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BIOENVIRONMENTAL ENGINEERING

Mechanical Ventilation Systems

QUALIFICATION TRAINING PACKAGE

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STS Line Item 4.13.11: Perform ventilation calculations

TRAINER GUIDANCE

Proficiency Code:	3c
PC Definition:	Can do all parts of the task. Needs only a spot check of completed work. Can identify why and when the task must be done and why each step is needed.
Prerequisites:	Perform in conjunction with 4.13.12 thru 4.13.15. Those QTPs as a whole, depending on trainer preference, may satisfy this QTP.
Training References:	• *Fundamentals of Industrial Hygiene*, 5th Ed, Chp 19. May differ as more current editions are published. • *ACGIH Industrial Ventilation, A Manual of Recommended Practice for Design, 28th edition* • *The Occupational Environment: Its Evaluation, Control, and Management*, 3rd Ed Chapter 38. May differ as more current editions are published.
Additional Supporting References:	None
CDC Reference:	4B051
Training Support Material:	• Calculator • Ventilation formulas • Ventilation system parameters
Specific Techniques:	Conduct hands-on training and evaluation.
Criterion Objective:	Given the proper parameters, solve various ventilation related equations successfully completing all checklist items with NO trainer assistance.
Notes: Table 6-3 and chapter 13 in ACGIH *Industrial Ventilation, A Manual of Recommended Practice for Design*, 26th Ed, offer capture velocity data for conditions of dispersion and certain types of processes. Consult with your supervisor or BEE when selecting the capture velocity. There are numerous formulas for calculating capture velocities and distances. See ACGIH Industrial Ventilation, A Manual of Recommended Practice for Design, Chapter 6, current edition. If the room has both supply and exhaust ducts, determine Q for supplied air and Q for exhausted air and use the value that is greater (the most airflow).	

TASK STEPS

1. Calculate area (*A*) of a rectangular duct.[1]
2. Calculate area (*A*) of a round duct.[2]
3. Convert square inches to square feet.[3]
4. Calculate volume of airflow (*Q*).[4]
5. Convert velocity pressure measurements to velocity – pitot traverse method.[5]
6. Calculate acceptable range for routine surveys - face velocity method.[6]
7. Calculate acceptable range for routine surveys - static pressure method.[7]
8. Calculate maximum distance from hood face to source to maintain proper capture velocity.[8]
9. Calculate room volume.[9]
10. Calculate air changes per minute or hour.[10]

LOCAL REQUIREMENTS: None

NOTES:

V = velocity
VP = velocity pressure
A = area
L = length
H = height
W = width
$\pi = 3.1416$
r = radius

1. Area of rectangular duct--Formula: $A = LW$

- Measure length (*L*) and width (*W*) of the duct
- Substitute *L* and *W* values in the equation and solve

2. Area of circular duct--Formula: $A = \pi r^2$

- Measure the radius (*r*) of the duct
- Substitute *r* value in the equation and solve

3. Conversion of square inches to square feet--Formula: $ft^2 = \frac{in^2}{144}$

- Divide square inch value by 144 (square inches per square foot)

4. Calculation for the volumetric airflow (Q) of a ventilation system--Formula:

$$Q = AV$$

- Calculate the area of the duct (*A*) (see above)
- Determine the air flowing through the duct (*V*)
- Substitute *A* and *V* values in the equation and solve

5. Conversion of velocity pressure readings to velocity (pitot traverse method)--Formulas:

$$V_{avg} = \left(\frac{\sqrt{VP_1} + \sqrt{VP_1} + ...\sqrt{VP_n}}{n}\right)^2$$

$$V_{actual} = 4005\sqrt{\frac{VP_{avg}}{d}}$$

- Determine the velocity pressure readings (*VP*)
- Substitute *VP* value in the equations and solve for velocity average

6. Face Velocity Method:

- Determine baseline airflow volume (*Q*)
- Determine the lower end of the range by multiplying the baseline airflow volume (*Q*) by 0.9
- Determine the upper end of the range by multiplying the baseline airflow volume (*Q*) by 1.1

7. Static Pressure Method:

- Determine baseline airflow volume (*Q*)
- Determine the lower end of the range by multiplying the baseline airflow volume (*Q*) by 0.81
- Determine the upper end of the range by multiplying the baseline airflow volume (*Q*) by 1.21

8. Calculation of maximum distance from hood face to source:

- Determine the required capture velocity (*V*) by defining the condition of contaminant dispersion[1]
- Determine hood type and corresponding formula for calculating airflow[2]
- Manipulate and solve formula for distance from hood face to the farthest point of the source in feet *(X)*
- Substitute known values in the formula: area of hood (*A*), volumetric airflow (*Q*), contaminant dispersion (*V*)
- Solve equation

9. Formula: $\text{Room volume} = \text{LWH}$

- Determine length of the room (*L*)
- Determine width of the room (*W*)
- Determine height of the room (*H*)
- Substitute *L, W and H* values in the equation and solve

10. Calculation of air changes per minute or hour--Formulas:

$$\text{AC/min} = \frac{\text{Q}}{\text{room volume}}$$

$$\text{AC/hr} = \frac{\text{Q} \times 60\ \text{mins/hr}}{\text{room volume}}$$

1. Determine the amount of air being supplied to or exhausted from the room (*Q*)[3]
2. Determine the room volume
3. Substitute *Q* and *room volume* values in the equation and solve

TRAINEE REVIEW QUESTIONS

STS Line Item 4.13.11: Perform ventilation calculations

1. Name the parameters at a given point in ventilation systems that are needed to calculate volumetric airflow (Q).
2. What is the number of cubic feet per minute (cfm) reading resulting from 125 cfm/ft^2 flowing through a booth 15 feet wide, 10 feet high, and 20 feet deep?
3. Calculate the area (in ft^2) of a duct that is 9 inches by 12.5 inches.
4. Calculate the area of a duct (in ft^2) with a diameter of 12 inches.

