The Elements of the Parts

Print:

How ratios and proportions are used by a blending technician in creating metal alloys

Industry Sector: Advanced Manufacturing
Content Area: Mathematics
Core Topic: Ratios, rates and proportions

Expand All | Collapse All

Common Core State Standards

Standards for Mathematical Practice

1. Make sense of problems and persevere in solving them.
2. Reason abstractly and quantitatively.
3. Construct viable arguments and critique the reasoning of others.
4. Model with mathematics.
5. Use appropriate tools strategically.
6. Attend to precision.

High School—Number & Quantity: Quantities

N-Q.1. Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

N-Q.2. Define appropriate quantities for the purpose of descriptive modeling.

N-Q.3. Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

Adult Basic Education Standards

Number Sense

N-1: Represent and use numbers in a variety of equivalent forms in contextual situations.
N-2: Understand meanings of operations and how they relate to one another.
N-3: Compute fluently and make reasonable estimates.

Patterns, Functions and Algebra

> **P-2:** Articulate and represent number and data relationships using words, tables, graphs, rules, and equations.

Geometry and Measurement

> **G-4:** Understand measurable attributes of objects and the units, systems, and processes of measurement and apply appropriate techniques, tools, and formulas to determine measurements.

Industry Overview

Today's Manufacturing Workplace

A manufacturing renaissance is occurring in the United States. The United States is the largest manufacturing economy in the world, producing 21 percent of the goods manufactured across the globe. In addition to the 12 million Americans working directly in the manufacturing industry, manufacturing supports more than 6.5 million other jobs, thus accounting for nearly 17 percent of all private sector jobs in the United States. In 2010, the average U.S. manufacturing worker earned $77,186, including pay and benefits (the average in all industries was $56,436).[1]

While manufacturing jobs in Massachusetts have declined, as they have nationally, manufacturing is still a critical industry in this state and provides opportunities for good, high-paying jobs. In the Greater Boston area, most of the manufacturing jobs are in computer and electronics companies, and much of the state relies on manufacturing positions in these and other very high-tech areas, such as aerospace and biotechnology.[2]

Advanced manufacturing involves the use of computers and technology in the manufacture of products. While not all manufacturing companies use technological innovations in developing their products or processes, the competitive advantage of the United States in the manufacture of goods relies on technological innovations. This means that today's manufacturing workplace is usually highly technical, which accounts for the high-paying positions many workers in this field receive in compensation for their work. It also means that today's advanced manufacturing workplace is very different from many people's conceptions of factories and mills as dark, dirty, and unsafe. Today's advanced manufacturing facilities are usually bright, clean, and very safe, and the emphasis is on working efficiently—with as little waste as possible.

In the advanced manufacturing industry, there has been a marked shift from the traditional role of line workers to workers who demonstrate creativity and innovation. Innovation is a hallmark of the U.S. manufacturing industry, and key to maintaining its position in the global market since products can often be produced at a lower cost in developing countries. Critical-thinking, problem solving and reasoning are important components of the innovation process. Today's manufacturing workers are expected to formulate solutions to problems using critical thinking and reasoning skills while working independently and/or in teams.

1. http://www.nam.org/~/media/AF4039988F9241C09218152A709CD06D.ashx
2. http://www.bostonglobe.com/business/2012/05/08/high-end-factory-jobs-boston-paying-high-wages/3gZuNc6GywDGKoYNP2hnaO/story.html?camp=pm

Careers in Advanced Manufacturing

The manufacturing sector includes jobs related to planning, managing, and performing the processing of materials into intermediate or final products and related activities such as production planning and control, maintenance, and engineering. Thus, this industry includes not only those people who actually produce the manufactured goods, but also managers, maintenance staff, scientists and researchers, analysts, administrative personnel, and IT personnel.

Career Pathways

The manufacturing industry includes six career pathways:

- Production is the construction and assembly of parts and final products. People in these positions work in factories and mills, with machines, to make or assemble parts, construct components of parts (such as plastics), and print materials. Occupations in this pathway range from production helpers who move parts and materials around the factory, to numerical control machine operators who run the computer-controlled machines that modify metal and plastic to create products, to manufacturing production technicians who oversee production.

