The Case of the
TOXIC FUME

By Mitch Ricketts

Math Toolbox is designed to help readers apply STEM principles to everyday safety issues. Many readers may feel apprehensive about math and science. This series employs various communication strategies to make the learning process easier and more accessible.

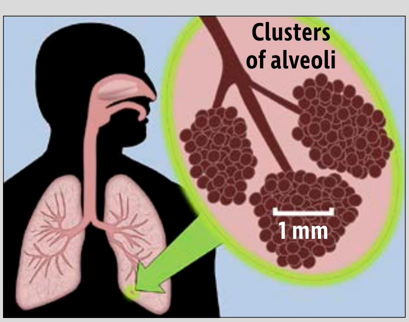
Metal fume fever is one of the most commonly reported respiratory ailments among welders and torch cutters. This disorder usually occurs as a brief flu-like illness, beginning a few hours after exposure and resolving on its own after 1 or 2 days. Typical signs and symptoms include fever, headache, fatigue, muscle ache and cough (Riccelli et al., 2020).

While metal fume fever normally resolves on its own, there are exceptions. In fact, as illustrated in Figure 1, metal fume fever sometimes leads to severe and persistent respiratory disability.

Besides metal fume fever, other disorders have been linked with overexposures to welding and cutting fumes. For instance, pulmonary siderosis may result when inhaled fumes deposit iron particles in the lungs. Likewise, pulmonary fibrosis occurs when injury from fumes causes scarring in lung tissues. Asthma, which can be caused by overexposure to fumes, is characterized by episodes of inflammation in the airways. Chronic obstructive pulmonary disease, also associated with welding and cutting, may involve chronic bronchitis (long-term inflammation of the bronchi) or emphysema (a disorder in which the walls of the alveoli break down). Finally, welding and cutting fumes are known to cause cardiovascular disease and cancer in workers (IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, 2018; Riccelli et al, 2020).

FIGURE 1
WORKERS' LUNGS DAMAGED BY METAL FUMES

Two workers used an acetylene torch to dismantle a galvanized steel shelving unit in a boiler room. Local exhaust ventilation was not used, and the workers did not wear respirators in the poorly ventilated area. Both workers became ill several hours later. Signs and symptoms included shortness of breath; cough; bloody, brown sputum; fever; drenching night sweats; and headache.



X-rays revealed that both workers suffered damage to the alveoli, tiny air sacs where oxygen is transferred to the bloodstream deep inside the lungs. Both workers were diagnosed with severe cases of metal fume fever caused by inhalation of zinc oxide fumes, possibly contaminated with cadmium.

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One worker, a 29-year-old nonsmoker, sought treatment 1 day after exposure. He was hospitalized, treated with steroids and released 4 days later with a prescription to wear oxygen when engaging in activity.

The other worker, a 51-year-old former smoker, waited 3 days before seeking help. After being admitted to the hospital, he was transferred to an intensive care unit and required 8 days of treatment. Upon release, he was sent home with oxygen.

Note. Adapted from "Metal Fume-Induced Diffuse Alveolar Damage," by J. Bydash, R. Kasmani and K. Naraharisetty, 2010, *Journal of Thoracic Imaging, 25*(2), W27-W29 (https://doi.org/10.1097/RTI.0b013e31819f937f).

Ventilation is often used to control fumes from hot work. General ventilation, for instance, supplies large volumes of clean air to dilute contaminants throughout the work space. When general ventilation fails to create acceptable air quality, local exhaust ventilation employs suction hoods near each source of emission. Local exhaust ventilation is designed to capture contaminants before they enter the breathing zones of workers.

Ventilation may be impractical or insufficient in confined spaces or when working with highly toxic metals. In these cases, respirators may be required to filter contaminants or to supply clean air from an external environment.

Figure 2 (p. 40) illustrates the use of a portable fume extractor, a form of local exhaust ventilation. The extractor consists of a hood to capture fumes at the source, a flexible duct to transport the contaminated air, an internal fan to move the air, an air cleaner to remove contaminants, and an exhaust system to send the cleaned air back into the work space or to an outdoor environment.

As with other forms of local exhaust, fume extractors must move a volume of air at velocities that will draw contaminants into the hood and keep them from reentering the work environment. Air volume, the total quantity of air transported in a span of time, is usually measured in cubic feet per minute (cfm) or cubic meters per second (m^3/s). In contrast, air velocity, the speed of air moving toward and within the exhaust system, is commonly expressed in units of linear feet per minute (fpm) or linear meters per second (m/s). Air velocity is easily measured within ducts (duct velocity) and at the hood opening (face velocity).

Capture velocity is a specific term that describes the minimum air velocity required to draw a contaminant into the hood. Typical capture velocities have been published for many emission sources (ACGIH, 2019). For welding and cutting fumes, ACGIH has reported the following capture velocities:

- 100 fpm (0.5 m/s) for low-toxicity fumes, and
- 120 to 150 fpm (0.6 to 0.75 m/s) for fumes of moderate toxicity.

