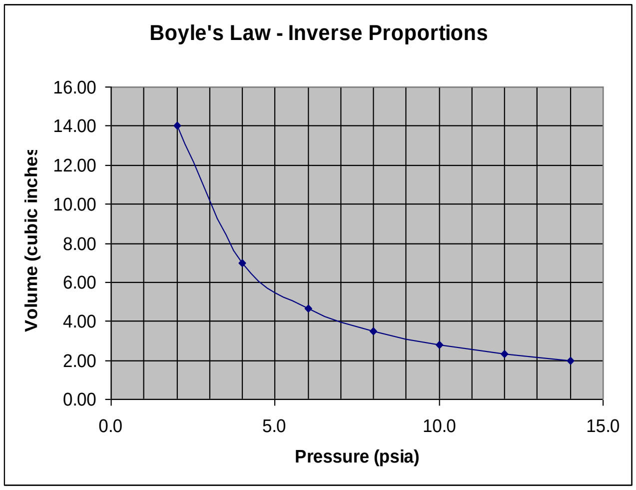
HVAC (47.0201) T-Chart

Describe the relationship between pressure and volume in the Refrigeration Cycle	=	Use reasoning to solve equations and justify the solution method

Program Task: Describe the relationship between pressure and volume in the Refrigeration Cycle.

Program Associated Vocabulary:
BOYLE'S LAW, OHMS LAW

Program Formulas and Procedures:
Boyle's Law is one of several examples of inverse proportions found in HVAC. Boyle's Law states that at constant temperature, the absolute pressure and the volume of gas are inversely proportional. The mathematical equation for Boyle's law is: PV = k
where: P denotes the absolute pressure of the system.
V is the volume of the gas.
k is a constant value representative of the pressure and volume of the system.



In the case of Boyle's Law, the constant value is always a theoretical value called "k" and the important thing to remember is that k always equals the product of Pressure x Volume (in the case of this theoretical gas, k = 28).

Example: Given that k remains constant at 28, what is the volume in cubic inches when the absolute pressure of the gas in question is 14 psia?

Solution:
PV = k
14V = 28
V = 2

PA Core Standard: CC.2.2.HS.D.9

Description: Use reasoning to solve equations and justify the solution method.

Math Associated Vocabulary:
INVERSE, RECIPROCAL, PROPORTION, CROSS MULTIPLICATION, RATIO, CONSTANT

Formulas and Procedures:
Direct Proportions:
Two quantities, A and B, are directly proportional if by whatever factor A changes, B changes by the same factor.

Example 1: Take the formula, distance = rate x time. If the rate remains constant, at 30 miles per hour, then the time and distance are directly proportional.

d = 30t
when t = 2, d = 60
when t = 4, d = 120

*Note that when the time doubles, so does the distance.

Example 2: If speed is directly proportional to distance, and a car can travel 100 miles at 50 miles per hour, how far can that car travel during the same time if it travels at 70 mph?

Step 1: Set up proportion.

$$\frac{50 \text{ mph}}{70 \text{ mph}} = \frac{100 \text{ mi.}}{x}$$

Step 2: Cross multiply and divide to solve.

50x = 70(100) → 50x = 7000 → x = 140 miles

Inverse Proportions:
Two quantities, A and B, are inversely proportional if by whatever factor A changes, B changes by the multiplicative inverse, or reciprocal of that factor.

Example 1: Take the formula, distance = rate x time. If the distance, 100 miles is constant, then as the rate increases, the time decreases.

100 = rt
When r = 100, t = 1
When r = 50, t = 2

*Note that when the rate doubles, the time is halved.

Example 2: The time needed to complete a job is inversely proportional to the number of people working. If it takes one person 8 hours to pain the room alone, how long would it take 4 people to paint a room?

Step 1: Set up the proportion.

$$\frac{1 \text{ person}}{4 \text{ people}} = \frac{8 \text{ hours}}{x \text{ hours}}$$

Step 2: Invert (flip) one ratio.

$$\frac{1 \text{ person}}{4 \text{ people}} = \frac{x \text{ hours}}{8 \text{ hours}}$$

Step 3: Cross-multiply and divide to solve.
4x = 8, x = 2
4 people can paint the room in 2 hours.

