred to gloves in most cases
d. are not effective industrial hygiene aids
e. a and b above

15. Impervious gloves:

a. can be selected which provide excellent long term protection against virtually any solvent
b. may be penetrated by many solvents in sufficient degree to be of industrial hygiene concern
c. are not as effective as barrier creams
d. are preferred to substitution of materials as means of dermatitis prevention
e. none of the above

16. Which of the following pairs is the least likely association?

a. eczema - metallic salts
b. acne - cutting oil
c. skin discoloration - silver
d. granulomas - arsenic trioxide
e. ulcerations - calcium nitrate

17. Systemic poisoning or intoxication through the skin occurs _____ poisoning through inhalation or ingestion.

a. far more frequently than
b. slightly more frequently than
c. about as frequently as
d. less frequently than

18. Which of the following is not likely to cause systemic effects when absorbed through the skin:

a. pentaborane
b. TNT
c. tetraethyllead
d. phenol
e. cyclohexane

19. Which of the following is the most frequent cause of dermatologic neoplasms?

    a. PAHs
    b. inorganic arsenic
    c. ionizing radiation
    d. ultraviolet radiation
    e. c and d above

20. Most occupational dermatitis is caused by:

    a. poison ivy and poison oak
    b. allergic reactions
    c. irritant chemicals
    d. mechanical irritation
    e. nonionizing radiation

21. Which of the following is <u>not</u> a dermal defense mechanism?

    a. antimicrobial function
    b. thermoregulation
    c. buffering action
    d. sensory mechanisms
    e. none of the above

22. Wet skin is _____ vulnerable to penetration by aqueous toxins than dry skin.

    a. more
    b. less
    c. equally
    d. indeterminate

23. Which of the following is least likely to enhance proneness to dermatological skin problems?

    a. dry skin
    b. oily skin
    c. fair skin
    d. chronic skin disease
    e. all of the above are likely to enhance proneness

24. The annual national cost (1976) of occupational skin disease is of the order of:

    a. 3 million dollars
    b. 30 million dollars
    c. 300 million dollars
    d. 3 billion dollars
    e. 30 billion dollars

## Answers to Review Questions

1. c correct. Dermatoses account for 40-45% of occupational disease.

2. b correct. Electroplating involves a high risk of contact with dermatitis causing materials through splashing and handling of wet parts, baskets, and controls. Without protective clothing, especially gloves, dermatitis is virtually assured. Without adequate exhaust ventilation and with gloves, respiratory problems, including chrome ulcers of the nasal passages, are a serious risk but dermatitis can nevertheless be controlled. (Ref. 2, p. 1157-1159.)

3. c correct. Incidence in descending order (cases per 1000 per year): leather tanning (21.2), fish packing (10.6), farm labor (8.9), forest services (includes lumbering)(8.9), asbestos processing (7.0). (Ref. 1, p. 10.)

4. b correct. Total annual man-days lost: meat packing (1561), leather tanning (1392), paint industry (794), electrical components (756), abrasive products (413). (Ref. 1, p. 11.)

5. a correct. Severity is measured by the fraction of the total number of cases with lost work days, e.g., if one half of all the reported cases had lost work days, the severity would be 0.5. Severities are as follows: silver (0.39), meat packing (0.31), lead battery (0.25), paint (0.21), concrete products (0.21). (Ref. 1, p. 13.)

6. a correct. The overall highest risk is defined as the product of incidence, target population, severity, and duration. Descending order of risks is as follows: poultry dressing, leather tanning, paint, small arms, non-ferrous foundries. Poultry dressing is high because it involves constant work with wet hands in a hot, steamy environment. Most workers are paid on a piecework basis which makes them reluctant to take any preventive measures which may slow them down. (Ref. 1, p. 15.)

7. e correct. (Ref. 3.)

8. b correct. (Ref. 3.)

9. d correct. See question 1.

10. d correct. The answer to this question depends on the definition of occupational dermatitis. Using the definition "any abnormal condition of the skin caused or aggravated by a substance or process associated with the work environment" the "correct" answer can be determined from the following data available from a 7 state date pool. (Ref. 1.)

| | chemical burns | other dermatosis | total |
|---|---|---|---|
| soaps and detergents | 483 | 958 | 1441 |
| acids and alkalis | 1114 | 142 | 1671 |

All other categories are much less frequent than these. Because of poor reporting and other data problems, it is probably not realistic to draw any conclusion regarding the relative incidence of these problems. In all likelihood under reporting is probably greatest in the soaps and detergents category because of the huge number of people involved in small business clothes laundering and dishwashing.

11. c correct. (Ref. 2, p. 235-6.)

12. c correct. Frequent washing of the face with an organic solvent must be considered ill advised under almost any circumstance and is a likely cause of dermatitis in itself. All other answers offer some promise of reducing the problem. (Ref. 1, p. 30.) Local exhaust ventilation has been notably successful in epoxy work. (Ref. 1, p. 59.)

13. 1 - b, 1 - c, 3 - d, 4 - a.

14. b correct. In the past, some barrier creams claimed to neutralize irritating chemicals. This mechanism is not now generally recognized as a significant contributor to their effectiveness. (Ref. 1, p. 63; Ref. 2, p. 229-230.)

15. b correct. Virtually every available material in glove thicknesses is penetrated by some common solvent. (Ref. 1, p. 61-62.)

16. d correct. Granulomas usually result from silica or Zn or Be salt exposures. $As_2O_3$ causes ulcerations. (Ref. 1, p. 40-41.)

17. d correct. For certian classes of exposure, e.g., insecticides, skin absorption is the most frequent route of entry. (Ref. 1, p. 26; Ref. 5, p. 63.)

18. e correct. a. Pentaborane TLV - 0.005 ppm. a CNS depressant.
    b. TNT TLV - .5 $mg/m^3$ causes dermatitis through little skin absorption
    c. Tetraethyllead skin hazard TLV - .1 $mg/m^3$
    d. Phenol - skin hazard, TLV - 5 ppm
    e. Cyclohexane TLV - 300 ppm - not known to cause systemic effects except at extremely high levels

19. d correct. All may cause neoplasms, therefore, the decision hinges on the relative incidence among the cases cited. All choices except ultraviolet radiation, most often sunlight, are either of low incidence because of small populations exposed or, in the case of ionizing radiation, low exposure due to rigid controls for purposes other than controlling dermatoses.

20. c correct. (Ref. 1, p. 32.)

21. e correct. Additional mechanisms are: sweat gland function, UV defense, resiliency, and immunologic processes. (Ref. 1, p. 26-28; Ref. 2, p. 79-80.)

22. a correct. (Ref. 1, p. 29-31.)

23. e correct. Oily skin enhances resistance to, not proneness to, damage from soaps, solvents and soluble cutting fluids. Oily skin does, however, predispose to acne. Lack of skin pigment can enhance damage propinsity from actinic (damaging ultraviolet) radiation and contact dermatological agents. Therefore any of these conditions could lead to dermatological problems. (Ref. 2, p. 207-208.)

24. c correct. (Ref. 1, p. 5.)

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Chapter 5: EXPOSURE CRITERIA

Reviewers: Herbert Christensen, Sc.D., NIOSH
Frank Mackison, NIOSH
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I. Threshold Limit Values
   A. Published by American Conference of Governmental Industrial Hygienists
   B. Consensus standards
      1. TLV Committee
   C. Not legally binding
   D. 197 standards codified as law by OSHA regulations
   E. Cover chemical and physical agents
   F. TLVs recommended, not applicable to entire population
   G. Intended only for normal-healthy workers exposed on the job
   H. See TLV booklet and back-up documentation

II. OSHA Permissible Exposure Limits
   A. Legally binding
   B. Original list adopted 1968 TLVs
   C. Same general limitations as TLVs

III. NIOSH Recommended Exposure Limits
   A. Not legally binding
   B. Formal recommendations to OSHA by NIOSH
   C. Development Procedures

IV. National Ambient Air Quality Standards
   A. EPA regulation
   B. Designed to protect the health of general public
   C. Only seven materials or classes of materials covered

V. Other Standards Writing Organizations
   A. American National Standards Institute (ANSI) (a private organization)
   B. State and local governments
   C. Nuclear Regulatory Commission
   D. Department of Defense and its components
   E. National Fire Protection Association
   F. National Safety Council
   G. American Public Health Association

## Review Questions

1. A TLV posted in the notice of intended changes becomes "adopted" after _____ years if no further action is taken by ACGIH.

   a. 1
   b. 2
   c. 3
   d. adoption requires specific action
   e. none of the above

2. Compute the TWA concentration from the following measurement data.

| Time Period | Concentration, ppm |
|---|---|
| 0600-0900 | 100 |
| 0900-0100 | 200 |
| 1100-1200 | 0 |
| 1200-1400 | 100 |

   a. 100 ppm
   b. 133 ppm
   c. 113 ppm
   d. <100 ppm
   e. >150 ppm

3. Compute the average TLV for the following liquid mixture:

   50% substance A, TLV = 1600 $mg/m^3$
   30% substance B, TLV = 1900 $mg/m^3$
   20% substance C, TLV = 670 $mg/m^3$

   a. 1390 $mg/m^3$
   b. 1300 $mg/m^3$
   c. 1204 $mg/m^3$
   d. TLVs for mixtures cannot be computed
   e. none of the above

4. When determining if a gaseous mixture violates the combined TLV, which of the following assumptions is/are made?

   a. gases have similar molecular weights
   b. gases have similar reactivities
   c. gases have similar toxic effects
   d. all of the above
   e. b and c above

5. PEL's are:

   a. Pollutant Emission Levels
   b. established by NIOSH
   c. Permissible Exposure Limits
   d. not associated with industrial hygiene

6. A very short, "instantaneous," excursion of $NH_3$ to 250 ppm should:

   a. be of no concern
   b. alert you to possible problems in ammonia emmission control
   c. be ignored when determining a TWA concentration
   d. be regarded as an artifact of your measurement system and ignored
   e. considered an unacceptable event and initiate control action

7. TLV-STEL refers to a concentration:

   a. that should never be exceeded
   b. permitted for a 30 minute exposure
   c. that is based in part on the California Short Term Limits
   d. that is an emergency exposure level
   e. below the TLV-TWA

8. TLVs for gases and vapors are estimated on what basis?

   a. weight to weight
   b. volume to volume
   c. volume to isotope number of contaminant
   d. volume to specific gravity

9. Why is 1,1,1 trichloroethane substituted for trichloroethylene?

   a. TLV is higher
   b. less volatile
   c. higher boiling point
   d. none of the above

10. The primary difference between TLVs and air pollution standards is:

    a. TLVs are based on 8-hour day exposures, A.P. on 24-hour exposures
    b. TLVs are based on 8-hour day exposures, A.P. on human data
    c. TLVs are expressed in ppm or $mg/m^3$, A.P. in $mg/m^3$ only
    d. no difference

11. All TLVs are:

    a. valuable in assuring workers are protected from overlifting
    b. designed to protect a healthy, working population
    c. values which should never be exceeded in the working environment
    d. given the force of law through OSHA regulations
    e. total lifting values

Answers to Review Questions

1. d correct, 2 years. (Ref. 1, p. 34.)

2. c correct, 113 ppm $c_1t_1 + c_2t_2 + \ldots + c_nt_n$ = TWA (8 hours)

$$\frac{(100)(3) + (200)(2) + (0)(1) + (100)(2)}{8} = 113$$

(Ref. 2, sect. 1000 (d).)

3. b correct, 1300 $\frac{mg}{m^3}$ (Ref. 1, p. 48.)

4. e correct, b and c. (Ref. 1, p. 47-49.)
   b. gases have similar reactivities
   c. gases have similar toxic effects

5. c correct. PELs are permissible toxicologic exposure limits established by OSHA regulations. The 1968 TLVs were adopted in their entirety to establish the initial PELs, but since that time OSHA has added and changed items. In addition, new TLV values adopted since 1968 have not, in general, been adopted by OSHA. (Ref. 2, sect. 1000 (d).)

6. e correct, considered an unacceptable event and initiate control action. See TLV pamphlet note on peak concentrations, page 51. Instantaneous peaks are of importance for contaminants that are "fast acting." Ammonia is given as a specific example.

7. a correct, that should never be exceeded - Page 3 TLV Booklet (1981.) STELS are a 15 minute limit based on a variety of standards including the Penn. Short Term Limits.

8. b correct, volume to volume. (Ref. 1, Chapter 4.)

9. a correct, TLV is higher.
   350 ppm vs. 50 ppm (intended change)
   Boiling point is actually lower, 74 C vs. 87 C.
   (Ref. 1, Sect. 1000 (d).)

10. a correct, TLVs are based on 8-hour day exposures, A.P. on 24-hour exposures. It is also notable that TLVs are designed to protect the healthy working population while air pollution standards protect the entire population. (Ref. 1, p. 2-8; Ref. 3, Chapter 9.)

11. b correct, See #10. TLVs may be exceeded for short terms as "instantaneous" excursions, see #s 5 and 6, or short term excursions. They are averages, not ceilings, unless so indicated by presence of "C" notation. (Ref. 2, Sect 1000 (d).)

References

1. American Conference of Governmental Hygienists, "Threshold Limit Values for Chemical Substances and Physical Agents," Cincinnati, Ohio, 1979.

2. Occupational Safety and Health Administration, "OSHA Safety and Health Standards, General Industry Standards," 29CFR1910.

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# Chapter 6: MEDICAL MONITORING

Reviewers: Joseph A. Thomasino, Major (P), USA, MC, U.S. Army Environmental Hygiene Agency
Robert J. P. DeTreville, Col, USAF, MC, USAF Occupational and Environmental Health Laboratory

I. Purpose
   A. Worker protection/education
   B. Reduce compensation
   C. Performance criteria
   D. Legal requirement
      1. documentation of controls/protection
      2. documentation of employee fitness

II. Types of Medical Examinations
   A. Pre-employment
   B. Routine periodic
   C. Termination

III. Examination Selection Considerations
   A. Operation Characteristics
      1. physical stresses
      2. mental stresses
      3. chronic or acute exposures
   B. Test Characteristics
      1. acute exposures
      2. chronic exposures
      3. reliability
      4. simplicity
      5. cost effectiveness
   C. Frequency of tests
      1. exposures
      2. employee health

IV. Components of Medical Evaluations
   A. General physical examination
   B. Blood tests
      1. chemistry
      2. hemotology
   C. Urine tests
      1. cytology
      2. trace metals
   D. Sputum cytology
   E. X-ray
   F. Pulmonary function
      1. FVC
      2. $FEV_1$
   G. Audiometry
   H. Liver function
      1. SGOT
      2. SGPT
   I. Electrocardiography
   J. History, genetics

V. Tests for Common Hazardous Contaminants
   A. Inorganics
      1. lead
      2. mercury
      3. beryllium
      4. cadmium
      5. chromium
      6. boron
      7. silica
      8. asbestos
      9. cyanide
      10. arsenic
      11. carbon monoxide
   B. Organics
      1. carbon tetrachloride
      2. benzene
      3. organophosphates
      4. trichloroethylene
      5. methanol
      6. phenol
      7. methyl ethyl ketone

VI. Actions to Reduce Exposure
   A. Restrict Worker Employment
      1. temporary
      2. permanent
   B. Appropriate protection
      1. engineering
      2. personal
   C. Exposure time limits

## Review Questions

1. Which of the following tests would best be used to identify between parathion intoxication?

   a. red cell count
   b. liver function test
   c. fat biopsy
   d. delta cholinesterase determination
   e. none of the above

2. Mercury exposure can effectively be monitored using:

   a. mercury in urine testing
   b. mercury in blood testing
   c. kidney function testing
   d. a and c above
   e. all of the above

3. A worker exposed to tritium should be monitored by a periodic:

   a. red blood count
   b. white blood count
   c. urine assay
   d. chest x-ray
   e. eye exam

4. In interpreting urinary bioassay results it is necessary to:

   a. know the period the sample was collected over
   b. correct the results for specific gravity
   c. allow for a range of normal variation
   d. a and c above
   e. b and c above

5. Which of the following cannot be monitored using a delta cholinesterase test?

   a. DDT
   b. DVP
   c. Parathion
   d. a and c above
   e. b and c above

6. Which of the following cause afebrile acute disease?

   a. metal fume
   b. teflon
   c. $NO_2$
   d. flax
   e. none of the above

7. A physical examination of the skin is least valuable for a worker exposed to:

   a. chlorobenzene
   b. fiber glass
   c. chromic acid
   d. osmium tetroxide
   e. nitrogen dioxide

8. Spirometric testing might include all of the following except:

   a. $FEV_1$
   b. FVC
   c. Airway resistance determination
   d. $FEV_3$
   e. $PCO_2$

9. Which of the following is a problem associated with spirometry?

   a. cannot detect changes in airway resistance and pulmonary compliance
   b. high cost
   c. may not detect early significant changes
   d. complex
   e. unreliable measure of alveolocapillary membrane changes

10. Sputum cytology is useful in:

   a. early detection of lung cancer
   b. analysis of toxic metal deposition in bone
   c. detecting size and location of asbestos fibers in lungs
   d. benzene surveillance
   e. none of the above

11. Occupational arsenic exposure:

   a. is normally indicated by urine levels over 0.1 mg/l
   b. is normally indicated by blood levels over 0.1 mg/l
   c. can be very effectively monitored by the arsenic content of hair
   d. may be falsely indicated by ingestion of foods normally high in arsenic
   e. may be easily confused with antimony poisoning because of its similar effects on hair growth

12. Which of the following is the best indicator of benzene exposure:

   a. blood benzene level
   b. urine benzene level
   c. blood sulfate ratio
   d. urine sulfate ratio
   e. urine phenol level

13. The Beilstein test is a rapid means for the detection of:

    a. aromatic hydrocarbons
    b. amines
    c. chlorinated hydrocarbons
    d. nitrocompounds
    e. never used in industrial hygiene

14. What level of blood lead is considered unacceptable?

    a. 80 ug/100g
    b. 20 ug/100g
    c. 0.04 ug/100g
    d. 0.01%
    e. none of the above

15. The federal government recommends which biological test for mercury:

    a. mercury in urine
    b. mercury in blood
    c. mercury in feces
    d. SGPBT

16. The risk of developing active pulmonary tuberculosis is substantially increased by which of the following?

    a. exposure to free silica dust
    b. exposure to alpha radiation
    c. the presence of coal worker's pneumoconiosis
    d. all of the above

17. Which of the following statements about brucellosis is false?

    a. it is most often seen among meat inspectors, slaughterhouse workers, and veterinarians
    b. having the disease produces immunity in most persons
    c. most patients can be successfully treated with antiobiotics
    d. all of the above

18. Which of the following is most useful for determining if a worker has abnormal lung function?

    a. $FEV_1$ (forced expiratory volume)
    b. FVC (forced vital capacity)
    c. $FEV_1/FVC$ ratio
    d. none of the above

19. Which of the following statements is <u>false</u>?

    a. the partial pressure of oxygen in arterial blood does not change substantially regardless of altitude
    b. the respiratory rate increases a high altitude
    c. underlying lung diseases impair the ability to adapt to high altitude
    d. all of the above

20. Which of the following is most appropriate in the routine pre-employment evaluation of a machinist?

    a. exercise stress test
    b. serum protease-inhibitor level
    c. allergy history assessment
    d. audiometric testing

21. Which of the following statements about chest x-rays is true?

    a. most cases of lung cancer discovered by annual chest x-rays can be cured
    b. it is unusual to see patients with a normal chest x-ray who also have abnormal pulmonary function tests
    c. the ILO/UC classification system for pneumoconiosis is most useful as an epidemiologic tool
    d. none of the above

22. Which of the following is not classified as an "obstructive" type of lung impairment?

    a. asthma
    b. asbestosis
    c. chronic bronchitis
    d. emphysema

23. A galvanizer is experiencing shortness of breath, fever, cough, chills, and a "flu-like" feeling at dinner time almost every Monday. These symptoms last all night but subside by morning. He is suffering from:

    a. occupational asthma
    b. hypersensitivity pneumonitis
    c. chronic bronchitis and emphysema exacerbated by dust
    d. none of the above

24. Which of the following diseases can be seen in animal handlers?

    a. anthrax
    b. brucellosis
    c. ornithosis
    d. bubonic plague
    e. a and b only
    f. all of the above

25. Type B hepatitis is a major problem among which of the following groups?

    a. vinyl chloride workers
    b. workers exposed to raw sewage
    c. renal dialysis technicians
    d. all of the above
    e. none of the above

26. What is the principle emphasis of an in-plant medical program?

a. diagnosis
b. treatment
c. prevention
d. rehabilitation

## Answers to Review Questions

1. d correct. Organophosphorous pesticides, such as parathion, are cholinesterase inhibitors causing CNS symptoms and cramps. While overexposure to chlordane may be detectable in a fat biopsy or manifest itself as an irregular liver function, neither of these tests is as simple or direct as delta cholinesterase testing. (Ref. 1, p. 1950-1951.)

2. e correct. The most useful test for inorganic mercury is probably urinary mercury (>0.1 to 0.5 mg/l is significant). Alkyl mercury may yield mercury in blood and urine. Mercury compounds affect kidney function and monitoring this is effective. (Ref. 3, p. 370-373.)

3. c correct. Tritium exposure in almost any form is quickly identified by urine radioassay. It should be remembered that the biological half-life of tritium is only twelve days, so delays of a month or more in sample collection after exposure will greatly reduce detectability.

4. d correct. This question appears to have no good answer. For materials that pass through the system quickly, it is obviously essential to coordinate sample collection and exposure times. In addition, spot and 24 hour samples may yield greatly different results. The concentration correction for specific gravity (see question 27, Chapter 1.) may yield a 10-fold correction for the normal range of specific gravities of 1.003 to 1.030. "Normal variation" is an element that must always be considered in bioassay. Given the question, one is forced to discard either a or b to determine the best answer. Since corrections for specific gravity are often not made in practice (the implication being that they are included in the "normal variation" component), the best answer must be d. (Ref. 7, p. 273-276.)

5. a correct. DDT is a chlorinated hydrocarbon insecticide and cannot be detected by cholinesterase monitoring. All others listed are organophosphorous insecticides which reduce cholinesterase levels. (Ref. 2, p. 400.)

6. c correct. Afebrile = without fever. (Ref. 2, p. 382-383.)

7. e correct. All other agents listed cause dermatological problems. a - chloracne, b - irritant dermatitis, c - irritant dermatitis and skin ulcers, d - irritant dermatitis, skin ulcers and green or black skin discoloration. (Ref. 3.)

8. e correct. $PCO_2$ is not a spirometric measurement although it is valuable in assessing respiratory problems. $FEV_3$ exists but is rarely used. (Ref. 4, p. 182-3.)

9. c correct. In some occupational diseases (e.g. silicotuberculosis) irreversible and progressive fibrosis may occur before changes in the $FEV_1/FVC$ ratio occur. This should not contraindicate pulmonary function testing because it is, when properly done, the best screening tool for obstructive bronchopulmonary diseases. (Ref. 4, p. 183.)

10. a correct. Cytology is the study of cells expelled in body fluids. Sputum cytology has been considered useful in detecting lung tumors. (Ref. 7, p. 602.)

11. d correct. Seafood, particularly lobster, is high in arsenic and will cause elevated arsenic in blood and urine. (Ref. 2, p. 110; Ref. 5.)

12. e correct. Urine sulfate ratio was formerly considered a good test but has now lost favor to urinary phenol. (Ref. 6.)

13. c correct. The Beilstein test is a test for chlorine in chlorinated hydrocarbons. It is not, however, usually employed in medical monitoring but was formerly used in air sample analysis.

14. a correct. (Values should be expressed as ug/100g). The maximum concentration acceptable by OSHA will decrease by 10 µg/100g each year until reaching 50 µg/100g effective 2 March 1983. Workers exceeding these values on initial and repeat tests must be withdrawn from work until values drop to 20 µg/100g below the standard for periods before 2 March 1983 and 10 µg/100g below the standards after 1 March 1983. (Ref. 7.)

15. a correct. (Ref. 3, p. 371.)

16. a correct. Exposure to free silica dust can cause a secondary pulmonary fibrosis which can make the lung more susceptible to active tuberculosis organisms. Normally, "coal worker nodules" do not create as significant an amount of scarring in the lungs as do silicotic nodules. (Ref. 10, p. 500.)

17. b correct. Infected animals and their carcasses are the primary sources of brucellosis, and by the nature of their work, meat inspectors, slaughterhouse workers, and veterinarians belong to that population most often exposed. Normally, antibiotics are 95% successful in brucellosis treatment. An individual who has had the disease can readily become infected again under similar conditions that yielded the original disease. (Ref. 91, p. 59.)

18. c correct. Although the $FEV_1$ analysis is a satisfactory method of determining the presence of obstructive lung disease, the $FEV_1/FVC$ ratio gives the clinician a more complete method of analysis in determining respiratory disease and limitations.

19. a correct. The partial pressure of oxygen in the atmosphere decreases with increasing altitude. There is less oxygen in inspired air and, subsequently, less to be carried in arterial blood from the lungs to the cells. To compensate for decreased oxygen at

altitude, the body will increase its respiratory rate. If an individual has a significant lung disease which either lessens vital capacity or diminishes oxygen uptake ability, the individual will find it difficult to adapt to the rarefied atmosphere. (Ref. 12, p. 38, 251.)

20. d correct. Individuals employed in machine shops are characteristically exposed to potentially hazardous noise from milling machines, drill presses, lathes, and other similar metalworking equipment. These individuals should be placed on a hearing conservation program which includes pre-employment and routine audiometric examinations.

21. c correct. The ILO/UC (International Lung Organization/University of Cincinnati) system of classification was designed as a reproducible grading system for pneumoconiosis. The system does not directly correlate the clinical status of the patient versus another individual with the same classification. Yet it is an effective epidemiological tool for recognition of pneumoconiosis problems. Most cases of lung cancer diagnosed through radiography have progressed beyond the point of effective treatment. There are cases where obstructive pulmonary disease is not readily detectable on x-rays yet yields abnormal values in pulmonary function tests. (Ref. 3, p. 116.)

22. b correct. Asbestosis is a pneumoconiosis which will affect the lung volume and elasticity through production of diffuse interstitial fibrosis. Asthma, bronchitis, and emphysema all restrict air flow through the bronchial passage and are thus defined as "obstructive". (Ref. 3, p. 115.)

23. d correct. The described symptoms are classic for metal fume fever. Asthma, pneumonitis, and bronchitis will not normally yield fever or flu-like symptoms and will not subside at regular intervals as will metal fume fever when the worker is removed from his hazardous environment. (Ref. 3, p. 409.)

24. f correct. Anthrax and brucellosis can be contracted through the handling of cattle and pigs. Ornithosis is a disease indigenous to birds and fowl which can be transmittd to man. Bubonic plague can find a human host if the carrier fleas leave the carcass of a handled dead rodent. (Ref. 11, p. 11, 148, 237, 371.)

25. c correct. Workers exposed to raw sewage would most likely be concerned with contracting Type A hepatitis. They might also be concerned with the presence of hydrogen sulfide and methane in their working environment. Vinyl chloride workers are concerned primarily with the carcinogenic effect of that compound. The technicians operating dialysis units have the potential of contracting Type B hepatitis by inadvertant bodily introduction of the organism when working with a patient infected with the disease.

26. c correct. The foundation of any industry's preventive/occupational medicine program is the prevention of disease and trauma. Diagnosis, treatment, and rehabilitation are associated with

resultant disease or injury, those situations the preventive medicine specialist is hired to curtail through engineering controls, personal protective equipment, and education.

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Chapter 7: HEAT STRESS

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I. Thermal Equilibrium in Man
   A. Mechanisms of Heat Gain and Loss
      1. metabolism
      2. radiation
      3. evaporation
      4. convection
      5. mechanical work (usually negligible)
   B. Physiological Mechanisms for Maintaining Hemostasis
      1. sweating
      2. shivering
      3. vasoconstriction/dilation
      4. heart and respiratory rate control

II. Heat Illness
   A. Hot Environments
      1. heat fatigue
      2. anhidrotic heat exhaustion
      3. prickly heat (miliaria rubra)
      4. heat syncope
      5. heat cramps
      6. heat exhaustion
      7. heat stroke
   B. Cold Environments
      1. chilblain
      2. hypothermia
      3. frostbite

III. Heat Stress Indices
   A. Effective temperature
   B. Corrected effective temperature
   C. Comfort health index (ET*)
   D. Wet bulb globe temperature (WBGT)
   E. The heat stress index (HSI)
   F. Predicted four-hour sweat rate

IV. Governing Environmental Parameters
   A. Dry bulb temperature
   B. Radiant temperature
   C. Moisture content of air, assessed by:
      1. relative humidity
      2. absolute humidity
      3. partial pressure of water vapor
      4. wet bulb temperature
   D. Air speed

V. Important Instruments
   A. WBGT apparatus
   B. globe thermometer
   C. wet bulb thermometer
   D. velometers

E. Botsball
F. Hygrometers

VI. Prevention of Heat Illness
A. Acclimatization
1. time to acquire and lose
2. optimum conditions for
3. salt intake
4. physiological changes
B. Water and Salt Requirements
C. Uses and Limitation of Heat Stress Indices
D. Proper Clothing
E. Radiant Shielding
F. Work/Rest Cycles
G. Ventilation
H. Temperature and Humidity Controls

## Review Questions

1. Effective temperature is an empirically determined index of the degree of warmth perceived on exposure to different combinations of:

   a. temperature, humidity and air movement
   b. temperature, humidity and type of clothing
   c. temperature, and humidity
   d. radiant heat, humidity, and air movement
   e. wet and dry bulb temperature and radiant heat

2. Radiant heat, a form of electromagnetic energy:

   a. is not important in heat stress
   b. is best controlled by materials that will absorb it
   c. does not heat the air in the room as it passes through
   d. can be controlled by cool air blasts

3. In heat stroke, the:

   a. body temperature is lowered
   b. body temperature is elevated
   c. body temperature is normal
   d. body salt is depleted
   e. patient sweats profusely

4. Humidity is determined by:

   a. wet bulb temperature alone
   b. vane anemometer
   c. impinger pump
   d. dry bulb temperature alone
   e. none of the above

5. Radiant heat, as from an industrial furnace, may be reduced by:

   a. ventilation
   b. blowing air on a person
   c. shielding
   d. cooling the roof

6. The wet bulb thermometer is part of the equipment used to determine:

   a. water temperature
   b. ambient air temperature
   c. radiant heat
   d. relative humidity

7. The heat emission of black surfaces varies directly with temperature as:

   a. $t^2$
   b. $t^3$
   c. $t^4$
   d. $t^5$

8. What is the best measure of heat stress to the body?

   a. pulse
   b. oral temperature
   c. blood pressure
   d. rectal temperature

9. A "BTU" is defined as:

   a. the amount of energy required to raise one pound of water 1°F
   b. 1/180 of the amount of energy required to raise the temperature of one pound of water from 32°F to 212°F
   c. 1/212 of the amount of energy required to raise the temperature of one pound of water from 32°F to 212°F
   d. the amount of energy required to raise the temperature of any liquid 1°F

10. Convection heat is determined by:

   a. wet bulb plus velometer
   b. wet bulb plus anemometer
   c. dry bulb plus anemometer
   d. dry bulb plus velometer

11. The formula for computing WBGT is (outdoor):

   a. WBGT = 0.7 (WBT) + 0.3 (GBT)
   b. WBGT = 0.7 (WBT) + 0.2 (GBT) + 0.1 (DBT)
   c. WBGT = 0.7 (WBT) + 0.2 (GBT) + velocity
   d. WBGT = 0.7 (WBT) + 0.3 (GBT) + (5/9°F + 32)

12. Metabolism is always:

   a. plus
   b. minus
   c. can be either plus or minus

13. The main part of the body involved in maintaining the body's heat balance is:

   a. skin
   b. lungs
   c. heart
   d. hair

14. Schemes commonly used for estimating heat stress are:

   a. HSI, DBT, WBGT, GBT
   b. WBGT, P4SR, HSI, R.H.GT., ET.
   c. HSI, WBGT, ET, CET, P4SR
   d. Belding-Hatch Index, CET, M = $\pm$ S + C, WBGT

15. What quantity of salt and water are needed in heat exposures in an acclimatized worker?

    a. 6-8 kg water, normal salt in diet (10-15 g/day)
    b. 4-10 kg water, 0.65 g salt additional to diet
    c. 11-15 kg water, 1-2 g salt additional to diet
    d. 1.4% of body weight of water, 0.65 g salt

16. How does a three day weekend affect heat acclimatization?

    a. no loss of acclimatization
    b. some loss of acclimatization
    c. near complete loss of acclimatization
    d. unknown

17. What is the most serious heat disease?

    a. heat neurosis
    b. heat stroke
    c. acute heat exhaustion
    d. heat syncope

18. Using the approximation for the maximum BTU expenditure per hour, calculate the number of heat relief periods that an acclimatized furnace tender would need per hour under normal operation if his job required an expenditure of 3600 BTU/hour.

    a. close to 3
    b. near 2
    c. at least 10
    d. 9
    e. none of these

19. For a worker exposed in a Michigan foundry to an air temperature of 105°F, which of the following control operations would be <u>least</u> appropriate?

    a. decreasing the humidity
    b. increasing the air velocity
    c. wearing clothing
    d. decreasing the air temperature

20. What formula is used for calculating the WBGT?

    a. .7 WB + .1 DB + .2 GT
    b. .7 WB + .3 DB
    c. .5 WB + .2 DB + .3 GT
    d. .8 WB + .1 DB + .1 GT

21. The term thermal stress refers:

    a. to only cold stress
    b. to only heat stress
    c. to heat and cold stress
    d. to the difference between skin temperature and deep temperature
    e. to the loss in efficiency that accompanies hard work

22. The Belding-Hatch index is applicable to:

    a. heat stress
    b. anoxia
    c. efficiency studies
    d. psychomotor function studies
    e. negative G stress

23. Of the following, which is not taken into account in the effective temperature index:

    a. ambient temperature
    b. wall temperature
    c. moisture
    d. air movement

24. Which factor least influences the interchange of heat between man and his environment:

    a. moisture content of the air
    b. air velocity
    c. air density
    d. mean radiant temperature
    e. air temperature

25. What is the amount of sweat loss during heat stress before heat stress is noticeable in the human?

    a. 1/2 - 1 qt.
    b. 1 - 2 qts.
    c. 2 - 3 qts.
    d. 3 - 4 qts.
    e. 4 - 5 qts.