Highly toxic contaminants usually require alternative control strategies such as hood enclosures, automation or the use of appropriate respirators. Because excessive air velocities may interfere with welding or cutting operations, ventilation must always be compatible with recognized quality control requirements (ANSI/AWS, 2021).

To summarize, a fume extractor must accomplish a delicate balance; it must draw air at a velocity that equals or exceeds the capture velocity of the fume without disrupting the arc or flame. Ventilation-induced air velocity in the capture zone is usually calculated, rather than measured directly. Because the welding or cutting operation is located some distance from the hood, velocity at the far edge of the capture zone will be much lower compared with velocity at the hood face. In this article, we will examine calculations to determine how closely the hood must be located to successfully capture welding and cutting fumes. These calculations generate approximate answers that tend to err on the side of safety.

FIGURE 2
WELDER USING A PORTABLE FUME EXTRACTOR

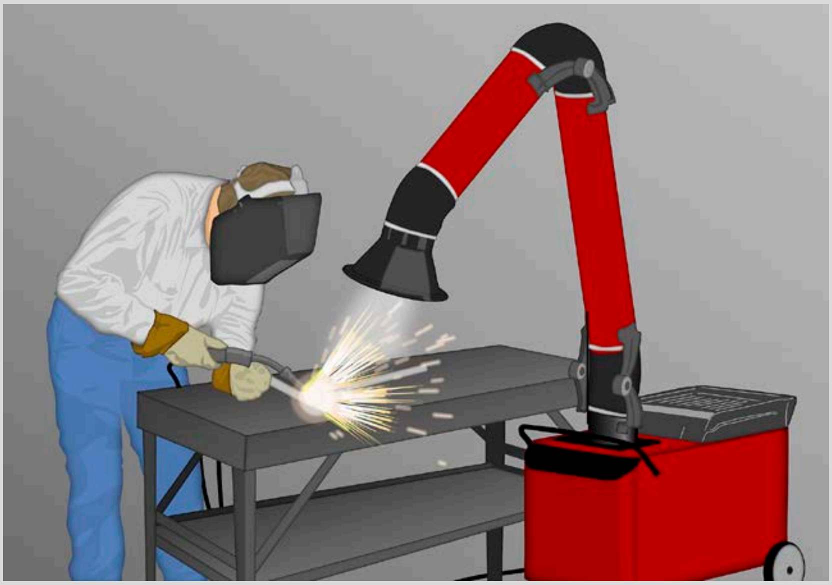
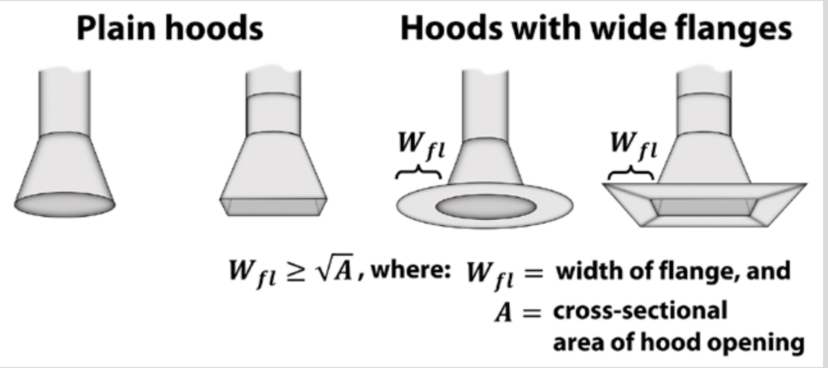


FIGURE 3
TYPES OF CAPTURE HOODS



Capture Velocity for Plain (Unflanged) Hoods That Are Round or Nearly Square

To begin, we will calculate appropriate distances for capturing fumes using plain hoods that are round or nearly square. Plain hoods do not have flanges around their edges (see Figure 3). For rectangular hoods, "nearly square" means that the ratio of the hood's narrowest to widest dimension is greater than or equal to 0.2 (i.e., narrowest dimension ÷ widest dimension ≥ 0.2). Different equations are used for hoods that do not meet these conditions (see ACGIH, 2019).

