****

**What does a Pipe have to do with Math?**

**VIDEO:** [**https://youtu.be/sn9LPikK\_9w**](https://youtu.be/sn9LPikK_9w)

**Lesson Plan**

**Teacher Note:** Please preview the entire video and pre-work the solutions in order to anticipate students’ needs, misconceptions, and resources unique to your classroom.

You will also need to determine the background knowledge of your students regarding the following topics, and decide the best method for providing that background in order to support the conceptual understanding of the mathematics shown in the video.

* What is a formula? Why do we use them?

**Common Core Mathematical Content Standards**

* 6.EE.2 Write, read and evaluate expressions in which letters stand for numbers
* 6.EE.9 Represent and analyze quantitative relationships between independent and dependent variables.
* 7.EE Use properties of operations to generate equivalent expressions
* 7.EE Solve real-life and mathematical problems using numerical and algebraic expressions and equations.
* 7.RP.3 Use proportional relationships to solve multistep ratio problems.

**Common Core Mathematical Practice Standards**

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.

7. Look for and make use of structure

**Company Information**

**Fincantieri Marinette Marine (FMM)** was founded in 1942 along the Menominee River in Marinette, Wisconsin to meet America's growing demand for naval construction. From humble beginnings with a contract to build five wooden barges, **FMM** has grown into a world-class shipbuilder, having designed and built more than 1,500 vessels.

Parent company, **FINCANTIERI**, has recently completed a $73.5 million capital expansion program for **Fincantieri Marinette Marine** which has transformed **FMM** into a modern shipbuilding powerhouse, now with 550,000 square feet of manufacturing, warehouse and receiving space, and the capacity to simultaneously build six Littoral Combat Ships in serial production. **FMM** employs cutting-edge computer-controlled manufacturing equipment and has heavy-lift capabilities to meet the most demanding requirement.

**FMM** boasts some of the best engineering and naval architecture minds in the industry, a skilled, safe and motivated workforce, and a management team keenly focused on quality. The company is internationally recognized for innovative and highly efficient, modular, subassembly and assembly-line manufacturing techniques. This sophistication in construction methods has allowed **Fincantieri Marinette Marine** to build some of the most technologically advanced vessels on the planet.

**Fincantieri Marinette Marine’s** performance on government contracts is impressive. Its portfolio includes the U.S. Navy’s Littoral Combat Ship, the improved Navy Lighterage System, mine countermeasure vessels and ocean tugs, as well as U.S. Coast Guard icebreakers, buoy tenders and response vessels. Because of its record of delivering ahead of schedule and within contracted costs, **FMM** has a long-standing relationship with the United States Navy and United States Coast Guard.

**Fincantieri Marinette Marine** is an FOCI mitigated SSA company and is part of the **Fincantieri Marine Group**, the United States division of Italian enterprise **FINCANTIERI**, one of the world's largest shipbuilders with 20 shipyards on four different continents and employing nearly 20,000 shipbuilding professionals. The company has a history dating back 200 years and a track record of producing more than 7,000 ships.

**Summary**

Clogged pipes don’t just happen in homes, they can happen on ships too. In this video you will learn how and why a ship’s pipe systems are cleaned. You will also help solve the mathematical calculations to make the flushing process efficient and effective. The ship can’t sail without your work on this!

**Pre-Activity Discussion:**

* Brainstorm with students about things that get “clogged” (toilets, gutters, storm drains). What are ways that they have used to get them “unclogged”? What are some things that affect the effectiveness of the method you choose? (force, time, material)
* Discuss with students the waste and debris that is generated by the manufacturing process…even debris we may not be able to see.
* Discuss how this debris can affect the performance of the mechanical systems of the item being built…in this case a ship.
* Discuss the two types of debris generated, industrial and non-industrial.
	+ Industrial waste is the waste produced by industrial activity which includes any material that is rendered useless during a manufacturing process such as that of factories, industries, mills, and mining operations. It does not include hazardous waste.
	+ Non-industrial waste is anything not produced by industrial activity, such as schools, hospitals, restaurants.
* Vocabulary
	+ Turbulent flow – a type of fluid (gas or liquid) flow in which the fluid undergoes irregular fluctuations, or mixing, in contrast to laminar flow, in which the fluid moves in smooth paths or layers. In turbulent flow the speed of the fluid at a point is continuously undergoing changes in both magnitude and direction.