26. Relative humidity is a ratio of:

    a. wet and dry bulb temperatures
    b. amount of water in the air and the maximum of water it could hold
    c. globe thermometer temperature and dry bulb temperature
    d. wet bulb temperature and effective temperature

27. What two instruments are commonly used to measure heat stress according to the ACGIH TLV's?

    a. globe thermometer and natural wet bulb thermometer
    b. relative humidity indicator and globe thermometer
    c. anemometer and dry bulb thermometer
    d. ventilated wet bulb thermometer and globe thermometer
    e. anemometer and globe thermometer

28. Metabolic processes cause the body:

    a. to be heated
    b. to shiver
    c. to sleep
    d. to lose heat

29. The original effective temperature scale _____ the effect of humidity on comfort at high temperatures.

    a. neglects
    b. underestimates
    c. compensates accurately for
    d. overexaggerates

30. Which of the following heat stress indices is most comprehensive in its approach?

    a. P4SR
    b. WBGT
    c. CET
    d. HSI
    e. CHI

31. Which of the following does not involve an allowance for radiant heat gain?

    a. ET
    b. CET
    c. HSI
    d. ET*
    e. two of the above

32. Which of the following organizations has been most influential in the area of temperature-humidity comfort research?

    a. ASHRAE
    b. ACGIH
    c. AIHA
    d. HSI
    e. NIOSH

## Answers to Review Questions

1. a correct. (Ref. 1, p. 419.)

2. c correct. Radiant heat is one of the major input terms in the heat stress equation. It is best controlled by shielding. It heats the air it passes through only insignificantly. (Ref. 2, p. 29.)

3. b correct. Elevated body temperature in heat stroke is a major factor in causing the most important other clinical symptom associated with it, i.e., lack of sweating. Lack of sweating, in turn, causes an increased rise in body temperature and the victim is placed in an extremely dangerous feedback situation. Body temperature up to approximately 1.5°C may occur in exhaustion. (Ref. 1, p. 410; Ref. 2, p. 8-9.)

4. e correct. Relative humidity is the ratio of amount of water present in air compared to the amount it will hold at a given temperature. Therefore, one must know the absolute humidity, the amount of water in the air, as well as the temperature to determine it. None of the methods listed provide any means of determining both these terms. (Ref. 1, p. 417.)

5. c correct. (See question 2.)

6. d correct. The wet and dry bulb temperatures together may be used with a psychrometric chart or appropriate tables to determine absolute and relative humidities. (See question 4.)

7. e correct. (Ref. 2, p. 29.)

8. d correct. Body core temperature rise is generally used in industrial hygiene as the limiting parameter in heat stress work, a temperature rise of up to 1°C being permitted. In heat stress environments pulse generally rises, a rise to 150 beats/min being acceptable, oral temperature may rise or fall depending on respiration rate, relative humidity, type of breathing and other factors and blood pressure may rise or fall depending on how an individual is stressed. (Ref. 3, p. 59; Ref. 1, p. 405, 408.)

9. b correct. Since the amount of heat required to raise water temperature a specific amount varies with temperature itself, temperature must be included in the definition. The definition given is the BTU (mean). BTU(60) at 60°F is also used. There is less than .1% difference between the two. (Ref. 4, p. 192.)

10. c correct. The convection term in the heat balance equation is a function of only the dry bulb temperature and the air velocity. Thus, increasing the air velocity may decrease or <u>increase</u> the convective load. The latter occurs if the air temperature is above the skin temperature (the latter usually assumed to be 95°F in a stressed individual). Even in cases where increasing the air velocity increases convective load, it <u>usually</u>, but not always, produces a net benefit since the maximum heat loss by evaporation increases more. (Ref. 2, Table 2-11, p. 24.)

11. b correct. This question is a little tricky. "a" is the correct answer for the indoor or outdoor conditions with no solar load. Since the most frequently encountered outdoor heat stress conditions include solar load, the general equation given in "b" must be correct. (Ref. 3, p. 58; Ref. 2, p. 16.)

12. a correct. In the convention normally used in heat stress work, heat gains by the body are positive. (Ref. 1, p. 413.)

13. a correct. Skin is the site of most thermoregulation activities including sweating, conductive and radiant heat transfer. (Ref. 1, p. 409.)

14. c correct. HSI - Heat Stress Index, also called Belding-Hatch Index; WBGT - Wet Bulb Globe Temperature; ET - Effective Temperature; CETS - Corrected (for radiation) Effective Temperature ("S" usually not included); P4SR - Predicted 4 hour Sweat Rate. All other answers contain at least one meaningless term. (Ref. 1, p. 399 ff.)

15. a correct. Supplemental salt is <u>not</u> recommended for acclimated workers. (Ref. 1, p. 408-9.)

16. b correct. According to Ref. 1, some loss may be observed after a 2 day lay-off. Ref. 2 indicates "acclimatization is well retained during periods of no exposure for about one week." (Ref. 1, p. 408; Ref. 2, p. 7.)

17. b correct. Under heat stroke, body temperature rises to dangerous levels causing potential irreversible damage and possibly death. (Ref. 1, p. 410.)

18. a correct. The permissible maximum sweat rate of 1 liter per hr. corresponds to a heat loss of 2400 BTU/hr. This leaves 1200 BTU/hr. unbalanced. The permissible body temperature rise of 2°F corresponds to a heat gain of 250 BTU. Therefore, the worker in this problem can work only 250/1200 = 0.208 hrs. before rest is required. It is in his rest environment he continues to sweat at the maximum rate of 2400 BTU/hr. but has a light heat load of 400 BTU/hr; he is cooling at a rate of 2000 BTU/hr. and will be completely cooled in 250/2000 = 0.125 hrs. Therefore, the cycle time is 0.125 + 0.208 = 0.333 hrs. Therefore 3 cycles would be required giving a total of 3 relief periods per hour. (Ref. 2, p. 11, 16.)

19. a correct. The principal heat load in a foundry is radiant. Wearing clothing is a suitable control measure for radiant heat. Decreasing air temperature and humidity will always improve cooling. Given an air temperature of 105°F, increasing the air velocity will increase the convective heat load. ($C=1.08V^{0.6}(ta - 95)$). It will also increase evaporative cooling if the vapor pressure of water is less than 42 mmHg ($E_{max}=4.0V^{0.6}(42 - VP)$). Equaling C to $E_{max}$, substituting ta=105 and solving for VP, one can compute that any vapor pressure less 39.7 mmHg (dew point = 93°F) will favor increasing the air velocity. It is highly unlikely that foundry air will have this much moisture. Therefore, all four methods given will provide some relief. Since dehumidification is the most expensive to accomplish

of the four, and air in Michigan is relatively dry most of the year in any case, the best answer must be a.

20. a correct. (Ref. 3, p. 58.)

21. c correct.

22. a correct. (See question 14.)

23. b correct. (Ref. 1, p. 419.)

24. c correct. All given except density appear as variables in the commonly used heat stress equations. (Ref. 1, p. 418-424.)

25. d correct. (Ref. 1, p. 409.)

26. b correct. (Ref. 4, p. 1244.)

27. a correct. A dry bulb thermometer is also required if major radiant heat loads are present. (Ref. 3, p. 58-9.)

28. a correct. (Ref. 1, p. 401.)

29. b correct. (Ref. 1, p. 14.)

30. d correct. (Ref. 1, p. 420.)

31. e correct. ET* is the new scale of effective temperature, also called the Comfort-Health Index, developed by ASHRAE (The American Society of Heating, Refrigerating and Air Conditioning Engineers). It is basically a temperature-humidity index. (Ref. 5, p. 8.19.)

32. a correct. (See question 31.) (Ref. 5, Ch. 8.)

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# Chapter 8: NOISE: EFFECTS AND PROTECTION

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I. Physiology of Ear
   A. External ear
      1. auricle
      2. canal
      3. tympanic membrane
   B. Middle ear
      1. malleus
      2. incus
      3. stapes
      4. eustachian tube
   C. Inner Ear
      1. vestibule
      2. cochlea
      3. organ of Corti
      4. hair cells

II. Hearing Loss
   A. Conductive
      1. tympanic membrane perforation
      2. ossicular chain interruption
      3. otosclerosis
   B. Sensorineural
      1. organ of Corti trauma
      2. neural degeneration
      3. presbycusis
      4. viruses
      5. congential defects
      6. drugs

III. Hearing thresholds
   A. Definitions, values
   B. Shifts, temporary and permanent
   C. Tinnitus
   D. Speech frequencies

IV. Audiometry
   A. Conduction, bone and air
   B. Instrumentation
   C. Limitations
   D. Audiogram interpretation
   E. Followup procedures

V. Standards
   A. ANSI
   B. ISO
   C. OSHA
      1. limits
      2. exposure calculations

VI. Protection
- D. ACGIH
- A. Ear plugs
  1. types
  2. advantages, disadvantages
- B. Ear muffs
  1. types
  2. advantages, disadvantages
- C. Miscellaneous
  1. headsets
  2. helmuts

VII. Hearing conservation program
- A. Operation, area monitoring
- B. Hazard posting
- C. Personnel education
- D. Audiometry
  1. routine
  2. special purpose

## Review Questions

1. For what noise measuring instruments have ANSI standards been established?

   a. octave band analyzers
   b. sound level meters
   c. audiometers
   d. all of the above

2. ANSI defines Acute Hearing as:

   a. 0-10 dB loss
   b. 11-20 dB loss
   c. 21-30 dB loss
   d. none of the above

3. The correct term for hearing loss that can be induced by occupational exposure to noise is:

   a. presbycusis
   b. sociocusis
   c. sensorineural
   d. conductive

4. At what frequency does noise induced hearing loss first show up on an audiogram?

   a. low frequencies (250-1000 Hz)
   b. high frequencies (3000-6000 Hz)
   c. equal distribution (250-8000 Hz)

5. What is the most expedient method to protect a worker from noise?

   a. ear defenders
   b. limit exposure time
   c. engineering principles
   d. none of the above

6. What is the best, but not the most expedient method, to protect a worker from noise?

   a. ear defenders
   b. limit exposure time
   c. engineering principles
   d. a and b combined

7. A worker has been subjected to 90 dBA for four hours. Based on an eight hour work day, how much longer can he work at that level of exposure and still remain within allowable limits? (use ACGIH Standard)

   a. one hr.
   b. two hrs.
   c. three hrs.
   d. no longer

8. In a work are the noise levels are 95 dBA for two hours, 90 dBA for four hours, and 80 dBA for two hours. Does this exceed the allowable OSHA limits?

   a. yes
   b. no

9. Noise in an area measures 90 dBA for two hours, 95 dBA for two hours, and for the remaining four hours there are alternate levels of 95 dBA for ten minutes and 80 dBA for ten minutes. The exposure exceeds the OSHA allowable since the C/T ratio:

   a. 1 3/8
   b. 1 3/4
   c. 2 5/8
   d. does not exceed the limit
   e. none of the above

10. If an audiobooth meets all but the 500 Hz criteria, what could this be attributed to?

   a. fan noise
   b. room noise
   c. road noise
   d. electronic interference

11. If a person is exposed to 90 dBA for four hours, to what level could he be exposed, if any, for the remaining four hours of his workday? (ACGIH std)

   a. 85 dBA
   b. 80 dBA
   c. 87 dBA
   d. none

12. Which instrument is recommended by ANSI (or NIOSH) for checking audiometric booths?

   a. dosimeter with earphone coupler
   b. sound level meters with octave band filter sets
   c. survey meter
   d. oscilloscope

13. Based on current federal standards, what formula is used in time-weighing noise environments?

   a. $C_1/T_1 + C_2/T_2 \ldots \frac{Cn}{TN} \leq 1$

   b. $\text{Time} = \frac{1}{C_1/T_1 + Cn/Tn}$

c. $SPL = 20 \log \frac{P}{.00002}$

d. $PWL = SPL + 20 \log r + 0.5$ dB

14. If a man is exposed to 75 dBA for years, what would his audiogram probably show at age 55?

a. 20-30 dB losses in lower frequencies
b. 10-20 dB losses in all frequencies
c. increasing losses with higher frequencies
d. all class c hearing

15. What is PSIL?

a. the average, in dB, of the SPL in octave band center frequencies 500, 1000, 2000 Hz
b. the average, in dB, of the SPL in octave bands 600-1200, 1200-2400 and 2400-4800 Hz
c. in decibels, ten times the logarithm to the base 10 of a ratio of a given power
d. noise whose noise-power-per-frequency is inversely proportional to frequency

16. In which part of the ear is the mechanical energy transferred to electrical energy?

a. outer ear (auricle and auditory meatus)
b. middle ear [malleus (hammer), incus (anvil), and stapes (stirrup)]
c. inner ear (labyrinth, semicircular canals and cochlea)

17. Impact noise at 120 dB, peak, is allowed for (ACGIH std):

a. 10 impacts per day
b. 100 impacts per day
c. 1000 impacts per day
d. 10,000 impacts per day
e. none of the above

18. Which frequency of vibration most affects humans?

a. 1-125 Hz
b. 140-250 Hz
c. 275-500 Hz
d. 500-1000 Hz

19. What is the ANSI hearing threshold level at 1000 Hz?

20. When cost and time permit, a pure tone threshold hearing test is always preferred to a pure tone screening test because of what?

21. It is well known that excessive exposure to noise wil cause a loss of hearing. In appraising a potential noise hazard, it is necessary to know that:

    a. damage always occurs slowly, and, if control measures are initiated immediately when noise-induced pain is experienced, loss of hearing can be prevented
    b. damage occurs rapidly but loss of hearing can be completely prevented if control measures are initiated immediately when pain is experienced from excessive noise exposure
    c. damage may occur very slowly and it may occur without pain being experienced
    d. the ear is most sensitive to the very high frequencies above 10 kcps and it is these frequencies that are responsible for most hearing losses
    e. even a small noise-induced hearing loss will be obvious to the employee, and, if he is instructed to report this loss, preventative measures can be taken in time to prevent serious impairment

22. If a person is exposed to 92 dB for 8 hours every workday, what type of action must be taken IAW OSHA?

    a. report to OSHA
    b. place on hearing conservation program
    c. wear hearing protection
    d. more than one of the above
    e. all of the above

23. An abrasive blaster is exposed to high noise levels for his 8-hour work shift. OSHA's allowable limit for an 8-hour noise exposure is:

    a. 80 dBA
    b. 85 dBA
    c. 90 dBA
    d. 95 dBA
    e. 100 dBA

24. Which of the following describes the type of health hazard produced by noise?

    a. long-term exposure to excessive noise has adverse effects on the bones of the middle ear, a condition correctable only through surgery
    b. excessive noise can cause permanent hearing loss but has no other health effects
    c. long-term exposure to excessive noise causes temporary hearing loss through reversible damage to hair cells of the inner ear
    d. long-term exposure to excessive noise causes permanent hearing loss which is not correctable through any known medical technique

25. Which of the following statements concerning the use of an audio dosimeter is not true?

    a. the results of the walk through survey with the SLM should be used to determine which subjects to sample
    b. the employee should be assured that the dosimeter will not interfere with his normal duties
    c. dosimeter readings shold be compared with daily noise doses calculated from SLM readings
    d. calibration of a DuPont D-100 dosimeter should give readings of 85-100 dB

26. Which of the following statements concerning personal hearing protective devices is not true?

    a. personal protective devices for noise control are acceptable only after engineering controls have been proven not to be feasible
    b. use of personal protective devices for noise control should be accompanied by an adequate hearing conservation program
    c. ear muffs have been shown to be superior to insert-type protective devices for all frequencies of noise
    d. helmets, because of their excessive cost, should never be used as noise protective devices in foundries
    e. all are true

27. Speech interference levels can be determined with which of the following instruments?

    a. sound level meters
    b. impact noise analyzers
    c. octave band analyzers
    d. noise dosimeters

28. State compensation boards use a "low fence" for hearing disability claims:

    a. because of inaccuracies in audiograms
    b. because small hearing losses do not represent a significant disability
    c. because of the variations in persons' hearing thresholds
    d. to avoid court fights later on
    e. none of the above

29. At a given intensity, sound in which frequency range is most likely to result in permanent hearing damage?

    a. 37.5-500 Hz
    b. 1000-4000 Hz
    c. 8000-1600 Hz

30. Early hearing loss caused by noise:

a. seriously affects speech reception ability
b. makes a person's speech sound distorted
c. affects telephone usage only
d. is generally not subjectively noticeable

## Answers to Review Questions

1. d correct. S1.11 - Octave Band Analysers, S1.4 - Sound level meters, S3.6 - Audiometers. (Ref. 1, p. 270.)

2. d correct. ANSI does not define "acute hearing."

3. c correct. Presbycusis - hearing loss due to aging. Sociocusis - hearing loss due to background noise level in the general societal environment. Some authors believe presbycusis is a form of sociocusis. Conductive hearing loss - loss due to interference in sound transmission between outer ear and cochlea. (Ref. 2, p. 33-35; Ref. 3, p. 315-6.)

4. b correct. (Ref. 3, p. 317.)

5. a correct.

6. c correct. However, OSHA gives equal weight to engineering and administrative actions (e.g., limiting exposure time). (Ref. 5, p. 428.)

7. d correct. 90 dbA for 4 hours is the ACGIH maximum daily noise exposure. (Ref. 4, p. 82.)

8. b correct. $C_n$ = exposure time at noise level n
   $T_n$ = maximum daily exposure time at level n
   For overexposure sum of $C_n/T_n$ must be greater than one

   $$2/4 + 4/8 = 1$$
   $$1 = 1$$

   therefore no overexposure occurred (Ref. 2, p. 43.)

9. e (none of the above).

| | level | exposure time | max exposure time |
|---|---|---|---|
| 1. | 90 dbA | 2 hrs. | 8 hrs. |
| 2. | 95 | 2 | 4 |
| 3. | 95 | 2 | 4 |
| 4. | 80 | 2 | infinite |

   $$2/8 + 2/4 + 2/4 = 1\ 1/4$$

   See answer to question 8. (Ref. 2, p. 43.)

10. b correct. Low frequency background room noise is difficult to attenuate and may penetrate booth (Ref. 2, p. 46.)

11. d correct. (See question 7.)

12. b correct. ANSI Standard S3.1 requires octave band data.

13. a correct. (See questions 8 and 9.)

14. c correct. (See question 3.)

15. a correct. (Ref. 1, p. 37-9.)
PSIL = Preferred (octave band) Speech Interference Level

16. c correct. (Ref. 3, p. 312-314.)

17. d correct. (Ref. 4, p. 82-3.)

18. a correct. (Ref. 3, p. 334.)

19. 7 db SPL

| Frequency | 125 | 250 | 500 | 1000 | 2000 | 4000 | 6000 | 8000 |
|---|---|---|---|---|---|---|---|---|
| Hearing Threshold, SPL | 45 | 25.5 | 11.5 | 7 | 9 | 9.5 | 16.5 | 13 |

(Ref. ANSI Standard S3.6; Ref. 2, p. 82.)

20. It provides more information.

21. c correct. (Ref. 3, p. 318.)

22. b correct. (Ref. 5, p. 429; 29CFR1910.95.)

23. c correct. (Ref. 5, p. 428-9; 29CFR1910.95.) OSHA Standards are law. All others are advisory recommendations.

24. d correct. (Ref. 2, p. 34.)

25. d correct. Noise dosimeters do not read out in dB.

26. c correct. (Ref. 6, p. 331, 338-9.)

27. c correct. (See #15.)

28. b correct. Also to avoid problems with presbycusis. State laws generally award for damage 25 db in average of 500, 1000, 2000 Hz bands. "Low fence" means the lowest loss level that is compensated.

29. b correct. The ear is most susceptible to damage from frequencies where sensitivity is the best, and the ear is most sensitive in the range from about 1000 through 4000 Hz. It is for this reason that the A weighted scale is used to estimate hearing damage risk.

30. d correct. The initial loss in hearing from noise is in the range above 2000 Hz. Loss in this range has little or no effect on speech communication and thus goes unnoticed. Loss becomes subjectively noticeable only when quite advanced and includes 2000 Hz and below.

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# Chapter 9: NOISE: MEASUREMENT, EVALUATION, AND CONTROL

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I. Physics of sound
   A. Pressure changes
   B. Wave motion
      1. transverse
      2. longitudinal
   C. Frequency
   D. Amplitude

II. Noise characteristics
   A. Steady state
   B. Impact
   C. Sound pressure
   D. Sound power
   E. Combining
      1. sources
      2. frequency bands

III. Propagation
   A. Free field
   B. Directivity
   C. Reverberation
   D. Absorption
   E. Transmission

IV. Instrumentation
   A. Sound level meters
      1. tolerances
      2. weighting
      3. speed
      4. calibration
   B. Impulse meters
   C. Frequency analyzers
   D. Dosimeters

V. Acceptability criteria
   A. Hearing damage
      1. exposure limits
      2. calculations
   B. Speech interference
   C. Annoyance

VI. Survey techniques
   A. Instruments
   B. Data gathering
   C. Interpretation

VII. Noise sources
   A. Vibrating surfaces
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VIII. Noise Control
- A. Plant layout
- B. Less hazardous equipment
- C. Noise reduction at source
  1. directional change
  2. enclosure
  3. dampening
- D. Noise reduction after leaving source
  1. absorption
  2. transmission loss

## Review Questions

1. If an octave band spectrum increases 3dB per octave, what type of noise is probably present?

   a. white noise
   b. pink noise
   c. peak-to-peak noise
   d. PSIL

2. An enclosure is placed around a worker and a noise source. Why is the sound pressure level experienced by the worker greater than without the enclosure?

   a. reverberation
   b. impact
   c. masking
   d. increase in line component

3. What is the best way to monitor exposure to a long-haul truck driver?

   a. sound level meter
   b. annual audio
   c. personal dosimeter
   d. octave band analyzer

4. Convert 3.5 microbars to dB.

   a. 65 dB
   b. 75 dB
   c. 85 dB
   d. 95 dB

5. Which noise source has the most directivity?

   a. jet engine
   b. planer
   c. axial saw

6. Shock mounts are responsible for reducing especially which section of the frequency range?

   a. <500 Hz
   b. <1000 Hz
   c. 1000-2000 Hz
   d. none of the above

7. The unit dB has become popular because:

   a. it is specific to noise and its action
   b. it is a relative quantity with a wide range of values
   c. it is the only term available to represent the "0" level of hearing
   d. it is easy to combine various sources

8. Given 122 dB at 4000 feet, what is the level at 125 feet?

   a. 135 dB
   b. 147 dB
   c. 152 dB
   d. 162 dB

9. The various units used to express noise include all except:

   a. PWL
   b. SPL
   c. dB
   d. micronewton

10. If an engineer notices a definite reduction in noise in moving from one point to another, what minimum reduction would this represent?

    a. a reduction of 3 dB
    b. a reduction of 5 dB
    c. need for a sound level survey
    d. impossible to tell with this information

11. How are the frequency bands in Octave Band Analyzers expressed?

    a. cut-off frequency limits
    b. center frequencies
    c. 1/3 octave band
    d. 1/10 octave band

12. An Octave Band analyzer is defined as:

    a. an instrument to determine the frequency distribution of sound energy
    b. an instrument to determine SPL in A, B, and C weighted networks
    c. an instrument to determine peak-to-peak SPLs
    d. an instrument to determine a sound level within a fraction of a decibel

13. You have one machine which generates 98 dB noise. You add another which produces 96 dB. What is the new reading?

    a. 97 dB
    b. 98 dB
    c. 99 dB
    d. 100 dB

14. Given the following readings taken from the same source, where are the predominant frequencies: dBA=65, dBB=83, dBC=90?

    a. between 20-600 Hz
    b. between 600-1200 Hz
    c. between 1200-2400 Hz
    d. between 2400-4800 Hz

15. An annoying noise is 73 dBA at a distance of 600 feet, what is the sound pressure level at 150 feet?

16. Which frequency on the G.R. 1562 oscilator is used to calibrate the 1565 SLM at 114 dBC?

    a. 250 Hz
    b. 500 Hz
    c. 1 K Hz
    d. 2 K Hz
    e. all of the above

17. At what frequency are A, B, C weighted scales equal?

    a. all
    b. none
    c. 1000 Hz
    d. <1000 Hz
    e. none of the above

18. When a sound source is located in a large room that has wall, ceiling, and floor surfaces that reflect a high percentage of the acoustic energy it may be expected that reverberant conditions exist. In a reverberant sound field the sound pressure created by a broad frequency band source will:

    a. decrease inversely with the distance from the source
    b. decrease inversely with the square of the distance from the source
    c. remain essentially constant throughout the reverberant room
    d. decrease with the square root of the distance from the source
    e. be highly variable due to standing waves

19. The primary function of a peak reading on impact noise analyzer is to:

    a. measure the sound power of the highest frequencies in a broad band noise
    b. measure the sound pressure level of the highest frequencies in a broad band noise
    c. measure the sound pressure level of broad band noises in terms of a peak-to-peak value
    d. measure the peak amplitude of the sound pressure and its duration, or decay time
    e. determine the highest frequency in the band being measured

20. An octave band analyzer is used with a sound level meter to determine:

    a. the sound pressure levels in frequency bands, the highest frequencies of which are twice that of the lowest frequencies
    b. the sound pressure levels in frequency bands, the lowest frequencies of which are equal to the square root of the highest frequencies
    c. the sound pressure levels in 1000 Hz frequency bands

d. the sound power levels in 1000 Hz frequency bands
e. the sound power levels in frequency bands, the lowest frequencies of which are equal to the square root of the highest frequencies

21. Given (X) dB at a point, what is dB at 3 times distance

a. X + 3.0 dB
b. X - 3.0 dB
c. X - 9.0 dB
d. X - 9.5 dB
e. X - 4.5 dB

22. The statement that "the decibel is basically a power ratio indication", (for the equation:

$$SPL = 10 \log (P_1/P_2)^2$$

has which of the following practical implications for your work:

a. the frequencies as well as the loudness of foundry noise must be measured in any inspection
b. the frequency of a noise is determined by the noise pressure and power; therefore measurement of noise frequency will give indication of health hazards
c. decibel readings from 3 different hours must be added and the total divided by 3 in order to find the average noise level
d. an upward change in a noise reading of 3 dB (e.g., from 90 to 93 dB) indicates approximately twice as great a noise intensity
e. noise readings must be made with both an audio dosimeter and a sound level meter in order to reflect the logarithmic nature of the decibel scale
f. audio dosimeter readings indicate the percentage of time that a particular worker is exposed to noise greater than 90 dB

23. Which of the following statements concerning the use of a sound level meter is <u>not</u> true?

a. the SLM must be calibrated both before and after each day's use and the calibration recorded
b. since the OSHA noise standard is based on dBA (use of A scale) only measurements using the A scale, slow response should be made during an inspection
c. the SLM should be held at arm's length and perpendicular to the noise path
d. at least 10 measurements should be made throughout the full work shift for each personal exposure determined

24. How often is calibration of sound level meters required?

a. monthly
b. quarterly
c. before each survey
d. before and after each survey

25. In the vicinity of a noise source it can generally be said:

    a. that in the far field the attenuation due to distance is predictable
    b. that it is impossible to predict levels in the far field
    c. that attenuation due to distance can best be predicted in the near field
    d. that the power distribution is always uniform
    e. that the directivity of the source is unimportant

26. During noise level surveys the orientation of the microphone:

    a. should be such that it is pointed at the noise source
    b. should be between the noise source and surveyor and pointed at the source
    c. should be perpendicular to the wavefront
    d. should be determined from the incidence response curve furnished by the manufacturer
    e. can be neglected

27. Two adjacent machines operate intermittently in a room. Each machine was studied individually and the overall noise level due to machine Y alone was 98 dB. The overall noise level due to machine Z alone was 96 dB. What overall noise level is to be expected when both machines operate simultaneously?

    a. 97 dB
    b. 98 dB
    c. 100 dB
    d. 102 dB
    e. 104 dB

28. What predominant frequency can be expected from a fan which is direct driven at 3600 rpm to deliver 2400 cfm at 1/4"? The fan has 60 backward curve blades.

    a. 3600 cps
    b. 2400 cps
    c. 1200 cps
    d. 4800 cps
    e. none of these

29. An octave band analysis gave the following results:

| 31.5 | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 | Hz |
|---|---|---|---|---|---|---|---|---|---|
| 82 | 83 | 90 | 93 | 86 | 83 | 92 | 92 | 92 | dBB |

    What is the overall sp level?

30. In an unchanging riveting operation, you obtained the following noise spectrum on "slow SLM and OBA settings, how would you explain the discrepancy between the overall reading and readings of the OBA?

| | |
|---|---|
| OA - 120 | 600 - 1200 - 125 |
| 20 - 75 - 112 | 1200 - 2400 - 118 |
| 75 - 150 - 109 | 2400 - 4800 - 115 |
| 150 - 300 - 115 | 4800 - 10,000 - 110 |
| 300 - 600 - 115 | |

## Answers to Review Questions

1. a correct. "White noise: power input per unit frequency is substantially independent of frequency over a specific range." This means there is twice the energy in each succeeding octave band because the succeeding band encompasses twice the number of frequencies. Doubling the energy produces a 3 dB increase in SPL. "Pink noise: noise where noise power per unit frequency is inversely proportional to frequency over a specified range." Therefore, each octave band possesses the same amount of energy and an octave band analysis should be "flat." (Ref. 1, p. 263 & 268.)

2. a correct. Enclosing a noise source always increases the noise level as perceived by someone enclosed with the source because the direct sound is added to the reflected sound. (Ref. 1, p. 192,3.)

3. c correct. A SLM or OBA would be impractical because someone would be required to constantly read and record the sound levels at the subject's ear. An annual audiogram monitors the effect not the exposure. Two individuals with the same exposure will generally have different responses as indicated by the audiogram. A dosimeter, while not perfect, reduces the above problems. (Ref. 3, p. 331; Ref. 2, p. 13.)

4. c correct. $P = 3.5\ \mu bar = 0.35\ N/m^2$
   $P_o = 0.00002\ N/m^2$
   $L_p = 20 \log (P/P_o)$
   $= 20 \log (0.35/0.00002) = 84.7$

   Alternately

   $L_p = 20 \log P + 94$
   $= 20 \log 0.35 + 94 = -9.1 + 94 = 84.9\ dB$

   note: $0.00002\ N/m^2 = 20\ \mu\ N/m^2 = 20\ \mu\ Pa$
   (Ref. 2, p. 2)

5. a best. This question lacks a good answer. Directivity of each source given varies greatly depending on the design of the specific machines. Jet engines are notably directional and so are planers; axial saws probably less so. Because of the generally acknowledged importance of directionality in jet engine operation and testing, "a" is probably the best source.

6. a correct. Shock mounts or vibration isolators are used primarily to control low frequency vibrations and associated noise. (Ref. 2, p. 78.)

7. b correct. (Ref. 2, p. 1.)

8. c correct. $L_i$ = sound pressure level at point i
   $I_i$ = sound intensity at point i

$r_i$ = distance of point i from source
$I_0$ = reference sound intensity

problem: determine difference between $L_2$ and $L_1$ (assume free field)

$$L_2 - L_1 = 10 \log (I_2/I_0) - 10 \log (I_1/I_0)$$

$$= 10 \log ((I_2/I_0)/(I_1/I/_0))$$

$$= 10 \log (I_2/I_1)$$

however the inverse square law applies in the free field, therefore:

$$I_2/I_1 = (r_1/r_2)^2$$

$$L_2 - L_1 = 10 \log (r_1/r_2)^2$$

$$L_2 - L_1 = 20 \log (r_1/r_2)$$

problem may be solved directly using this formula:

$$L_2 = L_1 + 20 \log (r_1/r_2)$$

$$= 122 + 20 \log (4000/125)$$

$$= 122 + 30.1 = 152.1 \text{ dB}$$

In general it is useful to know that doubling the distance from a source ($r_2 = 2r_1$) in the free field decreases the SPL by 6 dB.

$$L_2 = L_1 + 20 \log 0.5 = L_1 - 6.0$$

Going from 125 feet to 4000 feet doubles the distance 5 times. 5X6=30. Therefore, the SPL is 30 dB greater at the near point.