- Manufacturing production process development occupations are involved in designing products and manufacturing processes. People in these occupations work with production workers to set up the machines and processes to develop new products. These occupations include engineers and production managers.

- Maintenance, installation and repair workers take care of products after they've been sold and delivered to customers—they install the products, perform maintenance on machines, tools, and equipment so that they work properly, and repair systems that are not performing adequately. Workers in this pathway include automotive technicians, automotive electronics installers, building maintenance workers, industrial electronics repairers, industrial machinery mechanics, millwrights, and small engine mechanics.

- Quality assurance is provided by quality control inspectors and technicians, who ensure that products both meet design standards and are of high quality.

- Logistics and inventory control workers ensure that those working in Production have the materials they need to complete their work. Workers in these occupations inventory materials and products, move materials to the line, and pack and ship finished products. Thus, they include production and planning clerks, and operators of moving machinery such as cranes and forklifts, and packers.

- Health, safety and environmental assurance occupations are focused on keeping the workplace safe by ensuring that workers are using equipment safely and that manufacturing processes are as safe as they can be. The also conduct investigations and conduct inspections.

Mathematics and Communication Skills Needed in Advanced Manufacturing

Mathematics and communication are key skills needed for success in today's high-performance advanced manufacturing workplaces. Mathematics is used in the advanced manufacturing industry to measure the amounts and sizes of materials and parts, create "recipes" used to manufacture man-made materials, and analyze data. Data analysis is critical at many levels of a manufacturing organization in order to ensure quality and to continuously improve both quality and processes. Today's manufacturing industry must operate extremely efficiently and produce very high-quality products in order to maintain competitiveness. Many front-line workers are involved in collecting data and working to improve quality and efficiency. Thus, in addition to basic mathematical calculations (which rarely involve simple whole numbers), workers are engaged in mathematical reasoning and solving problems using a variety of mathematical tools.

To succeed and move up the ladder in today's advanced manufacturing workplace, workers need reading skills to understand technical concepts, vocabulary, and to bring together information needed for a particular situation; to locate, organize, and document written information from various sources needed by co-workers and customers; and to locate written information needed by co-workers and customers. They need to use correct grammar, punctuation and terminology to write and edit documents and to develop and deliver formal and informal presentations using appropriate media to engage and inform audiences. In addition, they need to interpret verbal and nonverbal behaviors to enhance communication with co-workers and clients/participants; apply active listening skills to obtain and clarify information; and interpret and use information in tables, charts, and figures to support written and oral communications. They also must communicate with co-workers and customers using technology tools. As they move up the corporate ladder they will need to explain written organizational policies, rules and procedures to help employees perform their jobs.

Career Opportunities in Advanced Manufacturing with Education from Community Colleges

Massachusetts Community Colleges play an important role in preparing the state's citizens to take advantage of the career opportunities available in advanced manufacturing. Degree and certificate programs prepare students to enter advanced manufacturing occupations, including:

- production occupations, including people who work as assemblers (such as airplane assemblers), machine operators, machinists, systems operators, CNC machine tool operators, machine setters, laminators/fabricators, metal and plastic workers, packers, molders, semiconductor processing operators, welders and solderers, tool and die makers, and other production workers;

- manufacturing production process development occupations, including numerical control tool programmers who write the programs that control machine tools and industrial production managers who plan and oversee production;

- maintenance, installation and repair occupations include automotive, electronics, and biotechnology technicians, industrial machinery mechanics, and millwrights (who install and maintain heavy equipment);

- quality assurance occupations including quality control technicians and inspectors.

Recent Career Opportunities in Massachusetts

The following is a sample of advanced manufacturing job listings in Massachusetts that require associate's degree or certificate:

- Manufacturing Engineering Technician, Randstad Corporation, Framingham, MA, [show]
- Quality Control Technician, QD Vision, Lexington, MA [show]
- Manufacturing Technican, Hologic, Marlborough, MA [show]

Employment Outlook for Advanced Manufacturing

Advanced manufacturing continues to be a high-growth industry, given the knowledge capital in the United States. However, the work in this industry is increasingly technical and requires far fewer workers as more tasks are automated. Entry-level positions in this industry require the same skills that only a select group of highly-experienced and well-paid workers once had. Unfortunately manufacturers find it difficult to fill these high-skill positions. A 2011 survey found that there is a persistent skills gap between the skills that are needed in the today's manufacturing workplace and the skills that candidates bring to the workforce.