5. Calculate the air flow volume of a ventilation system with an area of $0.036ft^2$ and an average velocity of 1600 feet per minute (fpm).

6. Calculate the maximum distance a freely suspended hood can be from the source to maintain the proper capture velocity given the information below.

   Formula for freely suspended hood: $Q = V(10X^2 + A)$
   Capture velocity: 200fpm
   Hood dimensions: 12 inches x 18 inches
   Average face velocity: 800 fpm

7. Average the following four velocity pressure readings: #1 – 0.67, #2 – 0.73, #3 – 0.75, #4 – 0.78
8. Calculate the acceptable range for a ventilation system with the total face velocity airflow volume of 1026 cfm.

PERFORMANCE CHECKLIST

STS Line Item 4.13.11: Perform ventilation calculations

Proficiency Code:	3c
PC Definition:	Can do all parts of the task. Needs only a spot check of completed work. Can identify why and when the task must be done and why each step is needed.

DID THE TRAINEE…	YES	NO
1. Calculate the area (A) of a rectangular duct?		
2. Calculate the area (A) of a circular duct?		
3. Convert square inches to square feet?		
4. Calculate the volumetric airflow (Q) of a ventilation system given area (A) and velocity (V)?		
5. Convert velocity pressure readings to velocity?		
6. Calculate acceptable range for routine surveys for face velocity measurements?		
7. Calculate acceptable range for routine surveys for static pressure measurements?		
8. Calculate the maximum distance from hood face to source to maintain proper capture velocity?		
9. Calculate room volume?		
10. Calculate air changes per hour?		
Did the trainee successfully complete the task?		

TRAINEE NAME (PRINT) TRAINER NAME (PRINT)

ANSWERS

1. Name the parameters at a given point in ventilation systems that are needed to calculate volumetric airflow (Q).

A: Velocity (V) and Area (A). Q = VA

(Source: ACGIH Industrial Ventilation, A Manual of Recommended Practice for Operation and Maintenance, 26th edition, Chapter 3, 4B051 CDC, The Occupational Environment: Its Evaluation, Control, and Management, 3rd Ed Chapter 37)

2. What is the number of cubic feet per minute (cfm) reading resulting from 125 cfm/ft^2 flowing through a booth 15 feet wide, 10 feet high, and 20 feet deep?

A:
Area = LW
15' X 10' = 150 ft^2
Q = AV
150 X 125 = 18,750 cfm

(Source: 4B051 CDC)

3. Calculate the area (in ft^2) of a duct that is 9 inches by 12.5 inches.

For rectangular areas, it is simply a matter of multiplying the length times the width and dividing by 144. The reason for this is that there are 144 square inches per square foot.

A:

$$A\left(ft^2\right) = \frac{9\ (inches) * 12.5\ (inches)}{144}$$

$$A\left(ft^2\right) = \frac{112.5\ in^2}{144}$$

$$A\left(ft^2\right) = 0.781\ ft^2$$

(Source: 4B051 CDC)

4. Calculate the area of a duct (in ft^2) with a diameter of 12 inches.

A:

$$A\left(ft^2\right) = \frac{\pi r^2}{144} \text{ where r} = \text{radius in inches (half the duct diameter)}$$

Find the radius: ½ * 12 = 6 inches
Square the radius: 6 * 6 = 36 inches $A\left(ft^2\right) = \frac{\pi\ 36\ in^2}{144}$
Multiply by π: $A\left(ft^2\right) = \frac{113.10\ in^2}{144}$ (*rounded number to .10)
Divide by 144 in^2: $A\left(ft^2\right) = 0.79$

(Source: 4B051 CDC)

5. Calculate the air flow volume of a ventilation system with an area of 0.036ft^2 and an average velocity of 1600 feet per minute (fpm).

A:
Q = VA
Q = 0.036ft^2 * 1600 fpm
Q = 57.6 cfm (cubic feet per minute)

(Source: 4B051 CDC)

6. Calculate the maximum distance a freely suspended hood can be from the source to maintain the proper capture velocity given the information below.

Formula for freely suspended hood: Q = V(10X^2 + A)
Capture velocity: 200fpm
Hood dimensions: 12 inches x 18 inches
Average face velocity: 800 fpm

A:

1. Manipulate formula to solve for X: $X = \sqrt{\frac{\frac{Q}{V} - A}{10}}$
2. Determine *Q*, *V*, and *A* values:
Q = (1.6 ft^2)(800 fpm) = 1280 cfm
V = 200 fpm
A = 1.6 ft^2
3. Substitute *Q*, *V*, and *A* values in the equation and solve

$$X = \sqrt{\frac{\frac{1280}{200} - 1.6}{10}}$$

$$X = \sqrt{\frac{6.4 - 1.6}{10}}$$

$$X = \sqrt{\frac{4.8}{10}}$$

$$X = \sqrt{.48}$$

$$X = \sqrt{.48}$$

$X = 0.69$ ft (8.3 inches)