As shown in Figure 4 (p. 42), the equation is:

$$Q = V_c \cdot (10 \cdot x^2 + A)$$

where:

Q = volumetric flow rate of the hood, in units such as cubic feet per minute (cfm) or cubic meters per second (m^3/s)

V_c = capture velocity, that is, air velocity at a distance x before the face of the hood; capture velocity must be expressed in units consistent with volumetric flow rate, such as feet per minute (fpm) or meters per second (m/s)

x = distance from the face of hood to the far end of the contaminant source, in units matching volumetric flow rate and capture velocity, such as feet (ft) or meters (m)

A = cross-sectional area of the hood opening, in matching units such as square feet (ft^2) or square meters (m^2); hood area is calculated as shown in Figure 5 (p. 43)

Engineers use this equation to design extractors with sufficient air flow to achieve a particular capture velocity. For everyday use, safety professionals are more often required to determine how closely to place the hood when capturing fumes from the welding or cutting zone. The equation can be rearranged to solve this common problem as follows:

$$x = \sqrt{\frac{Q - V_c \cdot A}{V_c \cdot 10}}$$

Calculated example. Imagine the workers in Figure 1 (p. 39) had used a portable fume extractor to capture and remove metal fumes from the workplace air. For the purposes of this exercise, imagine the extractor was designed with a plain (unflanged) hood having a cross-sectional area of 0.55 ft^2 and a volumetric air flow rate of 1,200 cfm as indicated in the manufacturer's specifications. Finally, imagine the workers decided on a capture velocity of 120 fpm which falls within the range recommended by ACGIH (2019) for torch cutting of moderately toxic metals. What distance from the cutting operation must the hood be placed to adequately capture the welding fume? Using the formula, we can solve for the recommended capture distance (distance x) based on the following data:

•The manufacturer's specifications indicate volumetric air flow rate is 1,200 cfm; this is the value of Q in the formula.

•The desired capture velocity is 120 fpm; this is the value of V_c.

•The manufacturer's specifications indicate the cross-sectional area of the hood opening is 0.55 ft^2; this is the value of A.

•The equation will solve for x, which is the recommended distance of the hood from the welding operation.

Step 1: Begin with the equation arranged to solve for x:

$$x = \sqrt{\frac{Q - V_c \cdot A}{V_c \cdot 10}}$$

Step 2: Insert the known values for volumetric air flow rate (Q = 1,200 cfm), capture velocity (V_c = 120 fpm) and the cross-sectional area of the hood opening (A = 0.55 ft^2). Then solve for x:

$$x = \sqrt{\frac{1{,}200 - 120 \cdot 0.55}{120 \cdot 10}} = 0.97\ ft$$

(rounded two places past the decimal)

Note: Most calculators have a √ (square root) button that will provide the correct answer with keystrokes similar to the following in this case: *√((1,200–120x0.55)÷(120x10))=*. Alternatively, in an Excel spreadsheet, the formula for this example is *=SQRT((1200-120*0.55)/(120*10))*.

Step 3: The calculation indicates the desired capture velocity of 120 fpm will be achieved when the hood face is located a distance of about 0.97 ft from the cutting operation. This is equivalent to about 11.64 in. because 0.97 · 12 in. per ft = 11.64 in. (See "Concluding Comments" for important limitations regarding our estimate.)

Alternate example. Now imagine a different scenario in which a worker is using a portable fume extractor while welding. In this case, we'll perform our calculations in metric units. Imagine the fume extractor was designed with a plain (unflanged) hood having a cross-sectional area of 0.07 m^2 and a volumetric air flow rate of 0.48 m^3/s. Finally, we'll imagine the worker has decided on a capture velocity of 0.65 m/s. At what distance from the welding operation must the hood be placed to achieve the capture velocity of 0.65 m/s? The variables can be summarized as follows:

•The manufacturer's specifications indicate volumetric air flow rate is 0.48 m^3/s; this is the value of Q in the formula.

•The desired capture velocity is 0.65 m/s; this is the value of V_c.

•The cross-sectional area of the hood opening is 0.07 m^2; this is the value of A.

•The equation will solve for x, which is the recommended distance of the hood from the welding operation.

Step 1: Begin with the equation arranged to solve for x:

$$x = \sqrt{\frac{Q - V_c \cdot A}{V_c \cdot 10}}$$

Step 2: Insert the known values for volumetric air flow rate (Q = 0.48 m^3/s), capture velocity (V_c = 0.65 m/s) and the cross-sectional area of the hood opening (A = 0.07 m^2). Then solve for x:

$$x = \sqrt{\frac{0.48 - 0.65 \cdot 0.07}{0.65 \cdot 10}} = 0.26\ m$$

(rounded)

Step 3: The calculation indicates the desired capture velocity of 0.65 m/s will be achieved when the face of the hood is located a distance of about 0.26 m from the welding operation (about 26 cm because 0.26 · 100 cm per meter = 26 cm).

You Do the Math

Apply your knowledge to the following questions. Answers are on p. 47.

1. Imagine a worker uses a portable fume extractor while torch cutting. The fume extractor was designed with a plain (unflanged) hood having a cross-sectional area of 0.04 m^2 and a volumetric air flow rate of 0.70 m^3/s as indicated in the manufacturer's specifications. The worker has decided on a capture velocity of 0.60 m/s. At what distance from the cutting operation must the hood be placed to achieve the capture velocity of 0.60 m/s?