9. d correct. The micronewton, uN, is a unit of force. Force by itself does not express noise. 20 uN/$m^2$, a pressure - i.e., force per unit area, is the common reference sound pressure. (Ref. 3, p. 302.)

10. a correct. It is generally accepted that 3 dB is the lowest noticeable difference in everyday surroundings, however all authors do not accept this, some stating that 1 dB is noticeable. One can easily relate to the audibility of 3 dB difference since it is the difference experienced when a second identical source is added to a noise field, e.g., two motorcycles instead of one, two jet engines instead of one, etc. (Ref. 1, p. 41.)

11. b correct. (Ref. 2, p. 13.)

12. a correct. (Ref. 2, p. 11-12.)

13. d correct. This problem may be solved by applying the dB addition tables (Ref. 3, p. 304, Ref. 1, p. 6), the simplified dB addition

table reproduced below (Ref. 6, p. 286) or a pure mathematical approach. The latter may be simpler than the former given the common availability of calculators. Using the simplified table:

| difference in levels, dB | add below to higher level |
|---|---|
| 0-1 | 3 dB |
| 2-4 | 2 |
| 5-9 | 1 |
| >10 | 0 |

98 - 96 = 2
98 + 2 = 100 dB

the mathematical approach:

$$\text{summed level} = \log\left(\log^{-1}(L_1/10) \pm \log^{-1}(L_2/10) + \ldots + \log(L_n/10)\right)$$

$$= \log\left(\log^{-1}(98/10) + \log^{-1}(96/10)\right)$$

$$= 100.0 \text{ dB}$$

This works because sound intensities, represented by $\log^{-1}(L_n/10)$ are additive.

14. a correct.
dBC - dBA = 25
dBC - dBB = 7
Referring to the figure defining A, B and C weighting, these differences occur at 100 Hz which therefore must be the predominant frequency. (Ref. 3, p. 306.)

15. 85 dBA (see question 9). Distance doubles twice, so difference is 12 dBA.

16. e correct. (Ref. 2, p. 11; manufacturer's literature.)

17. c correct. (Ref. 3. p. 306.)

18. c correct. (Ref. 3, p. 307.)

19. d correct. Most sound impulse meters do not measure duration. (Ref. 2, p. 11.)

20. a correct. (Ref. 2, p. 11.)

21. d correct. (see #8.)

$$L_2 = L_1 + 20 \log(r_1/r_2) = X + 20 \log(1/3)$$

$$= X - 9.5$$

22. d correct.

23. d correct. a. True. b. C scale readings are useful to indicate frequency distribution and help predict effectiveness of hearing protection, the less the difference the less effective protection

is likely to be. c. depends on microphone design. (Ref. 6, p. 309; OSHA Industrial Hygiene Field Operations Manual.)

24. d correct. Good practice.

25. a correct. (Ref. 3, p. 307.)

26. d correct (see #23.)

27. c correct. (see #13.)

28. a correct. The predominant frequency of a fan is given by the number of times per second the blades pass a fixed point.

$$f = \frac{N \times rpm}{60\ s/min} \quad Hz$$

N = number of blades

$$f = \frac{60 \times 3600}{60} = 3600\ Hz$$

29. Use short table from problem 13 and add levels

93 + 92 = 95
" + 92 = 96
" + 92 = 98
" + 90 = 99

All remaining are negligible. (Exact solution by mathematical approach in problem 13, 99.4 dB.)

30. The clear problem is that 600-1200 Hz band is 5 dB above the overall level. This is theoretically impossible. The sum of all bands, 127 dB, is worse yet. Since there appears to be no suitable theoretical explanation, the problem must be laid to an inaccurate machine response in the 600-1200 band caused by poor calibration, malfunction or an unusual phenomenon involving response to the impulse sound.

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Chapter 10: AIR SAMPLING AND ANALYSIS

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I. General Principles
- A. Reasons for survey
- B. Hazard recognition
- C. Pre-collection preparation
  - 1. limiting factors of method
    - a. sensitivity
    - b. specificity
    - c. accuracy and precision
  - 2. equipment calibration and testing
  - 3. method calibration and verification
  - 4. information resources
- D. Characteristics of environment
  - 1. air circulation
  - 2. work process
- E. Define purpose of sample, e.g., engineering design or personal exposure
- F. Deep accuracy and precision of elements in line with one another

II. Important laboratory analytical systems and uses
- A. Gas chromatograph (most often used)
- B. Atomic absorption spectometer
- C. Infrared, UV, fluorescent and visible light spectrometer
- D. High performance liquid chromatography
- E. X-ray diffraction
- F. pH meters
- G. Conductivity meters
- H. Mass spectrometers
- J. Light and electron microscopy

(Note: A - D account for more than 90% of NIOSH Methods)

III. Sampling Trains
- A. Most common elements and order:
  Inlet → collector → air flow meter → pump
- B. Special conditions require special arrangements, each arrangement has advantages and disadvantages
- C. Other elements may be added, e.g., absorbers to keep moisture from meter and pump
- D. Calibration and pump selection require special attention
- E. Primary and secondary standards for volume
- F. Inlet design especially important for particles

IV. Gaseous Collectors
- A. Adsorption - solid sorption surfaces, e.g., activated charcoal
  - 1. packed tubes
  - 2. passive personal dosimeters, diffusion badges
  - 3. solid catalysts and reactive materials (absorption followed by reaction)
- B. Absorption - liquid process, e.g., $SO_2$ in water
  - 1. bubblers, impingers and fritted disk absorbers

2. liquid-gas contact columns
3. absorption at static liquid surfaces
4. important adsorbents and uses

C. Grab samplers (bags and evacuated containers)

IV. Particle Collectors

A. Collection mechanisms
1. inertia
2. diffusion
3. interception
4. gravity settling
5. electrical

B. Filters
1. efficiency depends on
   a. particle physical, chemical, and electrical properties (5 S's - size, size distribution, shape, specific gravity, surface)
   b. filter physical, chemical, and electrical properties
   c. flow rate
2. for any particle and filter type there is a particle size collected with minimum efficiency. This minimum is typically at approximately 0.5 μ m diameter for high efficiency filters
3. filters may react with gases and particles; particles and gases may interact
4. specific types of specific problems
5. fiberglass and cellulose membrane most often used
6. important design parameters; particle size, filter, fiber size, velocity, particle specific gravity
7. efficiency may increase or decrease with flow rate, depending on controlling mechanism
8. weighing environment important in gravimetric determinations (50% RH, 70°F recommended)

C. Other important collectors
1. cyclones
2. elutriators (settling)
3. impingers and impactors
4. electrostatic and thermal precipitators

VI. Particle Counting and Sizing

A. Counting methods
B. Sizing techniques (microscopic and automatic counters)
C. Computations

VII. Direct Reading Instruments for Gaseous and Particulate Concentration Measurements

A. Many specific types
B. Known limitations

Part I
Review Questions
General Aspects of Air Sampling

1. What is used to calibrate a laboratory rotameter?

   a. spirometer
   b. wet test meter
   c. dry gas meter
   d. venturi tube

2. Equilibrating a wet test meter means:

   a. assuring proper level of distilled water in meter
   b. bubbling gas through the water at ambient temperature
   c. adjusting manometer to the "0" mark at mid scale
   d. leveling meter by adjusting inlet and outlet valve

3. How is flow through a critical orifice plotted?

   a. Q vs. $P_2/P_1$ ($P_1$ = upstream pressure; $P_2$ = downstream pressure)
   b. Q vs. K (K = constant with Reynolds Number)
   c. V vs. K (K = constant with Reynolds Number)
   d. V vs. temperature

4. The principle of the rotameter is similar to:

   a. venturi meter
   b. variable orifice meter
   c. pitot tube
   d. anemometer

5. A critical orifice flow is dependent upon upstream pressure:

   a. directly
   b. indirectly
   c. as the square
   d. square root

6. What is the major factor in determining the required sample volume?

   a. analytical sensitivity
   b. flow rate
   c. type of contaminant
   d. type of air mover

7. What is the first thing to do when a water sample comes into a lab?

   a. smell it
   b. take pH
   c. log it in
   d. analyze it

8. Personal portable samplers are better than fixed samplers in determining:

   a. average concentrations
   b. peak concentrations
   c. sources of emission
   d. reduction of emission

9. What flow rate is recommended for use with a Greenburg-Smith impinger?

   a. 0.1 cfm
   b. 1.0 cfm
   c. 0.1 lpm
   d. 1.0 lpm

10. Laboratory quality control samples control which type of error?

   a. random
   b. systematic
   c. sampler
   d. preservation

11. IR examination of breathing air is an acceptable method except for:

   a. CO
   b. $CO_2$
   c. HC
   d. mercury

12. Increasing the flow rate through a midget impinger used for gas sampling by:

   a. increasing efficiency proportionally to increased flow
   b. decreasing efficiency due to trapped contaminant in tubing
   c. decreasing efficiency due to decreasing absorption time
   d. increasing efficiency due to decreasing absorption time
   e. increasing or decreasing efficiency depending on existing flow rate and impinger design

13. The recommended flow rate through a midget impinger is:

   a. 0.1 cfm
   b. 1.0 cfm
   c. 0.1 lpm
   d. 1.0 lpm

14. How does sample volume affect sampling:

   a. establishes detection level
   b. affects calculated concentrations
   c. establishes the minimum sample time at a given flow rate
   d. all of the above

15. A primary standard for air flow measurements:

    a. requires no adjustment or maintenance
    b. can never be used in the field
    c. is used for calibration of flow meters
    d. does not require external apparatus for timing

16. With respect to flow through a critical orifice, which of the following is true?

    a. critical orifices should not be used in field sampling
    b. a critical orifice can only be used ahead of the sampling device in the air stream
    c. constant air flow will occur only when the downstream pressure is less than 53% of the upstream pressure
    d. constant air flow will occur only when the downstream pressure is more than 53% of the upstream pressure

17. A precision rotameter is calibrated at a standard temperature of 20°C and a standard pressure of 29.92" Hq. It is used in the field at 30°C and 29.29" Hq. The flow rate indicated by the float position and the calibration chart will be:

    a. correct for flow at standard temperature and pressure
    b. higher than the true flow rate at field conditions
    c. lower than the true flow rate at field conditions

18. A sampling line can introduce problems such as:

    a. interfering compounds
    b. loss of contaminant due to reaction
    c. condensation of contaminant
    d. lag time
    e. all of the above

19. Given the following, calculate the diameter for a constant flow orifice to provide an airflow of 0.5 cfm (for a 1 inch diameter Whatman #41 paper sampler).

    a. 2 cm Hg resistance through filter at 0.5 cfm
    b. source of suction capable of 28" Hg vacuum
    c. barometric pressure equal 30" Hg
    d. W = mass of air in lbs/sec = 0.00028
    e. Cv = 1
    f. $T_1$ = 70°F
    g. 1 inch Hg = 0.4912 lbs/sq in
    h. air density = 0.074 lbs/$ft^3$ at 79°F

    Formula = $w = \frac{0.533\ Cv\ A_2\ P_1}{\sqrt{T_1}}$

    a. 0.029 inches
    b. 0.039 inches
    c. 0.049
    d. 0.154
    e. equation does not apply

20. In a wet test meter, which of the following is not important in set up and use?

    a. orifice size
    b. levelness
    c. water level
    d. temperature
    e. all are important

21. Activation analysis is:

    a. use of activated charcoal in gas sampling
    b. analysis by detection of photo emissions from atoms excited by specific visible, infrared, or ultraviolet wavelengths
    c. analysis by activating chemical species to their gaseous state and observing the resulting pressure increase
    d. rendering elements radioactive by nuclear bombardment and detecting the resulting radionuclides
    e. none of the above

22. A critical orifice is dependent on which?

    a. humidity
    b. humidity/pressure
    c. temperature/pressure
    d. density/humidity
    e. all of the above

23. A midget impinger with a manual pump is used to collect airborne dust:

    a. by operating the impinger pump for 10 minutes
    b. by operating the pump at 12" water gauge without consideration of the sampling time
    c. because it shatters the dust into smaller particles for easier counting
    d. because it is portable and can be used in explosive atmospheres
    e. because it collects all dust as it exists in the air

24. For proper operation of a critical orifice:

    a. downstream pressure must be less than 53% of upstream pressure
    b. upstream pressure must be less than 53% of downstream pressure
    c. downstream pressure must be less than 76% of downstream pressure
    d. upstream pressure must be less than 76% of downstream pressure
    e. downstream pressure must be less than 23% of upstream pressure

25. Sensitivity of the Davis Halide Meter may be altered by changing:

    a. arc length
    b. line voltage
    c. slit width
    d. all of the above
    e. more than one of the above

26. Instantaneous (or grab) air samples are used to:

    a. determine the rate of flow
    b. determine the composition of the air at a specific time and location
    c. determine the number of samples to be taken
    d. determine the amount of air at any location
    e. determine the average composition of the air during a given time period

27. A certain industrial atmosphere contains trichloroethylene, vinyl chloride, acetone, and benzol. Which of the following field-type instruments is most likely to yield information regarding concentrations of the individual vapors?

    a. combustible gas indicator
    b. vapotester
    c. colorimetric tube-type detectors
    d. Halide meter
    e. mass spectrograph

28. A rotameter is put in front of a sampling train to:

    a. reduce the pressure drop
    b. increase collection efficiency
    c. measure the flow rate at atmospheric pressure
    d. none of the above

29. During sampling for welding fumes, the best placement of the sampling device is:

    a. immediately outside the helmet
    b. close to the welding
    c. inside the helmet
    d. near the exhaust system

## Part I
## Answers to Review Questions
## General Aspects of Air Sampling

1. b correct. A bubble meter, spirometer, or wet test meter could be used to calibrate a rotameter. However, wet test meters are more frequently used for rotameter calibration because of their much wider range. Bubble meters are limited to use for small rotameters. Spirometers larger than 1-2 $ft^3$ are rarely used because of their size. Dry gas meters are occasionally used but are considerably less accurate and are preferred only when high pressure or large volumes are involved. (Ref. 1, p. 104-106; Ref. 2, p. I-6 - I-8; Ref. 3, p. 1233.)

2. b correct. A wet test meter must be operated for several hours prior to use to assure thermal and absorbed gas equilibria are achieved. (Ref. 2, p. I-12.)

3. a correct. Plotting Q, the volumetric flow rate, against $P_2/P_1$ will allow selection of the critical flow rate for a critical orifice and also allow it to be used at less-than-critical conditions. (Ref. 1, p. 115.) None of the other answers are meaningful.

4. b correct. In a rotameter, the pressure drop as the air flows through the annular area between the float and the tube is analogous to the pressure drop in an orifice meter. Since the annulus width changes as the float rises, the "orifice size" varies. The pressure drop, on the other hand, remains essentially constant. (Ref. 1, p. 109.)

5. a correct. In a critical orifice, the mass flow rate is directly proportional to the upstream pressure. (See questions 16 and 19.) (Ref. 1, p. 115.)

6. a correct. The type of air mover determines the flow rates possible, and the flow rate determines the sampling time. The analytical sensitivity is a function of the type of contaminant and determines the amount of contaminant that must be collected, i.e., the sample volume. (Ref. 1, p. 98; Ref. 3, p. 715.)

7. c correct. (Ref. 3, p. 1227-1229.)

8. a correct. This question is somewhat ambiguous. "Average" and "peak" may refer to spacial and/or temporal conditions. Because of the ambiguity, one must fall back to the most common terminology. Average, therefore, is interpreted to mean the time-weighted-average concentration to which a worker is exposed. Portable personal samplers are well established for this purpose. For peak and emission reduction evaluation, portable samplers are useful but fixed samplers (single or in a network) may be more effective because they do not have to compromise quality to portablity. Therefore, a is the best answer. (Ref. 3, p. 711.)

9. b correct. (Ref. 1, p. A-1.)

10. b correct. Quality control samples include blanks and samples "spiked" to a known concentration prior to analysis. If the concentrations determined in these samples are in error, it is an indication that a

systematic error was made. That is, an error in the basic procedure was made. This is also called a determinate error. On the other hand, even if everything were carried out correctly, identical samples would yield different results due to inevitable differences from sample to sample. This is random or indeterminate error and it is manifest in the standard deviation of the results of identical samples. (Ref. 1, p. 278-286.)

11. d correct. CO and $CO_2$ absorb strongly in the infrared. Many hydrocarbons do also; mercury does not. (Ref. 2, p. U-7, SU-119.)

12. e correct. At low gas flow rates, large bubbles form which rise relatively rapidly through the solution and do not present a large surface area for mass transfer. As the velocity increases, the air stream begins to break into smaller bubbles as it "impinges" with progressively greater force on the glass surface. Smaller bubbles rise more slowly and mass transfer time is increased. Eventually, the flow rate becomes too great and liquid is carried out of the impinger entrained with the air. Thus, efficiency begins to drop. Therefore, without knowing the operational conditions, efficiency may increase or decrease. (Ref. 2, p. R-7; Ref. 1, p. 172.)

13. a correct. (Ref. 1, p. 0-37.)

14. d correct. (Ref. 1, p. 98.)

15. c correct. (Ref. 1, p. 118.)

16. c correct. (See questions 5 and 19.) (Ref. 1, p. 115.)

17. c correct. Rotameters can be corrected for changes in density using the following equation:

$$Q_a = Q_1\sqrt{\frac{1}{2}}$$

$Q_a$ = actual field volumetric flow rate
$Q_i$ = indicated field volumetric flow rate (from laboratory calibration curve)
$_1$ = density of calibration gas
$_2$ = density of field gas

Since the field gas is less dense (warmer) than the laboratory gas, the density ratio is greater than 1, and the indicated flow rate will be too low. (Multiplying it by a factor >1 will yield the actual flow rate.) (Ref. 4, p. 99; Ref. 3, p. 1281.)

18. e correct.

19. a correct. Before answering this question, one must first determine if $P_2/P_1<0.53$.

$$P_1 = 30" - (2\text{ cm})\frac{29.9"}{76\text{ cm}} = 29.2"\text{ Hg} = 14.35\text{ psi}$$

$$P_2 = 30 - 28 = 2"\text{ Hg}$$

$$P_2/P_1 = .07$$

$$.07<.53$$

The problem may now be solved by substitution and solving for $A_2$, the area of the critical orifice. The dimensions below must be used.

$$A_2 = \frac{W\sqrt{T_1}}{.533\ C_v P_1}$$

$$= \frac{0.00028\ \frac{\#}{s}\ \sqrt{530°R}}{(0.533)(1)(14.35)}$$

$$= 0.00084\ in^2$$

$$D^2 = \sqrt{\frac{4}{\pi} A_2} = 0.033\ in$$

(See questions 5, 16.)

20. a correct. There is no orifice in a wet test meter. (Ref. 1, p. 106.)

21. d correct. (Ref. 5, p. 20.)

22. c correct. (See questions 5, 16, 19.)

23. d correct. Older versions of the midget impinger were powered by a manually operated pump with the flow rate controlled by maintaining a suction pressure of 12 inches of water. This permitted use in explosive atmospheres. This pumping method has largely been replaced by miniature battery operated pumps. (Ref. 2, p. 0-37; MSA literature.)

24. a correct. (See question 16.)

25. a correct. The Davis Halide Meter measures halide concentration by halide intensification of allene in the copper spectrum. The spectrum is produced by an electric arc between copper and platinum electrodes. The arc intensity is related to the electrode separation which must be readjusted occasionally. (Ref. 2, P. U-139, U-147.)

26. b correct. (Ref. 1, p. 170.)

27. c correct. Combustible gas detector will not respond well to trichloroethylene. The vapotester is a combustible gas detector. The Halide meter cannot quantitate separately two halogenated compounds in the same atmosphere and does not respond to acetone or benzol. The mass spectrograph is a qualitative not quantitative instrument. Only detector tubes offer the versatility to resolve these gases quantatively. (Ref. 2.)

28. d correct. The first element in a sampling train is almost always a collection device. Placing a rotameter in front would permit operation at atmospheric pressure and thereby obviate the need for pressure corrections to the readings. This is a poor practice, however, because passing the test gas through the meter may interfere with collection, or particle deposition in the meter may upset meter calibration. (Ref. 1, p. 172.)

29. c correct. There should be no physical obstructions between the sampler inlet and the worker's nose or mouth.

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## Part II
## Review Questions
## Sampling for Gaseous Materials

1. Activated carbon would be the adsorbent of choice for which of the following:

   a. non-polar organic vapors and gases, boiling points above 0°C, humid atmosphere
   b. polar organic vapors and gases, boiling points below 0°C, dry atmosphere
   c. inorganic vapors and gases, boiling points above 0°C, humid atmosphere

2. Silica gel would be the adsorbent of choice for which of the following:

   a. non-polar organic vapors and gases, boiling points above 0°C, humid atmosphere
   b. polar organic vapors and gases, boiling points below 0°C, dry atmosphere
   c. inorganic vapors and gases, boiling points above 0°C, humid atmosphere

3. What agent is generally used to desorb a sample from an activated carbon tube?

   a. chloroform
   b. carbon disulfide
   c. toluene
   d. methyl chloroform

4. What percentage of oxygen is necessary to use a combustion gas indicator?

   a. 14%
   b. 8%
   c. 21%

5. The normal efficiency for bubblers is:

   a. 75%
   b. 80%
   c. 90%
   d. >95%

6. Why do tests on reactive gases in the field when doing grab sampling with a mylar bag?

   a. reaction with dust particles may affect results
   b. reaction with moisture may affect results
   c. reaction with wax sealing, glass, or other surfaces may affect results
   d. all of the above
   e. none of the above

7. Why do initial tests on reactive gases in the field when sampling with glassware?

   a. reaction with dust particles
   b. reaction with moisture
   c. reaction with wax sealing or glass
   d. all of the above
   e. none of the above

8. Why are mylar bags popular for collection of samples?

   a. complete recovery of samples for analysis is usually obtainable
   b. ease of sampling
   c. ease of recovering sample
   d. range of concentrations which can be sampled for
   e. all of the above

9. Sampling for HCN using a NaOH media involves:

   a. absorption
   b. adsorption
   c. neither absorption nor adsorption

10. Mercury analyzers most often involve which of the following:

    a. UV
    b. IR
    c. length of stain
    d. change of color

11. What would cause a low reading of ozone in KI sampling system?

    a. acid buffer
    b. too much buffer
    c. $SO_2$
    d. calcium in water

12. Why are color tubes not completely reliable?

    a. variations in the properties of batches of indicating gel
    b. varying diameter of tubes
    c. skill of sampler
    d. all of the above

13. Which does a combustible gas indicator best measure?

    a. mercury vapors
    b. lead vapors
    c. petroleum solvent vapors
    d. BeO

14. What element is sometimes included in a combustible gas indicator to detect percent oxygen?

    a. ionizing cell
    b. length of stain charcoal column
    c. depolarization cell
    d. amperometric cell

15. What instrument would be used to measure a leak of natural gas in a garage where other types of gases are used?

    a. halide leak detector
    b. combustible gas detector
    c. MIRAN
    d. LIRA

16. What chemicals are identified by a green flame from a copper wire?

    a. combustible gases
    b. trace concentrations of heavy metals
    c. organic halide vapors
    d. mercury vapors

17. What instrument would be used to check for a refrigerant?

    a. DU flame spectrophotometer
    b. halide meter
    c. combustible gas indicator
    d. gas chromatograph

18. Given bubblers with 75 percent efficiency and 95 percent efficiency in series, what is the resultant efficiency?

    a. 85%
    b. 90%
    c. 95%
    d. 99%

19. Why is a filter followed by a bubbler when sampling for fluoride from welding?

    a. to collect small particles which penetrate the filter
    b. to collect gaseous fluorides
    c. to stabilize flow rate
    d. none of the above

20. Which is not an advantage of the $H_2O_2$ sampling procedure to $SO_2$ over the West-Gaeke Method?

    a. simple equipment
    b. requires lesser skills
    c. longer storage of sample prior to analysis
    d. more specific for $SO_2$ in presence of other acid gases

21. In sampling for $NO-NO_2$ with Saltzman Reagent and using three bubblers in series, what media is in each?

    a. absorber (Griess-Saltzman), acid permanganate, absorber
    b. absorber, distilled water, acid permanganate
    c. acid permanganate, absorber, absorber
    d. distilled water, acid permanganate, absorber

22. What is the OSHA method for sampling for toluene?

    a. 100 l on silica gel
    b. 10 l on activated charcoal
    c. 10 l mylar bag
    d. 100 l evacuated glass flask

23. What is the OSHA method for sampling for trichloroethylene?

    a. 100 l on silica gel
    b. 10 l on hopcalite
    c. 10 l on activated charcoal
    d. 10 l mylar bag

24. What is the primary OSHA method for sampling for carbon monoxide?

    a. hopcalite direct reading meter
    b. gas detection tube certified under Title 42 CFR
    c. ecolyzer
    d. activated charcoal tube

25. Which of the following analytical procedures is colorimetric?

    a. determination of lead with dithizone
    b. atomic absorption
    c. gas chromatography
    d. vapotester

26. Spectrophotometry uses absorption in which wavelengths?

    a. UV
    b. IR
    c. visible
    d. all of the above

27. What is the principle of the fluoresimetric procedure of analysis?

    a. absorption and release of energy by compounds
    b. flame ionization
    c. phase contrast

28. How does one tell if there is sufficient water in a wet test meter?

    a. when equilibration occurs within 15 minutes
    b. observing the sight gauge
    c. when the thermometer remains constant

29. If the second portion of a charcoal tube contains _____ percent of the first stage, it is unacceptable.

    a. >10%
    b. >15%
    c. >20%
    d. >25%
    e. >0%

30. In gas chromatography, the separation of sample components is determined primarily by what physical property of substances?

    a. number of carbon atoms
    b. boiling point
    c. heat of vaporization
    d. ability to absorb UV

31. The preparation of a sample from a charcoal tube for analysis by a GLC includes:

    a. mixing with carrier gas
    b. desorption with a suitable solvent
    c. heating tube to a specified temperature
    d. pyrolysis

32. Atomic absorption is distinctly good for what type of analysis?

    a. metals
    b. solvents
    c. aromatic hydrocarbons
    d. aliphatic hydrocarbons

33. What feature of emission spectrography makes it a satisfactory analytical procedure?

    a. accomplishment of both quantitative and qualitative analysis
    b. low pressure of operation
    c. ability to operate in explosive atmospheres
    d. use of a double beam system to provide comparison with standards

34. The explosimeter, combustible gas indicator, and vapotester operate on what principle?

    a. adsorption
    b. absorption
    c. Beilstein reaction
    d. heat of combustion

35. Concentrations of gases and vapors are expressed as:

    a. parts per million by weight
    b. particles per million by volume
    c. parts per million by volume
    d. particles per million by weight

36. The preferred method of sampling for benzene is:

    a. fritted bubbler with NaOH
    b. activated charcoal tube
    c. portable LIRA
    d. midget impinger with $H_2O_2$

37. The method of sampling for phenol is:

    a. bubbler with 0.1 N NaOH
    b. activated charcoal tube
    c. portable LIRA
    d. midget impinger with $H_2O_2$

38. Which of the following is not an important sorption property of activated charcoal?

    a. non-polar nature
    b. high capacity
    c. effective for materials boiling as low as -160°C

39. Which of the following is/are important sorption properties of silica gel?

    a. polar nature
    b. moisture affinity
    c. a and b
    d. neither a nor b

40. What is the secondary (NIOSH) method for field CO determination?

    a. hopcalite catalytic combustion
    b. detector tubes
    c. gas chromatography
    d. infrared absorption spectrometry
    e. none of the above

41. Why is hydroquinone used as in inhibitor during chemical storage?

42. Which of the following has the weakest infrared absorption property?

    a. CO
    b. $CO_2$
    c. $NO_2$
    d. $SO_2$
    e. $H_2S$

43. Which of the following does not interfere with ozone determination by the KI method?

    a. $CO_2$
    b. $NO_2$
    c. $SO_2$
    d. PAN
    e. $Cl_2$

44. What is the advantage of the $H_2O_2$, $SO_2$ method over West-Gaeke?

    a. there is no advantage
    b. better sensitivity
    c. better sample stability
    d. better reliability
    e. none of the above

45. Which of the following is not involved in the OSHA toluene method?

    a. charcoal
    b. $CS_2$
    c. methyl ethyl ketone
    d. gas chromatography
    e. all are involved

46. What is a "typical" efficiency for a single fritted bubbler?

    a. <25%
    b. 25-50%
    c. 50-75%
    d. >75%
    e. varies widely depending on material collected and collection medium

47. Which of the following interferes most with hopcalite use in CO measurement?

    a. moisture
    b. pressure fluctuations
    c. temperature fluctuations
    d. hydrocarbon interference
    e. none of the above

48. Mylar collection bags are useful because they:

    a. are cheap
    b. are extremely rugged
    c. can effectively be used for long term sample storage
    d. all of the above

49. You are in a plant with a suspected $CH_4$ exposure. You are using a J-W combustible gas indicator. The L.E.L. for $CH_4$ is 5%. If the meter on the J-W combustible gas indicator indicates 20%, what is the concentration in ppm?

    a. 1
    b. 10
    c. 100
    d. 1000
    e. 10,000

50. Which is a paramagnetic gas?

    a. $H_2$
    b. $O_2$
    c. $N_2$
    d. air
    e. none of the above

51. Which instrument uses chemiluminescence?

    a. explosimeter
    b. ozone meter
    c. Ecolyzer
    d. Miran
    e. Interscan

52. Which is a primary standard?

    a. wet test meter
    b. erlenmeyer
    c. buret
    d. rotameter
    e. none of the above

The following are absorbing solutions used for trapping of vapors, gases, fumes, and dusts. More than one may be correct or satisfactory, but in each instance, the solution that is most efficient from the industrial hygienist's point of view should be chosen.

a. distilled water
b. diluted nitric acid
c. alcoholic sodium hydroxide
d. 2% cadmium chloride
e. electrostatic precipitator
f. p-naphthylamine and sulfanilic acid
g. carbon tetrachloride
h. 3% KI with 0.25% iodine
i. ethyl alcohol
j. aqueous 5% sodium hydroxide
k. diluted sulfuric acid
l. nitrating acid
m. activated charcoal or silica gel
n. o-tolidine

53. lead fumes - welding lead coated metals

54. mercury vapors - instrument repair shop

55. hydrogen sulfide - petroleum operations

56. bromine - manufacture of fumigants

57. ammonia gas - washing mirrors in silvering process

58. nitric oxides - welding

59. benzene - cleaning fluid

60. phosgene - manufacture of synthetic dyes

61. nitroglycerin - explosives

62. styrene monomer - plastics

63. methyl alcohol - solvent

64. A good analytical reagent for the determination of nickel is:

    a. dithizone
    b. alpha furildioxime
    c. EDTA
    d. B-napthylamine
    e. rhodamine-B

65. Of the following, the best reagent for the collection of aldehydes is:

    a. sodium carbonate
    b. sodium sulfate
    c. sodium sulfite
    d. sodium bisulfite
    e. plain distilled water

66. The reaction commonly used for detecting oxides of nitrogen is:

    a. chelation
    b. amination
    c. diazotization
    d. degradation

67. The reagents used for color development in the NBS tubes for carbon monoxide are:

    a. chromic oxide and platinum
    b. chromic oxide and palladium
    c. ammonium molybdate and chromic oxide
    d. palladium and ammonium molybdate

68. Which of the following reagents is not suitable for the detection of cyanide?

    a. benzidine and copper acetate
    b. methyl orange and mercuric chloride
    c. phenolphthalein
    d. pyridine - pyrazolone

69. Mercury vapor is best adsorbed by:

    a. activated charcoal
    b. activated charcoal impregnated with I
    c. calcium chloride
    d. activated charcoal impregnated with $CuSO_4$
    e. caustic

70. Which of the following is not an advantage of dynamic calibration over static calibration?

    a. reduction of contaminant on device walls
    b. low cost and simplicity
    c. provides high flows over long periods of time
    d. provides varying concentrations

71. In the determination of phosgene using aniline, the precipitate formed is:

    a. silver chloride
    b. diphenylurea
    c. diphenylamine
    d. aniline chloride

Part II
Answers to Review Questions
Sampling for Gaseous Materials

1. a correct. (Ref. 1, p. 174.)

2. b correct. (Ref. 1, p. 175.)

3. b correct. (Ref. 1, p. 177.)

4. a correct. (MSA literature.)

5. c correct. Bubbler efficiency is a widely variable function of the physical and chemical properties of the gas and liquid involved. For a system to be effectively used, the efficiency should be >90%. If "normal" efficiency is interpreted to mean "typical" efficiency of commonly used systems, 90% is the best answer, although some systems do have >95% efficiency. (Ref. 1, p. 167-173.)