Most of the advanced manufacturing companies in Massachusetts are small to mid-sized operations that employ smaller numbers of workers and rely on computer-operated machinery for production. While the numbers of workers are smaller than in the past, the more highly-skilled nature of the work means that these are high-paying jobs and provide workers with opportunities to grow through training and education and to be part of the effort to innovate.

Resources:

Advanced Manufacturing Industry

- National Council for Advanced Manufacturing
- Advanced Manufacturing
- Brookings: "Why Does Manufacturing Matter? Which Manufacturing Matters?" (2012)
- National Association of Manufacturers: "A Manufacturing Renaissance: Four Goals for Economic Growth" (2012)

Advanced Manufacturing Industry Outlook Information

- Bureau of Labor Statistics: Manufacturing Industry at a Glance
- Massachusetts Labor Market Data
- Massachusetts Career Information System

Careers in Advanced Manufacturing

- Massachusetts Career Information System
- Manufacturing Career Opportunities
- Manufacturing Career Pathways
- Industry Competency Model for Advanced Manufacturing shows the skills and knowledge needed to work in this industry
- National Association of State Directors of Career Technical Education Consortium's Common Career Technical Core
- National Association of State Directors of Career Technical Education Consortium's Knowledge and Skills: Manufacturing
- O*NET
- WorkKeys Occupational Profiles
- Manufacturing's Missing Generation
- A Career in Toolmaking or Machining Technologies: The Right Choice for Students, Community, & Country

Workplace Scenario (8th Grade Level)

This scenario is based on the work of a blending technician. For more information, review this webpage.

You work at a mid-sized manufacturing plant in Southeastern Massachusetts. Your employer is a leading producer of precision powder metal gears, sprockets and complex structural components. You are a blending technician at the company. This means you measure and mix the materials used in a powder metallurgy process. This is the process that makes metal shapes using powder metals. Your job is to find out the amount of the various powdered metal and other elements used in the alloy mixes. The metals include carbon steel, graphite, copper and iron. They are mixed based on proportions listed in recipes. These recipes are developed by a metallurgist at the company. You typically measure the elements by weighing each element on a scale. Then you add it to the mix. You have to know how much alloy mix by weight will produce how many parts. For example, it takes an alloy mix weighing 200 pounds to make 400 parts for one product the plant produces. Another product takes an alloy mix weighing 500 pounds to make 1000 parts.

The alloy mix is blended for a prescribed time, making it a uniform consistency. The alloy mix is then fed into a die and compacted into the desired shape. It is then ejected from the die. Each alloy mix is designed to produce a product with a specific strength and weight. Typically, you make several batches of an alloy mix. You vary it according to the properties needed. The metallurgist changes the recipe depending on the product to be made. For example, specific alloys are needed to make a product that is stronger or more flexible. This means that while the same elements may be used, they will be used in different proportions. At other times, different elements are added to the alloy. This gives the resulting product different properties. For example, an element might be added to provide greater tensile strength. Tensile strength refers to how much a product can be stretched or drawn out.

Workplace Scenario (High School Level)

This scenario is based on the work of a blending technician. For more information, review this webpage.

You work at a mid-sized manufacturing plant in Southeastern Massachusetts that is a leading producer of precision powder metal gears, sprockets and complex structural components. As a blending technician, you measure and mix the materials used in a powder metallurgy process, which makes metal shapes using powder metals. Your job is to determine the amount of the various powdered metals—such as carbon steel, graphite, copper and iron—and other elements used in the alloy mixes based on the proportions listed in recipes developed by a metallurgist at the company. You typically measure the elements by measuring each element on a scale and adding it to the mix. You have to know how much alloy mix by weight will produce how many parts. For example, it takes an alloy mix weighing 200 pounds to make 400 parts for one product the plant produces. Another product takes an alloy mix weighing 500 pounds to make 1000 parts.