(Source: ACGIH Industrial Ventilation Manual, 28th edition, Table 6-3)

7. Average the following four velocity pressure readings: #1 – 0.67, #2 – 0.73, #3 – 0.75, #4 – 0.78

$$V_{avg} = \left(\frac{\sqrt{VP_1} + \sqrt{VP_2} + \sqrt{VP_n}}{n} \right)$$

$$V_{avg} = \left(\frac{\sqrt{0.67} + \sqrt{0.73} + \sqrt{0.75} + \sqrt{0.78}}{4} \right)^2$$

$$V_{avg} = \left(\frac{0.82 + 0.85 + 0.87 + 0.88}{4} \right)^2$$

$$_{2}$$

$V_{avg} = \left(\frac{3.4}{4} \right)$

$V_{avg} = 0.72$

(Source: 4B051 CDC)

8. Calculate the acceptable range for a ventilation system with the total face velocity airflow volume of 1026 cfm.

-10% Q = 1026 X 0.9 = 923 cfm
+10% Q = 1026 X 1.1 = 1129 cfm
The acceptable range is 923 cfm – 1129 cfm.

(Source: 4B051 CDC)

STS Line Item 4.13.12: Perform face velocity ventilation survey

TRAINER GUIDANCE

Proficiency Code:	3c
PC Definition:	Can do all parts of the task. Needs only a spot check of completed work. Can identify why and when the task must be done and why each step is needed.
Prerequisites:	Training Module 4.13.11 - Perform Ventilation Calculations
Training References:	• *Fundamentals of Industrial Hygiene*, 5th Edition, Chapter 19. May differ as more current editions are published. • *ACGIH Industrial Ventilation, A Manual of Recommended Practice for Design, 28 th edition* • *The Occupational Environment: Its Evaluation, Control, and Management*, 3rd Edition, Chapter 37. May differ as more current editions are published. • *ACGIH Industrial Ventilation, A Manual of Recommended Practice for Operation and Maintenance, 26th edition*
Additional Supporting References:	AFRL-SA-WP-SR-2013-0008, *Ventilation Technical Guide*, 2nd ed.
CDC Reference:	4B051
Training Support Material:	• Air velocity meter (thermoanemometer, rotating vane, etc.) • Ventilation system
Specific Techniques:	Conduct hands-on training and evaluation.
Criterion Objective:	Given a ventilation system, survey equipment, and references, perform face velocity ventilation survey successfully completing all items on the performance checklist with NO trainer assistance.
Notes: See Notes Section for formulas.	

TASK STEPS

1. Determine key parameters for the ventilation system being surveyed (i.e. within design specifications or ± 10% of baseline *Q*).
2. Identify the number and location of measurements to be collected.
3. Determine proper meter for the ventilation system being surveyed (i.e. thermoanemometer, rotating vane, etc.).
4. Prepare the meter per the user's manual[1].
5. Position probe and measure the air velocity (at the hood face).
6. Record each location and measured velocity.
7. Calculate average velocity (V) in feet per minute (fpm).
8. Calculate the face area (A) in sq ft[2, 4].
9. Calculate volume (*Q*)[3].
10. Determine if the system is operating within tolerance (within design specifications or ± 10% of baseline *Q or V*)
11. Utilize OEHMIS (DOEHRS or equivalent), as applicable.

LOCAL REQUIREMENTS:

NOTES:

1. Ensure proper calibration/within range specifications.

Formulas:

2. Area:

   rectangle or square: A = L X W or H X W
   circle: $A = \pi r^2$

3. Volume: Q = VA

4. Convert square inches to square feet (144 square inches per square foot)

Where:
- Q = quantity
- V = velocity
- A = area
- L = length
- H = Height
- W = width
- r = radius
- Q = airflow volume, or mass flow in cubic feet per minute (cfm)

TRAINEE REVIEW QUESTIONS

STS Line Item 4.13.12: Perform face velocity ventilation survey

1. List key values needed to perform a face velocity ventilation survey.

2. Calculate the average velocity (Vm) in feet per minute (fpm) and area (A) for a flanged hood using the information below. All readings are in feet per minute (fpm).

[1] 100	[2] 105	[3] 97	[4] 103
[5] 106	[6] 101	[7] 100	[8] 99
[9] 95	[10] 104	[11] 101	[12] 102

14” W x 8” H

3. Calculate the air flow volume (Q) for a flanged hood using the information below. All readings are in feet per minute (fpm).

[1] 100	[2] 105	[3] 97	[4] 103
[5] 106	[6] 101	[7] 100	[8] 99
[9] 95	[10] 104	[11] 101	[12] 102

16” x 8”

PERFORMANCE CHECKLIST

STS Line Item 4.13.12: Perform face velocity ventilation survey

Proficiency Code:	3c
PC Definition:	Can do all parts of the task. Needs only a spot check of completed work. Can identify why and when the task must be done and why each step is needed.

DID THE TRAINEE…	YES	NO
1. Determine key parameters for the ventilation system being surveyed?		
2. Identify the number and location of measurements to be collected?		
3. Determine proper probe for the ventilation system being surveyed?		
4. Prepare the meter per the user's manual?		
5. Position probe and measure the air velocity?		
6. Record each location and measured velocity on AF Form 2764 or equivalent?		
7. Calculate average velocity (V) in feet per minute (fpm)?		
8. Calculate the face area (A) in sq ft (See Notes – H X W - convert sq in to sq ft /144)?		
9. Calculate volume (*Q*) (See Notes – V X A)?		
10. Determine if the system is operating within tolerance (within design specifications or ± 10% of baseline *Q*)?		
11. Utilize OEHMIS (DOEHRS or equivalent), as applicable?		
Did the trainee successfully complete the task?		