6. d correct. This question clearly refers to the text in the cited reference even though mylar bags do not usually involve sealing wax or glass. (Ref. 1, p. 170.)

7. d correct. (See question 6.)

8. e correct (all of the above). All answers are clearly cited in the reference. (Ref. 1, p. 171.)

9. a correct. Absorption is a solubility phenomenon whereas adsorption is a surface phenomenon.

10. a correct. (Ref. 1, p. 187; Ref. 2, p. U-121-123.)

11. c correct. Any oxidizing or reducing agent will interfere with the determination. (Ref. 1, p. 169; Ref. 6, p. 833.)

12. d correct. (Ref. 1, p. 193-4.)

13. c correct. (Ref. 1, p. 183.)

14. e correct. The amperometric cell is part of an oxygen deficiency measurement system. It is a desirable complement to a combustible gas meter because of its use to assure there is sufficient oxygen to operate the meter. In addition, oxygen deficiency meters are frequently used in sewer and petroleum tank cleaning operations where oxygen deficiency is a problem.

15. c correct. The instrument selected must have the ability to segregate methane from other gases. Both the MIRAN and LIRA could do this using infrared absorption techniques. The MIRAN is the best choice because of its portability. (Ref. 2, p. U-115-120.)

16. c correct.

17. b correct. Refrigerants are mostly non-combustible halocarbons. (Ref. 2, p. U-139.)

18. d correct.

$$\text{Overall Eff} = 1 - \left[(1 - \text{Eff}_1)(1 - \text{Eff}_2)\right]$$

$$= 1 - \left[(1 - .95)(1 - .75)\right]$$

$$= 0.9875$$

19. b correct. (Ref. 6, p. 795.)

20. d correct. Anions in general interfere with the $H_2O_2$ method. (Ref. 7, p. 215-220; Ref. 6, p. 852; Ref. 9, p. 447-455.)

21. a correct. (Ref. 6, p. 525.)

22. b correct. (Ref. 8, IX-57.)

23. c correct. (Ref. 8, IX-58.)

24. c correct. (NIOSH Pub. 77-157A.)

25. a correct. (Ref. 7, p. 78.)

26. d correct. (Ref. 1, p. 184-5.)

27. a correct. (Ref. 5, p. 569.)

28. b correct. (Ref. 1, p. 106.)

29. c correct. (Ref. 2, p. R-10.)

30. b correct. This is true within certain groups of compounds. Physical adsorption properties greatly affect separability. (Ref. 3, p. 738; Ref. 1, p. 184.)

31. b correct. (Ref. 1, p. 172-177.)

32. a correct. (Ref. 7, p. 52.)

33. a correct. (Ref. 7, p. 61.) Used especially for determining the metallic component of aerosols.

34. d correct. (Ref. 1, p. 183.)

35. c correct.

36. b correct. Different sources recommend different methods. The OSHA method was selected as best because the reference is more recent. (Ref. 8, p. IX-27.) ACGIH Method - silica gel or nitric acid bubblers. (Ref. 1, p. 168; Ref. 2, p. R-15.)

37. a correct. (Ref. 8, p. 9-52.)

38. c correct. Activated charcoal is considered effective for materials boiling above 0°C, moderately effective for materials boiling above -100°C, and ineffective below -150°C.

39. c correct. (Ref. 1, p. 175-6.)

40. b correct.

41. It is a good antioxidant. (Ref. 5, p. 717.)

42. c correct. (Wilks Scientific Corp. Literature.)

43. a correct. Oxydizing and reducing agents interfere. (Ref. 7, p. 280.)

44. c correct. The prime advantage is simplicity. (See question 20.)

45. c correct. (Ref. 10, p. 180.)

46. e correct. (Ref. 1, p. 172-4.)

47. a correct. (See question 8.)

48. a correct. (Ref. 2, p. R-4.)

49. e correct.

concentration = (Fraction of LEL)(LEL)
LEL = lower explosive limit
C = .2 x .05 = 0.01 = 10,000 ppm

50. b correct. (Ref. 2, p. 153.)

51. b correct. (Ref. 6, p. 568.)

52. c correct. The buret is considered a primary standard for volume in industrial hygiene work. (Ref. 1, p. 104.)

53-63. Note: Many of the methods cited are old or obscure; more current methods cited in Refs 8 and 10 are indicated.

53. e correct. (Ref. 1, p. 146.) 0.8 μ membrane filter. (Ref. 10, p. 118; Ref. 8, p. IX-44.)

54. b correct. (No ref.) OSHA method - direct reading mercury analyzer, UV (Ref. 8, p. IX-45.)

55. d correct. (Ref. 1, p. 168.) OSHA - midget impinger, $Cd(OH)_2$. (Ref. 10, p. 112.)

56. n correct. No current OSHA or NIOSH method.

57. k correct. (Ref. 1, p. 168; Ref. 8, p. IX-26.)

58. f correct. Saltzman Method. (Ref. 1, p. 169.) OSHA - molecular sieves. (Ref. 8, p. IX-50.)

59. m correct. (Ref. 8, IX-27.)

60. j correct. Phosgene is an acid gas that will quickly react with water to produce HCl.

61. i correct. Nitroglycerine is infinitely soluble in ethyl alcohol. OSHA method is adsorption on Tenax beads. (Ref. 8, p. IX-50.)

62. m correct. (Ref. 10, p. 168.)

63. a or m correct. (distilled water or silica gel.) (Ref. 8, p. IX-46.)

64. b correct. (Ref. 1, p. 168.)

65. d correct. (Ref. 1, p. 168.)

66. c correct. (Ref. 6, p. 527.)

67. d correct. ("Air Quality Criteria for Carbon Monoxide," USEDA, 1979, p. 5-33.)

68. c correct. Phenolphthalein requires presence of other reactants to detect cyanide. (NIOSH HCN Criteria Doc, USHEW, 1976, p. 97-100.)

69. b correct.

70. b correct.

71. b correct.

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4. Brief, Richard S., Basic Industrial Hygiene, A Training Manual, American Industrial Hygiene Association, 1975.

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7. Stern, Arthur C. (Editor), Air Pollution, Volume III, Measuring Monitoring, and Surveillance of Air Pollution, Third edition, Academic Press, Inc., NY, 1976.

8. OSHA Instruction CPL 2-2.0, Industrial Hygiene Field Operations Manual, April 2, 1979.

9. Stern, Arthur C. et al, Methods of Air Sampling and Analysis, American Public Health Association, 1972.

10. NIOSH/OSHA, Pocket Guide to Chemical Hazards, September, 1978.

Part III
Review Questions
Sampling For Aerosols

1. Phase contrast:

   a. is used to observe particles which do not absorb light in the visible wavelengths
   b. is used in liquid-liquid separations
   c. is a mircoscopic technique used to observe wood dust
   d. depends on the difference in contrast between liquids and solids

2. A dust sample collected on a filter for analysis on a weight basis:

   a. is not reliable under any circumstance
   b. can be collectd on any pore size paper as long as the particle size is more than one fourth the pore size
   c. should be collected over at least a two hour period
   d. must be weighed on a dual pan balance
   e. is subject to error due to weight loss or gain of the filter between weighing

3. What is the smallest size sieve used in the U.S.?

   a. 5
   b. 75
   c. 200
   d. 400
   e. 1000

4. If the flow rate through a Greenburg-Smith impinger is increased by 1 cfm from its normal value, what happens to the efficiency for dust?

   a. increases
   b. decreases
   c. unchanges
   d. greatly increases
   e. greatly decreases

5. What is resistivity of bulk dust?

   a. basic electrical resistance of the material involved
   b. effective electrical resistance of the bulk dust
   c. tendency to produce resistance in filtration
   d. resistance to collection by electrostatic precipitation

6. What method of sampling for dust is used for x-ray analysis?

   a. impingers
   b. any wet technique
   c. filtration
   d. any of the above
   e. none of the above

7. How are the readings from a shake-out sample best reported?

   a. mppcf
   b. $mg/m^3$ total
   c. $mg/m^3$ respirable dust
   d. % silica

8. Deposits on window in top of roof from iron oxide from welding probably result from:

   a. sedimentation
   b. thermal precipitation
   c. electrostatic precipitation
   d. diffusiophoresis
   e. one of the above

9. Why would a lead oxide particle settle faster than a silica particle?

   a. shape
   b. size
   c. density
   d. diffusion
   e. all of the above

10. Airborne particulates settle according to Stokes Law with a velocity:

$$V \text{ cm/sec} = \frac{1}{18} g d^2 (\rho p - \rho a) \quad \text{where}$$

   g = acceleration of gravity (981 $cm/sec^2$)
   d = diameter of particle (cm)
   p = sp. g. of particle
   a = sp. g. of air (neglected)
   = viscosity of air (poises) = $181 \times 10^{-6}$ poise

   For particles between 1 and 0.1 microns, a correction factor is applied (Cunningham's). Below 0.1 micron (smokes), velocity due to molecular shock exceeds that due to gravity, and motion of particles approach that of gas molecules.

   What is the settling velocity of a 1 micron particle of quartz (sp. g. = 2.65)?

   a. <0.1 cm/s
   b. 0.1 - 1.0
   c. 1.0 - 5.0
   d. 5.0 - 10.0
   e. >10.0

11. What is the OSHA method recommended for sampling asbestos in air?

   a. 37 mm millipore type AA filter at 1-2.5 LPM
   b. 0.8 mm millipore type AA filter at 0.1-1 LPM

c. 37 mm Whatman filter at 1-2.5 LPM
d. midget impinger with methyl alcohol

12. What is the desired method for sampling chromic acid?

a. millipore filter
b. PVC filter
c. bubbler with distilled water
d. portable IR

13. Why would a nylon cyclone not be placed in front of a filter when sampling for ZnO?

a. damage to cyclone from corrosive gases
b. TWA not based on respirable fraction
c. reduced pressure at filter
d. cyclone would bias sample to small particles

14. X-ray diffraction is based on:

a. physical properties related to atomic numbers of constituent atoms of a material
b. chemical properties related to atomic numbers of constituent atoms of a material
c. ability of a material to fluoresce when ionized
d. absorption of specific wavelength

15. Of the following airborne contaminants, which is likely to have the smallest average particle size?

a. zinc fumes
b. carbon monoxide
c. silica dust
d. chromate dust

16. The midget impinger dust sampler depends most on which of the following principles?

a. precipitation
b. wetting
c. settling
d. filtration

17. What is used to calibrate a Porton graticule?

a. calipers
b. stage micrometer
c. microscope
d. precision scale, weighing accuracy of 0.01 mg

18. If you were milling asbestos, what effect would this have on the fibers?

    a. nothing
    b. reduce diameter
    c. reduce diameter and shorten length
    d. increase length

19. From an aerosol generation standpoint, central vacuum systems are preferred over which of the following housekeeping techniques?

    a. dry sweeping
    b. wet scrubbing
    c. air blowing
    d. none of the above
    e. all of the above

20. Sampling for glass fibers may be done with:

    a. midget impingers
    b. total dust sampling
    c. respirable dust sampling
    d. all of the above
    e. only a and c above

21. A fiber is defined as having which aspect ratio (length to diameter) greater than:

    a. 5 to 1
    b. 2 to 1
    c. 3 to 1
    d. 10 to 1
    e. none of the above

22. Sampling from an exhaust stack at a velocity less than the isokinetic velocity would cause:

    a. increase in the number of large particles collected
    b. decrease in the number of large particles collected
    c. no effect on the number of large particles collected
    d. decrease in the concentration of CO measured

23. A 10 minute midget impinger sample which was counted in a Dunn cell indicated an air concentration of 48 mppcf. A Greenburg-Smith impinger taken for 30 minutes in the same area indicated a count of 55.2 mppcf. If the average free silica content of the dust is 4.92%, then which of the following is true?

    a. the operation is unsafe because the ACGIH standards and TLV are based on the Greenburg-Smith impinger
    b. the operation is safe since 55.2 mppcf x 4.92% = 2.71 mppcf which is well within accepted limits
    c. a size analysis would have to be made before we could determine which count represented the true concentration

d. the counts are comparable within the limits of accuracy of the methods
e. the operation is safe because the ACGIH standards and TLV are based on the midget impinger

24. Airborne dust had been sampled for 15 minutes at 0.1 cfm with a midget impinger. The sample was diluted to 20 ml, placed in a Dunn cell (1 mm deep), and counted under low power with a Page disc (area = 0.25 $mm^2$) in the eyepiece. Because of the high concentration, only 2 squares were counted. If the net count was 90 particles, what was the air concentration? (Page disc has a 5 by 5 grid.)

a. 60 mppcf
b. 900 mppcf
c. 600 mppcf
d. 90 mppcf
e. 6 mppcf

25. The geometric standard deviation of a particle size analysis (by weight) is:

a. calculated by Stokes' law (using Cunningham's correction)
b. equal to $\frac{\text{15.87 percent size by weight}}{\text{50 percent size by weight}}$
c. equal to the $\frac{\text{optical 50 percent size}}{\text{optical 15.87 percent size}}$
d. equal to $\frac{\text{50 percent size by weight}}{\text{84.13 percent size by weight}}$ x median particle size
e. none of the above

26. Calibration of a Filar micrometer eye piece with a 90X objective and a stage micrometer shows that 475 filar units represent 0.05 mm. What is the value in microns of one filar unit?

a. 0.105 microns
b. 0.210 microns
c. 1.05 microns
d. 2.10 microns
e. 10.5 microns

27. The standard deviation of a dust sample was found to be 3.62. Which of the following is true?

a. the dust is hazardous
b. the dust is capable of being retained in the lungs
c. the dust cannot enter the lungs
d. not enough information is given to determine whether or not the dust is hazardous.

28. The median size of a dust sample was found to be 1.12 microns. The 84% size was 2.39 microns. The geometric standard deviation is:

a. 2.68
b. 0.47
c. 2.13 micron

d. 2.68 micron
e. 2.13

29. Fumes may be (check all which apply):

a. counted microscopically using a light-field technique since they are particulate in character and have a large size
b. produced by a condensation process
c. independent of electrostatic or thermal forces
d. collected efficiently in a konimeter and sized microscopically
e. highly toxic in all cases if the TLV is greater than 15 $mg/m^3$
f. present in the form of brass fumes in a brass mine survey

30. Given the effective filter area (855 $mm^2$), the net asbestos fibers counted per (65 micron x 65 micron) field, and the air volume sampled (20 liters), calculate the asbestos concentration in fibers/cc.

a. <0.1
b. 0.1 - 1.0
c. 1.0 - 10
d. 10 - 100
e. none of the above

31. Which of the following forms of free crystalline silica cannot be identified by x-ray diffraction?

a. tridymite
b. cristobalite
c. quartz
d. flint
e. opal

32. Which of the following is false?

a. either the Page or Whipple discs may be used with the Sedgewick-Rafter cell
b. a shorter settling time is needed with the Hemocytometer than with the Sedgewick-Rafter cell
c. at least two cells should be made up from each sample
d. the Dunn cell is difficult to clean, especially in the corners
e. a Porton graticule may be used for dust counting as well as for sizing

33. Electrostatic precipitators are very useful because:

a. they have a preselector ahead of collecting
b. they can be used for mineral dust counts
c. they are highly efficient for separating particles greater than 1 micron
d. all of the above
e. none of the above

34. Which type of filters are used for asbestos counting?

    a. Whatman Ashless
    b. PVC
    c. mixed cellulose ester
    d. glass with PVC backing
    e. none of the above

35. In determining silica dust concentrations with the midget impinger, the particles are:

    a. counted
    b. weighed
    c. determined chemically
    d. dissolved

36. Which of these dust sampling instruments obtains a grab (instantaneous) sample?

    a. midget impinger
    b. thermal precipator
    c. electrostatic precipitator
    d. B & L dust sampler

37. Airborne zinc oxide resulting from welding galvanized iron would be classified as:

    a. dust
    b. smoke
    c. fume
    d. mist

True - False

T____ F____ 38. Dusts tend to flocculate more rapidly than do fumes.

T____ F____ 39. The cascade impactor is a device used to sample aerosols, separating the particles according to size.

T____ F____ 40. A fine mist of oil dispersed in the air might be called an aerosol.

T____ F____ 41. Chromic acid mists, because of their unusually small size, are most likely to produce injury to the upper respiratory tract.

42. The electrostatic precipator is used to sample:

    a. fumes
    b. vapor
    c. gas
    d. mist

43. Fume particle sizes are generally in the range of:

a. 1 - 10 μ
b. 10 - 100 μ
c. 0.01 - 1.0 μ
d. .001 - 0.1 μ

Part III
Answers to Review Questions
Air Sampling - Aerosols

1. a correct. Phase contrast microscopy is the use of the interference of light to yield an image of high contrast. The observed objects alter the phase of the incident light according to their optical thicknesses. Phase contrast systems render objects visible by making the normally unobservable differences visible. (Ref. 1, p. 1540.)

2. e correct. (Ref. 2, p. 146.)

3. d correct. Standard US sieve sizes represent the number of cells per inch in the mesh. Since the wire size itself varies from size to size, it must be known to determine the opening size. The smallest US standard sieve is No. 400 which has an opening size of 37 m. (Ref. 3, p. 21-41.)

4. a correct. The particle collection efficiency generally increases with increasing flow rate. However, at flow rates higher than standard (1.0 cfm), carry over and particle fracture may be a problem. Also for very small particles, such as fumes, inertia is not an effective mechanism and efficiency will drop with increasing flow. (Ref. 4, p. O-5, O-37.)

5. b correct. If resistivity is too high or too low, electrostatic precipitators will not function well. (Ref. 5, p. 92; Ref. 6, p. 905.)

6. d correct. Any of the techniques listed may be used if one is willing to resuspend th material and deposit in on an appropriate surface. Silver filters and thermal precipitators can be used to collect aerosols directly for x-ray analysis. (Ref. 4, p. N-11.) The NIOSH/OSHA x-ray diffraction method for quartz sampling utilizes collection on a PVC filter. (Ref. 7, p. IX-53.)

7. c correct. "Shake-out" refers to shake out of castings in foundry operations. The principal hazard is silica dust. The OSHA method for silica requires collection of the respirable fraction. (Ref. 5, p. 1165; Ref. 7, p. IX-53.)

8. b correct. Deposition in the downward face at a horizontal surface could occur by either thermal precipitation or electrostatic precipitation. In the latter case, deposition would occur on all surfaces. Thermal deposition would, on the other hand, be most evident where thermal gradients were greatest, i.e., windows. (Ref. 4, p. Q-2 - Q-4.)

9. c correct. Settling velocity is directly proportional to particle density (assuming the fluid phase is much less dense than the particle). (Ref. 4, p. O-9.)

10. b correct. Solve by substitution.

$$V_s = \frac{\left(981 \frac{cm}{s^2}\right)\left(10^{-4}\ cm\right)^2 \left(2.65 \frac{g}{cm^3}\right)}{(18)\left(181 \times 10^{-6} \frac{g \cdot cm}{s}\right)}$$

(Note: 1 poise = $1 \frac{g}{cm \cdot s}$)

$$V_s = 0.0080 \frac{cm}{s}$$

11. a correct. (Ref. 7, p. IX-27.)

12. b correct. (Ref. 7, p. IX-31.)

13. b correct. Fumes are of such a small particle size (all respirable) that placing a cyclone in front would only produce error. (Ref. 4, p. F-2.)

14. a correct. (Ref. 1, p. 2353-6; Ref. 8, p. 114.)

15. a correct. Condensation aerosols such as fumes usually have an upper limit of about 1 μm diameter while size reduction aerosols such as dusts have a 1 μm lower limit. (Ref. 4, p. F-2; Ref. 2, p. 139.)

16. b correct. A particle not wet in an impinger is likely to be resuspended and carried through. (Ref. 4, p. 0-36.)

17. b correct. (Ref. 8, p. 36.)

18. c correct. (Ref. 5, p. 194.)

19. e correct. All mechanical cleaning methods, including wet scrubbing, generate significant quantities of aerosols.

20. b correct. Most cyclone respirable dust separators do not work well with fibrous materials. In any case, the TLV-TWA is based on fibers 7.0 μm dia. NIOSH has recommended two filtration sampling systems, both of which should be used; one to collect a sample for sizing and counting, and the other to determine the total gravimetric contaminant concentration. NIOSH does not recommend midget impingers. (Ref: "Criteria for a Recommended Standard...Occupational Exposure to Fibrous Glass," NTIS Pub PB-274195, April 1977.)

21. c correct. (Ref. 2, p. 149.)

22. a correct. (Ref. 8, p. 540-543.)

23. a correct. First, one must assume a type of silica. Since quartz is most common, it is the reasonable assumption. The TLV (based on impinger samples) is given by the formula:

$$TLV = \frac{300}{\%\ \text{Quartz} + 10} = \frac{300}{4.92 + 10} = 20.1\ \text{mppcf}$$

Thus, the operation is unsafe. Since the TLVs for other silica types are more restrictive than that for quartz, the initial assumption makes no difference in the solution. (Ref. 9, p. 32.)

24. a correct. The concentration in the air is given by the following formula:

$$C = \frac{V_w\,(N_S - N_C)}{V_a\ A\ D}$$

$C$ = concentration, mppcf
$V_a$ = gas volume sampled, $ft^3$
$V_w$ = total water volume, $cm^3$
$A$ = area of counting field, $cm^2$
$D$ = depth of cell, cm
$N_S$ = mean count per field
$N_C$ = mean count per field (blank)

$$C = \frac{\left(\frac{(90\ \text{particles})}{2/25\ \text{field}}\right)(20\ cm^3)}{(15\ \text{min})\left(0.1\ \frac{ft^3}{\text{min}}\right)\left(0.0025\ \frac{cm^2}{\text{field}}\right)(0.1\ \text{cm})}$$

$$= 60\ \text{mppcf}$$

This problem may be solved logically by determining the concentration in one cell 1 mm deep by 2/25 of 0.25 mm in surface, converting this concentration to particles per ml, multiplying by the sample volume in ml to get the total number of particles and then dividing by total volume sampled. (Ref. 8, p. 26.)

25. e correct. None of the answers is correct. The correct answer is the inverse of answer c. Geometric standard deviation applies to log-normal distributions. Since the differences in logs is the log of the quotient (a dimensionless ratio), the geometric standard deviation is dimensionless. (Ref. 2, p. 159.)

26. a correct.

$$\text{Filar Unit} = \frac{0.05\ \text{mm}}{4.75\ \text{filar units}} = 0.105\ \frac{\mu m}{\text{filar unit}}$$

(Ref. 8, p. 34.)

27. d correct. The type of distribution (log, gaussian, etc.), the mean and the standard deviation must be known to determine the respirable character of the dust. (Ref, 2, p. 155-159.)

28. e correct. Assume a log-normal distribution.

$$\text{geo} = \frac{50\%\ \text{size}}{16\%\ \text{size}} = \frac{84\%\ \text{size}}{50\%\ \text{size}} = \frac{2.39}{1.12} = 2.13$$

(Ref. 2, p. 159.)

29. b correct. (Ref. 2, p. 139-144.)

30. Insufficient information. The asbestos concentration is

$$\text{Fiber concentration} = \frac{\left(\frac{\text{Filter Area}}{\text{Field Area}}\right)\left(\frac{\text{Fibers}}{\text{Field}}\right)}{(\text{Sample volume})}$$

The sample volume must be provided. (Ref. 8, p. 27-8.)

31. e correct. Of the forms given, opal is amorphous, hence not crystalline, and cannot be identified by x-ray diffraction. All others can be identified. (Ref. 1, p. 1063, 1681, 1857.)

32. d correct. (Ref. 8, p. 22-27.)

33. b correct. (Ref. 4, p. 13.)

34. c correct. (Ref. 7, p. IX-27.)

35. a correct. (Ref. 9, p. 33.)

36. d correct. The Bausch and Lomb Dust Counter, Model 40-1, is a real-time aerosol counter and therefore is effectively a "grab sampler." All others listed involve sample collection over a specified sampling period and determine a time weighted average concentration. (Ref. 4, p. T-16.)

37. c correct. (Ref. 2, p. 139.)

38. F. Flocculation (agglomeration) rate varies inversely with particle size.

39. T. (Ref. 4, p. 18-36.)

40. T. (Ref. 1, p. 51.)

41. F. Relatively large particles are more likely to be deposited in the upper respiratory tract, the site of most frequent attack by chromic acid mist.

42. a correct. Electrostatic precipitators are most often used for solid particles although they may be used for liquid particles also. (Ref. 2, p. 143; Ref. 4, section P.)

43. c correct. Fume is normally considerd to be from 0.001 μm diameter to 1.0 um. (Ref. 6, p. 3.)

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Chapter 11: AIR POLLUTION

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I. Standards
   A. Ambient - 7 national, each with specified sampling method
   B. Stationary source
      1. hazardous materials
      2. process and industry
   C. Mobile source

II. Atmospheric Dispersion
   A. Micrometeorology
      1. atmospheric stability and mixing
      2. wind
   B. Dispersion modeling
      1. gaussian (Pasquill)
      2. box models
   C. Source sampling
      1. EPA methodology
      2. particles - isokinetic for particles greater than 5 um diameters

III. Control Techniques
   A. Particles
      1. collection mechanisms
         a. particles
            1. inertial
            2. electrical
            3. diffusion
            4. interception
         b. gases
            1. absorption
            2. adsorption
            3. diffusion
      2. Collection and control systems
         a. particles
            1. filters
            2. cyclones
            3. electrostatic precipitators
            4. scrubbers
            5. incinerators
         b. gases
            1. scrubbers
            2. adsorbers
            3. incinerators

## Review Questions

1. A fabric dust collector handles 300 cfm with a dust loading of 10 grains per cubic foot. Its initial resistance is 1" of water. At the end of six hours, it reaches a maximum permissible resistance of 5" of water. How soon would 5" of water gauge be reached for a dust loading of 20 grains per cubic foot and a flow rate of 300 cfm?

   a. 1.1 hours
   b. 1.5 hours
   c. 3.0 hours
   d. 4.5 hours

2. Recirculation of ventilated air which has been passed through a scrubber is not advisable primarily because:

   a. air is corrosive
   b. it adds moisture to the air
   c. improper operation of unit could result in return of contaminated air
   d. air can be recirculated

3. When can air be recirculated?

   a. when it passes through a dry filter
   b. when it passes through a wet filter
   c. when it is a nuisance hazard
   d. when a sensor is in the return duct

4. The disadvantage of a packed tower is:

   a. dust will plug the packing requiring unreasonable maintenance
   b. efficiency sensitive to changes in cfm
   c. requires small space
   d. limited use due to temperature sensitivity
   e. a and b
   f. c and d

5. The principal advantages of the cyclone collector are:

   a. low cost, low maintenance, low pressure drop
   b. collection of fine particles, low cost, low maintenance
   c. collection of coarse particles, low pressure drop, little space
   d. collection of wet material, collection of fine particles, low cost

6. Given a probe 0.1992 inches in diameter, stack velocity of 3000 fpm, what must the probe flow rate be to obtain isokinetic sampling?

   a. 0.6 cfm
   b. 6.0 cfm
   c. 60.0 cfm
   d. 600 cfm

7. If V stack is greater than V probe, what type sample would be collected?

   a. excess of large particles
   b. excess of small particles
   c. lower $CO_2$ concentration
   d. higher amount of moisture

8. What dust collector uses the most electrical power?

   a. electrostatic precipitator
   b. impingement separators
   c. combustion incinerators
   d. fabric filters

9. The advantage(s) of the ESP over the bag collectors is (are):

   a. can be used for higher temp of contaminants and humid atmosphere
   b. takes up much less space
   c. uses less water
   d. no advantages

10. What is the major pollutant from steam plants?

   a. $SO_X$
   b. $NO_X$
   c. particles
   d. CO

11. If the flow is doubled, with the same grain loading, what happens to the cycle time for bag filters?

   a. resistance increases in proportion to time
   b. resistance increases inversely to time
   c. resistance decreases with time
   d. resistance increases at time required

12. A visible cloud may exist from a stack even though the collection device is 95% efficient because:

   a. visibility of an effluent is a function of the light reflecting surface area and light scattering properties of escaping material and removal of coarse particles may significantly reduce these characteristics
   b. the remaining 5% may be sufficient to create large clouds of contaminants
   c. visible clouds are usually 90% moisture and the efficiency does not address moisture
   d. not possible

13. Which air pollutant causes corrosion of buildings and statues?

   a. $SO_X$
   b. $NO_X$
   c. CO
   d. particles

14. There is a concentration of 15 grams/$m^3$ of agriculture dust in the air. You can see:

    a. practically nothing
    b. hand of a watch
    c. about three feet
    d. unlimited

15. What is the primary purpose of having a waterfall in a paint spray booth?

    a. filter gases and vapors
    b. filter particles
    c. provide correct capture velocity
    d. control temperature in booth

16. The advantages of a packed tower include all except:

    a. compact design
    b. not subject to freezing
    c. works in high temperature
    d. has constant pressure drop

17. Which is not a typical type of plume behavior?

    a. coning
    b. fanning
    c. fumigation
    d. trapping
    e. looping
    f. lofting
    g. all of the above are types of plume behavior

18. One would most likely require isokinetic conditions when:

    a. testing an automobile for CO emissions
    b. analyzing noise from an impact source
    c. sampling an industrial sewage effluent line for suspended solids
    d. sampling a continuous welding operation for zinc oxide fume
    e. sampling a beryllium machining exhaust system for airborne beryllium particles

19. A secondary air pollutant:

    a. has a national air quality secondary standard
    b. is of little practical consequence
    c. is formed in the atmosphere
    d. is emitted from a process of secondary importance because of the quantity of emissions involved
    e. is a member of the group of pollutants secondary in importance to those with primary standards

20. Virtually all atmospheric oxygen is produced by:

    a. nighttime plant respiration
    b. photosynthesis
    c. lightning
    d. fungi
    e. none of the above

21. Why are diesel engines preferred to gasoline engines for underground operation?

    a. less noise
    b. less carbon monoxide
    c. cheaper
    d. more efficient
    e. all of the above

22. What is the pollutant normally of most concern for diesel buses traveling at 60 km/hr?

    a. CO
    b. hydrocarbons
    c. particulate matter
    d. nitrogen oxides
    e. sulfur oxides

23. Which of the following is not included among the National Ambient Air Quality Standards?

    a. ozone
    b. lead
    c. sulfates
    d. oxides of nitrogen
    e. carbon monoxide

24. Null probes:

    a. are most suited to low velocity sampling conditions
    b. reliably produce isokinetic sampling conditions if the observed static pressure differential is zero
    c. work better if probe sizes are small
    d. not generally used in air pollution work
    e. are necessary to properly evaluate particulate emission problem

25. In-stack particle collectors are used because they:

    a. are easily fit through common sampling ports
    b. avoid problems of aerosol deposition in sampling lines
    c. eliminate condensation problems
    d. eliminate need for pumps
    e. are cheap

26. Which of the following factors need not be determined for a moist stack when using an EPA Method 2 train if one wishes to compute the actual stack flow rate?

a. stack diameter
b. velocity head
c. barometric pressure
d. volume sampled
e. all are required

27. Which is <u>not</u> an advantage of bag filters?

a. not sensitive to wide process variations
b. can handle combustion process emissions
c. simplicity
d. low initial cost
e. reliability

28. Which of the following is a disadvantage or difficulty in electrostatic precipitator operation?

a. difficult to maintain at high efficiency
b. high energy costs
c. safety
d. corrosion
e. none of the above

29. The major U.S. source of sulfur oxide air pollution is:

a. sulfuric acid manufacture
b. petroleum processing
c. electric power generation
d. mobile sources
e. smelting

30. As a fabric filter becomes clogged with filtered particles its efficiency:

a. decreases
b. remains unchanged
c. increases
d. increases for large particles only
d. increases for small particles only

31. If all other factors remain constant, what happens to the ground concentration of a pollutant emitted by a nearby source when the air speed doubles? (Assume Gaussian dispersion from a continuous source)

a. increases by more than a factor of 2
b. increases by a factor of 2
c. increases by less than a factor of 2
d. decreases by a factor of 2
e. decreases by less than a factor of 2

32. Which of the following air pollutant-plant injury associations is incorrect?

    a. sulfur dioxide - blotchy leaf damage
    b. ozone - chlorosis
    c. phosphate fertilizer production emissions - leaf margin damage
    d. nitrogen dioxide - generalized chlorosis
    e. all are correct

33. A dust collector which depends on the difference in the density of dust and air for separation is:

    a. a wet collector
    b. a fabric collector
    c. an electrostatic collector
    d. a centrifugal collector

34. Orsat readings are given how?

    a. % by weight dry basis
    b. % by weight wet basis
    c. % by volume dry basis
    d. % by volume wet basis

35. In a packed tower, how can flooding be prevented?

    a. increase surface area
    b. concurrent air flow
    c. countercurrent air flow
    d. increase air flow rate
    e. all of the above

36. What does positive lapse rate imply?

    a. turbulence
    b. isothermal condition
    c. inversion
    d. air pollution episode underway
    e. good high altitude mixing

37. Which contaminant is a primary contributor to the formation of smog?

    a. olefins
    b. paraffins
    c. alkanes
    d. acetylene
    e. aromatics

38. The number of points required in a velocity traverse:

    a. depends on the duct diameter
    b. will be equal to or greater than 16, 8 for each direction
    c. does not exceed 25 for a single diameter
    d. depends on the distance to the nearest downstream disturbance
    e. all of the above

39. For a reverse jet continuous duty bag filter being loaded at x lb/hr, a flow of 7000 cfm causes filter pressure drop of 3.5 inches of water. If the flow is raised to 12000 cfm, what will the pressure drop be?

a. <5.7
b. 5.7 - 8.9
c. 8.9 - 14
d. >14

## Answers to Review Questions

1. c correct.
Maximum pressure drop due to cake is: 5 - 1 = 4 inches of water

The cake pressure drop as a function of time and velocity is given by:

$$\Delta P_{cake}(t) = KCtV^2$$

K = const
C = dust concentration in air stream
t = time
V = superficial velocity (volumetric flow rate/filter face area)

Therefore doubling C will necessitate halving t if the same maximum $\Delta P_{cake}$ is used. (Ref. 1, p. 47.)

