HVAC (47.0201) T-Chart

Determine compression ratios	=	Use reasoning to solve equations and justify the solution method

Program Task: Determine compression ratios.

Program Associated Vocabulary:
RATIO, SCALE, PARTS PER X, PROPORTION, ABSOLUTE PRESSURE (PSIA)

Program Formulas and Procedures:
In HVAC work, there are a many different scenarios in which we analyze proportional relationships for assessment or diagnostic purposes.

Compression Ratio is an application of **direct proportion** in HVAC. Excessively high or low compression ratios are signs of trouble. They indicate low refrigerant flow and reduced cooling capacity. It is critical that the technician determine the cause and solution (e.g., dirty condenser, over charged, faulty compressor valves, worn rings, etc.).

To determine compression ratio, we use this formula:

$$\text{Compression ratio} = \frac{\text{Absolute Discharge Pressure}}{\text{Absolute Suction Pressure}}$$

NOTE: Absolute Pressure (psia) = gauge pressure + 14.7

Example: Direct Proportion
A compression ratio is equal to the absolute discharge pressure divided by the absolute suction pressure. If a compressor has a compression ratio of 4.5 and an absolute discharge pressure of 230 psia, what would the absolute suction pressure be?
In this scenario, a student would have to set up the proportions as follows:

$$\frac{4.5}{1} = \frac{230}{x} \quad \rightarrow \quad 4.5x = 230$$

$$\frac{4.5x}{4.5} = \frac{230}{4.5} \quad \rightarrow \quad x = 51.11$$

51.11 is the absolute suction pressure.

Example: Inverse Proportion
If the blower sheave has a 10" diameter and the motor sheave has a 5" diameter, and the motor is running at 1,725 rpm, at what speed will the blower sheave be turning?

The size of a sheave and its related rpm are inversely proportional.
Step 1: Set up the proportion. Step 2: Invert (flip) one ratio.

$$\frac{10''}{5''} = \frac{x \text{ rpm}}{1725 \text{ rpm}} \qquad \frac{10''}{5''} = \frac{1725 \text{ rpm}}{x \text{ rpm}}$$

Step 3: Cross-multiply and divide to solve.
10x = 8625, x = 862.5rpm
The blower sheave will be running at 862.5 rpm.

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.

$50x = 70(100) \rightarrow 50x = 7000 \rightarrow x = 140$ 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. Step 2: Invert (flip) one ratio.

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

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
Many times a compression ratio is not given and the HVAC technician must determine the compression ratio. He/She can use the compression ratio formula as a guideline to determine the ratio.

Example:
A technician determines that a certain R-22 refrigeration compressor has a suction pressure of 83.2 psia and a discharge pressure of 274.7 psia. What is the compression ratio (c) in this set of conditions?

Solve for c: $\frac{274.7}{83.2} = \frac{c}{1}$

$274.7 = 83.2c$

$3.302 = c$ (It is okay to round this to 3.3.)

Hence, the compression ratio is 3.3:1, or simply, **3.3**

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., $\frac{12}{24} = \frac{100 \text{ lbs.}}{x \text{ lbs.}}$
2. Beneath that line, place the other pair of values,
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

Compression ratios are not the only examples where we see $\frac{a}{b} = \frac{c}{d}$ as being a true statement. When we see terms like scale, rates, parts per million, ratios, proportions, etc., we should expect to see a proportional relationship.

Another example is the proportion of fresh air to return air as determined by damper position in an air handling unit. If the outside air damper and return air dampers are set to deliver 15% fresh air to a building, how many total cfm (d) of air are being delivered if the fresh air cfm = 740 cfm?

$\frac{15}{100} = \frac{740}{d}$

$15d = 74{,}000$

$d = 4{,}933$ cfm

$740/4933 = 0.15$ (i.e., 15%)

Problems	Occupational (Contextual) Math Concepts	Solutions
1. A technician determines that a certain R-134A system has a suction pressure of 50 psia and a discharge pressure of 200 psia. What is the compression ratio (c) in this set of conditions?		
2. A motor with a 3" sheave (diameter) is driving a fuel pump whose sheave has an 8" diameter. If the motor speed is 1,100 RPM's, at what speed (x) is the pump operating?		
3. A certain R-11 centrifugal chiller begins to surge (not good!) when the compression ratio exceeds 3.2. If the suction pressure is 8 psia and the discharge is 27 psia, should surging be expected?		
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. A technician determines that a certain R-134A system has a suction pressure of 50 psia and a discharge pressure of 200 psia. What is the compression ratio (c) in this set of conditions?		**(Direct)** 200 = 50c 4 = c In other words, the compression ratio = 4:1
2. A motor with a 3" sheave (diameter) is driving a fuel pump whose sheave has an 8" diameter. If the motor speed is 1,100 RPM's, at what speed (x) is the pump operating?		**(Inverse)** $\frac{3}{8} = \frac{1100}{x}$ Flip right side and solve $\frac{3}{8} = \frac{x}{1100}$ 3300 = 8x 413 = Fuel Pump RPM
3. A certain R-11 centrifugal chiller begins to surge (not good!) when the compression ratio exceeds 3.2. If the suction pressure is 8 psia and the discharge is 27 psia, should surging be expected?		**(Direct)** 27 = 8c 3.375 = c Since 3.375 is greater than 3.2, this chiller may be surging!
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)** $\frac{5 \text{ pounds}}{20 \text{ people}} = \frac{x \text{ pounds}}{50 \text{ people}} \rightarrow 20x = 5(50) \rightarrow 20x = 250$ $x = 12.5$ 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)** $\frac{0.24 \text{ m}^3}{0.060 \text{ m}^3} = \frac{0.5 \text{ atm}}{x \text{ atm}}$ $\frac{0.24 \text{ m}^3}{0.060 \text{ m}^3} = \frac{x \text{ atm}}{0.5 \text{ atm}}$ $.24 \times 0.5 = .060x$ 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)** $\frac{1}{5} = \frac{x}{15} \rightarrow 5x = 1(15) \rightarrow x = 3$ hours