Instructor's Script - Comparing and Contrasting

Students need to be able to recognize direct and inverse proportional relationships in various forms. For instance, in some cases, they will just see an equation or formula and will have to recognize the relationship between two variables; in other instances, they will be given a word problem and will need to be able to recognize direct and inverse proportions in the situation or context presented. Scenarios that are more basic will identify the type of proportional relationship. The ability to recognize and use direct and inverse proportions to solve problems is essential in most career fields.

Common Mistakes Made By Students

When students compare direct and inverse proportional relationships, they may become confused and have difficulty differentiating one from the other. One way to keep them straight is to:

1. Set up one pair of values on the same line, e.g., 12 = 100 lbs.
2. Beneath that line, place the other pair of values, 24 x lbs.
3. Students need to be aware that direct proportions mean that as one variable increases so does the other variable. An inverse proportion means that one variable increases when the other one decreases. Students struggle with this concept.
4. If the problem is a direct proportion, students should cross multiply (24 times 100) and (12 times x) and then divide to solve the problem.
5. If an inverse relationship exists, then students should first invert one ratio before cross multiplying and dividing to solve the problem.

If need be, have the student set up the problem and do it both ways to see which answer makes sense! We know in problem #9, for example, that it won't take 5 rabbits more time than it took 1 rabbit to eat 20 carrots, so it must be an inverse proportion.

CTE Instructor's Extended Discussion

Though other systems are in use, compression refrigeration systems make up the vast majority of cooling systems throughout the world. In order to understand the compressed refrigerant cycle, one must understand Boyle's Law, which states that at constant temperature, the absolute pressure and the volume of gas are inversely proportional.

Using Boyles Law, if the pressure is doubled to 28 psia, the volume would be reduced again to ½ of 2 (1 cubic inch). Whatever happens to one variable, must happen inversely to the other, and in this case (and this case only) the two numbers must always = 28 when multiplied together (this is demonstrated in the graph above).

To help clarify the concept, discuss other examples of **inverse proportional relationships** in this lesson or in a follow up lesson. Some examples would include but are not limited to:

Boyle's Law - Pressure × Volume = k (Think of k as a place holder, a means to show that P × V is constant).
Pressure (A) and Volume (B) must be inversely proportional if k (C) is constant.

Ohm's Law - Amperes × Ohms = Volts
Amperage (A) and Ohms (B) must be inversely proportional if Voltage (C) is constant.

Watts - Volts × Amps = Watts
Voltage (A) and Amperage (B) must be inversely proportional if Wattage (C) is constant.

Work - Force × Distance = Work (Remember this when you teach the Torque Wrench.*)*
Force (A) and Distance (B) must be inversely proportional if Work (C) is constant.

Direct Proportions found in HVAC

This T-chart focuses on inverse proportional relationships, however, there are many examples of direct proportional relationships as well.

Example:
Volume = rate × time
Where: Rate (r = gallons per hour) × time (t = time of burn) = total Gallons of fuel burned (g)
$r \times t = g$ (r and t are directly proportional)
$2r \times t = 2g$ (we doubled the value on the left side by doubling the rate; we then had to double the value on the right side)
or $r \times 2t = 2g$ (we doubled the value on the left by doubling time; we then had to double the value on the right side)

HVAC (47.0201) T-Chart

Problems	Occupational (Contextual) Math Concepts Solutions
1. Work = Force × Distance. A technician using a 12" pipe wrench (12" from the fulcrum) must apply 100 pounds of force to tighten iron fittings. He switches to a 24" pipe wrench. Assuming that the work applied is equal, how much force is required with the 24" pipe wrench to provide an equal amount of torque at the iron fitting?	
2. One mechanic can perform preventive maintenance on 25 rooftop units in 62 hours. How many hours would it take 4 mechanics to do the same 25 units?	
3. One mechanic can perform preventive maintenance on 25 rooftop units in 62 hours. How many similar units would 4 mechanics be able to service in 62 hours?	

Problems	Related, Generic Math Concepts Solutions
4. If you need 5 pounds of chicken to serve 20 people, how many pounds will you need to serve 50 people?	
5. The pressure of a gas and its corresponding volume are inversely proportional. If the pressure of 0.24 m^3 is 0.5 atm, what would the pressure be of 0.060 m^3 of the same gas at the same temperature?	
6. If it takes 26 lbs. of metal to make 10 castings, how many pounds of metal will be needed to make 14 castings?	