2. b correct. a - clearly false. b - wet scrubber effluents are saturated with moisture; this is a definite problem in recirculating the treated air; few environments could accommodate the amount of moisture released by a scrubbing system. c - this is always a potential problem, however controls and alarms can be included in the system to reduce the risk to acceptable levels. d - air should be recirculated only when the amount of moisture added to the environment is tolerable.

3. c correct. Under certain circumstances, each answer could be correct; however, the only answer not requiring some qualification is c. You may not find recirculating a nuisance contaminant pleasant, but the health risk in doing so is minimal.

4. e correct. a - true (Ref. 1, p. 101.) b - true (Ref. 1, p. 17 and 102.) c -true for some types of wet collectors, particularly venturis, but packed beds are in an intermediate size category (Ref. 1, p. 103.) d - false. Packed towers are often employed where temperature is a problem. (Ref. 1, p. 101-3.)

5. a correct. b and d are incorrect because cyclones are not good for small particle removal on a large scale. Special cyclones have been designed to remove "nonrespirable" particles in industrial hygiene samplers. c is incorrect because cyclones, while not as large as electrostatic precipitators or bag houses, are still big enough to create space problems. (Ref. 1, p. 28-31; Ref. 2, p. 645.)

6. a correct. For isokinetic sampling the velocity at the sampling probe tip must be the same as that in the sampled stream. Therefore:

$$Q = AV = \frac{\pi d_p^2}{4} \cdot V = \left(\frac{\pi \cdot (0.1992)^2 \text{ in}^2}{4}\right)\left(\frac{1}{144}\frac{\text{ft}}{\text{in}^2}\right)\left(3000\frac{\text{ft}}{\text{min}}\right) = 0.65\frac{\text{ft}^3}{\text{min}}$$

(Ref. 3, p. 540 ff.)

7. a correct. For stack velocities greater than the probe velocity, the air stream diverges around the probe tip. Some particles are unable to follow the stream lines of the diverging air stream and continue straight into the probe. These are sampled when in fact they should not have been and therefore cause too high a reported concentration. (Ref. 3, p. 54.)

8. b correct. Electrostatic precipitators are lowest in power consumption, the power to drive the precipitator itself being negligible. Combustion incinerators are not "collectors" and, in any case, are usually gas fired. Fabric filters are moderate power consumers operating at typical pressure drops of about 3 inches of water. Impingement separators are not used for particles smaller than about 20 μm diameter; since these particles are relatively easy to remove, the pressure drop is fairly low, typically 0.5 to 3 inches of water. However, to make them as efficient as filters for the same stream, pressure drop would have to be much greater. (Ref. 1, p. 55 and 60.)

9. a correct. (Ref. 2, p. 645.)

10. a correct. On a mass basis $SO_2$ is the major source from stationary combustion sources. (Ref. 4, p. 16-18.)

11. a correct. See question 1.

12. c correct. a - true to the extent that if you increase the total projected area of particles in the light path, keeping the particle size and optical properties constant, you will increase plume visibility. It is not a good generalization, however, because the visibility of a plume is a complex function of the particles' optical and physical properties, including size. For any particle there is a size which has a maximum effect on visibility. This size is typically near the wavelength of the light being observed. If one removes only large particles, thereby reducing the projected area, the plume may appear unaltered if the small particles absorbed and scattered light much more strongly than the relatively massive large particles. The latter may easily account for a large fraction of the mass emission. It is possible to decrease the total projected area of an aerosol comprised of particles below the size for maximum scattering effect by increasing the particle size and simultaneously increase the plume visibility. (Ref. 5, p. 3-8.)

13. a correct. $SO_2$ reacts with oxygen and atmospheric moisture to form corrosive sulfuric acid. (Ref. 4, p. 76.)

14. a correct. For large particles the total extinction increases with the total projected area of the particles in the optical path. Assuming a particle size of 50 m diameter ($25X10^{-4}$ cm radius) and a density of one, the total projected area in 1 $m^3$ of particles is:

$$Ap = \text{number of particles/m}^3 \times \frac{\text{projected area}}{\text{particle}} \quad \text{(neglects particle coincidence)}$$

$$Ap = \frac{\text{particle mass concentration}}{\text{particle density}} \times \frac{\text{projected area}}{\text{volume /particle}} \times \text{particle}$$

$$= \frac{\left(15\ \frac{g}{m^3}\right)}{\left(1\ \frac{g}{cm^3}\right)(25 \times 10^{-4}\ cm)^3\left(\frac{4\pi}{3}\right)} (\pi)(25 \times 10^{-4} cm)^2 \left(10^{-4}\right) \frac{m^2}{cm^2}$$

$$= 0.45\ \frac{m^2 \text{ projected area}}{m^3 \text{ aerosol}}$$

Thus, neglecting particle coincidence, in a path length of 1 meter, 45% of the field would be directly obscured. Unfortunately, obscuration due to other factors, such as light scattering, essentially doubles the obscuration and the presence of a significant number of smaller particles probably redoubles it and would probably eliminate this hope. In short, 15 $g/m^3$ is such a high concentration that you would see practically nothing. (Ref. 6, p. 127.) (See also Patty, Vol. III, p. 1407ff.)

15. b correct. The waterfall captures particles that would otherwise collect and build up on the duct surface.

16. b correct. Packed towers are usually, but not always, run with water and are therefore subject to freezing. (Ref. 2, p. 645.)

17. g correct. (Ref. 7, p. 406.)

18. e correct. Isokinetic sampling is generally unnecessary for particles greater than 5 um unless velocities are very high. (Ref. 3, p. 545.)

19. c correct. Primary and secondary pollutants should not be confused with primary and secondary air pollution standards. A primary pollutant originates at a fixed or mobile source and a secondary pollutant originates in the atmosphere as a result of chemical or photochemical reactions. Primary air pollution standards have been established by the U.S. Government to protect the health of the population. They have been established for both primary and secondary pollutants. Secondary standards have been established to protect the public welfare, e.g., prevent economic loss. (Ref. 8, p. 494; Ref. 7, p. 14.)

20. b correct. (Ref. 7, p. 45.)

21. b correct. Diesels emit more noise and are initally more expensive than gasoline engines. They are cheaper to run and emit as little as 1/50 the amount of carbon monoxide (but somewhat more $SO_x$ and $NO_x$). (Ref. 4. p. 23.)

22. d correct. First, one must assume the bus is diesel powered. For diesel engines, $NO_x$ is the pollutant of most concern, typical conditions yielding:

| Pollutant | Typical Emission #/ton fuel | Ambient Std $\mu/m^3$ |
|---|---|---|
| $NO_x$ | 49 | 100 |
| Particles | 34 | 75 |
| $SO_x$ | 10 | 80 |
| Hydrocarbons | 15+ | 160 |
| CO | 15 | 10,000 |

The emission is particularly significant when viewed in the context of the primary ambient air quality standards. (Ref. 4, p. 21-23.)

23. c correct. National Ambient Air Quality Standards exist for carbon monoxide, hydrocarbons, lead, oxides of nitrogen, oxides of sulfur, ozone and particulate matter. The oxides of sulfur standard is measured so as to include only gaseous sulfur oxides and specifically exclude sulfates which appear as particulate pollutants. (Ref. 40CFR60.)

24. d correct. Null probes are designed to achieve isokinetic conditions by equalizing the static pressure at the probes interior with that at the exterior approximately the same distance from the tip. In reality, most do not work well, particularly for low speed streams and small diameter probes. A null condition may easily be 25% off isokinetic. They are not typically used in air pollution work. (Ref. 3, p. 551.)

25. b correct. In-stack systems may require heating to avoid condensation from supersaturated effluent streams or to avoid condensation on a cold sampler. (Ref. 3. p. 555.)

26. d correct. Method 2 is the "Determination of Stack Gas Velocity and Volumetric Flow Rate." It does not require collection of a sample and hence no sample volume is needed. (Ref. 40CFR60, Appendix A, Method 2.)

27. b correct. Hot, moist gases are difficult to filter because of filter plugging and bag degradation. (Ref. 2, p. 645; Ref. 1, p. 46.)

28. a correct. Precipitators may quickly drop from 98% to 75% efficiency without careful maintenance. This represents a 12-fold increase in emissions. (Ref. 1, p. 93.)

29. c correct. Power generation accounts for over 40% of our emissions. (Ref. 4, p. 19.) Note the data in this reference is old but proportions are about right.

30. c correct. The efficiency of a filter used in industrial gas cleaning is due primarily to the dust cake on the filter cloth. Increasing the thickness of the cake increases the efficiency. Unfortunately, it also increases the work one has to do to force gas through the filters. At some point this work becomes unacceptably great, usually because of the energy requirement, too great a pressure on the filter making failure likely, or the amount of air passing through the filter becomes too low. (Ref. 1, p. 46-47.)

31. d correct. The Gaussian dispersion equation is:

$$\text{ground concentration } (x,y,z) = \frac{Q}{\pi \bar{u}_x \sigma_y \sigma_z} \exp - \frac{y^2}{2\sigma_y^2} + \frac{h^2}{2\sigma_z^2}$$

$Q$ = emission rate
$u_x$ = aug. wind velocity
$\sigma_y$ = lateral dispersion coefficient
$\sigma_z$ = verticle disperison coefficient
$h$ = release height

Thus doubling the wind speed halves the concentration. In actuality, doubling the wind speed would probably imply a decrease in stability and concomitant increase in $\sigma_y$ and $\sigma_z$. These factors would serve to decrease the concentration beyond a factor of 2. (Ref. 4, p. 221; Ref. 7, p. 440.)

32. e correct. Generalized chlorosis may occur with $NO_2$, but more typical is collapse near the apex and leaf margins, premature aging and leaf drop. Plants in general are much more sensitive to $SO_2$ than to $NO_2$. (Ref. 4, p. 62-68; Ref. 5, p. 166-167.)

33. d correct. (Ref. 2, p. 634.)

34. c correct. Orsat analysis is a field method for measuring $CO_2$, CO, $O_2$ and $H_2$ usually used for flue gas. It utilizes water solution absorption technique and hence cannot determine moisture. (Ref. 4, p. 166.)

35. a correct. Flooding can only be prevented by decreasing the air flow rate; increasing the surface area will do this. (Ref. 4, p. 166.)

36. c correct. Under positive lapse, air temperature increases with altitude as opposed to the normal adiabatic condition of a decrease with altitude. This condition is called a temperature inversion. Under inversion conditions, there is very little verticle mixing of pollutants so pollutants accumulate near the ground where they are emitted. Thus air pollution episodes, periods of particularly severe pollution conditions, are linked to inversions. (Ref. 4, p. 208; Ref. 7, p. Ch. 9.)

37. a correct. Relative reactivity of compounds (ethylene = 1.0)

| | |
|---|---|
| Olefins | 1 - 4 |
| Aromatics | 0.9 - 3 |
| Alkanes (Paraffins) | ~ 0 |
| Acetylene | ~ 0 |

From among the reactive groups, ethylene and propylene are by far the most concentrated in the atmosphere, therefore the olefins (which include them) are the primary contributors to photochemical smog. (Ref. 7, p. 41, 264-265.)

38. e correct. Depending on the duct diameter and the proximity of up and down stream obstructions causing turbulence which interferes with sampling, the number of points required by EPA ranges from 8 to 25 per diameter on each of the two diameters. (40CFR60, Appendix A, Method 1, section 2.2.)

39. b correct. (Compare with question 1.) At any given time, the pressure drop in a fabric filter is directly proportional to the face velocity because flow is laminar. Thus the new pressure drop is (3.5)(12/7)=6.0 inches $H_2O$.

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Chapter 12: RESPIRATORY AND EYE PROTECTION

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I. Respiratory Protection
  A. Standards
    1. CFR
    2. ANSI
    3. NIOSH
    4. MSHA
  B. Environments
    1. hazardous
    2. IDLH
    3. oxygen deficient
  C. Respiratory types
    1. air purifying
      a. particulate
        (1) dusts
          (a) nuisance
          (b) pneumoconiosis, fibrosis producing
          (c) toxic
          (d) high efficiency dust filters
          (e) single use
        (2) fumes
        (3) mists
      b. gas and vapor
        (1) cannisters
          (a) industrial
          (b) emergency escape
          (c) chin
        (2) cartridges
          (a) organic
          (b) acid gases
          (c) specific, combination
          (d) absorption, adsorption
          (e) resistance
    2. Atmosphere supplying
      a. supplied air
        (1) continuous flow
        (2) demand
        (3) pressure demand
        (4) hose mask with blower
        (5) hose mask without blower
      b. self contained
        (1) open circuit
        (2) closed circuit
      c. oxygen generating
    3. Combination systems
  D. Protection factors
  E. Selection decision logic
  F. Respirator fitting

1. measurement
2. test environment
3. leak, fit testing
    a. qualitative
    b. quantitative
4. education
    a. use
    b, maintenance
5. medical concerns
    a. heart problems
    b. claustrophobia
6. issuance documentation

II. Eye protection
    A. Standards
        1. NIOSH
        2. ANSI
    B. Environments
        1. splash
        2. missile
        3. radiation
    C. Types
        1. face shields
        2. safety spectacles
        3. goggles
            a. splash protection
            b. missile protection
            c. radiation protection
                (1) visible light
                (2) ultraviolet
                (3) infrared
                (4) laser
                    (a) element specificity
                    (b) ocular density
        4. helmets
            a. welders
            b. sandblasters
            c. general maintenance operations

## Review Questions

1. A mechanical filter respirator is designed to prevent entrance to the respiratory system of:

   a. gases
   b. gases and dusts
   c. dusts and mists
   d. gases and fumes

2. Which respirator is an air-purifying type?

   a. abrasive blasting helmet
   b. open circuit SCBA
   c. particulate filter
   d. gas mask
   e. c and d above

3. Which one of the following is not a recommended engineering control method?

   a. isolation or enclosure
   b. substitution of less toxic materials
   c. continued use of approved respirators
   d. local exhaust ventilation
   e. dilution with uncontaminated air

4. A dust respirator may be recommended for personal protection from a contaminant (check all which apply):

   a. when the solvent is only used for short, intermittent exposures
   b. when used in pits when a low oxygen content exists
   c. only at screening operations for an 8-hr exposure
   d. as a stop-gap measure until adequate ventilation is installed

5. Which of the following is not a NIOSH respirator category?

   a. gas masks
   b. SCBA
   c. supplied-air
   d. dust, fume, vapor
   e. chemical cartridge

6. Air-purifying and air-supply are:

   a. types of respirators
   b. ventilation system designations
   c. ASTM respirator classes
   d. Bureau of Mines respirator classes
   e. none of the above

7. Which of the following is not a limitation of chemical cartridge respirators:

   a. prohibited use in oxygen-deficient atmospheres
   b. limited to less than 10 X TLV
   c. limited to less than 5 X the TLV without a fitting test
   d. prohibited for use in IDLH atmospheres
   e. all are limitations

8. IDLH means:

   a. Industrial Department, Labor and Health
   b. Immediately Dangerous to Life or Health
   c. Identification, Detection, and Limitations of Hazardous Environments
   d. nothing pertaining to industrial hygiene

9. Protection factor is defined as:

   a. (ambient airborne concentration) - (concentration inside facepiece or enclosure)
   b. multiplier of the TLV used to determine maximum safe concentration for use of a particular respirator
   c. 10
   d. TLV/(concentration inside respirator)
   e. PF = STEL/TLV

10. The US agency(ies) designated to certify respiratory protection for the Federal Government is(are):

   a. B of M
   b. DoA
   c. DoL
   d. NIOSH, B of M or DoA
   e. NIOSH/MSHA
   f. ANSI

11. "Universal Canisters" are tested using:

   a. 20 specific gases
   b. gases, aerosols, biologicals
   c. water vapor and 5 toxic gases
   d. carbon monoxide at 20,000 ppm
   e. a variety of organic gases

12. Airline respirators differ from hose masks in that:

   a. pure oxygen is used in the former
   b. the former utilizes a pressurized supply line
   c. the former require a clean supply at atmospheric pressure
   d. the former may always be used in IDLH atmospheres
   e. no difference

13. Which of the following types is not identified by 30 CFR 11 as a type of gas mask cannister?

    a. Type N
    b. Type I
    c. chest cannister
    d. chin-style cannister
    e. escape mask cannister

14. The negative pressure required to activate the demand valve in an air line respirator is typically _____ that encountered in an air-purifying respirator with the same face piece.

    a. equivalent to
    b. less than
    c. greater than
    d. not related to

15. SCBA is:

    a. Service Connected Binding Arbitration
    b. Society for Certification of Breathing Apparatus
    c. Service Certified Breath Analysis
    d. Self Contained Breathing Apparatus

16. A means of avoiding problems associated with leaks into the face masks is to:

    a. specify full-face masks only
    b. exclude air purifying respirators
    c. utilize positive pressure respirators
    d. all of the above
    e. none of the above

17. An air purifying respirator fit test:

    a. may be conducted using a challenge gas or aerosol
    b. is required if the respirator is to be used at its maximum PF
    c. is required prior to any use
    d. all of the above
    e. a and b above

18. Given a challenge atmosphere of 150 ppm and a quantitative fit test result of 3 ppm measured inside the mask, what is the PF for that mask?

    a. 0.02
    b. 3
    c. 50
    d. 147

19. Federal standards for eye protection for non-ionizing, laser, visible, UV and IR light are published by:

    a. OSHA
    b. NIOSH
    c. NSF
    d. ANSI
    e. NBS
    f. none are published

20. Which of the following is not an element of an acceptable respiratory protection program?

    a. fit testing
    b. training employees using respirators
    c. selection of respirators according to hazard
    d. requiring employees to provide their own replacement cartridges
    e. cleaning and disinfection of respirators

21. Safety spectacles would be least effective in protecting an employee's eyes in which of the following situations?

    a. chipping rock
    b. pouring molten metals
    c. handling a caustic soda solution
    d. working in a strong concentration of ammonia gas
    e. sharpening tools at a stand grinder

22. Federal standards specifically address which component characteristic(s) of safety spectacles?

    a. lens impact absorption capability
    b. frame combustibility
    c. side shield anchoring
    d. all of the above
    e. none of the above

23. OSHA approves:

    a. respirators
    b. safety helments
    c. safety-toe footwear
    d. all of the above
    e. none of the above

24. Federal standards require that the protective lens in a welder's helmet:

    a. protect eyes against UV
    b. is not degenerated by UV
    c. has a clear outer lens to protect against metal missiles
    d. all of the above

25. In a machine shop, protective eyewear should be worn by:

    a. operators employing equipment
    b. supervisory personnel
    c. "casuals" walking through the shop
    d. a and b only
    e. all of the above

26. Which of the following items does not affect the fit of a respirator?

    a. strap tension
    b. sideburns
    c. dentures
    d. exhalation valve cover
    e. width and length of face

27. An air-purifying, half-facepiece respirator is expected to have a protection factor of:

    a. 1
    b. 2
    c. 5
    d. 10
    e. 50

28. A respirator protection factor of 100 means:

    a. the concentration of a contaminant outside the respirator should not exceed 100 times the TLV or OSHA PEL
    b. the respirator will last 100 times longer than one with a protective factor of 1
    c. the concentration inside the mask is not expected to exceed 1/100th of the concentration outside the mask
    d. a and c only
    e. all of the above

## Answers to Review Questions

1. c correct. Mechancial filters are designed to reduce the entrance of all types of particles into the respiratory tract. This includes liquid droplets (fogs and mists). It is important to remember that some droplets may evaporate in the atmosphere or in the respirator itelf and produce significant gas phase contamination which would not be controlled by the respirator. (Ref. 1, p. 519.)

2. e correct. All respirators fall in to one of two basic categories - air purifying or atmosphere(air) supplying. a and b are of the latter type and c and d of the former. (Ref. 1, p. 519-522; Ref. 2, p. 651-659.)

3. c correct. (Ref. 1, p. 519.)

4. d correct.

5. d correct. Correct category is dust, fume, mist. (Ref. 2, p. 656-658.)

6. a correct. d may also be correct, but a is selected because of its broader application. See question 2. (Ref. 1, p. 519-522; Ref. 2, p. 651-659.)

7. e correct. b and c are read "10 times" and "5 times the TLV" respectively. (Ref. 2, p. 667-672.)

8. b correct. (Ref. 2, p. 665.)

9. a correct. (Ref. 2, p. 668.)

10. e correct. MESA has been renamed MSHA (Mine Safety and Health Administration). It is part of the Department of Labor. NIOSH is part of the Department of Health and Human Services (formerly the health and welfare portions of the Department of Health, Education, and Welfare which no longer exists).

11. d correct. Universal canisters (Type N) are tested against the following gases: $SO_2$, $Cl_2$, $CCl_4$, $NH_3$, CO; all at 2% except ammonia which is 3%. The test gas is humidified to a standard level but no specific test against water vapor is performed. (Ref. 4, p. 1011-1012.)

12. b correct. In actuality the hose mask with blower supplies air under pressure as does the air line respirator, however the pressure of the former is very low. (Ref. 4, p. 1013.)

13. b correct. There is no "Type I" cannister. (Ref. 4. p. 1012.)

14. a correct. (Ref. 4. p. 1015.)

15. d correct. (Ref. 4. p. 1016.)

16. c correct. (Ref. 4, p. 1019-1020.)

17. e correct. (Ref. 2, p. 668-670; Ref. 4, p. 1025-1029.)

18. c correct. $PF = \frac{\text{outside concentration}}{\text{inside concentration}} = \frac{150 \text{ ppm}}{3 \text{ ppm}} = 50$

19. d correct. This question is tricky. The Federal Government has not developed its own standards but government publications do cite and adopt standards for protective eyeware published by ANSI, a private non-profit organization. Given this situation d appears the best answer. (Ref. 2, p. 663-664; 667-678.)

20. d correct. A company must insure that it has adequate and proper replacement cartridges for all employees utilizing respirators. Preventive medicine personnel must be consulted as to equating proper respirators to evaluated potential hazards. Fit testing in a controlled atmosphere accompanied by training of employees in use, maintenance, and disinfection of respirators form the foundation for a basic respiratory protection program. (Ref. 5, p. 59.)

21. d correct. Safety spectacles are not designed to protect the eyes from hazardous or irritating gas or vapor environments. The primary purpose of safety spectacles is for protection against splash and missile hazards such as rock chips, ground tool sparks, caustics, acids, and molten metals.

22. d correct. Specifications outlined by federal testing agencies require minimum impact absorption capability for safety spectacle lenses as measured by dropping steel spheres from specific heights onto the lens and evaluating shatter characteristics. Stability of side shield anchoring is tested to insure minimum hazard potential from splashes or missiles entering the area of the eyes from the side. Frame combustibility is evaluated in elevated temperature environments and sparking situations to insure that the frame material will not ignite causing facial injuries. (Ref. 7. p. 3-5.)

23. e correct. OSHA does not approve respirators, safety helmets, or safety toe footwear. Other federal agencies such as NIOSH are given this responsibility. (Ref. 6, sect. 20.)

24. d correct. The two primary functions of a welding helmet are to protect the welder from missiles such as sparking or molten metal, and to screen ultraviolet radiation. Testing by federal agencies such as NIOSH evalute these characteristics, including the helmet's lens ability to retain its UV protection capabilities even after consistent exposure to the radiation. (Ref. 8, p. 3-9.)

25. e correct. It is basic industrial hygiene practice to require all individuals in a machine shop to utilize protective eyewear when in the vicinity of operating equipment. Often, it is the unsuspecting "casual" walking through the shop who is the victim of a missile injury.

26. d correct. The exhalation valve cover has no bearing on the fit of a respirator. If strap tension, either side or head straps, is not sufficient, air contaminants may infiltrate the face seal. Sideburns and dentures may interfere with face seal integration. The length and width of the employee's face must be taken into consideration during fitting procedures to insure that the properly sized respirator is procured thus minimizing leakage potential. (Ref. 5, p. 63, 67.)

27. d correct. The half-facepiece, air purifying respirator for either dust, fumes, or "high efficiency" categories has a protection factor of 10. (Ref. 5, table 6-1.)

28. d correct. The basic definition of the protection factor of a respirator is that fraction of the environment concentration for a contaminant which will reach the breathing zone of the wearer through the respirator mechanisms. Basic industrial hygiene practice recommends that an exposure situation should not subject an employee to a breathing zone concentration which exceeds the TLV or OSHA PEL. Protection factors are not directly related to the working lifetime of a protection mechanism such as a filter cartridge since this characteristic is normally based on respirator usage and maintenance. (Ref. 5, p. 55.)

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Chapter 13: OXYGEN LIMITED ENVIRONMENTS

Reviewer: Charles Billings, Ph.D., Johns Hopkins University

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   A. Closed and partially closed spaces
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## Review Questions

1. An aviator uses supplemental $O_2$ when above 12,000 ft. because:

   a. he needs more oxygen to prevent bends
   b. the total pressure is too low
   c. the partial pressure of oxygen is too low
   d. the vapor pressure of oxygen is too low

2. Bends is caused by:

   a. lack of oxygen
   b. lack of air
   c. too high a pressure on circulatory system
   d. rapid release of dissolved gases from blood
   e. toxic effects of nitrogen and its compounds amplified by high pressure

3. Why is helium preferable to nitrogen as an oxygen diluent for divers?

   a. because it is more physiologically inert than nitrogen
   b. because it diffuses from tissue and into blood more rapidly
   c. because it is less toxic than nitrogen at high concentrations
   d. a and c above
   e. all of the above

4. At ambient pressure, the lowest oxygen concentration permitted by OSHA is:

   a. 10%
   b. 15.5%
   c. 17.5%
   d. 19.5%
   e. 25.5%

5. Caisson disease is:

   a. one of the pneumoconioses
   b. found in foundry workers
   c. a disease affecting the bone marrow
   d. involves entrapped nitrogen
   e. unlikely to cause lost work time

6. Numbness of the fingers is associated with:

   a. siderosis
   b. Raynaud's Syndrome
   c. lead poisoning
   d. tetanus
   e. none of the above

7. Accumulation of respiratory carbon dioxide in crowded offices is:

   a. unimportant
   b. a common cause of drowsiness and inattention
   c. a common cause of headache
   d. lowers resistance to disease
   e. causes respiratory problems in workers

## Answers to Review Questions

1. c correct.

   not a. nitrogen release upon decompression causes the bends.

   not b. aviators can operate at low pressures as long as the partial pressure of $O_2$ is adequate.

   c. when the partial pressure of $O_2$ drops, the driving force of all $O_2$ exchange reactions drops and the level of $O_2$ in the blood and tissues drops causing anoxia.

   not d. vapor pressure is temperature dependent only.

2. d correct. The bends is a relatively common manifestation of decompression sickness. The formation of gas bubbles, primarily nitrogen, as the gas leaves solution in the blood and tissues causing the dull throbbing pain in the joints and deep in the muscles and bones known as the bends. If decompression is excessively rapid the danger of an air embolism increases. (Ref. 1, p. 240.)

3. b correct. Helium diffuses from the tissues and into the blood more uniformly, thus preventing narcotic effects of nitrogen at high partial pressures. (Ref. 1, p. 244.)

4. d correct - 19.5%--OSHA standard for most surface work. Special standards exist for special environments. The ACGIH standard is 18% or 135 mm Hg $P(O_2)$, whichever is greater. Symptoms of hypoxia typically begin at approximately 16% $O_2$. (Ref. 1, p. 143.)

5. d correct. Caisson disease involves entrapped nitrogen and decompression sickness (Ref. 1, p. 253.)

6. b correct - Raynaud's Syndrome. Use of hand held vibrating tools eventually causes numbness of fingers.

7. a correct. Carbon dioxide at normal pressures is normally considered to be a simple asphyxiant. Most deaths attributed to $CO_2$ have been caused by asphyxiation. 3% $CO_2$ causes an increase in blood pressure and pulse as well as stimulating respiration. Atmospheric air contains 0.03% $CO_2$. 0.5% $CO_2$ has been demonstrated to cause no ill effects. Insignificant accumulation of respiratory $CO_2$ will occur in a room unless it is sealed and then asphyxiation will be due to lack of $O_2$.

## References

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# Chapter 14: INDUSTRIAL VENTILATION

Reviewers: Charles Billings, Ph.D., Johns Hopkins University
Robert E. Donadio, Ph.D., OSHA

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## Review Questions

1. Calculate the cost of heating each 1000 cfm of air exhausted from a building during the heating season. Use the following conditions:

   a. mean indoor temperature to be maintained = 65° F
   b. mean outdoor temperature (October-April) = 35° F
   c. ventilation system operates 9 hrs/day for 175 days/year
   d. 0.24 BTU's required to raise one pound of air 1° F
   e. 13 cubic feet average per pound of air heated 35° to 65° F
   f. 24,000 BTU's/ton of coal at 100% efficiency
   g. over-all efficiency of building's heating system = 55%
   h. cost of coal = $10.00/ton

2. 1000 cfm is to be exhausted through a round, freely suspended duct (6" dia). Calculate the expected velocity at 6" and 12" from the duct opening along the centerline of the duct.

3. A freely suspended hood 2" wide and 72" long exhausts 500 cfm. What is the velocity at a point 12" from the opening for both a flanged and unflanged hood?

4. Calculate the velocity pressure for the following velocities: 1266 lfm; 4005 lfm; and 5664 lfm.

5. A 10 point Pitot tube traverse for air at 70° F and normal barometric pressure flowing in a 12" circular duct gives the following data:

| Traverse point in. from wall | Vertical traverse h ("$H_2O$) | Horizontal traverse h ("$H_2O$) |
|---|---|---|
| 3/8 | .11 | .16 |
| 1 | .12 | .18 |
| 1-3/4 | .18 | .23 |
| 2-3/4 | .28 | .29 |
| 4-1/8 | .36 | .35 |
| 7-7/8 | .35 | .35 |
| 9-1/4 | .29 | .26 |
| 10-1/4 | .22 | .20 |
| 10-7/8 | .17 | .15 |
| 11-5/8 | .15 | .12 |

   a. How many cfm are flowing through the pipe?

   b. The throat suction at the inlet to this pipe is found to be 0.44 "$H_2O$. What is the coefficient of entry, Ce, of the inlet?

   c. A subsequent throat suction measurement gives a reading of 0.28 "$H_2O$. If the inlet is unchanged, what is the quantity of air flowing through the pipe under these conditions?

6. A hood is found to have a coefficient of entry, Ce = 0.65. If the duct area is 0.2 square feet, and 800 cfm of air flows through the hood, the static pressure just downstream from the hood is:

   a. -1.65 inches of water
   b. -0.65 inches of water
   c. -2.37 inches of water
   d. -1.00 inches of water
   e. -1.54 inches of water

7. Because of an addition to the system, it is necessary to double the air flow through a section of existing 12 inch duct. Friction loss through this section will be:

   a. 32 times the original
   b. doubled
   c. the same
   d. four times the original
   e. eight times the original

8. At a junction in an unbalanced exhaust system, the calculated loss from branch A = 3.75 inches, while those from B = 4.45 inches. If the air flow from A = 3250 cfm and that from B = 3250 cfm, the proper way to balance the system would be to:

   a. adjust the blast gate in branch A until static loss is equal to that at B
   b. increase air flow in Branch A to 3860 cfm
   c. resize Branch A since the two presures differ by more than 5%
   d. increase air flow in Branch A to 3530 cfm
   e. neglect the differences since the pressures differ by less than 20%

9. A Buffalo Forge, backward curved, 21 inch fan had been drawing 4000 cfm against 16 inches of water while rotating at 2500 rpm. Power consumption was 8 HP. It is proposed that a Westinghouse backward-curve, 21 inch fan be used at 2000 rpm. From the fan laws, which of the following would be expected?

   a. the new P could be calculated from $\frac{(2000)^2}{2500}$

   b. the new HP could be calculated from $\frac{3\sqrt{2500}}{2000}$

   c. the new Q could be calculated from $\frac{2000}{2500} = \frac{x}{4000}$

   d. the new Q could be calculated from $\frac{2500}{2000} = \frac{x}{4000}$

   e. none, since the fan laws don't apply

10. A backdraft hood is especially useful from an industrial hygiene standpoint because it:

    a. is unusually efficient
    b. encloses the process
    c. draws the contaminant from the breathing zone
    d. is less expensive than others

11. The basic purpose of local exhaust ventilation is to:

    a. prevent re-entrance of air contaminants to a work room
    b. remove contaminants at their source
    c. provide dilution ventilation of volatile substances
    d. provide dilution ventilation of micro-organisms

12. Welding is performed at a distance from a flanged hood (3 ft. x 5 ft.) not exceeding 15 inches from the hood. If a control velocity of 150 fpm is required, how much air must be moved through the hood, and what size flexible duct is required if the velocity through the hose is to be more than 3,000 fpm?