2. In this case, imagine a worker is using a portable fume extractor while welding. The fume extractor was designed with a plain (unflanged) hood having a cross-sectional area of 0.35 ft^2 and a volumetric air flow rate of 1,400 cfm. The worker has decided on a capture velocity of 110 fpm. At what distance from the welding operation must the hood be placed to achieve the capture velocity of 110 fpm?

Capture Velocity for Flanged Hoods That Are Round or Nearly Square

Some hoods have wide flanges designed to increase airflow directly in front of the hood opening. The term "wide flange" means the width of the flange is greater than or equal to the square root of the area of the hood opening (see Figure 3). To calculate the proper placement of wide-flanged hoods, we use the following equation (as illustrated in Figure 4 (p. 42) and with the variables defined as before):

$$Q = 0.75 \cdot V_c \cdot (10 \cdot x^2 + A)$$

which can be rearranged to solve for x as follows:

$$x = \sqrt{\frac{Q - 0.75 \cdot V_c \cdot A}{V_c \cdot 7.5}}$$

Calculated example. This time, imagine the workers in Figure 1 (p. 39) had used a portable fume extractor with a wide-flanged hood. Once again, we'll say the cross-sectional area of the hood opening is 0.55 ft^2, with a volumetric air flow rate of 1,200 cfm. Assuming a desired capture velocity of 120 fpm, we can calculate the proper distance for the hood (distance x) based on the following data:

•The volumetric air flow rate is 1,200 cfm; this is the value of Q in the formula.

•The desired capture velocity is 120 fpm; this is the value of V_c.

•The cross-sectional area of the hood opening is 0.55 ft^2; this is the value of A.

•The equation will solve for x, which is the recommended distance of the hood from the cutting operation.

Step 1: Begin with the equation for wide-flanged hoods, arranged to solve for x:

$$x = \sqrt{\frac{Q - 0.75 \cdot V_c \cdot A}{V_c \cdot 7.5}}$$

Step 2: Insert the known values for volumetric air flow rate (Q = 1,200 cfm), capture velocity (V_c = 120 fpm) and the cross-sectional area of the hood opening (A = 0.55 ft^2). Then solve for x:

$$x = \sqrt{\frac{1{,}200 - 0.75 \cdot 120 \cdot 0.55}{120 \cdot 7.5}} = 1.13\ ft$$

(rounded)

Step 3: The calculation indicates the desired capture velocity of 120 fpm will be achieved when the hood face is located a distance of about 1.13 ft (13.56 in.) from the cutting operation. Compared with the result from the first example, the wide flange allows the hood to be pushed back almost 2 in., giving the workers more room to maneuver.

Alternate example. Next, we'll calculate the proper position for a wide-flanged hood from the second example, in which a worker was welding with an extractor having a hood opening with a cross-sectional area of 0.07 m^2 and a volumetric air flow rate of 0.48 m^3/s. As before, we'll calculate the distance at which the hood will achieve a capture velocity of 0.65 m/s. The variables are as follows:

•The volumetric air flow rate is 0.48 m^3/s; this is the value of Q in the formula.

•The desired capture velocity is 0.65 m/s; this is the value of V_c.

•The cross-sectional area of the hood opening is 0.07 m^2; this is the value of A.

•The equation will solve for x, which is the recommended distance of the hood from the welding operation.

Step 1: Begin with the equation for wide-flanged hoods, arranged to solve for x:

$$x = \sqrt{\frac{Q - 0.75 \cdot V_c \cdot A}{V_c \cdot 7.5}}$$

Step 2: Insert the known values for volumetric air flow rate (Q = 0.48 m^3/s), capture velocity (V_c = 0.65 m/s) and the cross-sectional area of the hood opening (A = 0.07 m^2). Then solve for x:

$$x = \sqrt{\frac{0.48 - 0.75 \cdot 0.65 \cdot 0.07}{0.65 \cdot 7.5}} = 0.30\ m$$

(rounded)

Step 3: The calculation indicates the desired capture velocity of 0.65 m/s will be achieved when the face of the hood is located a distance of about 0.30 m from the welding operation (about 30 cm), which means the wide-flanged hood can be located about 4 cm further from the weld, compared with the plain (unflanged) hood from our earlier calculation.