TRAINEE NAME (PRINT) TRAINER NAME (PRINT)

ANSWERS

1. List key values needed to perform a face velocity ventilation survey.

   A: Velocity (V), area (A) and the airflow volume (Q), or mass flow in cubic feet per minute (cfm).

   (Source: 4B051 CDC)

2. Calculate the average velocity (Vm) in feet per minute (fpm) and area (A) for a flanged hood using the information below. All readings are in feet per minute (fpm).

1 100	2 105	3 97	4 103
5 106	6 101	7 100	8 99
9 95	10 104	11 101	12 102

   14" W x 8" H

   A:

   Calculate the average - 100 + 105 + 97 + 103 + 106 + 101 + 100 + 99 + 95 + 104 +101 +102 = 1213

   1213 / 12 = 101.08

   Vm = Average Velocity feet per minute (fpm)

   Vm = 101

   A = Area (sq ft) = 14" X 8" = 112"

   A = 112"(sq inches)

   Convert sq inches to sq feet 112/144 (inches in sq ft) = 0.78 sq ft

   OR - Can also convert the inches 14" X 8" to sq ft by dividing by 12

   14/12 = 1.17 8/12 = .67

   1.17 X .67 = 0.78

   A = 0.78

   (Source: 4B051 CDC)

3. Calculate the air flow volume (Q) for a flanged hood using the information below. All readings are in feet per minute (fpm).

1 100	2 105	3 97	4 103
5 106	6 101	7 100	8 99
9 95	10 104	11 101	12 102

   16" x 8"

A:
Calculate the average - 100 + 105 + 97 + 103 + 106 + 101 + 100 + 99 + 95 + 104 +101 +102 = 1213
1213 / 12 = 101.08
Vm = Average Velocity feet per minute (fpm)
Vm = 101 fpm

A = Area (sq ft) = 16" X 8" = 128"
A = 128"(sq inches)
Convert sq inches to sq feet 128/144 (inches in sq ft) = 0.89
OR - Can also convert the inches 16" X 8" to sq ft by dividing by 12
16/12 = 1.33 8/12 = .67
1.33 X .67 = 0.89
A = 0.89 ft^2

Volume: Q = VA
101 X 0.89 = 89.89
Volume: Q = 90 ft^3 (round up)

(Source: 4B051 CDC)

STS Line Item 4.13.13: Perform capture velocity ventilation survey

TRAINER GUIDANCE

Proficiency Code:	3c
PC Definition:	Can do all parts of the task. Needs only a spot check of completed work. Can identify why and when the task must be done and why each step is needed.
Prerequisites:	Training Module 4.13.11 – Perform Ventilation Calculations
Training References:	• *Fundamentals of Industrial Hygiene*, 5th Edition, Chapter 19. May differ as more current editions are published. • *ACGIH Industrial Ventilation, A Manual of Recommended Practice for Design, 28th edition* • *ACGIH Industrial Ventilation, A Manual of Recommended Practice for Operation and Maintenance, 26th edition* • *The Occupational Environment: Its Evaluation, Control, and Management*, 3rd Edition Chapter 37. May differ as more current editions are published.
Additional Supporting References:	AFRL-SA-WP-SR-2013-0008, *Ventilation Technical Guide*, 2nd ed.
CDC Reference:	4B051
Training Support Material:	• Velometer • Ventilation system • User's manual for manometer (as applicable) • Tape measure
Specific Techniques:	Conduct hands-on training and evaluation. Training on this task item can be performed in conjunction with 4.13.12, *Perform face velocity ventilation survey*. Also, the trainer may consider completing 4.13.11, *Perform ventilation calculations*.
Criterion Objective:	Given a ventilation system, survey equipment, and references, calculate and measure capture velocity successfully completing all checklist items with NO trainer assistance.
Notes: Capture velocity is air velocity at any point in front of a hood necessary to capture a contaminant at that point and convey the contaminant into the hood. Capture velocity is a product of hood airflow rate and hood design. It is important to note that capture velocity refers to the centerline velocity, which is the air velocity along a line extending out from the center of the hood or duct, and does not describe the velocity distribution across the hood opening.	

TASK STEPS

1. Determine hood type and corresponding formula for calculating airflow.[1]
2. Determine the required capture velocity by defining the condition of contaminant dispersion (*V*),[2]
3. Calculate area of hood (*A*).[4, 5, 6]
4. Measure and calculate the volumetric airflow into the hood (*Q*).[7]
5. Calculate distance outward from hood face to point of required capture velocity (*X*).[3] (using the appropriate formula from Table 6-3 to manipulate and solve for *X*).
6. Measure centerline airflow at the calculated distance (*X*) to verify required airflow is achieved.
7. Utilize OEHMIS (DOEHRS or equivalent), as applicable.

LOCAL REQUIREMENTS:

Select appropriate local ventilation system to perform task.