13. A kitchen range against a wall, 3' x 10', is ventilated by means of a canopy hood, 4' above the top of the range. How much air must be moved through the hood to develop an average velocity of 50 fpm across the open area between the hood and the range (assume a one-foot overhang on the three sides of the hood).

    a. 3200 cfm
    b. 4000 cfm
    c. 5600 cfm
    d. none of the above

14. At a point upstream from the fan in an exhaust system, the velocity pressure is two inches of water and that static pressure is 3 1/2 inches of water. What is the total pressure?

    a. 1 1/2 inches of water
    b. -1 1/2 inches of water
    c. 5 1/2 inches of water
    d. -5 1/2 inches of water

15. General ventilation is not suitable for:

    a. acetone
    b. odors
    c. $CO_2$
    d. $V_2O_5$ dust

16. A rotating vane anemometer is best used for:

    a. 3 inch ducts
    b. 6 inch ducts
    c. 8 inch ducts
    d. paint spray booths

17. In a mine opening you found a total flow of 2000 cfm. The opening was 10' x 10'. What is the velocity of the air in the entrance?

    a. 3000 fpm
    b. 2 fpm
    c. 20 fpm
    d. 3 cfm

18. What predominant frequency can be expected from a fan which is direct driven at 3600 rpm to deliver 2400 cfm at 1/2 inch of water. The fan has 60 backward curved blades.

    a. 3600 cps
    b. 2400 cps
    c. 1200 cps
    d. 4800 cps

19. Room air at 70° F is exhausted at a rate of 100 cfm per enclosure to each of 10 enclosures where enamel frit is fused. The air temperature rises to 600° F before leaving the enclosure. The duct work is insulated to the lower housing. What volume of air must the fan be capable of handling?

    a. 2000 cfm at standard conditions
    b. 2000 cfm at 600° F
    c. 1000 cfm at standard conditions
    d. 1000 cfm at 600° F

20. The static pressure immediately downstream from a 24" wheel grinder hood was measured to be 1.69" water. The duct diameter was 6" and the hood shape was that of a standard grinder hood, having a coefficient of entry of 0.78. What air flow would this reading indicate?

    a. 400 cfm
    b. 800 cfm
    c. 1200 cfm
    d. 1600 cfm

21. Which factors must be considered for hazard or nuisance control by dilution ventilation (check all that apply).

    a. quantity of contaminant generated
    b. worker's position
    c. toxicity of contaminant
    d. rate of evolution of contaminant
    e. all of the above

22. What ventilation is required in a circular duct 1 sq. ft. in area to control a contaminant 5 ft. from the duct where a velocity of 50 fpm is required?

    a. 2,550
    b. 1,255
    c. 12,550
    d. 800

23. For local exhaust ventilation of an electro-plating tank, the preferable type hood is:

    a. slot
    b. canopy
    c. enclosing
    d. down draft

24. Which of the following may be used to measure air velocity (check all which apply).

    a. Kata thermometer
    b. Smoke tube
    c. Vane anemometer
    d. Pitot tube
    e. Thermal precipitator
    f. Inertial settling chamber
    g. Vane axial impeller
    h. Velometer

25. A room has been calculated to require 5 air changes per hour to ventilate it. Which statement best describes the situation?

    a. this is not sufficient since 10 air changes per hour is only considered to be a "fair" ventilation rate
    b. the rate is adequate if only solvents with a TLV of more than 200 ppm are used in the room
    c. the exhaust rate of a 3 sq. ft. fan must be 5000 cfm to accomplish this
    d. the selection of the fan and fan speed are dependent on knowing the dimensions of the room
    e. the room is very large, because such a small ventilation rate is needed

26. Round ducts are better than square ducts because:

    a. can be made air tight easier
    b. uses less material for same size
    c. stronger
    d. less friction

27. The function of a slot in a slot hood is to:

    a. decrease capture velocity
    b. reduce material required to build system
    c. obtain proper air distribution
    d. increase capture velocity

28. In many cases, canopy hoods are not considered very good because:

    a. more material is needed to construct system
    b. larger fans are needed
    c. contaminant is drawn thru the breathing zone
    d. are always considered good

29. Which instrument would be used to measure the flow in a 12" duct?

    a. pitot
    b. venturi meter
    c. rotating vane
    d. smoke tube

30. What type of gauge would be used to measure a small h with a pitot tube?

    a. vertical U tube manometer
    b. inclined manometer
    c. bourdon gauge
    d. barometer

31. A hood with 50' of 8" diameter ducting has the face of the hood blocked. The absolute value of the static pressure will:

    a. increase
    b. decrease
    c. stay the same
    d. double

32. In the system above what happens to total pressure?

    a. increase from negative to positive
    b. decrease from positive to negative
    c. stay the same
    d. none of the above

33. How is pressure normally stated when taken in exhaust ducts?

    a. mm Hg
    b. inches of water
    c. psi
    d. none of the above

34. If a reading of 50 fpm at an exhaust is measured when the original reading was 150 fpm, what is probably the trouble?

    a. fan stopped-system is OK
    b. axial fan running backwards
    c. BHP has been reduced
    d. fan is old and not operating at maximum output

35. A tank is 30" x 48" and sits in a corner. A slot ventilation system is to be placed on the free 4 foot side. How wide must the slot be to assure 50 fpm/$ft^2$ of area exhaust if V = 1000 fpm?

    a. 2.3 inches
    b. 2.0 inches
    c. 1.8 inches
    d. 1.4 inches
    e. 1.5 inches

36. Why use a centrifugal fan instead of an axial flow fan for dusty operations?

    a. erosion
    b. quieter
    c. cheaper
    d. all of the above

37. What type of hood is best for electroplating?

    a. canopy
    b. slot
    c. downdraft
    d. booth

38. Which of the following velocity measuring instruments should not be used at elevated temperatures?

    a. vane anemometer
    b. "S" shaped pitot tube
    c. standard pitot tube
    d. hot wire anemometer

39. A fan is rated in a manufacaturer's catalog as delivering 10,500 $ft^3$/min of air at 3 inches of water fan static pressure when running at 400 revolutions per minute and requiring 6.2 horsepower. If the fan speed is increased to 500 rev/min, determine the volume, static pressure and horsepower, assuming standard conditions.

    a. Q = 14,250 cfm; fsp = 6.2 in. of water; HP = 13.6
    b. Q = 13,125 cfm; fsp = 4.7 in. of water; HP = 12.1
    c. Q = 12,253 cfm; fsp = 4.3 in. of water; HP = 11.6
    d. Q = 11,158 cfm; fsp = 3.7 in. of water; HP = 10.4

40. Toluene is used in a glove box at the rate of 0.5 pt/hr. Assuming the temperature is 70° F, how much air flow is needed to reduce the concentration to 25% of the LEL? (LEL = 1.27%, liquid density = 0.9 g/$cm^3$, mw = 92, TLV = 50 ppm).

    a. 10.3 $ft^3$/min
    b. 15.6 $ft^3$/min
    c. 18.1 $ft^3$/min
    d. 21.6 $ft^3$/min

41. A method frequently used to balance ventilation systems is:

    a. reduce velocity
    b. equal friction
    c. equal velocity
    d. equal pipe sizing

42. The two methods are available to design a system for proper air distribution in an exhaust system are:

    a. balance without blast gates and balance with blast gates
    b. pipe sizing and dampers
    c. modifying static pressure and modifying velocity pressure
    d. correcting cfm and correcting branch of greatest resistance

43. If two branches are entering a main exhaust duct, a difference of _____ inches or greater between the main VP and the resultant VP from the two branches should be corrected.

    a. 0.01 inches
    b. 0.10 inches
    c. 1.0 inches
    d. 10.0 inches

44. The use of the pitot tube in the field is limited at velocities lower than:

    a. 800 - 1000 fpm
    b. 600 - 800 fpm
    c. 100 - 200 fpm
    d. 1000 - 2000 fpm

45. The velocity of air in a duct can be calculated using the velocity pressure which is measured with:

    a. a spirometer
    b. a pitot tube
    c. a thermal anemometer
    d. a dry gas meter
    e. any of the above instruments

46. Dilution ventilation is:

    a. used to control a contaminant at its source
    b. more effective in dust control
    c. satisfactory for controlling vapors having low toxicity which are produced at uniform rates
    d. generally more economical than local exhaust ventilation
    e. to be considered first in control of all hazards

47. Of the following devices a primary standard is the:

    a. velometer
    b. wet test meter
    c. venturi meter
    d. thermal anemometer
    e. spirometer

48. When designing exhaust ventilation one should:

a. add 50% capacity to handle infiltration
b. also insure provision for adequate make-up air
c. maximize the number of bends and turns to reduce pressure losses
d. oversize the fan 50% to achieve more efficient operation
e. not be concerned with the availability of duct sizes

49. In industrial hygiene a "pitot tube traverse" refers to:

a. systematic equal-area velocity measurements to determine flowrates
b. a one point method of establishing the flowrate through a section
c. measurements made on a ventilation system when the fan is inoperative
d. measurements of velocity along the length of the duct
e. random velocity measurement in a cross-section to determine flowrates

50. The velocity area method as used in determining the average flowrate of air for industrial hygiene purposes:

a. is most useful in determining the peak flow velocity
b. gives a good approximation of the true flowrate
c. requires a minimum of 8 equal areas
d. becomes very accurate when the peak velocity is more than twice the average velocity
e. requires that the center-most areas be neglected

51. All the following pieces of equipment except one are used in ventilation studies. The exception is:

a. a pitot tube
b. a thermal anemometer
c. a hygrothermograph
d. a spirometer
e. a psychrometer

52. Which of the following statements concerning dilution (or general) ventilation is <u>not</u> true?

a. it should be used only where the evolution of contaminants is reasonably uniform
b. general ventilation is often used to maintain proper room temperature
c. air movement in dilution system may depend on gravity, the action of the wind, or the use of mechanical supply
d. the effectiveness of the system depends on, among other things, the location of personnel relative to the air stream
e. it can be used to safely control highly toxic material if sufficient dilution volumes are employed

53. Which of the following statements concerning various types of air pressure is not true?

    a. velocity pressure may be a positive or a negative number
    b. static pressure may be a positive or a negative number
    c. static pressure is pressure exerted perpendicularly to the walls of the enclosure
    d. TP = SP + VP

54. Which of the following concerning duct work carrying aerosols is not true?

    a. transport velocity for gases and vapors can vary from 2000 to 4500 fpm; for dust-laden air from 100-2000 fpm
    b. inspecton or clean-out doors should be provided in duct work every 12 feet
    c. support for duct work must take into account the weight of the duct work itself, weight of normal accumulation of materials and the stress of negative air pressure
    d. ducts conveying oil mists should be equipped with traps

55. Blast gates are used to:

    a. generate proper capture velocities within the hood
    b. balance the resistance to air flow in different air ducts
    c. remove toxic contaminants from the air stream
    d. reduce the energy loss in the air flow when velocity pressure is converted to static pressure

56. Smoke tubes may be used to determine:

    a. if ventilation at core-making operations is controlling fumes
    b. to determine if a grinder wheel's exhaust system is working
    c. if air flow from supply systems is disrupting the exhaust system
    d. all of the above
    e. none of the above

57. A pitot tube:

    a. should not be used in an atmosphere containing toxic substances
    b. can be used to determine both static pressure and velocity pressure
    c. contains a filter which may itself be a source of error
    d. relies on the cooling effect of air passing over the probe

58. Which of the following are not characteristics of backward curved blade centrifugal fans?

    a. low noise
    b. low efficiency
    c. smooth operation
    d. particle deposit accumulation on blades
    e. all of the above

59. Which of the following is not characteristic of a centrifugal fan?

    a. high volume - low pressure drop
    b. low space requirement
    c. often used with particle laden air streams
    d. low to medium noise
    e. none of the above

60. What type of centrifugal fan is characterized by medium tip speed and low particle build up on blades?

    a. forward curved blades
    b. backward curved blades
    c. straight blades
    d. any of the above
    e. none of the above

61. Baffles are put on the canopy of a shake out hood because:

    a. channel dust to hopper
    b. prevent plugging of grid
    c. provide better air distribution
    d. all of the above

62. Why would 4000 fpm be maintained in an exhaust duct?

    a. prevent settling
    b. reduce abrasion
    c. minimize noise
    d. minimize energy consumption
    e. minimize leakage

63. What air sampling instrument do you use to measure a turbulent air stream?

    a. pitot tube
    b. thermal anemometer
    c. velometer
    d. rotating vane anemometer

64. Having an R number below 2100 implies what about flow characteristics?

    a. laminar flow
    b. turbulent flow
    c. too fast for dust transport
    d. too slow for dust transport
    e. an energy wasteful design

65. The rule of thumb for determing the average duct velocity from the center point velocity is to multiply the center point velocity by:

    a. 0.9
    b. 1.0
    c. 0.75
    d. no generalization can be made

66. How does cfm vary with rpm?

a. inversely
b. directly
c. square
d. cube

# Answers to Review Questions

1. Calculate heating cost per 1000 cfm/year

$q_{req.} = M\ C_p\ \Delta t_{mean}$

$\Delta t_{mean} = (65 - 35) = 30°\ F$

9 hrs/day x 175 days/yr = 1575 hrs/yr

$C_p = 0.24$ Btu/lb - °F

specific volume = 13 $ft^3$/lb

Cost of coal = \$10.00/ton

$$q_{req} = \left[1000\ ft^3/min \quad \frac{1}{13\ \frac{ft^3}{lb}} \times 60\ min/hr \times 1575\ hrs/yr\right]$$

$$(.24\ Btu/lb\text{-}°F)(30°F) = 52.3 \times 10^6\ Btu/year$$

$$cost/year = \frac{52.3 \times 10^6\ Btu/year \times \$10/ton}{24 \times 10^6\ Btu/ton \times 0.55\ eff} \qquad \$39.60/year$$

2. Exhaust 1000 cfm through round, freely suspended 6" duct

Find velocity at 6" and 12" from duct opening along centerline

$$V = \frac{Q}{10x^2 + A} \qquad Q = 1000\ cfm,\quad A = 0.1964\ ft^2$$

At 6": $V = \dfrac{1000}{10(1/2)^2 + 0.1964} \quad \dfrac{1000}{2.6964} = 372$ ft/min

At 12": $V = \dfrac{1000}{10(1)^2 + 0.1964} \quad \dfrac{1000}{10.1964} = 98.2$ ft/min (Ref. 1, p. 601.)

3. Freely suspended hood 2" wide - 72" long

Q = 500 cfm
Find velocity 12" from opening - flanged and unflanged

Flanged: $V = \dfrac{Q}{2.8xL} = \dfrac{500}{(2.8)(1)(6)} = 29.8$ ft/min

Unflanged: $V = \dfrac{Q}{3.7xL} = \dfrac{500}{(3.7)(1)(6)} = 22.5$ ft/min (Ref. 1, p. 602.)

4. Velocity pressures for:

1266 ft/min $h = \left[\frac{V}{4005}\right]^2 = 0.1"\ H_2O$

4005 ft/min $h = 1"H_2O$

5664 ft/min $h = 2"H_2O$ (Ref. 1, p. 616.)

5. Assume a standard traverse with measurements at centers of annuli of equal areas. This can be verified using data in Fig. 40-7, Ref 1, or Tab. 9-1, Ref. 2. Given: Ten Point-Pitot Traverse in 12" circular duct (70°F)(1 atm)

| Vertical | | Horizontal | |
|---|---|---|---|
| h | V=4005$\sqrt{h}$ | h | V=4005$\sqrt{h}$ |
| 0.11 | 1328 | 0.16 | 1602 |
| 0.12 | 1387 | 0.18 | 1699 |
| 0.18 | 1699 | 0.23 | 1921 |
| 0.28 | 2119 | 0.29 | 2157 |
| 0.36 | 2403 | 0.35 | 2369 |
| 0.35 | 2369 | 0.35 | 2369 |
| 0.29 | 2157 | 0.26 | 2042 |
| 0.22 | 1879 | 0.20 | 1791 |
| 0.17 | 1651 | 0.15 | 1551 |
| 0.15 | 1551 | 0.12 | 1387 |
| | 18543 | | 18888 |

18543 + 18888 = 37431

average velocity = $\frac{37431}{20}$ = 1872 ft/min

a. $Q = VA = 1872 \left(\frac{\pi}{4}\right)(1)^2$

Q = 1470 cfm (Ref. 1, p. 589-592.)

b. Throat suction at inlet = $0.44"H_2O$

Find $C_e$ $V = 4005\ C_e\sqrt{h}$

$C_e = \frac{1872}{4005\sqrt{0.44}} = \frac{1872}{2660} = 0.70$

$C_e = 0.70$ (Ref. 1, p. 603.)

c. Later throat suction reading = 0.28"

Find $Q_2$ $Q_2 = 4005\ C_e \sqrt{0.28} \left(\frac{\pi}{4}\right)$

$Q_2 = 4005\ (0.70)(0.53)\left(\frac{\pi}{4}\right)$

Q = 1165 cfm (Ref. 1, p. 592.)

6. c correct. $Q = 4005\ Ce\ A \sqrt{SP_h}$

$800 = 4005(0.65)(.2)\sqrt{SP_h}$

$\sqrt{SP_h} = \frac{800}{(4000)(.65)(.2)} = 1.54$

$SP_h = 2.37$ Since air is being drawn thru the duct, static pressure is negative. (Ref. 1, p. 592.)

7. d correct. Assuming the friction factor remains constant, the total pressure loss is a constant multiple of the velocity pressure (this is a good first order approximation, actually the friction factor decreases with increasing velocity). Since VP increases with $Q^2$ the total loss will increase by a factor of 4. (Ref. 2, p. 6-31, footnote.)

8. d correct. The difference in pressure is 4.45 - 3.75 = .70

0.7/3.75 = 18.7%

When the error is less than 20% adjustment is usually made by increasing volume through the line with the lowest resistance.

Corrected cfm = Design flow $\sqrt{\frac{\text{SP of run with higher loss}}{\text{SP of run with lower loss}}}$ = 3250 $\sqrt{\frac{4.45}{3.75}}$ = 3530

(Ref. 2, p. 6-5.)

9. e correct. Changing brands and models renders direct application of fan law inappropriate since other things are different.

10. c correct.

11. b correct. (Ref. 1, p. 597; Ref. 2, p. 4-14.)

12. Q = 0.75 V($10x^2$ + A) where x - distance from hood

$$Q = 0.75 \left(150 \frac{ft}{min}\right) \left[(10)\left(\frac{15}{12}\right)ft^2 + (5 \times 3)\ ft^2\right] = 3445 \text{ cfm}$$

A = flexible duct cross-sectional area

$$A = \frac{Q}{V} = \frac{3445}{3000} = 1.15\ ft^2$$

$$A = \frac{D^2}{4}$$

$$\text{Flexible duct Diameter} = D = \sqrt{\frac{4A}{\pi}} = \sqrt{\frac{(4)(1.15)}{3.14}} = 1.21 \text{ ft} = 14\ 1/2 \text{ in.}$$

(Ref. 1, p. 601.)

13. b correct.

Q = WLV or (2W + L) H 50 whichever is greater
W = hood width, ft
L = hood length, ft
H = height of hood above range, ft
V = capture velocity ft/min
(minimum 6 in. overhang required)

$Q_1$ = (4)(10)(50) = 2000 $ft^3$/min
$Q_2$ = (8 + 12)(4)(50) = 4000 $ft^3$/min

4000 $ft^3$/min are required (Ref. 2, p. 5-108.)

14. b correct. Since air is being drawn thru the duct, the total pressure is negative, static pressure is negative and velocity pressure is positive.

Total pressure = velocity pressure + static pressure

Total pressure = + 2.0 + (-3 1/2) = - 1 1/2 inches (Ref. 2, p. 1-2.)

15. d correct. (Ref. 1, p. 613.)

16. d correct. (Ref. 1, p. 586.)

17. c correct. $Q = AV = 2000\ ft^3/min = (100)(V)$

$$V = \frac{2000\ ft^3/min}{100\ ft^2} = 20\ ft/min$$ (Ref. 1, p. 535.)

18. a correct. $3600\ \frac{rev}{min} \times \frac{1}{60}\ \frac{min}{sec} = 60\ \frac{rev}{sec}$

$$60\ \frac{rev}{sec} \times 60\ \frac{blades}{rev} = 3600\ \frac{blades}{sec}$$

since 1 blade pass creates a pressure wave, the frequency is 3600 Hz.

19. b correct. $\frac{V_1}{T_1} = \frac{V_2}{T_1}$ where V = volume in cfm

Temperatures in degrees absolute, °R = 460 + °F

$V_2$ = (100 cfm/enclosure x 10 enclosures) x $\frac{600 + 460}{70 + 460}$ =

2000 cfm
@ 600°F

20. b correct. For given conditions:

$Q = VA = 4000 \times VP \times A = 4000 \times C_e \times SP_h \times A$

Q = hood volumetric flow rate, $ft^3/min$
A = hood area, $ft^2$
$C_e$ = coefficient of entry
$SP_h$ = static pressure, hood
v = velocity
VP = velocity pressure
$Q = (4000)(0.78)(1.69)(0.5)^2 \left(\frac{\pi}{4}\right) = 796$ cfm

(Ref. 1. p. 601, 603.)

21. e correct. (Ref. 1, p. 573.)

22. c correct. $Q = V\ (10x^2 + A)$

$= 50\ (10(5)^2 + 1) = 12{,}550$ cfm (Ref. 1, p. 601.)

23. a correct. (Ref. 2, p. 5-62.)

24. all except e and f. A thermal precipitator is an aerosol particle collection device. Inertial settling chambers are also particle collectors. The Kata thermometer is an obsolete device with which one measures air velocity by determining the rate of cooling. Answer "g" is a fan impeller blade such as used in a rotating vane anemometer (Ref. 1, p. 586-589.)

25. d correct. In order to size the fan one needs to know how much air it must move. Therefore the room size must be known. In addition, the air flow path must be defined to determine the pressure that the fan must develop.

26. c correct. While all of the answers are true, ventilation systems are normally fabricated with ducts of rectangular crossection because of the need to fit them into rectangular spaces. However, in industrial systems transporting dusts, relatively high velocities are used. Consequently static pressures are greater and duct collapse is sometimes a problem. This is minimized by selecting circular ducts which have greater strength. (Ref. 2, p. 6-13.)

27. c correct. The capture velocity of a slot is essentially independent of its slot air velocity ($V_{capture} = Q/(2.8 \times L)$). High slot velocities simply add more pressure loss. The slot and its plenum are sized to assure that the pressure drop through the slot is large compared to that through the plenum. If this is not true, too much air flows through the portion of the slot closest to the air mover. (Ref. 1, p. 602; Ref. 2, p. 4-8.)

28. c correct. (Ref. 1, p. 604.)

29. a correct. (Ref. 1, p. 589.)

30. b correct. (Ref. 1, p. 589.)

31. a correct. Assume a suction hood with the 50 feet of duct between the hood and the fan. In closing of the duct, most of the velocity pressure is converted to static pressure. Therefore the static pressure increases. (On the suction size, as in this problem, this means more negative.) Fan performance curves will support this occurrence. (Ref. 1, p. 576.)

32. d correct. Decreasing the velocity decreases the energy loss due to turbulence. The change in static pressure equals the change in velocity pressure plus the change (reduction) in turbulent energy loss. On the suction side of a fan the total pressure is always negative. (Ref. 1, p. 576.)

33. b correct. (Ref. 1, p. 589.)

34. a correct. A drop in velocity to 1/3 the original value implies a drop in input power to 1/9 the original value. Thus, almost all power has been lost. Since velocities of 50 fpm can occur by natural draft alone, it is likely that all power has, in fact, been lost. Running an axial fan backwards would reverse the flow (running a centrifugal fan backwards would decrease the flow). A decrease of this magnitude by age alone is unlikely.

35. e correct.

$$Q = AV$$

$$Q_{slot} = Q_{surface}$$

$A_{slot}\ V_{slot} = A_{surface}\ V_{surface}$

$$A_{slot} = \frac{\frac{30}{12}\text{ft} \times \frac{48}{12}\text{12}\ (50\ \text{fpm})}{1000\ \frac{\text{ft}}{\text{min}}} = 0.5\ \text{ft}^2$$

$A_{slot} = W \times L$

$W = 0.5\ \text{ft}^2 / 4\text{ft} = 0.125\ \text{ft} = 1.5\ \text{in.}$

36. d correct. (Ref. 1, p. 582, 621-623.)

37. b correct. (Ref. 2, p. 5-62 to 65.)

38. d correct. General temperature limit of hot wire anemometers is 250°F. (Ref. 1, p. 588.)

39. b correct.

Flow varies directly with speed
Pressure varies with speed squared
Power required varies with speed cubed

New Flow $= 10{,}500 \times \frac{500}{400} = 13{,}125$ cfm

New Pressure $= 3.0 \times \left(\frac{500}{400}\right)^2 = 4.7$ in $H_2O$

New Power $= 6.2 \times \left(\frac{500}{400}\right)^3 = 12.1$ Hp (Ref. 1, p. 622.)

40. a correct.

Toluene evaporation rate =

$$\frac{0.5\ \frac{\text{pt}}{\text{hr}} \times 3.8\ \frac{1}{\text{gal}} \times 0.9\ \frac{\text{g}}{\text{cm}^3} \times 1000\ \frac{\text{cm}^3}{1} \times 24.13\ \frac{1}{\text{g mole}}}{60\ \frac{\text{min}}{\text{hr}} \times 8\ \frac{\text{pt}}{\text{gal}} \times 28.3\ \frac{1}{\text{ft}^3} \times 92\ \frac{\text{g}}{\text{g mole}}}$$

$= 0.066\ \frac{\text{ft}^3}{\text{min}}$

$$\text{Total air req} = \frac{\text{toluene evap. rate}}{\text{toluene concentration}}$$

$$= \frac{0.066\ \frac{\text{ft}^3\ \text{toluene}}{\text{min}}}{0.0127\ \frac{\text{ft}^3\ \text{toluene}}{\text{ft}^3\ \text{air}} \times 0.25}$$

(LEL) (Fract. LEL permitted)

= 10.4 $ft^3/min$ (Ref. 1, p. 580-581.)

41. b correct. (Ref. 1, p. 6-4.)

42. a correct. (Ref. 1, p. 615; Ref. 2, p. 6-4.)

43. b correct. This applies to "the balance with blast gate" design method. It refers to a point in the balancing calculation at which the velocities of two branches and trunk at a juncture have been computed and the trunk down stream of the junction requires a velocity greater than that resulting from mixing of the streams. A correction is made by increasing the static pressure in the main down stream duct and proceeding with the calculation. (Ref. 2, p. 6-10.)

44. b correct. (Ref. 1, p. 590.)

45. b correct. (Ref. 1, p. 589-590.)

46. c correct. (Ref. 1, p. 573.)

47. e correct. (Ref. 1, p. 105.)

48. b correct. (Ref. 1, p. 623.)

49. a correct. (Ref. 1, p. 589-591.)

50. b correct. (Ref. 1, p. 590; Ref. 1, p. 9-1, 2.)

51. d correct. The spirometer is used to calibrate air sampling instruments. (Ref. 1, p. 105, 414-418, 586-590.)

52. e correct. (Ref. 1, p. 573-4.)

53. a correct. Velocity pressure is a measure of the kinetic energy in the system and hence must always be positive. (Ref. 1, p. 570.)

54. a correct. Dust laden air should be transported at 3500 - 4000 fpm. (Ref. 1, p. 603.)

55. b correct. (Ref. 1, p. 615.)

56. d correct. (Ref. 1, p. 584-586.)

57. b correct. (Ref. 1, p. 589.)

58. b correct. Backward curved blades are the most efficient of common available types. (Ref. 2, p. 10-1.)

59. a correct. "a" is the most noticeable characteristic of axial flow fans. (Ref. 2, p. 10-1.)

60. c correct. (Ref. 2, p. 10-1.)

61. c correct. "Shake-out" refers to shaking sand from metal molds in foundries.

62. a correct. A velocity this high would normally be used only if dust transport were involved. (Ref. 1, p. 603.)

63. a correct. Assuming the airstream is in a duct the pitot tube is the instrument of choice. A thermal anemometer may be a problem in turbulent streams because its reading does not provide a good indication of direction, therefore an artificially high velocity might be indicated in a turbulent eddy. (Ref. 1, p. 585-589; Ref. 1, p. 9-12 to 9-15.)

64. a correct. Reynolds' Number is a dimensionless ratio characterizing the flow of any fluid. It is the product of stream diameter, density, and velocity divided by viscosity. For values below 2100 flow is always laminar, that is, smooth and steady. For values of 2100 and 4000 flow becomes turbulent. Ventilation streams are essentially always turbulent. (Ref. 1, p. 575.)

65. a correct. (Ref. 1, p. 592.)

66. b correct. (Ref. 1, p. 622.)

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# Chapter 15: ERGONOMICS

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I. Definitions
- A. Ergonomics
- B. Biomechanics
- C. Biotechnology
- D. Engineering anthropometry
- E. Stress, strain
- F. Tolerance

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  D. Strength/endurance

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  B. Gravitational components
  C. Inertial forces
  D. Task frequency
  E. Handle design

VII. Handtool evaluaton
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- C. Ganglion formation
- D. Tennis elbow
- E. Raynaud's syndrome
- F. "Trigger" finger

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## Review Questions

1. Ergonomics is:

   a. the study of energy.
   b. the field devoted to minimizing damage caused by high energy ionizing radiation.
   c. not a subject related to industrial hygiene.
   d. the study of man's interactions with his work environment.

2. In the broad sense of the word, ergonomics is:

   a. a subset of industrial hygiene.
   b. a subject which includes industrial hygiene as a subset.
   c. a subject related to industrial hygiene in a parallel sense.
   d. unrelated to industrial hygiene.

3. Any action of an external vector (physiological or psychological) upon the human body can be classified as:

   a. work stress
   b. work strain
   c. ergonomic syndrome
   d. none of the above

4. Carpal tunnel syndrome occurs more frequently in:

   a. men
   b. women
   c. approximate equal distribution

5. The most sensitive and accurate method of physiologically measuring work is:

   a. heart rate
   b. oxygen consumption
   c. respiratory minute ventilation
   d. none of the above

6. In an automated man-machine system, man acts as:

   a. a power source and controller
   b. a controller
   c. a power source
   d. a monitor

7. The most important sensory input for human decision making is:

   a. visual
   b. auditory
   c. vibratory
   d. olfactory

8. If machines are designed for efficiency, human comfort will automatically follow:

   a. true
   b. false

9. The most common underlying cause of ergonomically-related orthopedic problems is:

   a. overextension of a joint
   b. severe flexion of tendons and ligaments
   c. repetition of awkward or unnatural movements
   d. mechanical trauma (soft tissue injury) occuring at the man-machine interface

10. Which of the following ergonomically-related orthopedic problems leads to the greatest morbidity and cost?

    a. carpal tunnel syndrome
    b. low back syndrome
    c. ganglion formation
    d. "trigger" finger

11. In the optimal man-machine interface, the amount of sensory input should be maximized.

    a. true
    b. false

12. In general, personal protective equipment tends to increase worker efficiency and decrease personnel injury.

    a. true
    b. false

13. The most important aspect(s) in the historical evaluation of ergonomically-induced inefficiency in a particular operation is (are):

    a. cause
    b. consequence
    c. cure
    d. cost
    e. a and b only
    f. all of the above

14. A technique concerned with the measurement of the force-time relationship of strength of joint movement is:

    a. myography
    b. dynamometry
    c. anthropometry
    d. none of the above

## Answers to Review Questions

1. d correct. Ergonomics - "A multidisciplinary activity dealing with the interactions between man and his total working environment plus such traditional environmental elements as atmosphere, heat, light and sound as well as tools and equipment of the workplace. (Ref 1, p. 489)

2. c correct. Compare ergonomics (see question 1) with industrial hygiene - "the science of protecting man's health through control of the workplace." (Ref 3, p. 1) Ergonomics does not normally include the problem of day to day environmental surveillance that is essential to industrial hygiene and hence is best seen as a parallel field.