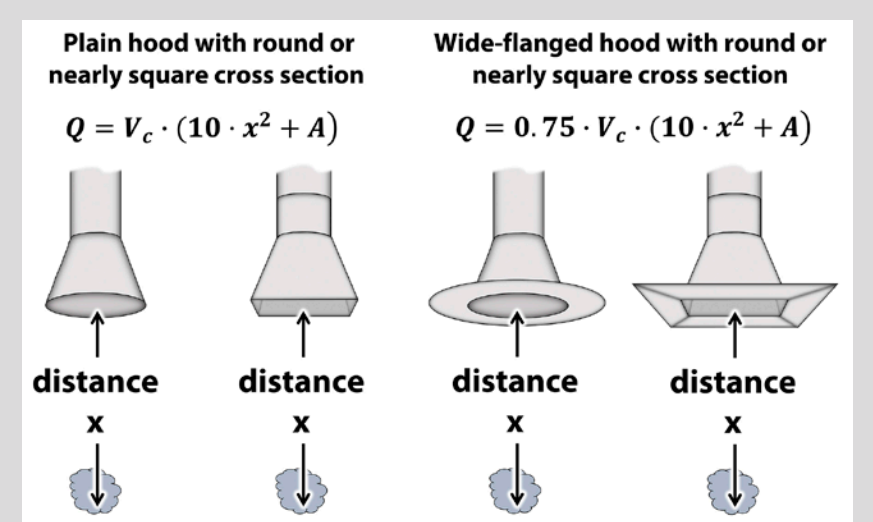
You Do the Math

Apply your knowledge to the following questions. Answers are on p. 47.

3. Imagine a worker uses a portable fume extractor while torch cutting. The fume extractor was designed with a wide-flanged hood having an opening with a cross-sectional area of 0.04 m^2 and a volumetric air flow rate of 0.70 m^3/s as indicated in the manufacturer's specifications. The worker has decided on a capture velocity of 0.60 m/s. At what distance from the cutting operation must the hood be placed to achieve the capture velocity of 0.60 m/s?

4. Now imagine a worker uses a portable fume extractor while welding. The fume extractor was designed with a wide-flanged hood having an opening with a cross-sectional area of 0.35 ft^2 and a volumetric air flow rate of 1,400 cfm as indicated in the manufacturer's specifications. The worker has decided on a capture velocity of 110 fpm. At what distance from the welding operation must the hood be placed to achieve the capture velocity of 110 fpm?

FIGURE 4
CAPTURE VELOCITY EQUATIONS



Estimating Capture Velocity at a Distance From the Hood

In addition to determining the proper distance for the hood, safety professionals may need to estimate the capture velocity when a hood is located a particular distance from the cut or weld. We can accomplish this by rearranging the equation to solve for capture velocity (V_c).

For plain (unflanged) hood openings, the rearranged equation is:

$$V_c = \frac{Q}{10 \cdot x^2 + A}$$

Similarly, for wide-flanged hood openings, the rearranged equation is:

$$V_c = \frac{Q}{0.75 \cdot (10 \cdot x^2 + A)}$$

Calculated example. Once again, imagine the workers in Figure 1 (p. 39) had used a portable fume extractor, this time with a plain (unflanged) hood. For this example, suppose the cross-sectional area of the hood opening is 0.78 ft^2, with a volumetric air flow rate of 1,300 cfm. Now imagine the workers place the face of the hood at a distance of 1.25 ft (15 in.) from the cutting operation. We can estimate the capture velocity (V_c) at the point of the cutting operation based on the following data:

•The air flow rate is 1,300 cfm; this is the value of Q in the formula.

•The distance between from the cutting operation to the face of the fume hood is 1.25 ft; this is the value of x.

•The cross-sectional area of the hood opening is 0.78 ft^2; this is the value of A.

•The equation will solve for V_c, which is the estimated capture velocity at the point of the cutting operation.

Step 1: Begin with the equation for plain (unflanged) hoods, arranged to solve for V_c:

$$V_c = \frac{Q}{10 \cdot x^2 + A}$$

Step 2: Insert the known values for volumetric air flow rate (Q = 1,300 cfm), distance ($x = 1.25$ ft), and the cross-sectional area of the hood opening ($A = 0.78\ ft^2$). Then solve for V_c:

$$V_c = \frac{1{,}300}{10 \cdot 1.25^2 + 0.78} = 79.24\ fpm$$

(rounded)

Step 3: The calculation estimates the capture velocity is about 79.24 fpm when the plain hood face is located a distance of 1.25 ft from the cutting operation. This velocity is inadequate since it falls below the range normally recommended to control welding and cutting fumes. The hood must be placed closer to increase capture velocity. Alternatively, we could try a different fume extractor, such as one with a wide-flanged hood or a greater volumetric air flow rate.

Alternate example. Recalculate the previous example, imagining that the workers used fume extractor with wide-flanged hood. Again, the data are as follows:

•The air flow rate is 1,300 cfm; this is the value of Q in the formula.

•The distance between from the cutting operation to the face of the fume hood is 1.25 ft; this is the value of x.

•The cross-sectional area of the hood opening is $0.78\ ft^2$; this is the value of A.

•The equation will solve for V_c, which is the estimated capture velocity at the point of the cutting operation.