NOTES:

1. See Table 6-3, Summary of Hood Flow Equations, ACGIH Industrial Ventilation, A Manual of Recommended Practice for Design, 28th edition.
2. Table 6-2, Recommended Capture Velocities and chapter 13 in ACGIH Industrial Ventilation, A Manual of Recommended Practice for Design, 28th edition, offer capture velocity data for conditions of dispersion and certain types of processes. Consult with your supervisor or BEE when selecting the capture velocity.
3. Depending on the type of hood, the variable X (capture distance) will be in various places within the formulas in Table 6-3.

4. Area of rectangular hood--Formula: $A = LW$

- Measure length (*L*) and width (*W*) of the duct
- Substitute *L* and *W* values in the equation and solve

5. Area of circular hood--Formula: $A = \pi r^2$

- Measure the radius (*r*) of the duct
- Substitute *r* value in the equation and solve

6. Conversion of square inches to square feet--Formula: $ft^2 = \frac{in^2}{144}$

- Divide square inch value by 144 (square inches per square foot)

7. Calculation for the volumetric airflow (Q) of a ventilation system--Formula:

$$Q = AV$$

- Calculate the area of the duct (*A*) (see above)
- Determine the air flowing through the duct (*V*)
- Substitute *A* and *V* values in the equation and solve

TRAINEE REVIEW QUESTIONS

STS Line Item 4.13.13: Perform capture velocity ventilation survey

1. What is the capture velocity for contaminants released at low velocity into moderately still air?

2. After calculating the distance outward from hood face to point of required capture velocity (*X*), what must you do?

3. Select the appropriate formula and calculate the capture velocity distance for an 8" x 10" flanged opening hood with 355 feet per minute of air flowing through it. Contaminants generated during the process are released at low velocity into moderately still air.

Formula: $Q = 0.75V\left(10X^2 + A\right)$

PERFORMANCE CHECKLIST

STS Line Item 4.13.13: Perform capture velocity ventilation survey

Proficiency Code:	3c
PC Definition:	Can do all parts of the task. Needs only a spot check of completed work. Can identify why and when the task must be done and why each step is needed.

DID THE TRAINEE…	YES	NO
1. Determine hood type and corresponding formula for calculating airflow?		
2. Determine the required capture velocity by defining the condition of contaminant dispersion?		
3. Calculate area of hood?		
4. Measure and calculate the volumetric airflow into the hood?		
5. Calculate distance outward from hood face to point of required capture velocity?		
6. Measure centerline airflow at the calculated distance to verify required airflow is achieved?		
7. Utilize OEHMIS (DOEHRS or equivalent), as applicable?		
Did the trainee successfully complete the task?		

TRAINEE NAME (PRINT) TRAINER NAME (PRINT)

ANSWERS

1. What is the capture velocity for contaminants released at low velocity into moderately still air?

   A: 100-200 fpm

   (Source: Table 6-2, ACGIH *Industrial Ventilation, A Manual of Recommended Practice for Design*, 28th edition)

2. After calculating the distance outward from hood face to point of required capture velocity (*X*), what must you do?

   A: Measure centerline airflow at the calculated distance (*X*) to verify required airflow is achieved.
   (Source: 4B051 CDC)

3. Select the appropriate formula and calculate the capture velocity distance for an 8" x 10" flanged opening hood with 355 feet per minute of air flowing through it. Contaminants generated during the process are released at low velocity into moderately still air.

   Formula: $Q = 0.75V\left(10X^2 + A\right)$

   A:
   Where:
   Q = airflow into the hood, ft^3/min
   V = centerline air velocity at *X* distance, ft/min
   X = distance outward from hood along hood centerline
   A = area of hood face, ft^2

   Manipulate formula to solve for *X*:

   $$X = \sqrt{\frac{\frac{Q}{0.75(V)} - A}{10}}$$

   Substitute values in formula:

   $$X = \sqrt{\frac{\frac{198.8}{0.75(100)} - .56}{10}}$$

   $$X = \sqrt{\frac{\frac{198.8}{75} - .56}{10}}$$

   $$X = \sqrt{\frac{2.65 - .56}{10}}$$

   $$X = \sqrt{\frac{2.09}{10}}$$

   $$X = \sqrt{.209}$$

   $$X = .46 \text{ feet or } 5.5 \text{ inches}$$

(Source: Table 6-3, ACGIH Industrial Ventilation Manual, 28th edition)

STS Line Item 4.13.14: Perform pitot traverse ventilation survey

TRAINER GUIDANCE

Proficiency Code:	3c
PC Definition:	Can do all parts of the task. Needs only a spot check of completed work. Can identify why and when the task must be done and why each step is needed.
Prerequisites:	Training Module 4.13.11
Training References:	• *Fundamentals of Industrial Hygiene*, 5th Ed, Chp 19. May differ as more current editions are published. • *ACGIH Industrial Ventilation, A Manual of Recommended Practice for Design*, 28th edition • *ACGIH Industrial Ventilation, A Manual of Recommended Practice for Operation and Maintenance*, 26th edition • *The Occupational Environment: It's Evaluation, Control, and Management*, 3rd Ed Chapter 37. May differ as more current editions are published.
Additional Supporting References:	AFRL-SA-WP-SR-2013-0008, *Ventilation Technical Guide*, 2nd ed.
CDC Reference:	4B051
Training Support Material:	• Dwyer incline manometer with pitot tube • Ventilation system • Survey form (OEHMIS generated or equivalent) • User's manual for manometer • Tape measure
Specific Techniques:	Conduct hands-on training and evaluation. Training on this task item should be performed in conjunction with or after 4.13.15, *Perform Static Pressure Checks*. Also, the trainer may consider completing 4.13.11, *Perform ventilation calculations.*
Criterion Objective:	Given a ventilation system, survey equipment, and references, perform pitot traverse ventilation survey successfully completing all checklist items with NO trainer assistance.
Notes: See Notes section for formulas.	