* + Reynolds number (Re) – a dimensionless quantity that is used in the study of fluid mechanics to help predict the flow patterns in different situations.
	+ Flow Rate (gal/min) – the volume of fluid that passes per unit time
	+ Density (lbs/ft3) - the degree of compactness of a substance
	+ Diameter (inches) – distance from one side of a circle to the other and passing through the center of the circle.
	+ Viscosity (centipoise) - the state of being thick, sticky, and semifluid in consistency, due to internal friction.
	+ Flushing Rig – An external device that is hooked up to various sections of a piping system. Fluid is pushed through the system and the debris is collected in the filters of the flushing rig.

**Differentiation:**

* Unit analysis could be used when solving the problems posed.
* Students may also benefit by working with others as part of a partner/group investigation.

**Part 1: (0:00 – 2:58)**

BREAK 1

* Information presented in Part 1
	+ Turbulent flow requires a minimum Reynolds number of 4000 in this situation.
	+ Pipes in the piping system being flushed have an inside diameter, d, of 2.209 inches.
	+ Formula for Reynolds number

Re = $\frac{50.6 Qρ}{dη}$

Q = flow rate (Gallons/minute or GPM)

ρ = density of fluid (lbs/ft^3)

d = inside diameter of the pipe (inches)

η = viscosity of fluid (centipoise)

|  |  |  |  |
| --- | --- | --- | --- |
| **Fluid Type** | **Fluid Temperature****(Fahrenheit)** | **Density of Fluid (ρ)** | **Viscosity of fluid (η)** |
| Fresh Water | 60 | 62.371 | 1.124 |
| Fresh Water | 100 | 61.996 | 0.684 |
| Fresh Water | 140 | 61.376 | 0.469 |
| Hydraulic Oil | 60 | 54.154 | 72.571 |
| Hydraulic Oil | 100 | 53.190 | 21.536 |
| Hydraulic Oil | 140 | 52.225 | 9.300 |

* Problems posed:

1. Using fresh water at 100 degrees Fahrenheit, what flow rate would be required to achieve turbulent flow in the system?

2. Using hydraulic oil at 100 degrees Fahrenheit, what flow rate would be required to achieve turbulent flow in the system?

* Have students use Part 1 of student handout to document their solution methods.
* Before showing Part 2 have students share their answers and methods.
* Discuss any errors or misconceptions in student thinking and calculations.
* Discuss how the temperature, density and viscosity of the fluid type affect the Reynolds number (turbulent flow).

**Part 2: (3:03 – 4:44)**

 BREAK 2

* Information presented in Part 2
	+ The stricter the cleanliness requirement, the longer the flushing time required…unless we can be more efficient with our flushing processes.
	+ Initial clean - Circulating flushing fluid through the pipe system segment until the cleanliness requirement is met.
	+ Final flush - Performed in presences of the Customer Representative or Regulatory Authority to validate results.
	+ Shipbuilding Industry standard is to perform the final flush by circulating the flushing fluid through the entire piping system segment volume 20 times or at least for 20 minutes whichever is greater.
* Problems posed:

3. Assuming the pipe system volume being flushed is 100 Gallons and using fresh water at 100 degrees F, how many minutes will it take to circulate the pipe system 20 times?

4. Assuming the pipe system volume being flushed is 100 Gallons and using Hydraulic Oil at 100 degrees F, how many minutes will it take to circulate the pipe system 20 times?

* Have students use part one of student handout to document their solution methods.
* Have students share their answers and methods.
* Discuss any errors or misconceptions in student thinking and calculations.
* Bonus Question

5. We have seen in this example that systems can be flushed more quickly with oil versus water. But using oil introduces other variables like safety considerations, cost of purchasing oil and disposal of oil. How could we use water to flush that would give us the same results as oil, without the extra costs?