The alloy mix is blended for a prescribed time to homogenize the mix, making it a uniform consistency. The alloy mix is then fed into a die, compacted into the desired shape, and ejected from the die. Each alloy mix is designed to produce a product with specific properties of strength and weight. Typically, you make several batches of an alloy mix, varying it according to the properties needed. Depending on the product to be made, the metallurgist changes the recipe to make a product that is stronger or more flexible. This means that while the same elements may be used, they will be used in different proportions. At other times, different elements are added to the alloy to give the resulting product different properties, such as greater tensile strength.

Core instructional context

Ratios, rates, and proportions are used when making comparisons between different quantities. A ratio is a comparison between two quantities, and a rate is a special kind of ratio that compares the change in one measurement to the change in another measurement. Proportions are two ratios that have been set equal. These mathematical comparisons allow people to understand and communicate about how quantities are related to each other, such as how long it takes to perform certain tasks (for example, extruding one mold takes 1.25 minutes on average if 48 molds are produced each hour), or the cost per unit for an item (for example, $7.99 per pound for one brand of sliced deli cheese versus $5.99 per pound for another brand). Proportional reasoning and understanding the relative way quantities change (for every 5 units up we move 3 units over), is an important building block of algebraic thinking. Developing a students proportional reasoning skills, will help students differentiate between processes that are additive and multiplicative, interpret graphs that represent proportional relationships, and open pathways to further mathematical understandings.

Ratios and rates are important in many industries—to monitor how efficiently work is done, to control machinery, or to determine the quantity of medication to administer. In manufacturing, workers and managers may look at the rate of production and the spoilage rate. For example, a certain amount of goods produced in the production process will not pass a quality standard and are accounted for as a spoilage rate; however, an overly high rate of unusable products indicates a problem in production that needs to be dealt with, such as machine that needs to be replaced. Materials such as metal alloys and plastics are manufactured using recipes that are based on ratios and workers will often use proportions to create different batch sizes.

Powder Metallurgy
Powder metallurgy (PM) is a process for manufacturing metal parts such as metal gears, sprockets, rods and surgical equipment. Over 70% of PM parts are used in the automotive industry. Industry professionals consider it to be a better, greener process than other types of metalworking because there is little scrap loss (more than 97% of the raw materials go into the final product). The Metal Powder Industries Federation has an extensive website with more detailed information.

Worked Example

Powdered Element	**Percent of AlloyMmix**	**Measured Weight to Use**
Iron	98%	
Graphite	1%	
Lubricant	1%	

You realize that yesterday you mixed a 90-pound batch of steel alloy using the recipe above, but were told to stop processing it because the customer changed the spec. So, the mixture was never heated—it is still in powder form. You can save your company money if you can figure out how to use the 90 pounds of steel alloy powder that has already been measured to make the 175 pounds mix of steel alloy for the car company. How much more iron, graphite, and lubricant do you add?

- Calculate the amount of additional steel needed
175 lbs. desired – 90 lbs. pre-mixed = 85 lbs. left to mix

- Calculate the lbs. of each ingredient needed to add 85 lbs. to the mix.
Iron: 0.98 * 85 lbs. = 83.3 lbs.

Graphite: 0.01 * 85 lbs. = 0.85 lbs.
Lubricant: 0.01 * 85 lbs. = 0.85 lbs.

Contextualized learning activities

Reading the Scenario

- Ask students to read the scenario. Have them look for unfamiliar words or concepts, and write those on the board.
- To familiarize students with the field and the manufacturing process, show at least one video about powder metallurgy. There are several freely available videos on YouTube:
  - Powder Metallurgy Touches Your Life, Part 1 and Part 2: This two-part video series provides an introduction to powdered metallurgy and provides many examples of products fabricated using PM.
  - Career Gates PA – Powdered Metals: This segment from the PBS series *Career Gates*, provides a quick look at a career in powdered metal fabrication and engineering.
- Ask students to reread the scenario and share their ideas for how mathematics is used in this career.

Building from Prior Knowledge

Many of your students will have more experience measuring ingredients to cook food than mixing metals for powder metallurgy parts. How does the measuring of ingredients for making a loaf of bread differ from the measuring of powdered metals to make 1,000 pounds of gears for a car? If students need hands-on experience to understand that weight is a better measure than volume for large recipes of anything, bring in flour, a digital scale, cup measures, and a sifter. Have students experiment with different ways of measuring a cup of flour and then weighing them. Have them create a chart to see how the different ways of measuring flour affects the weight (sifting, scooping, banging cup on the table, packing it with a spoon). What are the consequences of using volume versus weight when baking large amounts of bread? Now discuss their thoughts about measuring powdered metals in terms of volume or weight. Which is the best measure?