TASK STEPS

1. Determine key parameters (minimum airflow requirements) for the system.
2. Measure duct diameter and calculate duct area (*A*).[3, 4, 5]
3. Determine traverse measurement points.[1]
4. Prepare the manometer per the user's manual.
5. Drill pitot tube/SP access holes in ventilation duct.[2]
6. Measure and note velocity pressure (VP) across the duct at all predetermined measurement points along the first traverse.
7. Measure and note VP across the duct at all predetermined measurement points along the second traverse.
8. Measure static pressure (SP).
9. Convert VP readings to velocity (*V*).[7]
10. Calculate the average duct velocity (V_{avg}).[7]
11. Calculate the total volume of airflow for the system (*Q*).[6]
12. Calculate the acceptable range (+/- 10% of baseline) using SP measurements for future routine surveys.[8]
13. Correct readings to standard temperature and pressure (V_{actual}) if necessary.
14. Utilize OEHMIS (DOEHRS or equivalent), as applicable.

LOCAL REQUIREMENTS:

Select appropriate local ventilation system to perform task.

NOTES:

1. Use ACGIH Industrial Ventilation Manual, A Manual of Recommended Practice for Operation and Maintenance, 26th Edition, Tables 3-4, 3-5, 3-6, and 3-7 to determine appropriate insertion depths.

2. System components, elbows and other obstructions affect airflow; therefore, holes should be at least 7.5 duct diameters downstream and two duct diameters upstream from these elements. If you cannot find a location that meets these limitations, use the best available location. Drill two holes at right angles of each other. Remove any burrs around the drilled hole protruding into the flowing airstream.

3. Area of rectangular duct--Formula: $A = LW$

   - Measure length (*L*) and width (*W*) of the duct
   - Substitute *L* and *W* values in the equation and solve

4. Area of circular duct--Formula: $A = \pi r^2$

   - Measure the radius (*r*) of the duct
   - Substitute *r* value in the equation and solve

5. Conversion of square inches to square feet--Formula: $ft^2 = \frac{in^2}{144}$

   - Divide square inch value by 144 (square inches per square foot)

6. Calculation for the volumetric airflow (Q) of a ventilation system--Formula:

$$Q = AV$$

- Calculate the area of the duct (*A*) (see above)
- Determine the air flowing through the duct (*V*)
- Substitute *A* and *V* values in the equation and solve

7. Conversion of velocity pressure readings to velocity (pitot traverse method)--Formulas:

$$V_{avg} = \left(\frac{\sqrt{VP_1} + \sqrt{VP_1} + \ldots\sqrt{VP_n}}{n}\right)^2$$

$$V_{actual} = 4005\sqrt{\frac{VP_{avg}}{d}}$$

- Determine the velocity pressure readings (*VP*)
- Substitute *VP* value in the equations and solve for velocity average

8. Static Pressure Method:

- Determine baseline airflow volume (*Q*)
- Determine the lower end of the range by multiplying the baseline airflow volume (*Q*) by 0.81
- Determine the upper end of the range by multiplying the baseline airflow volume (*Q*) by 1.21

V = velocity
VP = velocity pressure
A = area
L = length
H = height
W = width
π = 3.1416
r = radius