Step 1: Begin with the equation for wide-flanged hoods, arranged to solve for V_c.

$$V_c = \frac{Q}{0.75 \cdot (10 \cdot x^2 + A)}$$

Step 2: Insert the known values for volumetric air flow rate ($Q = 1{,}300$ cfm), distance ($x = 1.25$ ft) and the cross-sectional area of the hood opening ($A = 0.78\ ft^2$). Then solve for V_c:

$$V_c = \frac{1{,}300}{0.75 \cdot (10 \cdot 1.25^2 + 0.78)} = 105.66\ fpm$$

(rounded)

Step 3: The calculation estimates the capture velocity is about 105.66 fpm when the wide-flanged hood face is located a distance of 1.25 ft from the cutting operation. This capture velocity falls within the range normally recommended for controlling low-toxicity welding and cutting fumes.

You Do the Math

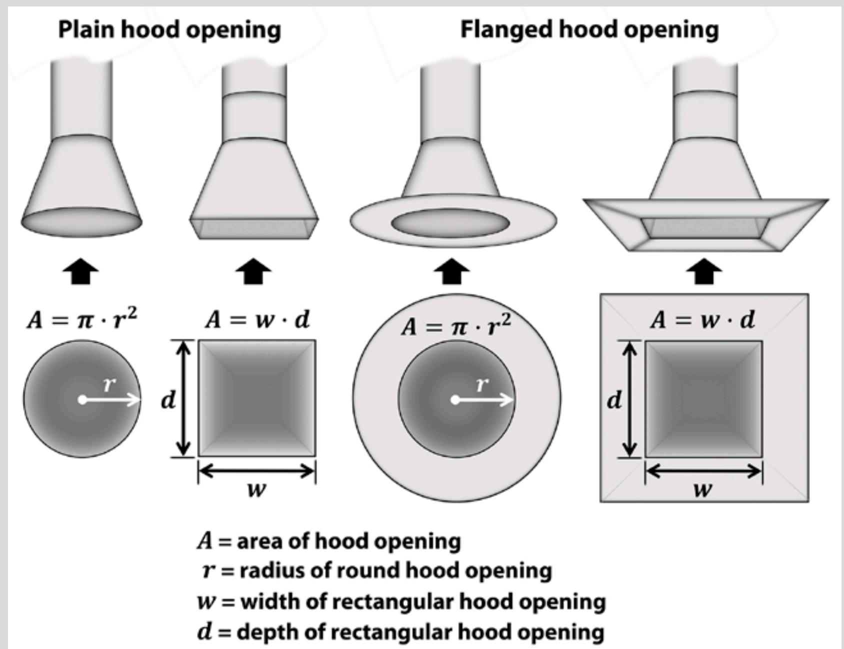
Apply your knowledge to the following questions. Answers are on p. 47.

5. Imagine that a worker uses a portable fume extractor while welding. The fume extractor was designed with a plain (unflanged) hood having a cross-sectional hood opening of $0.05\ m^2$ and a volumetric air flow rate of $0.72\ m^3/s$. The worker has placed the face of the hood at a distance of 0.40 m from the weld. What is the capture velocity (V_c) at the point of the weld? Be sure to use the equation for plain hoods, arranged to solve for V_c.

6. Again, imagine that a worker uses a portable fume extractor while welding. This time, suppose the extractor was designed with a wide-flanged hood having an opening with a cross-sectional area of $0.05\ m^2$ and a volumetric air flow rate of $0.72\ m^3/s$. The worker has placed the face of the hood at a distance of 0.40 m from the weld. What is the capture velocity (V_c) at the point of the weld? Be sure to use the equation for wide-flanged hoods, arranged to solve for V_c.

FIGURE 5

AREA OF THE HOOD OPENING FOR PLAIN & FLANGED HOODS



Concluding Comments

The equations examined here will estimate the velocity of air at varying distances from the face of a capture hood. These equations apply to freestanding hoods with openings that are round or nearly square. Different equations are used for enclosing hoods that partially or totally surround the emission source (ACGIH, 2019). Because air velocity falls off rapidly at increasing distances, capture hoods are effective only when they are placed relatively close to the point at which a contaminant is released. As general guidelines, it is recommended that hoods be located no more than 18 in. (45.7 cm) from the contaminant source. It is also recommended that the hood be at least as wide as the distance (x) from the contaminant source or 50% wider than the cloud of contaminants, whichever is greater. Be sure to consult ACGIH's (2019) Industrial Ventilation manual and ANSI/ASSP (2018; 2021) ventilation standards for other considerations when using local exhaust ventilation for welding, torch cutting and other applications.

How Much Have I Learned?

Try these problems on your own. Answers are on p. 47.