Problems	PA Core Math Look Solutions
7. Given that y and x are **directly** proportional and y = 2 when x = 5, find the value of y when x = 15.	
8. Given that y and x are **inversely** proportional and y = 2 when x = 5, find the value of y when x = 15.	
9. If one rabbit can chew 20 carrots in 15 hours, how long will it take 5 rabbits to chew the same number of carrots?	

Problems	Occupational (Contextual) Math Concepts	Solutions
1. Work = Force × Distance. A technician using a 12" pipe wrench (12" from the fulcrum) must apply 100 pounds of force to tighten iron fittings. He switches to a 24" pipe wrench. Assuming that the work applied is equal, how much force is required with the 24" pipe wrench to provide an equal amount of torque at the iron fitting?	**(Inverse)** $\frac{12"}{24"} = \frac{100 \text{ lbs.}}{x \text{ lbs.}}$ $\frac{12"}{24"} = \frac{x \text{ lbs.}}{100 \text{ lbs.}}$ 1200 = 24x; x = 50 lbs.	Invert one ratio since it's an inverse proportion.
2. One mechanic can perform preventive maintenance on 25 rooftop units in 62 hours. How many hours would it take 4 mechanics to do the same 25 units?	**(Inverse)** $\frac{1 \text{ worker}}{4 \text{ workers}} = \frac{62 \text{ hours.}}{x \text{ workers}}$ $\frac{1 \text{ worker}}{4 \text{ workers}} = \frac{x \text{ hours}}{62 \text{ hours}}$ $\frac{1}{4} = \frac{x}{62} \rightarrow 4x = 1(62) \rightarrow x = 15.5 \text{ hours}$	Invert one ratio since it's an inverse proportion.
3. One mechanic can perform preventive maintenance on 25 rooftop units in 62 hours. How many similar units would 4 mechanics be able to service in 62 hours?	**(Direct)** $\frac{1}{4} = \frac{25}{x} \rightarrow x = 4(25) \rightarrow x = 100$ units serviced	

Problems	Related, Generic Math Concepts	Solutions
4. If you need 5 pounds of chicken to serve 20 people, how many pounds will you need to serve 50 people?	**(Direct)** $\frac{5 \text{ pounds}}{20 \text{ people}} = \frac{x \text{ pounds}}{50 \text{ people}} \rightarrow 20x = 5(50) \rightarrow 20x = 250$ $x = 12.5 \text{ pounds}$	
5. The pressure of a gas and its corresponding volume are inversely proportional. If the pressure of 0.24 m^3 is 0.5 atm, what would the pressure be of 0.060 m^3 of the same gas at the same temperature?	**(Inverse)** $\frac{0.24 \text{ m}^3}{0.060 \text{ m}^3} = \frac{0.5 \text{ atm}}{x \text{ atm}}$ $\frac{0.24 \text{ m}^3}{0.060 \text{ m}^3} = \frac{x \text{ atm}}{0.5 \text{ atm}}$ .24 × 0.5 = .060x	Invert one ratio since it is an inverse proportion. x = 2 atm
6. If it takes 26 lbs. of metal to make 10 castings, how many pounds of metal will be needed to make 14 castings?	**(Direct)** $\frac{10 \text{ castings}}{14 \text{ castings}} = \frac{26 \text{ lbs.}}{x \text{ lbs.}}$ 10x = 26(14) x = 36.4 lbs.	

Problems	PA Core Math Look	Solutions
7. Given that y and x are **directly** proportional and y = 2 when x = 5, find the value of y when x = 15.	**(Direct)** $\frac{5}{15} = \frac{2}{y} \rightarrow 5y = 2(15) \rightarrow y = 6$	
8. Given that y and x are **inversely** proportional and y = 2 when x = 5, find the value of y when x = 15.	**(Inverse)** $\frac{5}{15} = \frac{y}{2} \rightarrow 15y = 2(5) \rightarrow y = 0.667$	
9. If one rabbit can chew 20 carrots in 15 hours, how long will it take 5 rabbits to chew the same number of carrots?	**(Inverse)** $\frac{1}{5} = \frac{x}{15} \rightarrow 5x = 1(15) \rightarrow x = 3 \text{ hours}$	