TRAINEE REVIEW QUESTIONS

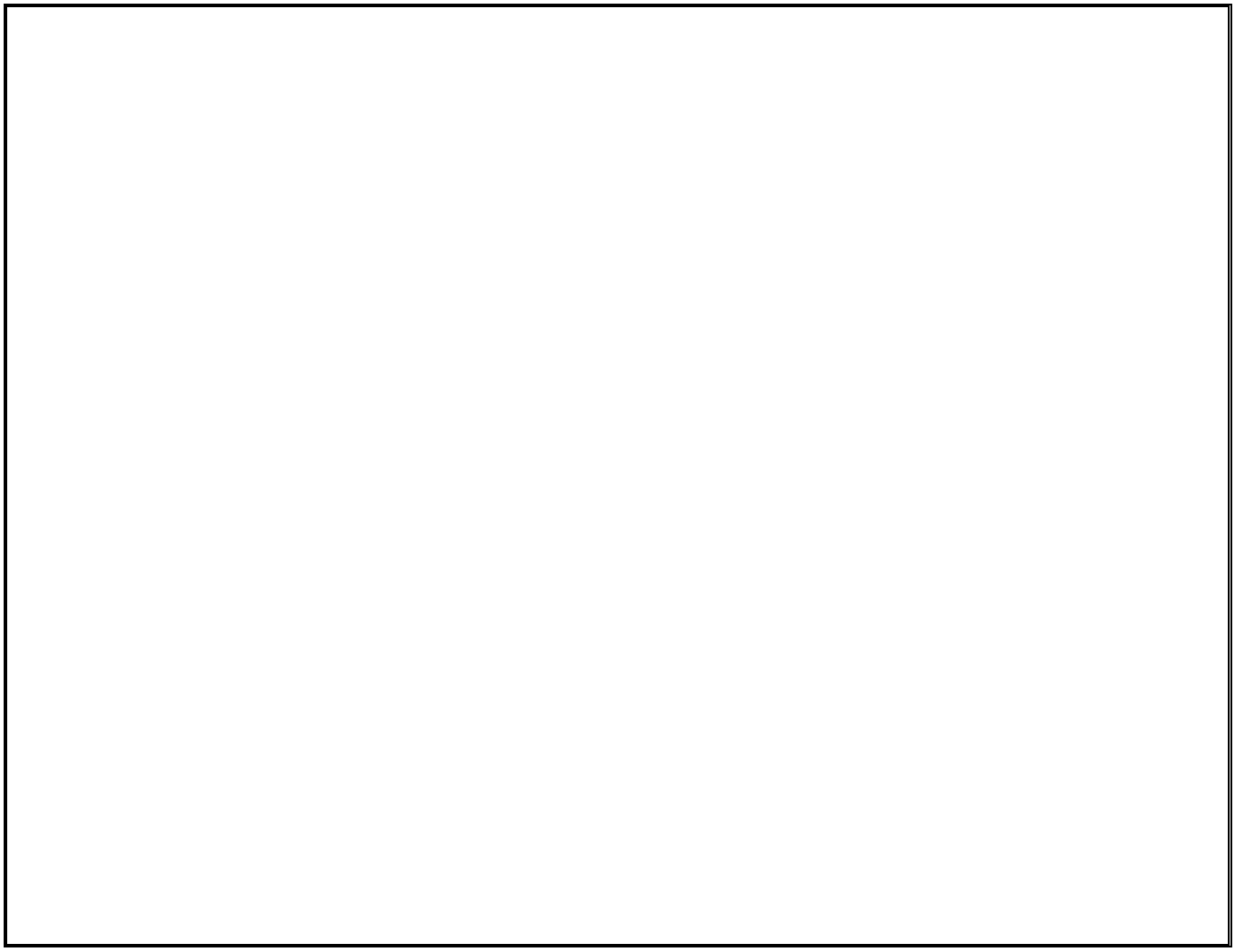
STS Line Item 4.13.14: Perform pitot traverse ventilation survey

1. What type of instrument is used to perform a pitot traverse ventilation survey?

2. At what distance from any elbow is the best place to perform pitot traverse measurements?

3. Calculate the air flow volume (Q) for a 5” duct using the information below.

- ¼”: .21
- ¾”: .26
- 1½”: .32
- 3½”: .37
- 4¼”: .24
- 4¾”: .23



PERFORMANCE CHECKLIST

STS Line Item 4.13.14: Perform pitot traverse ventilation survey

Proficiency Code:	3c
PC Definition:	Can do all parts of the task. Needs only a spot check of completed work. Can identify why and when the task must be done and why each step is needed.

DID THE TRAINEE…	YES	NO
1. Determine key parameters for the system?		
2. Measure duct diameter and calculate duct area (*A*)?		
3. Determine traverse measurement points?		
4. Prepare the manometer per the user's manual?		
5. Drill pitot tube/SP access holes in ventilation duct?		
6. Measure and note velocity pressure (VP) across the duct at all predetermined measurement points along the first traverse?		
7. Measure and note VP across the duct at all predetermined measurement points along the second traverse?		
8. Measure static pressure (SP)?		
9. Convert VP readings to velocity (*V*)?		
10. Calculate the average duct velocity (V_{avg})?		
11. Calculate the total volume of airflow for the system (*Q*)?		
12. Calculate the acceptable range (+/- 10% of baseline) using SP measurements for future routine surveys?		
13. Correct readings to standard temperature and pressure (V_{actual}), if necessary		
14. Utilize OEHMIS (DOEHRS or equivalent), as applicable?		
Did the trainee successfully complete the task?		

TRAINEE NAME (PRINT) TRAINER NAME (PRINT)

ANSWERS

1. What type of instrument is used to perform a pitot traverse ventilation survey?

   A: Incline manometer with pitot tube.

   (Source: 4B051 CDC)

2. At what distance from any elbow is the best place to perform pitot traverse measurements?

   A: At least 7 duct diameters downstream and one duct diameters upstream from these elements.

   (Source: ACGIH Industrial Ventilation, A Manual of Recommended Practice for Operation and Maintenance, 28th edition, Table 3-8)

3. Calculate the air flow volume (Q) for a 5" duct using the information below.

   - ¼": .21
   - ¾": .26
   - 1½": .32
   - 3½": .37
   - 4¼": .24
   - 4¾": .23

   A:

   Calculate area of 5" duct (*A*):

   $A = (\pi)(.422)$

   $A = (\pi)(.18)$

   $A = .57$

   Calculate average velocity pressure (VP_{avg}):

$$VP_{avg} = \left(\frac{\sqrt{.21} + \sqrt{.26} + \sqrt{.32} + \sqrt{.37} + \sqrt{.24} + \sqrt{.23}}{6} \right)^2$$

$$VP_{avg} = \left(\frac{.46 + .51 + .57 + .61 + .49 + .48}{6} \right)^2$$

$$VP_{avg} = \left(\frac{3.12}{6} \right)^2$$

$$VP_{avg} = .52^2$$

$VP_{avg} = .27$

Calculate velocity (*V*):

$V = 4005\sqrt{.27}$

$V = (4005)(.52)$

$V = 2082.6$

Calculate quantity (*Q*):