7. Imagine that a worker uses a portable fume extractor while welding. The fume extractor was designed with a plain (unflanged) hood having a cross-sectional area of $0.65\ ft^2$ and a volumetric air flow rate of 1,250 cfm as indicated in the manufacturer's specifications. The worker has decided on a capture velocity of 115 fpm. At what distance from the welding operation must the hood be placed to achieve a capture velocity of

115 fpm? Use the equation for plain (unflanged) hoods, arranged to solve for x:

$$x = \sqrt{\frac{Q - V_c \cdot A}{V_c \cdot 10}}$$

8. A worker uses a portable fume extractor while torch cutting. The fume extractor was designed with a wide-flanged hood having an opening with a cross-sectional area of 0.65 ft^2 and a volumetric air flow rate of 1,250 cfm. The worker has chosen a capture velocity of 115 fpm. At what distance from the cutting operation must the hood be placed to achieve a capture velocity of 115 fpm? Use the equation for wide-flanged hoods, arranged to solve for x:

$$x = \sqrt{\frac{Q - 0.75 \cdot V_c \cdot A}{V_c \cdot 7.5}}$$

9. A worker uses a portable fume extractor while welding. The fume extractor was designed with a plain (unflanged) hood having a cross-sectional hood opening of 0.45 ft^2 and a volumetric air flow rate of 1,125 cfm. The worker has placed the face of the hood at a distance of 1.15 ft from the weld. What is the capture velocity (V_c) at the point of the weld? Use the equation for plain (unflanged) hoods, arranged to solve for V_c:

$$V_c = \frac{Q}{10 \cdot x^2 + A}$$

10. A worker uses a portable fume extractor while welding. The fume extractor was designed with a wide-flanged hood having a cross-sectional hood opening of 0.45 ft^2 and a volumetric air flow rate of 1,125 cfm. The worker has placed the face of the hood at a distance of 1.15 ft from the weld. What is the capture velocity (V_c) at the point of the weld? Use the equation for wide-flanged hoods, arranged to solve for V_c:

$$V_c = \frac{Q}{0.75 \cdot (10 \cdot x^2 + A)}$$

The Language of Local Exhaust Ventilation

You may encounter the following concepts in certification exams and conversations with engineers and healthcare professionals. Match the numbered concepts with their paraphrased definitions (lettered). All concepts have been defined in the text, formulas and illustrations. Answers are on p. 47.

Concepts

11. Asthma
12. Capture velocity
13. Chronic obstructive pulmonary disease
14. Face velocity
15. Fumes from welding and torch cutting
16. General ventilation
17. Local exhaust ventilation
18. Metal fume fever
19. Plain hood
20. Pulmonary fibrosis
21. Pulmonary siderosis
22. Wide-flanged hood

Definitions (in random order)

a. Aerosols created when vapors from melted metal condense into tiny particles in the air
b. Ailment characterized by chronic bronchitis or emphysema
c. Air velocity required to draw a contaminant into a hood
d. Average air velocity measured at the hood opening
e. Condition that usually occurs as a brief flu-like illness beginning a few hours after exposure and resolving on its own after one or two days (although severe and permanent disability sometimes occurs)
f. Disease in which fibrous tissue or scars form in the lungs
g. Disorder characterized by episodes of inflammation in the airways
h. Hood with a flange having a width greater than or equal to the square root of the area of the hood opening
i. Hood with no flange around its edge
j. Illness caused by deposits of iron particles in the lungs
k. Ventilation system that draws large volumes of air through work areas to dilute the concentration of contaminants in the breathing zones of workers
l. Ventilation system that uses suction hoods to capture and contain contaminants at their source, before they have a chance to enter the breathing zones of workers PSJ

COMPOSITION OF FUMES MAY AFFECT THE SEVERITY OF METAL FUME FEVER

In the context of air contaminants, fumes are mixtures of tiny liquid droplets and solid particles that form when vapors condense in air. More specifically, welding and cutting fumes consist of aerosols from melted base metals, fillers, coatings and electrodes. In addition to fumes, hot work generates hazardous gases such as ozone and carbon monoxide (ACGIH, 2019).

Mild cases of metal fume fever are commonly associated with fumes containing zinc oxides, as well as copper, manganese, cadmium and certain other metals. It has been suggested that the most severe cases of metal fume fever may occur with fumes containing traces of cadmium oxide and zinc chloride (Greenberg & Vearrier, 2015).

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Online
5/12-6/9 ● Corporate Safety Management. ASSP; (847) 699-2929; www.assp.org.

Online
5/12-6/9 ● Safety Management I. ASSP; (847) 699-2929; www.assp.org.

Scottsdale, AZ
5/16-5/18: 2022 NECA Safety Professionals Conference. National Electrical Contractors Association; (202) 991-6300; www.necanet.org.

Fort Lauderdale, FL
5/16-5/19: NAEP Annual Conference and Training Symposium. National Association of Environmental Professionals; (856) 283-7816; www.naep.org.

Online
5/16-5/19: OSH Standards for the Construction Industry Trainer. Chesapeake Region Safety Council; (800) 875-4770; www.chesapeakesc.org.