3. a correct. The statement is the classic definition of work stress. Work strain is the physiological response of the body to stress. Ergonomic syndrome may be a general definition of a variety of physiological strains. (Ref 1, p. 447)

4. b correct. Statistics indicate that women are more susceptible to carpal tunnel syndrome than men. The carpal tunnel is a channel in the wrist through which nerves, vessels, and tendons pass to the hand. Specific pressures on the tunnel and adjacent areas, normally due to improperly fitting working gloves, precipitates those physical manifestations labeled carpal tunnel syndrome. (Ref 1, p. 458)

5. b correct. Indirect calorimetry based on oxygen uptake is an extremely accurate method of measuring work output. This procedure can be more effectively equated to parameters such as body weight than can heart or ventilation rates. (Ref 1, p. 400)

6. d correct. Man acts as a monitor in the automated man-machine system, such as monitoring a digital computer. Man acts as the power source and controller in non-automated systems such as a carpenter employing a saw. Man acts soley as a controller in mechanical systems such as an automobile.

7. a correct. Visual input is the most important physiological entity for decision making. Eye-hand coordination is basic for successful completion of most workplace operations. Standards for visual and head movement criteria are outlined in basic ergonomic analyses. (Ref 1, p. 450)

8. b correct. Frequently, workplace and equipment design based on established industrial engineering principles to increase efficiency and simplicity are conducive to generating physiological problems for the worker. (Ref 1, p. 439)

9. c correct. In any workplace, repetition of movements beyond those considered mechanically advantageous in terms of body lever systems coupled with stressing muscles too small to continually handle a particular repetitive task will yield a significant number of orthopedic problems in workers. (Ref. 1, p. 439)

10. b correct. Statistics indicate that low back syndrome is responsible for more lost time than any other ergonomically-related problem. Approximately one third of all disabling injuries are due to manual handling of objects, and a large share of just this particular statistic manifests itself as low back injury.

11. b correct. Equipment and process design is currently oriented toward minimizing total sensory input by the worker. More automated systems are being adapted to previously man-controlled operations. Even in simple systems, qualitative displays are replacing quantitative displays to decrease sensory input, as is demonstrated by red warning lights replacing oil guages in automobiles.

12. b correct. The statement is only partially true in that personal protective equipment will normally decrease injury of personnel. However, worker efficiency is usually decreased since most protective equipment will hinder sensory input and themselves be an additional burden to the worker. Examples are air-supplied respirators or bulky work gloves.

13. f correct. A historical evaluation of an industrial practice which is experiencing an obvious breakdown in associated safety and health aspects encompasses all four listed criteria. In most cases, the consequences of the problem and resulting costs are known. Professional analyses must focus in on the cause of the problem and develop an effective cure. (Ref 1, p. 472)

14. b correct. Myography is a technique employed to make a projective prediction of potential overexertion of a single kinetic element or of reduced work tolerance through muscular input-biomechanical output measurement. Anthropometry is the general discipline concerned with the body measurements of man as they relate to the maintenance of occupational health, safety, and efficiency. (Ref 1, p. 439, 474)

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Chapter 16: HEALTH PHYSICS

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I. Radiation Physics
   A. Atomic
      1. structure and structural notation
      2. stability of nuclei
      3. modes of decay
      4. radiation and radioactivity
      5. half life and decay mathematics
   B. Electromagnetic radiation (gamma and x-rays)
   C. Particulate radiation (alpha, beta and neutrons)
   D. Activity
   E. Interactions with matter
      1. photoelectronic effect
      2. compton interaction
      3. pair production
      4. electron interactions
      5. bremsstrahlung
      6. photo-like particle interactions
   F. Important units
      1. curie, Becquerel
      2. roentgen
      3. rad, Gray
      4. rem, Sievert

II. Biological Effects
   A. Relative biological effectiveness (RBE), Quality factor
   B. Acute radiation syndrome
   C. Carcinogenesis
   D. Teratogenesis
   E. Mutagenesis
   F. Dose-response relationships
   G. Natural, medical and occupational dose levels
   H. Quantification of risks

III. Exposure Sources
   A. Natural
      1. internal
      2. external
   B. Medical
   C. Occupational
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      2. research
      3. industrial
      4. power production
   D. Anthropogenic (man originated) exposures to general population

IV. Occupational Dose Control
   A. Time Restrictions
   B. Distance restrictions
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      2. atmospheric absorption

C. Shielding
    1. different effects on different types of radiation
    2. half-value thickness
    3. bremsstrahlung
D. Radiation protection standards
    1. rationale
    2. ALARA
    3. limitations
    4. occupational vs. public
    5. special populations

V. Measurement
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    2. types
    3. advantages, disadvantages
B. Source and area surveys
    1. methods
    2. requirements
    3. instrumentation

VI. Important Regulatory Agencies
A. Nuclear Regulatory Commission
B. Bureau of Radiological Health
C. Environmental Protection Agency
D. Occupational Safety and Health Administration
E. Department of Transportation

## Review Questions

1. Sealed sources should be tested for leakage at least:

   a. weekly
   b. monthly
   c. quarterly
   d. annually
   e. none of the above

2. In the most often encountered situations, the survey meter of choice for x-rays is (45 second exposure)?

   a. GM
   b. ion chamber
   c. scintillation counter
   d. gas proportional counter
   e. power density meter

3. What dosimeter(s) would be used most often for monitoring weekly exposure to x-ray?

   a. film badge
   b. pencil dosimeter (pocket chamber)
   c. thermoluminescent dosimeter
   d. any of the above
   e. a and c above

4. Plutonium, when taken into the circulatory system, will deposit in what areas of the body?

   a. bone
   b. liver
   c. kidney
   d. thyroid
   e. none of the above

5. A low energy alpha detector is usually effective if detector is _____ distance from source?

   a. 1/4"
   b. 1/2"
   c. 1 1/2"
   d. 1"
   e. all of the above

6. The very thin windowed Geiger Mueller detector can detect which of the following radiations?

   a. alpha
   b. beta
   c. gamma
   d. gamma/beta
   e. alpha/beta
   f. alpha, beta, gamma

7. Which instrument is most suitable for detecting ionizing radiation in a microwave environment:

   a. Geiger Mueller
   b. Ion Chamber
   c. Victoreen 440 RF
   d. Wet Test Meter
   e. none of the above

8. In equipment using high voltage ($\geq$ 15 kV), which problem is most likely to arise:

   a. high frequency noise
   b. laser dopler effect
   c. x-rays
   d. none of the above
   e. all of the above

9. The curie is defined as _____ disintegrations/second.

   a. $2.2 \times 10^6$
   b. $2.2 \times 10^{12}$
   c. $3.7 \times 10^6$
   d. $3.7 \times 10^{10}$

10. A typical nuclear U.S. power reactor gets its energy from which nuclear reaction?

    a. fission
    b. fusion
    c. alpha
    d. gamma

11. A sample of radioactive material is reported to contain 2000 picocuries of activity. Express this value as disintegrations per minute.

    a. 370 dpm
    b. 900 dpm
    c. 4440 dpm
    d. 3700 dpm

12. Gamma radiation produces ionization by:

    a. photoelectric effect, Compton effect and bremsstrahlung
    b. bremsstrahlung, proton recoil, and pair production
    c. excitation, photoelectric effect, and pair production
    d. photoelectric effect, Compton effect, and pair production
    e. bremsstrahlung, Compton effect, and excitation

13. The roentgen is a unit used to express:

    a. the energy deposited in a unit weight of any material
    b. the ionization in air due to all radiation types
    c. the biological effectiveness of gamma radiation
    d. the ionization in air due to gamma radiation

14. Which instrument would you use to locate a lost, small radium source?

    a. cutie pie
    b. condenser R meter
    c. roentgen rate meter
    d. Geiger-Mueller meter
    e. scintillation detector

15. In looking for radionuclides using a high volume filter sample, you should count the sample at the end of 4 hours and again at the end of one day because:

    a. of carbon 14 present in the atmosphere
    b. of strontium 90 present in the atmosphere
    c. radon and/or thorium daughters in air
    d. absorption changes in filter
    e. instability of counting system

16. The radon daughters inhaled during uranium mining are normally deposited in what part of the human body?

    a. bone
    b. kidneys
    c. liver
    d. lungs
    e. none of the above

17. Given a reading of 100 mr/hr, gamma, at 10 feet, what would be the reading at 2 feet assuming a point source geometry?

    a. 6400 mr/hr
    b. 2500 mr/hr
    c. 5000 mr/hr
    d. 3000 mr/hr

18. A "High Radiation" area is defined as:

    a. an area in which an individual could receive a dose to a major portion of the body of 100 or more millirem in one hour
    b. an area in which an individual could receive a dose to a major portion of the body of 10 or more millirem in one hour
    c. an area in which an individual could receive a dose to a major portion of the body of 1000 millirem or more in one hour

19. What type of radiation is the greatest internal hazard?

    a. alpha
    b. beta
    c. gamma

20. What type of radiation is the greatest external hazard?

    a. alpha
    b. beta
    c. gamma

21. Which radionuclide in soil is the most important contributor to genetically significant radiation exposure?

    a. $C^{14}$
    b. $H^{3}$
    c. $Ra^{226}$
    d. $K^{40}$

22. Which biological test is best for determining tritium burden?

    a. blood
    b. urine
    c. sputum

23. Isotopes are defined as:

    a. nuclides with same number of protons but different number of neutrons
    b. nuclides with same number of neutrons but different number of protons
    c. nuclides with same number of protons and neutrons
    d. none of the above

24. Given 400 mr at 5 feet, at what distance would 2 mr be measured?

    a. 14.4 ft
    b. 70.7 ft
    c. 30.3 ft
    d. 60.6 ft

25. Which instruments would best be used to survey for P-32?

    a. GM survey meter
    b. ionization survey meter
    c. liquid scintillation spectrometer
    d. thermoluminescent dosimeter

26. The knowledge of risks of radiation protection upon which exposure standards are based is gained from:

    a. persons exposed to nuclear weapons
    b. medical radiation exposures
    c. accidental radiation exposures
    d. animal experiments
    e. all of the above

27. What is the detection method choice for short x-ray exposure times (< 1 sec)?

    a. ionization rate meter
    b. Geiger survey meter
    c. ionization chamber

28. Given 400 mr/hr at 5 feet, where would a "High Radiation" area begin?

    a. 5'
    b. 10'
    c. 15'
    d. 20'

29. What is the special unit used to express activity of radioactive materials?

    a. microrad
    b. curie
    c. gamma
    d. dose

30. What is the most common ionizing radiation hazard associated with anti-static bars?

    a. alpha
    b. beta
    c. gamma
    d. all of the above

31. Air concentrations for radioisotope standards are set by what method?

    a. non-threshold theory for critical organs
    b. threshold theory for critical organs
    c. human radiological exposure experiments
    d. all of the above

32. The annual, whole-body occupational radiation exposure limit for a worker with no knowledge of previous exposure is:

    a. 3
    b. 4
    c. 5
    d. 12

33. Which of the following is the preferred method for reducing internal radiation hazards?

    a. distance limits
    b. engineered protection systems
    c. exposure time limits
    d. housekeeping
    e. procedural controls

34. Which of the following should be used in evaluating the severity of an internal radiation hazard?

a. type of radiation emitted
b. amount of radionuclide in the body
c. energy of the radiation emitted
d. effective half-life of the radionuclide
e. all of the above

35. Shielding against beta radiation becomes complicated because:

a. sudden deceleration of betas may produce more penetrating rays
b. beta radiations cannot usually be completely absorbed
c. beta particles are scattered by shields
d. deceleration of beta particles produces neutrons
e. the continuous beta energy spectrum creates neutrons

36. The roentgen:

a. is the special unit of exposure
b. applies only to "X" or gamma radiation
c. is defined in terms of air effects
d. can be conveniently measured
e. all of the above

37. The fundamental principle upon which gas filled radiation detection instruments operate is:

a. photomultiplication
b. recombination
c. ionization
d. amplification
e. excitation

38. Match the following:

| | | |
|---|---|---|
| a. _____ | Expression of the rate of radioactive decay | a. RBE |
| b. _____ | Unit of quantity of radioactive material | b. Rad |
| c. _____ | Unit of dose equivalent | c. Compton |
| d. _____ | Unit of absorbed dose | d. half-life |
| e. _____ | Unit of radiation exposure | e. rem |
| f. _____ | A high speed electron from nuclear decay | f. Curie |
| g. _____ | Consists of two protons and two neutrons | g. Roentgen |
| h. _____ | Very penetrating non-particulate radiation | h. beta |
| i. _____ | A particle of zero charge & unit mass | i. alpha |

| | | |
|---|---|---|
| j. _____ | A nuclear breakup with energy release | j. gamma |
| k. _____ | Combination of two light nuclei with energy release | k. fission |
| l. _____ | Result of high speed electrons striking a target | l. fusion |
| m. _____ | The three interactions of gamma rays with matter | m. x-ray |
| | | n. pair production |
| | | o. photo electric |
| | | p. proton |
| | | q. neutron |
| | | r. counts/min |
| | | s. GM counter |

39. The bacquerel is a measure of _____?

a. the rate of disintegration of a radioisotope
b. the ionizing power of a radioisotope
c. the quantity of a radioisotope
d. the specific activity of a radioisotope

40. If the HVL of Pb for Cobolt-60 gamma radiation is 11 mm, the thickness of Pb that would reduce a narrow beam of Cobolt-60 gammas to 1/32 its original value is _____:

a. 352 mm
b. 0.34 mm
c. 2.91 mm
d. 55 mm

41. The quality factor, QF, _____:

a. when multiplied by roentgens gives rems
b. relates curies to roentgens
c. is used to calculate the dose equivalent
d. is used by a health physics inspector to rate the radiation protection program of a licensee

42. The regulatory authority for basic radiation safety for occupational exposure in the U.S. is the responsibility of _____.

a. Bureau of Radiological Health, FDA
b. Environmental Protection Agency
c. Nuclear Regulatory Commission
d. Each state
e. All of the above

43. A survey meter reads 10 mR/hr when exposed in an x-ray field for a period of time equal to the instrument's time constant. If the meter had been held in the x-ray field 5 times as long as the time constant, the meter reading would be about _____ mR/hr.

a. 50
b. 15
c. 10
d. 250

44. When shielding against electrons, we must consider _____.

a. bremsstrahlung
b. ion pair production
c. annihilation radiation
d. neutrinos

45. A proportional counter differs from a Geiger counter in _____.

a. its ability to distinguish between alpha and beta radiation
b. its ability to detect alpha and beta radiation
c. the geometrical relationship between the cathode and the anode

46. The erg is a measure of _____.

a. energy
b. potential
c. force
d. charge

47. The electron volt is a measure of _____.

a. energy
b. voltage
c. electronic state
d. electronic charge

## Answers to Review Questions

1. e correct. Semiannually (10 CFR 34.25 (b)).

2. b correct. GM instruments may grossly overrespond to x-ray while scintillation counters are unnecessarily expensive for routine field use. Gas proportional counters are usually used for alpha and beta radiation and power density meters for microwave. One must remember, however, that special x-ray situations may require other instruments.

3. e correct. (Ref. 1, p. 392.)

4. a correct. Insoluble plutonium particles deposit in the lung and do not reach the circulatory system; soluble plutonium deposits primarily in the bone. (Ref. 2, p. 208.)

5. a correct. "Low energy" alpha particles would have a range in air of the order of one-half inch. Therefore one must be closer than this to detect them or there would be no energy left to penetrate the window and interact in the detector. (Ref. 1, p. 382-284.)

6. f correct. (Ref. 1, p. 385-6.)

7. c correct. The "RF" signifies suitability for use in "Radio Frequency" (microwave) environments.

8. c correct. (Ref. 3, p. 450.)

9. d correct. The SI unit intended to replace the curie is the bacquerel, 1 disintegration per second. (Ref. 1, p. 378.)

10. a correct. (Ref. 1, p. 395.)

11. c corect. (see question 9.)

    $$\text{disintegration per minute} = \text{dpm} = 2000\ \text{pCi} \times 10^{-12}\ \frac{\text{ci}}{\text{pci}} \times 3.7 \times 10^{10}\ \frac{\text{dps}}{\text{Ci}} \times 60\ \frac{\text{s}}{\text{min}} = 4440\ \text{dpm}$$

12. d correct. (Ref. 1, p. 380.)

13. d correct. (Ref. 1, p. 378-9.)

14. e correct. The source would be giving off gamma radiation of moderate energy. Therefore a common Geiger-Mueller instrument would be suitable, however, a scintillation counter would be more sensitive. (Ref. 1, p. 386; Ref. 2, p. 83.)

15. c correct.

16. d correct. The most important radon daughters are radionuclides of Bi, Po and Pb. They are deposited in the lung where they may lead to lung cancer.

17. b correct. Direct application of inverse square law:

$$\frac{r_2}{r_1} = \left(\frac{d_1}{d_2}\right)^2$$

$$r_2 = (100)\left(\frac{10}{2}\right)^2 = 2500 \frac{mr}{hr}$$

18. a correct. (Ref. 10, CFR 20.202(b)(2); Ref. 3, p. 483.)

19. a correct. Alpha radiation, because of its particular nature, cannot penetrate the skin and therefore is only hazardous if taken into the body by ingestion or respiration, through a break in the skin, or absorption. Once inside the body, however, alpha emitters present a great danger because of high linear energy transfer. This is shown in the high Quality Factor for alpha radiation (20 vs. 1 for beta and gamma). (Ref. 1, p. 388-390.)

20. c correct. Gamma, because of its ability to penetrate the skin (see question 20).

21. d correct. (Ref. 4.)

22. b correct. (Ref. 3, p. 462.)

23. a correct. (Ref. 1, p. 379.)

24. b correct. Inverse square law, (see question 18.)

$$d_2 = d_1\sqrt{\frac{r_1}{r_2}} = 5\sqrt{\frac{400}{2}} = 5\sqrt{200} = 70.7 \text{ ft}$$

25. a correct. P-32 is a relatively high energy beta emitter. Therefore, any instrument with a "beta window" could be used for surveying. Ionization chambers are not good beta detectors, liquid scintillation spectrometers are too expensive and cumbersome for field work, and a dosimeter would never be used for survey work (Ref. 3, p. 464-469.)

26. e correct.

27. c correct. Only an ionization chamber of those offered has the ability to integrate the exposure and store the result for later readout. (Ref. 3, p. 468.)

28. b correct. High radiation area sign must be posted at the 100 mr/hr point. Inverse square law application.

$$d_2 = d_1\sqrt{\frac{r_1}{r_2}} = 5\sqrt{\frac{400}{100}} = 10 \text{ ft}$$ (Ref. 3, p. 483.)

29. b correct. (Ref. 1, p. 378.)

30. a correct. (Ref. 3, p. 450.)

31. a correct. (Ref. 3, p. 451-453.)

32. c correct. (Ref. 3, p. 475.)

33. c correct. For radiation protection, as well as for all industrial hygiene exposure control objectives, engineering solutions are preferred.

34. e correct. (Ref. 1, p. 388; Ref. 2, p. 458-50.)

35. a correct. Rapid deceleration of beta particles by high molecular weight materials gives rise to emission of bremsstrahlung radiation. This may present a significant ionizing radiation hazard. (Ref. 3, p. 446.)

36. e correct. (Ref. 1, p. 378.)

37. c correct. (Ref. 3, p. 468-9.)

38.

| | | | |
|---|---|---|---|
| a. | d | g. | i |
| b. | f | h. | j,m |
| c. | e | i. | q |
| d. | b | j. | k |
| e. | g | k. | l |
| f. | h | l. | m |
| | | m. | c,o,n |

39. c correct. The becquerel (Bq.) is a special unit in the S.I. system used to express the magnitude of the quantity called activity. Another special unit of activity is the curie (Ci.) One Bq. equals one disintegration per second. One curie equals $3.7 \times 10^{10}$ Bq.

40. d correct. 1/32 is $(1/2)^5$, therefore the desired attenuation would require 5 HVLs (half value layers) or 55 mm of lead.

41. c correct. The Quality Factor is an empirical constant used to compute the equivalent biological dose of a specific radiation from the absorbed dose. It is equal to one for beta and gamma radiation and 20 for alpha. Thus an absorbed dose of one rad of alpha radiation is equal to 20 rem. (Ref. 1, p. 389-390.) It is also used to convert grays to sieverts.

42. e correct. The NRC is responsible only for byproduct, special nuclear, and source materials. There are other types of radioactive materials -- acceleration produced and naturally occurring radioactive materials. There is also a variety of machines which produce ionizing radiations -- x-ray machines and accelerators. Each of these agencies have regulatory responsibilities for different types of ionizing radiation sources.

43. b correct. The time constant is defined in terms of the exponential coefficient in the equation defining the time-response curve of an instrument or process which approaches its true reading in an exponential fashion. Specifically, $R_a = R_t \left(1 - e \exp\left(\frac{-t}{T}\right)\right)$, where $R_a$ is the actual reading, $R_t$ the true reading, t the time and T the time constant. Inspection of this equation shows that t = 0, the instrument reads zero and at t = infinity it reads R. The following values are useful:

| t | $R_a/R_t$ |
|---|---|
| 0 | 0.00 |
| T | 0.67 |
| 2T | 0.86 |
| 3T | 0.95 |
| 5T | 0.99 |
| Infinity | 1.00 |

Thus, at t = 5T any instrument is essentially at its stable value which is 33% greater than t = T value or approximately half again as much. This is a general definition of time constant and is applicable to many situations. In radioactive decay, the time constant is the inverse of the decay constant.

44. a correct. Bremsstrahlung is the electromagnetic (x-ray) radiation produced by the rapid deceleration of charged particles. It typically arises when high energy beta particles are slowed down by shielding. Thus the shielding must be designed to protect against it. The production of bremsstrahlung is proportional to E, the particle's energy, and the square of the material's atomic number ($Z^2$).

45. a correct. The proportional counter output is proportional to the energy of the incident radiation, thus it can distinguish between radiations. (Ref. 1, p. 386.)

46. a correct.

47. a correct.

References

1. Amdur, Mary O. et al, The Industrial Environment--Its Evaluation and Control, NIOSH, 1973.

2. Bureau of Radiological Health et al, Radiological Health Handbook, Revised edition January 1970, U.S. Dept. of Health, Education, and Welfare.

3. Cralley & Cralley, Patty's Industrial Hygiene and Toxicology, Volume III, John Wiley & Sons, NY, 1979.

4. National Council for Radiation Protection, Handbook 45.

Chapter 17: NON-IONIZING RADIATION

Reviewers: Zory R. Glaser, Ph.D., Bureau of Radiological Health
John C. Taschner, Bureau of Radiological Health

I. Electromagnetic radiation spectrum
   A. Ionizing
   B. Non-ionizing
      1. ultraviolet
      2. visible light
      3. laser
      4. infrared
      5. radiofrequency
      6. microwave
   C. Parameter relationships
      1. Plank's constant
      2. wave length
      3. frequency
      4. photon energy

II. General controls
   A. federal health and safety criteria (exposure)
   B. performance criteria (emission)
   C. energy absorption
   D. shielding
   E. distance increase
   e. exposure time limitation
   G. beam access limitations

III. Ultraviolet
   A. Physical characteristics
      1. vacuum
      2. far
      3. middle
      4. near
      5. TLV curve
   B. Sources
      1. sun
      2. mercury vapor lamps
      3. quartz lamps
      4. welding, plasma torches
      5. lasers
      6. xenon discharge lamps
      7. fluorescent lamps
      8. other
   C. Biological effects
      1. erythema
      2. corium, dermis penetration
      3. corneal epithelium
      4. lens, vitreous humor
      5. skin cancer
      6. photokeratitis
      7. bactericidal

D. Exposure criteria
   1. biological action
   2. ACGIH TLV
E. Measurement
   1. photoelectric cells
   2. photoconductive cells
   3. photovoltaic cells
   4. photochemical detectors
   5. thermopiles
F. Exposure control
   1. shielding
   2. eyewear
   3. barrier creams
   4. exposure time limitation

IV. Visible
A. Physical characteristics
   1. wavelength spectrum
   2. intensity
B. Sources
   1. sun
   2. incandescent lamps
   3. fluorescent lamps
   4. elemental lamps
   5. other
C. Biological effects
   1. occular pain
   2. retinal injury
   3. other
D. Exposure criteria
   1. pain threshold
   2. sensitivity
   3. standards
E. Measurement
   1. photoelectric cells
F. Exposure control
   1. shielding
   2. eyewear
   3. exposure time limitation

V. Laser
A. Physical characteristics
   1. slight divergence
   2. monochromatic
   3. coherent
   4. intense energy capability
   5. continuous, pulsed, Q switched
   6. specular, diffuse reflection
   7. system components
      a. medium
         (1) liquid
         (2) solid
         (3) gas
         (4) semiconductor

- b. pump
- c. optical cavity

B. Laser system sources
- 1. micromachining
- 2. welding
- 3. cutting
- 4. optical alignment
- 5. spectroscopy
- 6. surgery
- 7. communications
- 8. other

C. Biological effects
- 1. erythema
- 2. surface tissue exfoliation
- 3. stromal haze
- 4. cornea
- 5. retina
- 6. skin burns

D. Exposure criteria
- 1. retina lesions
- 2. radiant exposure
- 3. limiting aperture
- 4. collimated source viewing
- 5. wavelength
- 6. power limited pulses
- 7. federal standards
- 8. ACGIH

E. Measurement
- 1. photoelectric detectors
- 2. thermopiles
- 3. photovoltaic cells
- 4. calorimeters
- 5. microammeters

F. Exposure control
- 1. enclosures
- 2. beam stops
- 3. beam enlargement
- 4. interlocks
- 5. shutters
- 6. isolation
- 7. protective eyewear
  - a. specificity
  - b. optical density
    - (1) emergent beam radiant exposure
    - (2) emergent beam irradiance

VI. Infrared

A. Physical characteristics
- 1. wavelength spectrum
- 2. intensity

B. Sources
- 1. sun
- 2. lamps
- 3. lasers
- 4. molten metal, glass

5. furnaces
6. other

C. Biological effects
1. lens
2. cornea
3. iris
4. retina
5. skin burns
6. cataracts
7. "dry eye"

D. Exposure criteria
1. pain
2. TLV

E. Measurement
1. photo-sensitive cells
2. calorimeters
3. black bulb thermometers
4. other

F. Exposure control
1. protective eyewear
2. shielding
3. exposure time limit

VII. Radiofrequency

A. Physical characteristics
1. wavelength spectrum
2. frequencies

B. Sources
1. dielectric heaters
2. sealers
3. radio, television
4. induction furnaces
5. other

C. Biological effects
1. skin heating
2. deep body heating
3. other

D. Exposure criteria
1. OSHA
2. ANSI
3. ACGIH
4. other

E. Measurement
1. dipole antenna
2. loop antenna

F. Exposure control
1. enclosures
2. shields
3. exposure time limitation

VIII. Microwave

A. Physical characteristics
1. wavelength spectrum
2. frequencies

B. Sources
   1. klystrons
   2. magnetrons
   3. oscillators
   4. microwave ovens
   5. diathermy units
   6. induction heaters
   7. radar
   8. solar
C. Biological effects
   1. external skin heating
   2. internal organ heating
   3. cataracts
   4. "pearl chain effect"
   5. genetic
   6. other
D. Exposure criteria
   1. OSHA
   2. TLV
   3. ANSI
   4. other
E. Measurement
   1. mathematical evaluation
      a. near field
      b. far field
   2. bolometry
   3. calorimetry
   4. voltage changes
   5. resistance changes
F. Exposure control
   1. radar azimuth, elevation restrictions
   2. enclosures
   3. shields
   4. signs
   5. exposure time limitations
   6. other

## Review Questions

1. What is the organ of impact for microwave?

   a. eye
   b. gonads
   c. skin
   d. blood forming organs
   e. a & b

2. Glassblowers' cataracts are normally experienced by workers exposed to what form of radiation?

   a. alpha
   b. beta
   c. UV
   d. IR
   e. microwave

3. Which range (nm) of U.V. light is the most hazardous to the eyes?

   a. 280 - 300 nm
   b. 300 - 340 nm
   c. 260 - 280 nm
   d. 240 - 260 nm
   e. none of the above

4. The portion of the body most susceptible to laser damage is:

   a. gonads
   b. eye
   c. skin
   d. thyroid
   e. blood cells

5. The units most commonly used to express limits for exposure to U.V. light are:

   a. foot candles
   b. lumens
   c. ergs/g
   d. calories/sec
   e. milliwatts/$cm^2$

6. Exposure to coal tar products has been shown to increase adverse effects from the following:

   a. IR radiation
   b. asbestos
   c. UV radiation
   d. chromates
   e. chlorine

7. The current OSHA standard for far field exposure to microwave radiation averaged over any 0.1 hour period is:

   a. 0.01 $W/cm^2$
   b. 0.1 $W/cm^2$
   c. 1.0 $W/cm^2$
   d. 10 $W/cm^2$

8. Dielectric heaters, high frequency sealers, and diathermy machines are all sources of:

   a. x-ray radiation
   b. UV radiation
   c. IR radiation
   d. microwave radiation
   e. RF radiation

9. Q switching allows lasers to generate:

   a. variable frequency emissions
   b. high power continuous emissions
   c. high power pulsed emissions
   d. simulated monochromatic emissions
   e. simulated coherent emissions

10. Conjunctivitis may result from a welding arc due to:

    a. intense visible light radiation
    b. UV radiation
    c. IR radiation
    d. soft x-ray radiation
    e. metal sparks

11. The flux density at 1 meter from a radar (microwave) antenna is 40 $mW/cm^2$. What is the flux density at 2 meters from the antenna?

    a. 30 $mW/cm^2$
    b. 20 $mW/cm^2$
    c. 10 $mW/cm^2$
    d. 5 $mW/cm^2$
    e. 4 $mW/cm^2$

12. Carbon dioxide lasers are particularly hazardous because:

    a. they are Q switched
    b. they produce a continuous beam
    c. they produce a beam to which the human eye is particularly sensitive
    d. they produce a beam which is invisible to the human eye
    e. they are P switched

13. Microwave ovens generally operate at:

    a. 8000 MHz
    b. 1215 MHz
    c. 2450 MHz
    d. 3000 GHz

14. The most common exposure to ultraviolet radiation is from:

    a. welding
    b. germicidal lamps
    c. direct sunlight
    d. black lights

15. Generally speaking, lasing action has been obtained in:

    a. gases
    b. crystalline materials
    c. liquids
    d. semi-conductors
    e. a and b only
    f. all of the above

16. Where can microwaves be measured?

    a. near field
    b. intermediate field
    c. far field
    d. at source

17. How is the limit of laser energy expressed?

    a. $J/cm^2$ or $W/cm^2$
    b. $H/cm^2$ or $E/cm^2$
    c. $g/cm^2$ or $m/cm^2$
    d. J/min or W/min

18. Given the emergent beam radiation exposure and MPE of a laser, the formula for calculating the minimum optical density of protective eyewear is:

    a. $OD = H_2O/MPE$
    b. $OD = \log (H_o/MPE)$
    c. $OD = \log (MPE/H_o)$
    d. $OD = MPE/H_o^2$

19. If the diameter of the laser beam at the corneal plane is equal to or less than the diameter of the eye, the amount of beam assumed to enter the eye is:

    a. all the beam
    b. inversely proportional to the size of the beam
    c. half the beam
    d. unimportant in terms of effects on the eye

20. A radar unit has the following characteristics:

frequency = 10 GHz
peak power = 2 MW
peak repetition rate = 200 pulses/second
pulse width = 5 microseconds
beam width = 2.5 degrees
rotational frequency = 4 RPM
antenna dish diameter = 1.22 meters

What is the average power for the unit?

a. 100 W
b. 200 W
c. 2000 W
d. 4000 W

21. For the system in #17, what is the distance to the far field?

a. 19.5 m
b. 195 m
c. 6.5 m
d. 65 m

22. For the system in #17, what is the power density at 100 meters?

a. 900 $mW/cm^2$
b. 9.0 $mW/cm^2$
c. 26 $mW/cm^2$
d. 0.026 $mW/cm^2$

## Answers to Review Questions

1. e correct. Classic industrial hygiene literature refers primarily to occular and gonadal effects. Skin effects also occur and more recent data confirms effects on the blood-forming organs caused by local heating. The current best answer is e but publication of the forthcoming NIOSH microwave criteria document will probably make an "all of the above" more appropriate. (Ref. 1, p. 371, Ref. 2, p. 410-415.)

2. d correct. (Ref. 2 p. 373.)

3. c correct. The most important occular effect is photokeratitis, an inflammation of the cornea which gives the sensation of sand in the eye. The peak wavelength producing this effect is 270-280 nm depending on the author. The cornea in general absorbs over the range 100-400 nm. (Ref. 1, p. 360-361, Ref. 2, p. 364-467, Ref. 3, p. 89.)

4. b correct. Skin burns are of second greatest importance. (Ref. 1, p. 303.)

5. e correct. The TLV is expressed in joules/$cm^2$. A joule is a watt x second. Power standards, such as watts, must be accompanied by an exposure duration to determine energy doses (joules) since power is the time rate of energy transfer. (Ref. 3, p. 84.)