$Q = (2082.6)(.57)$

$Q = 1187.1$

(Source: QTP 4.13.11 and 4B051 CDC)

STS Line Item 4.13.15: Perform static pressure checks

TRAINER GUIDANCE

Proficiency Code:	3c
PC Definition:	Can do all parts of the task. Needs only a spot check of completed work. Can identify why and when the task must be done and why each step is needed.
Prerequisites:	QTP Journeyman Training Module 4.13.11
Training References:	• *Fundamentals of Industrial Hygiene*, 5th Edition, Chapter 19. May differ as more current editions are published. • • *ACGIH Industrial Ventilation, A Manual of Recommended Practice for Design, 28 th edition* • *ACGIH Industrial Ventilation, A Manual of Recommended Practice for Operation and Maintenance, 26th edition* • *The Occupational Environment: Its Evaluation, Control, and Management*, 3rd Edition, Chapter 38. May differ as more current editions are published.
Additional Supporting References:	AFRL-SA-WP-SR-2013-0008, *Ventilation Technical Guide*, 2nd ed.
CDC Reference:	4B051
Training Support Material:	• Dwyer incline manometer (or equivalent) with pitot tube • Ventilation system • Survey form (OEHMIS generated or equivalent) • User's manual for manometer
Specific Techniques:	Conduct hands-on training and evaluation. Training on this task item should be performed in conjunction with or after Journeyman Training Module 4.13.14 - *Perform Pitot Traverse Survey*.
Criterion Objective:	Given a ventilation system, survey equipment, and references, perform static pressure checks successfully completing all checklist items with NO trainer assistance.
Notes: According to AFRL-SA-WP-SR-2013-0008, *Ventilation Technical Guide*, 2nd ed., "A baseline survey for a ventilation system is the combination of collecting ventilation data in the form of volumetric flow rate, static pressure, and velocity pressure along with air sampling data to ensure exposures to the worker are acceptable. Once a baseline survey is completed, the exposure to the worker, as determined by air sampling, can be linked to the ventilation system through the performance metrics (static pressure, velocity pressure, and volumetric flow rate) of the system. To determine whether a system is in compliance or not, technicians should compare future ventilation surveys to the baseline criteria, not design criteria.	

TASK STEPS

1. Find the measurement point(s) (holes) drilled in the duct during the baseline survey.
2. Prepare the manometer as instructed in the user's manual for the method of measurement[1].
3. Measure and record static pressure (SP.)[2]
4. Correct readings to standard temperature and pressure (SP_s) if necessary.
5. Compare the SP measurement to the baseline value to determine if the system is operating within tolerance (± 10% of baseline survey)[3].
6. Utilize OEHMIS (DOEHRS or equivalent), as applicable.

LOCAL REQUIREMENTS:

Select appropriate local ventilation system to perform task.

NOTES:

1. Static pressure can be measured at the holes drilled in the duct (wall taps) during the baseline survey or with a Pitot tube inserted to the centerline of the duct.
2. If measuring the pressure at the wall taps and the location of the holes is closer than 7.5 duct diameters downstream from any disturbances, four readings should be taken 90 degrees apart around the duct and the measured static pressure values averaged.

3. Static Pressure Method:

- Determine baseline airflow volume (*Q*)
- Using the static pressure reading, determine the lower end of the range by multiplying the baseline airflow volume (*Q*) by 0.81
- Using the static pressure reading, determine the upper end of the range by multiplying the baseline airflow volume (*Q*) by 1.21

TRAINEE REVIEW QUESTIONS

STS Line Item 4.13.15: Perform static pressure checks

1. Describe where static pressure measurements can be taken.
2. If the location of the wall taps is six duct diameters downstream from an elbow, describe how SP measurements should be taken.
3. After measuring SP, what must you do before comparing the reading to a baseline value?

PERFORMANCE CHECKLIST

STS Line Item 4.13.15: Perform static pressure checks

Proficiency Code:	3c
PC Definition:	Can do all parts of the task. Needs only a spot check of completed work. Can identify why and when the task must be done and why each step is needed.

DID THE TRAINEE…	YES	NO
1. Find the measurement point(s) (holes) drilled in the duct during the baseline survey?		
2. Prepare the manometer as instructed in the user's manual for the method of measurement?		
3. Measure and record static pressure?		
4. Correct readings to standard temperature and pressure, if necessary?		
5. Compare the SP measurement to the baseline value to determine if the system is operating within tolerance?		
6. Utilize OEHMIS (DOEHRS or equivalent), as applicable		
Did the trainee successfully complete the task?		

TRAINEE NAME (PRINT)

TRAINER NAME (PRINT)

ANSWERS

1. Describe where static pressure measurements can be taken.

   A: Static pressure can be measured at the holes drilled in the duct (wall taps) during the baseline survey or with a Pitot tube inserted to the centerline of the duct.

   (Source: ACGIH Industrial Ventilation, A Manual of Recommended Practice for Operation and Maintenance, 26th edition)

2. If the location of the wall taps is six duct diameters downstream from an elbow, describe how SP measurements should be taken.

   A: Four readings should be taken 90 degrees apart around the duct and the measured static pressure values averaged.

   (Source: Fundamentals of Industrial Hygiene, 5th Ed, Chapter 19, pg 627)

3. After measuring SP, what must you do before comparing the reading to a baseline value?

   A: Correct readings to standard temperature and pressure, if necessary

   (Source: 4B051 CDC)