Contextualized Problems

Before having students work on problems on their own, you might first have them work through the worked example problem, either individually or in pairs, and share their answers with the class.

1. There are three blending technicians at your company and you are each measuring materials for three slightly different alloy mixes. You typically have your own digital scales, but today only two of the scales are working correctly. One of the technicians tells you that he has developed a work around: he weighed one pound of powdered copper and then put it in a measuring cup. He knows that he needs 98 pounds of copper in the final product, so he is measuring the copper in the cup instead of using the scale. What do you think of his work around? Explain.

   Answer: This technique should work well as long as the technician is always measuring copper. Other metals will have different densities, which means that 1 cup of one metal may not weigh the same as 1 cup of another.

2. The metallurgist gives you the following recipe for steel alloy and asks you to mix 300 pounds. You apologize, but tell him that you cannot mix this particular steel. Why?

Powdered Element	**Percent of Alloy Mix**
Iron	95%
Copper	2%

Carbon	1.2%
Chromium	0.9%
Lubricant	1%

Answer: The total exceeds 100%—the metallurgist made a mistake in his math.

3. Your plant has produced two award-winning PM parts this year. The marketing department is publishing an international press release and needs to know the size and weight of each part, in both metric and standard U.S. measures. You consult the fabrication chart from the metallurgist and see that he only listed the measurements in metric units. You look up the conversion and see that 1 millimeter = 0.0393701 inches and 1 gram = 0.0022 pounds. Convert the measurements from metric to U.S. standard for the parts below.

Part	**Size (mm and in.)**	**Weight (g and lb.)**
Auto transmission sprockets: Each transmission has two sprockets in the set: a drive sprocket and a driven sprocket 	Metric: Drive: 90–100 mm Driven: 100–106 mm	Metric: Drive: 450–590 g Driven: 505–570 g
	U.S. standard (in.) Drive: Driven:	U.S. standard (lbs.) Drive: Driven:
Polarizing keys: These keys are used as rack and panel connectors on aircraft flight data recorders. 	Metric: 2.05 mm	Metric: 0.5 g
	U.S. standard (in.):	U.S. standard (lbs. or oz.):

Photos courtesy of Metal Powder Industries Federation, Princeton, NJ)

Answers:

Sprockets:
Drive = 3.54–3.94 in. & 0.99–1.30 lbs.
Driven = 3.94–4.17 in. & 1.11–1.25 lbs.

Polarizing Keys:
0.08 in. & 0.02 oz.

4. Your company is working with a major car company to develop a lighter version of one of their top-selling cars. One of the strategies to reduce the weight of the car is to lighten the gears. The metallurgist at your company creates two recipes for the gears, as shown in the tables below

(one for a steel alloy and the second for nickel steel). The total mix for each alloy should weigh 175 pounds. How much of each element by weight should be added to the alloy mixes?

Alloy: Steel

Powdered Element	Percent of Alloy Mix	Measured Weight to Use
Iron	98%	
Graphite	1%	
Lubricant	1%	

Alloy: Nickel Steel

Powdered Element	Percent of Alloy Mix	Measured Weight to Use
Iron	96%	
Nickel	2%	
Graphite	1%	
Lubricant	1%	

Answers

Steel:
Iron = 171.5 lbs.; Graphite = 1.75 lbs.; Lubricant = 1.75 lbs.

Nickel Steel:
Iron = 168 lbs.; Nickel = 3.5 lbs.; Graphite = 1.75 lbs.; Lubricant = 1.75 lbs.

5. You get a request to mix an aluminum alloy that will be used to produce 120,000 camshift bearing caps. You weigh the sample cap and see that it weighs 225 grams. The metallurgist gives you the formula as shown in the table below.

Alloy: Aluminum

Powdered Element	Percent of Alloy Mix	Measured Weight to Use
Aluminum	94%	
Copper	2%	
Magnesium	1%	
Silicon	1%	
Lubricant	1%	

a. How many pounds of each element will you need to fulfill the order?
b. Your machinery can only handle 5,000 pounds of mix at a time. How many batches will you need to mix, and what is the measured weight of each element you'll use in each batch?