**Part 3: (4:50–** **5:04)**

**Extension:**

* Use other fluid values from the chart to calculate other Reynolds numbers.
* Have students use the multiplication and division relationships in the Re formula to ESTIMATE the solutions when values are changed. Example – if the viscosity is doubled, what would happen to the flow rate?
* Why only water or hydraulic oil? Are there any other fluids that are used to flush piping systems? If so, determine density and viscosity at various temperatures and recalculate questions 1 - 4. With all the information you have gathered, prepare a proposal to persuade the company to change to your flushing method. Be sure to include supporting details related to time and cost.
* What happens to the waste and debris that is flushed out? What are the regulations for the disposal of this waste?
* Can the water or oil used in the flushing process be re-used once the waste is filtered out?

**Student Handout - *What does a Pipe have to do with math?***  Name(s):

**Pre-Video Discussion:**  *Notes on important background information.*

**Part 1 Break:**

**The formula presented in the graphic was:**

Reynolds number Re = $\frac{50.6 Qρ}{dη}$

Q = flow rate (Gallons/minute or GPM)

ρ = density of fluid (lbs/ft^3)

d = inside diameter of the pipe (inches)

η = viscosity of fluid (centipoise)

|  |  |  |  |
| --- | --- | --- | --- |
| **Fluid Type** | **Fluid Temperature****(Fahrenheit)** | **Density of Fluid (ρ)** | **Viscosity of fluid (η)** |
| Fresh Water | 60 | 62.371 | 1.124 |
| Fresh Water | 100 | 61.996 | 0.684 |
| Fresh Water | 140 | 61.376 | 0.469 |
| Hydraulic Oil | 60 | 54.154 | 72.571 |
| Hydraulic Oil | 100 | 53.190 | 21.536 |
| Hydraulic Oil | 140 | 52.225 | 9.300 |

Pipe diameter = 2.209 inches

1. Using fresh water at 100 degrees Fahrenheit, what flow rate would be required to achieve turbulent flow in the system?

2. Using hydraulic oil at 100 degrees Fahrenheit, what flow rate would be required to achieve turbulent flow in the system?

**Part 2 Break:**

3. Assuming the pipe system volume being flushed is 100 Gallons and using fresh water at 100 degrees F, how many minutes will it take to circulate the pipe system 20 times?

4. Assuming the pipe system volume being flushed is 100 Gallons and using Hydraulic Oil at 100 degrees F, how many minutes will it take to circulate the pipe system 20 times?

Bonus Question:

5. We have seen in this example that systems can be flushed more quickly with oil versus water. But using oil introduces other variables like safety considerations, cost of purchasing oil and disposal of oil. How could we use water to flush that would give us the same results as oil, without the extra costs?

**ANSWER KEY – What does a Pipe have to do with Math?**

1. Using fresh water at 100 degrees Fahrenheit, what flow rate would be required to achieve turbulent flow in the system?

 (50.6 x Q x 61.996) / (2.209 x 0.684) = 4000

Q = 1.927 gal/min

2. Using hydraulic oil at 100 degrees Fahrenheit, what flow rate would be required to achieve turbulent flow in the system?

 (50.06 x Q x 53.190) / (21.536 x 2.209) = 4000

 Q = 70.703 gal/min

3. Assuming the pipe system volume being flushed is 100 gallons and using fresh water at 100 degrees F, how many minutes will it take to circulate the pipe system 20 times?

 1.927 gal / 1 min = 100 gal / x min

 X = 51.894 min

 20 x 51.894 min

1037.9 minutes

4. Assuming the pipe system volume being flushed is 100 Gallons and using Hydraulic Oil at 100 degrees F, how many minutes will it take to circulate the pipe system 20 times?

 70.703 gal / 1 min = 100 gal / x min

 X = 1.414 min

 20 x 1.414 min

28.3 minutes

Bonus Question:

5. We have seen in this example that systems can be flushed more quickly with oil versus water. But using oil introduces other variables like safety considerations, cost of purchasing oil and disposal of oil. How could we use water to flush that would give us the same results as oil, without the extra costs?

 flush with water at a higher flow rate