6. c correct. Significant numbers of workers who are routinely exposed to coal tar products while working outdoors in sunlight experience a photosensitization of the skin due to the inherent ultraviolet radiation from the sun. (Ref. 1, p. 360.)

7. a correct. This value is normally listed as 10 $mW/cm^2$. (Ref. 1, p. 371.)

8. e correct. The units described all operate within that part of the electromagnetic spectrum designated as radiofrequency radiation. (Ref. 1, p. 358.)

9. c correct. Q switched lasers can be particularly hazardous due to the enhanced storage and dumping of energy to produce extremely high power pulses. (Ref. 1, p. 362.)

10. b correct. Exposure to ultraviolet radiation can generate conjunctivitis termed "welder's flash". (Ref. 4, p. 474.)

11. c correct. Assuming that these measurements were made in the far field, the inverse square law applies to the system. If $I_1$ and $I_2$

are original and final flux densities respectively, and $d_1$ and $d_2$ are the associated distances from the source, then:

$$I_2/I_1 = (d_1/d_2)^2$$

$$I_2 = 40 \text{ mW/cm}^2 \times (1 \text{ m}/2\text{m})^2 = 10 \text{ mW/cm}^2$$

12. d correct. The carbon dioxide infrared laser cannot be seen with the human eye thus eliminating one physical "warning" property of laser presence and orientation.

13. c correct. It is 2450 MHz at which a majority of microwave ovens operate. Survey meters for ovens are manufactured to measure this particular frequency of the non-ionizing electromagnetic radiation spectrum. (Ref. 1, table 28-11.)

14. c correct. Although the other listed sources are generators of ultraviolet radiation, the sun is the major source of UV. (Ref. 1, p. 359.)

15. f correct. Lasing action has been successfully obtained in all the media listed. (Ref. 1, p. 362.)

16. c correct. The far field is the region which is sufficiently removed from the source to eliminate any interaction between the propagated wave and the source. This is the only area where the simple proportionality between the electric field (E) and the magentic field (H) is valid. (Ref. 1, p. 372.)

17. a correct. Normally equated to a 7mm aperture, the pupil of the eye, limits of laser energy exposure are expressed in either joules/cm$^2$ or watts/cm$^2$. (Ref. 1, p. 365.)

18. b correct. The minimum optical density is given as the logarithm of the direct proportion of emergent beam radiation in joules/cm$^2$ to the maximum permissible exposure or:

$$OD = \log \frac{H_o}{MPE}$$ (Ref. 1, p. 367.)

19. a correct. All the beam is assumed to enter the eye for industrial hygiene purposes and reacts with components such as the retina.

20. c correct. Average power is the product of the peak power and the duty cycle by definition.

duty cycle = pulse width x peak repetition rate

duty cycle = $(5 \times 10^{-6} \text{ sec})$ (200 pulses/sec) = $10^{-3}$

average power = peak power x duty cycle

average power = $(2 \times 10^6 \text{ watts})$ $(10^{-3})$ = 2000 watts

21. a correct. Distance to the far field ($r_{ff}$) is equated to the antenna area (A) and wavelength (L) by:

$$r_{ff} = \frac{A}{2L}$$

Wavelength (L) is equal to the speed of light divided by the frequency, or:

$$L = \frac{3 \times 10^{10} \text{ cm/sec}}{f}$$

$$L = \frac{3 \times 10^{10} \text{ cm/sec}}{10 \times 10^{9} \text{ Hz}} = 0.03 \text{ meters}$$

$$r_{ff} = \frac{\pi/4 \ (1.22 \text{ m})^2}{2 \ (0.03 \text{ m})} = 19.5 \text{ meters} \quad \text{(Ref. 1, p. 372.)}$$

22. c correct. Power density in the far field is related to the average power (P), antenna area (A), wavelength (L), and distance (r) by:

$$W_{ff} = \frac{PA}{L^2 r^2}$$

$$W_{ff} = \frac{(2000 \text{ watts})(\pi/4)(1.22 \text{ meters})^2}{(0.03 \text{ meter})^2 \ (100 \text{ meters})^2} = 260 \text{ W/m}^2$$

$$W_{ff} = 260 \text{ W/m}^2 \times 10^3 \text{ mW/W} \times 1 \text{ m}^2/10^4 \text{ cm}^2 = 26 \text{ mW/cm}^2$$

(Ref. 1, p. 372.)

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1. Amdur, Mary O. et al, The Industrial Environment--Its Evaluation and Control, NIOSH, 1973.

2. Cralley & Cralley, Patty's Industrial Hygiene and Toxocology, Volume III, John Wiley & Sons, NY, 1979.

3. TLV Booklet, 1981.

4. Key, Marcus M. et al, Occupational Diseases, Dept HEW, 1978.

Chapter 18: ILLUMINATION

Reviewer: Howard Haynes, Illuminating Engineering Society

I. Important Terms and Units
   A. Intensity, candela
   B. Illuminance, footcandles, lux
   C. Luminance (brightness), footlambert, candela per sqare mile
   D. Reflectance

II. Task Performance Factors
   A. Time
   B. Color
   C. Contrast
   D. Luminance (light level)
   E. Illumination quality
      1. glare
      2. distribution

III. Lighting Standards - Illuminating Engineering Society

IV. Factors in System Design
   A. Task
   B. Maintenance
   C. Color of light and work
   D. Efficiency of lamp and luminaire
   E. Lamp life

V. Light Measurements
   A. Survey techniques
   B. Meters
      1. color corrected
      2. cosine corrected

## Review Questions

1. Red light is sometimes used to illuminate instrument panels because:

   a. the eye is most sensitive to red
   b. red light is less of a power drain on the electrical system
   c. it interferes least with dark adaptation
   d. it is less irritating than other colors for people with eye problems
   e. statement is in error, red light is almost never used

2. Which is the correct unit for expressing luminance (brightness)?

   a. footcandles
   b. footlamberts
   c. candelas
   d. candle power
   e. lux

3. The four factors considered to determine if the quantity of light is sufficient to make details visible and recognizible are:

   a. contrast, size of pupil, light adaptation, lumens
   b. size of object, contrast, brightness, time for viewing
   c. size of object, wavelength, footcandles, exposure time
   d. reflectance, lumen/sq. meter, light source, contrast

4. The quality of illumination includes:

   a. size of object, contrast with background, time required or available for viewing, brightness of object
   b. accuracy required, contrast, footcandles, lumenaires
   c. color of light, direction, diffusion, degree of glare
   d. none of the above

5. One undesirable effect of fluorescent lamps in carpenter and machine shops is:

   a. color of light adversely affects some color-matching equipment
   b. danger of breaking from projectiles
   c. stroboscopic effect on moving saws, lathes, etc.
   d. ultra-violet portion of spectrum hazards due to high levels of illumination required.

6. The inverse-square law and the Lambert Cosine law can be combined as follows:

   a. $E = I/d^2$
   b. $E = (I/d^2)\cos\theta$
   c. $E = \dfrac{I}{d^2 \cos\theta}$

   d. $E = \dfrac{d}{I \cos\theta}$

7. In industrial illumination, which is most easily controlled?

   a. size of the object being used
   b. brightness level to which object is illuminated
   c. time available to perform task
   d. contrast at the task

## Answers to Review Questions

1. c correct. Red light is sensed primarily in the cones of the eye concentrated in the fovea. Cones are the dominant receptor for daylight (photopic) vision. Night vision (scotopic) is most sensitive to rods located in the eye's periphery and sensitive to blue light. By illuminating an instrument panel with red light, you provide acuity for instrument reading without interfering with dark adaptation for seeing outside of the illuminated area. (Ref. 2, p. 2-5.)

2. b correct. (Ref. 1, p. 349.)

3. b correct. (Ref. 1, p. 350.)

4. a correct. (Ref. 1, p. 350.)

5. c correct. Rotating machinery by design often has a frequency that is an even multiple of the 60 hertz flicker of fluorescent lights. Thus, the appearance of lack of motion is a potential danger.

6. b correct. The angle of incidence, $\theta$, is the angle between the verticle and the light ray. When $\theta = 0$, $\cos \theta = 1$ and the illumination of the surface is essentially perfect. Conversely, if light strikes at a grazing angle, $\theta \rightarrow 0$, there is essentially no reflection.

7. b correct. Size is fixed by the task, time is costly to increase, contrast may be controllable to some extent but is usually fixed by the task or requires general work procedure changes to improve it. (Ref. 1, p. 350.)

References

1. Amdur, Mary O. et al, The Industrial Environment--Its Evaluation and Control, NIOSH, 1973.

2. Kaufman, John E. (Ed), IES Lighting Handbook, 4th Ed., Illuminating Engineering Society, 1966. (Note: 1981 edition available.)

Chapter 19: STATISTICS IN INDUSTRIAL HYGIENE

Reviewer: Nelson Leidel, Sc.D., NIOSH

I. Causes of Variations in Industrial Hygiene Measurement Results
   A. Random errors
   B. Systematic errors
   C. Environmental variations
   D. Work practice variations

II. Basic Statistical Distributions and Their Characteristics
   A. Frequency distributions
   B. Normal distribution
      1. range
      2. mean
      3. standard deviation
   C. Log-Normal distribution
      1. geometric mean
      2. geometric standard deviation

III. Statistical Considerations in Sampling Strategy Selection
   A. Grab samples
   B. Continuous samples

IV. Inference and Hypothesis Testing

## Review Questions

1. Which of the following is the most frequently occurring value for a series of observations?

   a. mode
   b. median
   c. average
   d. standard deviation
   e. b and c above

2. Which of the following is not an indicator of the variability of observations in an experiment?

   a. mean
   b. standard deviation
   c. range
   d. upper and lower confidence limits
   e. none of the above

3. Which statement is true about the geometric mean?

   a. it is always dimensionless
   b. it can be determined by a graphical technique using log-log graph paper
   c. is it the nth root of the product of n observations
   d. it is always greater than the arithmetic mean
   e. none of the above are true

4. Which type of graph paper would you use to estimate the geometric standard deviation of a data set that was assumed to be log-normally distributed?

   a. arithmetic
   b. semi-log
   c. log-log
   d. arithmetic-probability
   e. log-probability

5. Which of the following is the correct formula for computing the standard deviation of a data set?

   a. $s = \sqrt{\frac{x_1 + x_2 + x_3 + \ldots + x_n}{n}}$

   b. $s = \sqrt{\frac{x_1 + x_2 + x_3 + \ldots + x}{n-1}}$

   c. $s = 1/n\sqrt{(x_1 - x)^2 + (x_2 - x)^2 + \ldots (x_n - x)^2}$

   d. $s = \sqrt{\frac{(x_1 - x)^2 + (x_2 - x)^2 + \ldots + (x_n - x)^2}{n-1}}$

   e. $s = \frac{x_1 + x_2 + \ldots + x_n}{n}$

6. Compute the standardized lower confidence limit (95%) for the following air sampling results. (The SAE, sampling and analytical error, for the contaminant is 0.15, the PEL is 5.0 $mg/m^3$):

| SAMPLE | TIME | CONCENTRATION |
|---|---|---|
| A | 240 min. | 5.400 $mg/m^3$ |
| B | 210 min. | 5.936 $mg/m^3$ |

a. 0.98
b. 1.28
c. 1.01
d. 1.13
e. 1.25

7. Which statement is false? The geometric standard deviation . . .

a. is never less than 1
b. is dimensionless
c. characterizes the variability of log-normal distributions
d. is computed directly from the arithmetic mean
e. is the ratio of two specific values on the cumulative distribution curve

8. Under which of the following situations could an OSHA citation be issued? (All CLs at 95% confidence)

a. LCL > standard
b. UCL > standard
c. LCL < standard
d. UCL < standard
e. UCL < standard and LCL < standard

9. From a statistical standpoint grab sampling is _____ continuous sampling when trying to verify compliance with an OSHA 8-hour TWA standard.

a. simpler than
b. more difficult than
c. about as difficult as
d. treated in exactly the same way as
e. none of the above

## Answers to Review Questions

1. a correct. The mode is the most frequently occurring value. The mean and the average are the same and equal the sum divided by the number of observations. The standard deviation is defined in the answer to Question 5. For a normal distribution, the mode, median and average are equal.

2. a correct. All quantities cited except the mean increase as variability increases. In the case of confidence limits, their difference increases.

3. c correct. Geometric means can also be computed as the antilog of the average of the logarithms of the observations. This is identical to the computational formula given in answer c.

$$\bar{x}_g = 1/n \sqrt{(x_1)(x_2) \ldots (x_n)} = \text{antilog} \left( \frac{\log x_1 + \log x_2 + \ldots \log x_n}{n} \right)$$

4. e correct. A log-normally distributed population will present a straight line if the cumulative frequency is plotted on log-probability paper. The geometric mean is the value corresponding to P=0.5. (Same refs as Question 7.)

5. d correct.

6. a correct.

   1. Calculate the standardized concentration, Y.

      $$Y = \frac{\text{Actual Concentration}}{\text{PEL}}$$

      $$= \frac{5.65}{5.0} = 1.13$$

   2. Calculate confidence limits.

      Lower Confidence Limit = Y - SAE
      LCL = 1.13 - 0.15 = 0.98

      Since the LCL does not exceed 1.0, i.e., there is less than 95% confidence that the test value exceeds the standard, noncompliance is not established and the UCL (upper confidence limit) should be calculated.

      UCL = 1.13 + 0.15 = 1.28
      This UCL >1 indicates there is less than 95% confidence that the test value is below the standard.

   3. Classify the exposure.

      Since the LCL < 1.0 and the UCL > 1.0, classify as possible overexposure.

7. d correct. The geometric standard deviation is normally used to characterize the variability of log normal distributions, that is, distributions in which the logarithms of the data are normally distributed. The geometric standard deviation can be simply estimated from the ratio of the particle size corresponding to the cumulative frequency of 50% (50th percentile size) divided by the particle size corresponding to the cumulative frequency of 16% (actually 15.87% or the 84% (84.13%) size divided by the 50th percentile size. Thus, this ratio can never be less than 1. (Ref. 1 p. F-6 to F-10; Ref. 2, p. 159.)

8. a correct. An OSHA citation could only be issued if the data indicate that a violation exists at the 95% CL (confidence level.) Therefore the lower (95%) confidence limit of the TWA exposure estimate must exceed the standard. (Ref. 3, Chapter II, p. 32.)

9. b correct. Grab sampling is much more difficult because of the many variables that must be taken into account in setting up the sampling procedure and in the greater uncertainty in the TWA exposure estimate obtained with grab samples. (Ref. 3 Chapter II, p. 29.)

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Chapter 20: SAFETY

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I. Loss history
  A. Human
    1. fatalities
    2. disabling injuries
    3. frequency rates
    4. severity rates
  B. Economic
    1. injury costs
    2. property damage
    3. indirect costs

II. Source of injuries
  A. Causes
    1. unsafe acts
    2. unsafe conditions
  B. Accident Factors
    1. object handling
    2. falls
    3. falling objects
    4. machinery
    5. vehicles
    6. striking objects
    7. electricity
    8. heat, explosions
    9. hoists

III. Inspections
  A. Formal
  B. Informal
  C. Specific items
    1. environment
    2. containers
    3. pressure vessels
    4. materials
    5. electrical
    6. engines
    7. lifts
    8. fire fighting equipment
    9. machinery
    10. tools
    11. transportation
    12. personal protective equipment
  D. Critical parts
    1. gear covers
    2. guards
    3. valves
    4. switches
    5. grinding, cutting

IV. Hazard classification
  A. Class A
  B. Class B
  C. Class C

V. Job analysis
  A. Methodology
    1. job recognition
    2. step sequence
    3. key factors
    4. efficiency analysis
  B. Benefits
    1. environmental health
    2. traumatic injury minimization

VI. Engineering controls
  A. Control points
  B. Energy control

VII. Personal protective equipment
  A. Key considerations
    1. selection
    2. fitting
    3. enforcement
    4. maintenance
  B. Specific items
    1. helmets
    2. footwear
    3. eyewear
    4. respirators
    5. outerwear
    6. ear defenders

VIII. Accident investigation and reporting
  A. Obtaining data
    1. timely
    2. comprehensive
  B. Reporting
    1. OSHA
    2. local program
  C. Compensation
    1. legal requirements
    2. governmental programs
    3. supplemental programs

IX. Specific interest areas
  A. Fire
    1. flammable, combustible material
      a. handling
      b. storage
    2. fire codes
    3. fire extinguishers

B. Explosion
   1. upper, lower limits of materials
   2. organics
   3. dusts
   4. peroxides, azides
C. Compressed gases
   1. cylinders, vessels
   2. valves
   3. color coding
D. Cryogenics
   1. vessels
   2. handling
   3. storage
E. Missiles
   1. grinding
   2. cutting
   3. drilling
F. Splashes
   1. acid, caustic
   2. molten metal
G. Electrical
   1. wiring
   2. grounding

X. Accident prevention
   A. Worker education
      1. initial
      2. routine
   B. Supervisory control
   C. Worker incentive programs

## Review Questions

1. In which of the following situations is the worst eye hazard encountered?

   a. splashes of molten metal
   b. flying particles
   c. sprays of hazardous liquid
   d. ultraviolet radiation
   e. infrared radiation
   f. intense light
   g. exposure to toxic or irritating gases

2. Accident statistics show that:

   a. old men have more accidents.
   b. young men have more accidents.
   c. old men have fewer accidents but spend more time off due to illnesses.
   d. no noticeable trend.

3. For an air-vapor mixture above its upper flammable limit:

   a. the hazard will be reduced by dilution with air.
   b. additional volatilization of fuel will increase the explosion hazard.
   c. increasing the pressure may increase the explosion hazard.
   d. the mixture may normally be thought of as homogeneous and therefore there is no combustion hazard since the upper limit is exceeded.
   3. all of the above.

4. At the minimum autoignition temperature:

   a. increasing the combustible vapor concentration will cause ignition.
   b. the combustible vapor concentration is between the UEL and LEL.
   c. combustion will occur only if an ignition source is present.
   d. increasing the pressure will prevent autoignition.
   e. all of the above.

5. The flash point:

   a. is the lowest temperature at which a fuel vapor-air mixture will burn.
   b. is the lowest concentration at which a fuel vapor mixture will burn.
   c. is always higher than the autoignition temperature.
   d. is the same as the autoignition temperature.
   e. none of the above.

6. Compressed acetylene cylinders

   a. need no special handling consideration.
   b. are partially filled with acetone to reduce explosion hazard.
   c. may be safely discharged when upside down if the discharge rate is less than one seventh of the cylinder capacity per hour.
   d. are normally stored on their sides.
   e. are partially filled with an inert gas to avoid spontaneous explosion.

7. Calculate the accident frequency (f) if there were 10 lost-time accidents, 10 first aid cases, and 300 non-eventful accidents during 100,000 man-hours at work.

   a. 10
   b. 20
   c. 100
   d. 200
   e. 300

8. Each year, approximately how many employment-related deaths occur in the U.S.?

   a. 1,000
   b. 10,000
   c. 12,000
   d. 14,000
   e. 20,000

9. Long-term storage of ethers is dangerous because:

   a. the container may burst
   b. dangerous peroxides may be formed
   c. dangerous pressures may build up in the container
   d. ethers decompose making them useless
   e. ethers will leak out of almost any normal container

10. When moving into a laboratory used by others, you can determine the contents of an old compressed gas cylinder by:

    a. the color code
    b. the label on the cylinder
    c. the shape and type of the cylinder
    d. the laboratory records
    e. no reliable method

11. An explosion-proof apparatus has all the following features except:

    a. it does not allow gases, dusts, or vapors to enter the apparatus
    b. it operates with a low external temperature to prevent ignition of a surrounding flammable atmosphere
    c. the apparatus is enclosed in a case which will withstand an internal explosion
    d. the apparatus will contain any sparks or flashes which may occur within it so that a surrounding flammable atmosphere will not be ignited
    e. the apparatus is approved for use in specific types of hazardous environments

12. If a certain plant worked 365,000 man-hours during a year in which there were five disabling injuries with a total of 175 days charged, the severity rate(s) would be:

    a. 95
    b. 190
    c. 479
    d. 640
    e. 958

13. The LEL is:

    a. lower explosive limit
    b. lower explosive level
    c. lower explosion lock
    d. lowest entry level
    e. lowest entry limit

14. An oil fire should be extinguished with which of the following types of extinguishers?

    a. carbon tetrachloride
    b. pressurized water
    c. carbon dioxide
    d. dry sand
    e. loaded stream

15. Workmen's compensation in 1970 cost employers almost:

    a. $5 billion
    b. $10 billion
    c. $1 billion
    d. $2 billion
    e. $20 billion

16. The two most important objectives of Workmen's Compensation programs are:

    a. income replacement and restoration of earning capacity
    b. proper allocation of costs and industrial accident prevention
    c. restoration of earning capacity and proper allocation of costs
    d. income replacement and industrial accident prevention
    e. none of the above

## Answers to Review Questions

1. a correct. This is the most likely source to result in loss of vision although "b" might be argued as a better answer because it is a broader catagory that includes "a."

2. b correct. In general older men have fewer accidents than younger men and lose about the same amount of time due to illness.

3. c correct. Increasing the pressure generally widens flammability limits. (Ref 1, p. 1383)

4. b correct. If ignition is to occur, the concentration must always be between the upper and lower explosive (flammability preferred) limits. (Ref 1, p. 1383)

5. e correct. Flash points are an approximation of the minimum temperature for ignition. Because flash point is a physical approximation of a theoretical minimum it will always be somewhat higher, typically 2 to 12°C. (Ref 1, p. 1395-6)

6. b correct. Because pure acetylene under pressure will spontaneously explode, cylinders are filled with a porous mineral material (typically limestone) and some acetone to inhibit the reaction. Thus, operating cylinders in any position other than vertical may result in acetone being delivered inadvertently. (Ref 2, p. 45-19)

7. c correct. In accordance with American National Standards Institute document ANSI Z16.1, the accident frequency (f) is calculated by:

$$f = \frac{\text{number of lost-time accidents} \times 1{,}000{,}000}{\text{employee-hours of exposure}}$$

For the data given:

$$f = \frac{10 \times 1{,}000{,}000}{100{,}000} = 100 \quad \frac{\text{accidents}}{\text{million employee hours}}$$

8. d correct. Occupational accidents claimed the lives of 14,200 workers in 1970, and there had been no significant deviation from that annual figure since 1950. (Ref 3, p. 682)

9. b correct. The ability of ether to form explosive peroxides over a period of time makes the compound extremely hazardous. Ether will not degenerate proper storage containers more than any other hydrocarbon with similar chemical characteristics and will build up dangerous pressures in a container only if placed in an environment with excessively high temperatures or extremely low pressures. (Ref 4, p. 722)

10. e correct. An experienced safety or preventive medicine professional realizes that sometimes individuals filling compressed gas cylinders will not adhere to proper color coding standards. There have been cases where improper valves had been substituted on cylinders color coded for a gas requiring a specific type valve assembly. Labels and

laboratory records may not always be up to date, and the shape and type of cylinder are also unreliable indicators as to what may be contained in the cylinder. Thus, there is no reliable method of determining the contents of the cylinder short of chemical analysis.

11. a correct. The design theory on which explosion-proof equipment is based is that it is not necessary to seal the unit against all dusts and vapors, but to insure that generated temperatures associated with the equipment are not sufficient to precipitate a secondary explosion or fire.

12. c correct. In accordance with American National Standards Institute document ANSI Z16.1, the severity rate (s) is calculated by:

$$s = \frac{\text{number of days charged x } 1{,}000{,}000}{\text{employee-hours of exposure}}$$

For the data given:

$$s = \frac{175 \times 1{,}000{,}000}{365{,}000} = 479 \ \frac{\text{days loss}}{\text{million employee hours}}$$

13. a correct. The lower explosive limit (LEL) is the lower limit of flammability or explosivity of a gas or vapor at ordinary ambient temperatures expressed in percent of said gas or vapor in air by volume. (Ref 5, p. XII)

14. c correct. Carbon dioxide extinguishers are specifically designed for Class B fires such as flammable liquids, grease, gasoline, oils, and paints. (Ref 4, p. 246)

15. a correct. Federal and insurance statistics indicated that workmen's compensation cost employers $5 billion in 1970. This figure simply illustrates the extent of these programs.

16. a correct. Whan an employee is disabled, the most important compensation consideration is the replacement of his income until such time as he can return to work. In the interim, efforts must be made to restore his capacity to earn a living through application of techniques such as physical therapy, occupational therapy, or cross training. Industrial accident prevention is the primary function of the overall safety program within a plant. Cost allocation is a fiscal characteristic of a secondary nature when compared to the primary workmen's compensation functions.

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5. Industrial Ventilation, 16th ed., ACGIH, 1980.

Chapter 21: OSHA

Reviewers: Patricia A. Stewart, OSHA
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I. History
   A. Factory Act, 1833
   B. Bureau of Mines, 1910
   C. Division of Industrial Hygiene and Sanitation, 1914
   D. Walsh-Healy Public Contracts Act, 1936
   E. Federal Mine Inspection Act, 1941
   F. Longshoreman's Act, 1959
   G. Federal Coal Mine Health and Safety Act, 1969
   H. Occupational Safety and Health Act, 1970

II. Occupational Safety and Health Act
   A. Definitions
      1. "Secretary"
      2. "Commission"
      3. "Employer"
      4. "Director"
      5. "Institute"
   B. Applicability
   C. General Duty Clause
   D. Standards
      1. types
         a. general industry
         b. maritime
         c. construction
      2. procedures for new standards
      3. variances
         a. temporary
         b. permanent
      4. temporary standards
   E. Right of entry
   F. Record keeping
   G. Walk-around rights
   H. Inspections
      1. imminent danger
      2. fatalities and catastrophies
      3. complaints
      4. special emphasis
      5. general schedule
   J. Citations
      1. violation and abatement
      2. De Minimis
      3. posting
      4. time limitation
   K. Enforcement
      1. penalty
      2. contest
         a. procedure
         b. review commission
         c. court of appeals
      3. abatement

L. Penalties
   1. willful
   2. serious
   3. non-serious
   4. failure to correct
   5. advance notice
M. Establishment of State Plans
N. Federal Agencies
O. Research
   1. Dept. of Health and Human Services - NIOSH
      a. criteria documents
      b. occupational safety and health research
      c. toxic substances list
      d. health hazard evaluations
      e. current information bulletins
P. Training
   1. NIOSH
   2. OSHA
Q. Bureau of Labor Statistics
R. Workmen's Compensation

## Review Questions

1. An epidemiological study is a study of:

   a. an epidemic
   b. the skin
   c. factors determining the frequency and distribution of disease
   d. the factors causing an epidemic
   e. none of the above

2. Who accredits industrial hygiene laboratories?

   a. OSHA
   b. NIOSH
   c. ABIH
   d. AIHA
   e. ANSI

3. By legislative fiat, who trains employers and employees?

   a. NIOSH
   b. OSHA
   c. AIHA
   d. EPA
   e. none of the above

4. By legislative fiat, who has the responsibility for conducting educational programs to ensure an adequate supply of qualified safety and health professionals?

   a. NIOSH
   b. OSHA
   c. private sector organizations
   d. no one
   e. none of the above

5. What recourses do employers cited and fined by OSHA have?

   a. appeal to OSHA and the Review Commission
   b. require OSHA repeat inspection
   c. appeal to courts
   d. require NIOSH to verify OSHA finding
   e. more than one of the above

6. Who is responsible for standards promulgation?

   a. NIOSH
   b. OSHA
   c. Congress
   d. Federal Register
   e. none of the above

7. Laboratory accreditation is good for how many years?

   a. 1 year
   b. 2 years
   c. 3 years
   d. 5 years
   e. 10 years

8. A laboratory director, if not a diplomat, must have how many years of industrial hygiene experience?

   a. 2 years
   b. 3 years
   c. 6 years
   d. 8 years
   e. 10 years

9. Which of the following is(are) not a necessary operation before a noise hazard citation can be issued:

   a. the sound level meter must have been calibrated before use
   b. a full shift audio dosimeter sample must be collected from a single area or worker
   c. a minimum of 10 sound level readings must be made with an SLM in the same area in which the dosimeter is used
   d. a determination must be made of the average noise level of sound level readings made in 10 different noise areas of the plant

10. Which of the following individuals normally issues an OSHA citation?

    a. OSHA compliance officer
    b. OSHA senior industrial hygienist or senior safety engineer
    c. OSHA area director
    d. OSHA regional administrator
    e. Assistant Secretary of Labor for OSHA

11. Which of the following statements is false?

    a. the term "Secretary" in the OSH Act refers to the Secretary of Labor
    b. the OSHA compliance officer can shut a plant or operation down if an imminent danger is encountered
    c. failure of an employer to post a citation after receipt could cost the employer $1,000 in penalties
    d. the OSH Act specifically created and established the National Institute for Occupational Safety and Health

12. Once cited, how much time does an employer have to contest the citation?

    a. 1 day
    b. 7 working days
    c. 15 working days
    d. 30 calendar days
    e. none of the above

13. Under the OSH Act, which of the following is OSHA not responsible for?

    a. developing recommendations for standards
    b. promulgation of standards
    c. enforcement of standards
    d. the issuance of temporary emergency standards
    e. publishing proposed rule making in the Federal Register

14. Under the OSH Act, which of the following is NIOSH not responsible for?

    a. conducting research for the development of criteria for recommended standards
    b. developing a list of all known toxic substances by generic family and the concentrations at which such toxicity is known to occur
    c. conducting research into the motivational and behavioral factors relating to the field of occupational safety and health
    d. determination of variances from OSHA standards
    e. training of safety and health professionals to carry out the Act

15. Section 5(a)(1) of the OSH Act:

    a. gives OSHA the "right of entry" into workplaces
    b. defines the Secretary of HHS's responsibility to conduct research
    c. is the "General Duty Clause"
    d. both a and c
    e. none of the above

16. The penalty for intentionally providing erroneous information or withholding information from an OSHA compliance officer is:

    a. $500
    b. $10,000
    c. $10,000 and/or up to six months in prison
    d. up to a year in prison

17. The NIOSH Health Hazard Evaluation Program:

    a. was developed in response to a specific requirement in the OSH Act
    b. requires NIOSH to annually evaluate health hazards in selected high hazard industries
    c. all of the above
    d. none of the above

18. A firm is penalized for an OSHA violation that was corrected before the inspector left the premises. The company should:

    a. pay the fine
    b. forget about the fine and not pay it
    c. contest the fine
    d. appeal to the district court for curtailment of fine payment
    e. a or c above

## Answers to Review Questions

1. c correct. (Ref 1, p. 113)

2. d correct. (Ref: AIHA Certification Guide)

3. b correct. (Ref: Pub. Law 91-596, Sect 21c)

4. a correct. (Ref: 42 CFR 86.1)

5. e correct. One may always appeal to the courts. An employer may also appeal to OSHA and the Review Commission.

6. b correct. NIOSH serves in an advisory role. (Ref: Pub. Law 91-596, Sect. 6)

7. c correct. (Ref: AIHA Certification Guide)

8. c correct. (Ref: AIHA Certification Guide)

9. b, c, d correct. A full shift sample need not be collected if 132% of the permissible exposure is indicated on a noise dosimeter. While SLM readings should be taken periodically during dosimeter use, 10 is not a magic number.

10. c correct. Although an OSHA compliance officer physically inspects plants and operations, it is the OSHA Area Director who makes the final decision and issues the citation for noted discrepancies. (Ref. 2, sect. 9)

11. b correct. The OSHA compliance officer does not have the authority to shut down a plant or operation, even when an imminent danger situation is noted. This can be done only with a Federal District Court restraining order. (Ref 2, sect. 13)

12. c correct. The employer has 15 working days to contest a citation with the OSHA Area Director through a Notice of Contest. (Ref. 2, sect. 10)

13. a correct. Developing the criteria for standards is the responsibility of the Secretary of Health and Human Services through NIOSH. (Ref 2, sect. 20)

14. d correct. Determination of variance from OSHA standards is the responsibility of the Secretary of Labor through OSHA. (Ref. 2, sect. 6)

15. c correct. Section 8 of the Act gives OSHA the "right of entry", while Section 20 outlines the Secretary of HHS's responsibility to conduct research. Section 5 (a)(1), General Duty Clause, allows OSHA to cite when no specific standard exists for the situation which must be recognized as a hazard likely to cause death or serious injury. (Ref. 2, sect. 5)

16. c correct. The "$10,000 and/or up to six months in prison" penalty is one of the most stringent which OSHA can impose. (Ref. 2, sect. 17)

17. a correct. The evaluation program is outlined in Section 20 of the Act. NIOSH can act upon a written request from employers for specific evaluations. There is no requirement for NIOSH to annually evaluate selected high hazard industries. (Ref. 2, sect. 20)

18. e correct. The company is required to pay the fine even though it corrected the discrepancy prior to the inspector's departure, even if it decides to contest the fine through procedures outlined in the OSH Act. (Ref. 2, sect. 17)

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