Answers:

a. Aluminum = 55,836 lbs.; Copper = 1,188 lbs.; Magnesium = 594 lbs.; Silicon = 594 lbs.; Lubricant = 594 lbs.
b. 12 batches. Aluminum = 4,700 lbs.; Copper = 100 lbs.; Magnesium = 50 lbs.; Silicon = 50 lbs.; Lubricant = 50 lbs.

6. One of your powdered metal suppliers was unable to deliver your order last week, so your stock of several metal elements is low. You have three orders from different clients (below), but you are fairly certain you do not have enough supplies to mix all three orders. In stock, you have 285 pounds of iron, 3 pounds graphite, and 6 pounds nickel. Which of the order(s) should you fulfill and why?

   Orders:

   - Fhjord Motor Company: 200 pounds steel alloy (98% iron, 1% graphite, 1% lubricant)
   - Standard Motors: 120 pounds nickel steel (96% iron, 2% nickel, 1% graphite, 1% lubricant)
   - Bowing Aircraft: 175 pounds nickel steel alloy (96% iron, 2% nickel, 1% graphite, 1% lubricant)

   Answer: You fulfill the orders for Standard Motors and Bowing Aircraft. Even though each order is smaller than Fhjord Motor Company, your company sells more total product.

Contextualized test items

1. Your supply of powdered copper and graphite are running low—you only have 2 pounds of each left. The metallurgist gives you a recipe for steel that has a little copper in it to make it stronger. What is the maximum amount of total product you can mix with your current supplies?

   Alloy: Steel

Powdered Element	Percent of Alloy Mix
Iron	96%
Copper	2%
Graphite	1%
Lubricant	1%

   a. **100 pounds**
   b. 200 pounds
   c. 300 pounds
   d. None of the above

2. Your company has been experimenting with formulas to make a cost-effective titanium alloy using powder metal technology. The metallurgist gives you a new recipe and asks you to measure a small batch of just 25 pounds. How much titanium do you use?

   Alloy: Titanium

Powdered Element	Percent of Alloy Mix
Aluminum	5.5%
Vanadium	3.5%
Tin	1.5%
Copper	0.40%
Iron	0.35%
Carbon	0.10%
Silicon	0.10%

Lubricant	1.0%
Titanium	remainder

a. 19.5 pounds
b. 20.2 pounds
c. 21.43 pounds
d. **21.89 pounds**

3. A blending technician measures powdered metals by both volume and weight to make precise recipes.

   a. This statement is true.
   b. **This statement is false.**

Contextualized project

According to work done by the Right Question Institute, students can be more successful learners if they learn how to ask questions. Their Question Formulation Technique (QFT) provides strategies for explicitly teaching this skill in the classroom. Using this idea that student-generated questions are a powerful learning tool, try the QFT technique to help students generate their own math questions about powder metallurgy and the scenario presented in this module.

1. Divide class into teams of three and ask them to write questions that involve computation and questions that involve concepts only (no computation needed to solve the problem); questions that are multistep and questions that are just one step. Teams should work to produce as many questions as they can without stopping to discuss or answer them.
2. Next, they should look at the questions and decide if each is conceptual or procedural, multistep or single step, and should discuss the advantages and disadvantages of each type of question.
3. Teams should then prioritize the three most important questions on their list.
4. Finally, have teams share their questions. You may either facilitate a full class discussion to identify the three most important questions in the whole class or teams can swap their questions with another team for a competition.

To learn more, you may read an article and download free resources (login required) from the Right Question Institute to help with facilitating QFT in your classroom.

Additional or extension activities, multimedia, readings and/or resources

Powder Metallurgy Touches Your Life, Part 1 and Part 2
This two part video series provides an introduction to powdered metallurgy and provides many examples of products that were fabricated using PM.

Career Gates PA – Powdered Metals
This segment from the PBS series called Career Gate, provides a quick look at a career in powdered metal fabrication and engineering.

Metal Powder Industries Federation: A Career in PM
For students interested in learning more about the profession.

Powder Metallurgy Technologist Certification Program
This certification program does not require a college degree.

Universities with PM Programs

Please contact ETLO to report any broken links or other problems with this page.

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