Online
5/16-5/20: Mobile Crane Train-the-Trainer. North American Crane Bureau; (800) 654-5640; www.cranesafe.com.

Online
5/17 ● How Marketable Am I? How to Keep Your Career Moving Forward in Today's Job Market. Learn how to utilize the resources provided to benefit your career and understand how to keep your career moving forward in today's job market. ASSP Hispanic Safety Professionals Common Interest Group; https://bit.ly/3MOPcRU.

Phoenix, AZ
5/17-5/18: 10-Hr OSHA Construction. ETC Compliance Solutions; (602) 923-9673; www.e-t-c.com.

Boardman, OR
5/17-5/18: Confined Spaces Train-the-Trainer. D2000 Safety; (800) 551-8763; www.d2000safety.com.

Online
5/17-5/20: Work Health and Well-Being. Harvard School of Public Health; (617) 384-8692; https://ecpe.sph.harvard.edu.

Hillside, IL
5/19: Rigging Hazard Awareness. Construction Safety Council; (800) 552-7744; www.buildsafe.org.

Online
5/19-6/16 ● Risk Assessment. ASSP; (847) 699-2929; www.assp.org.

Online
5/19-6/16 ● Enterprise Risk Management for Safety Professionals. ASSP; (847) 699-2929; www.assp.org.

Online
5/19-6/16 ● Implementing ISO 45001. ASSP; (847) 699-2929; www.assp.org.

Online
5/23: Confined Space Safety. Argus Pacific; (206) 285-3373; www.arguspacific.com.

Online
5/23-5/25: AIHce EXP 2022: American Industrial Hygiene Conference and Expo. AIHA; (703) 849-8888; www.aihceexp.org.

Seattle, WA
5/23-5/26: OSH Standards for General Industry Trainer. Northwest Center for Occupational Health and Safety; (800) 326-7568; http://nwcenter.washington.edu.

Dallas, TX
5/24-5/27: Electrical Safety for Utilities. AVO Training; (877) 594-3156; www.avotraining.com.

JUNE 2022

Online
6/6-6/9: Mass Care/Emergency Assistance Planning and Operations. Emergency Management Institute; (301) 447-1000; http://training.fema.gov/emiweb.

Online
6/8-6/9: AAOHN National Conference. American Association of Occupational Health Nurses; (312) 321-5173; www.aaohn.org.

Hannover, Germany
6/20-6/25: Teams, Tactics, Technology—Connecting Protection and Rescue: Interschutz 2022. Hannover Fairs USA; +49 0 511 89 31622; www.interschutz.de/en.

Online
6/21-6/13: Construction Quality Management. Building Industry Association of Hawaii; (808) 847-4666; www.biahawaii.org.

San Fransisco, CA
6/27-6/30: AWMA 115th Annual Conference and Exhibition. Air and Waste Management Association; (412) 904-6018; www.awma.org.

Math Toolbox, continued from pp. 39-44

Answers: The Case of the Toxic Fume

You Do the Math

Your answers may vary slightly due to rounding.

1. $x = \sqrt{\frac{0.70 - 0.60 \cdot 0.04}{0.60 \cdot 10}} = 0.34\ m$ (rounded)

2. $x = \sqrt{\frac{1{,}400 - 110 \cdot 0.35}{110 \cdot 10}} = 1.11\ ft$ (rounded)

3. $x = \sqrt{\frac{0.70 - 0.75 \cdot 0.60 \cdot 0.04}{0.60 \cdot 7.5}} = 0.39\ m$ (rounded)

4. $x = \sqrt{\frac{1{,}400 - 0.75 \cdot 110 \cdot 0.35}{110 \cdot 7.5}} = 1.29\ ft$ (rounded)

5. $V_c = \frac{0.72}{10 \cdot 0.4^2 + 0.05} = 0.44\ m/s$ (rounded)

6. $V_c = \frac{0.72}{0.75 \cdot (10 \cdot 0.4^2 + 0.05)} = 0.58\ m/s$ (rounded)

7. $x = \sqrt{\frac{1{,}250 - 115 \cdot 0.65}{115 \cdot 10}} = 1.01\ ft$ (rounded)

8. $x = \sqrt{\frac{1{,}250 - 0.75 \cdot 115 \cdot 0.65}{115 \cdot 7.5}} = 1.18\ ft$ (rounded)

9. $V_c = \frac{1{,}125}{10 \cdot 1.15^2 + 0.45} = 82.27\ fpm$ (rounded)

10. $V_c = \frac{1{,}125}{0.75 \cdot (10 \cdot 1.15^2 + 0.45)} = 109.69\ fpm$ (rounded)

The Language of Local Exhaust Ventilation

11. g; 12. c; 13. b; 14. d; 15. a; 16. k; 17. l; 18. e; 19. i; 20. f; 21. j; 22. h.