STEAM FORWARD – EPISODE 2
A Mysterious Build up [Teacher Version]

Welcome to STEAM FORWARD!

Solving problems with science and engineering!
Career: Chemist
Episode: A Mysterious Build up

Cellulose fibers, hemicellulose, and lignin naturally occur in all trees. Georgia Pacific's Foley Cellulose Mill extracts only the cellulose to use it in all sorts of things, like diapers, tires, and even hot dogs. It's a very precise chemical process.

This is a huge operation, one that produces 465,000 metric tons of cellulose product every year. With that kind of output leaving this place, the mill needs to run as efficiently as possible .

So how do you find potential problems and solve them before they cause any hold up in production? Chemist Brian Tish shows us how he uses science and engineering when he reaches in his tool kit.

During this episode, hosted by Dr. Meisa Salaita, we follow Brian as he investigates build up on one of the mill's pipes that could slow down production.

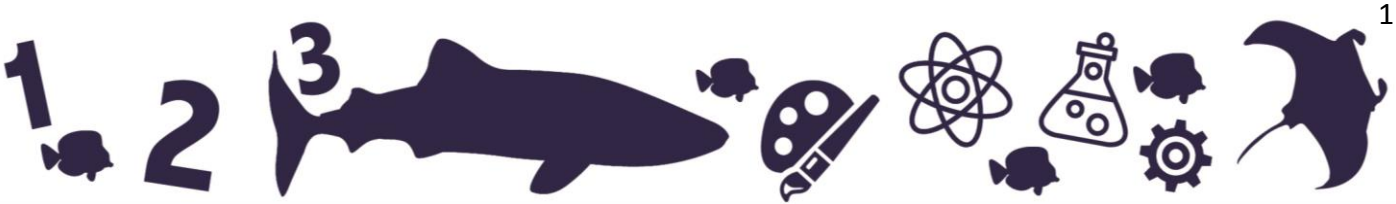
OBJECTIVES: Why am I learning this?

At the completion of this mini-unit, you will be able to:

- Use data to create a line graph
- Construct engineering diagrams from data in a table
- Use data evidence to support a scientific claim.

THE ESSENTIALS: ASK & ANSWER

- How do Georgia Pacific Mills monitor output in their pipes
- What comprises the build up?
- What further investigation can we do once we know the chemicals in the build up?



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Activity 1

Video segment: 00:00–2:21

OBJECTIVES: Why am I learning this?
At the end of this lesson, you will be able to:

- Explain the relationship between flow and efficiency
- Create line graphs

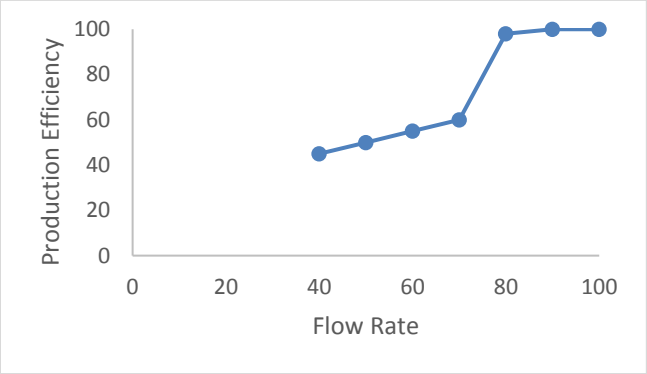
Introduction
Every time a pipe is shut down to clean it, the plant produces less pulp. That means that you don't want to shut pipes down too often. But, you need to clean the pipes before a blockage causes even bigger problems!

Table 1 provides information on how well the system works when pipes have different rates of flow. The lower the rate of flow, the more buildup there is in a pipe. These data are based on many observations of pipes at different flow rates. Use the data in Table 1 to make a decision about when you should shut down the system to clean a pipe!

Table 1. Cellulose production efficiency based on average pipe flow rates.

Flow rate (% of maximum)	Production efficiency
100	100
90	100
80	98
70	60
60	55
50	50
40	45

1. Graph the data from Table 1 using a line graph. Be sure to label your axes.



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2. At what flow rate do you think the plant manager should shut down a pipe in order to clean it? Use evidence from your graph and the table to support your answer.

Accept reasonable answers but students probably should say that between 70-80% flow rate the plant should shut a pipe down because a lot of efficiency is lost between flow rates of 80% and 70%.

Table 2. Flow rates in ten pipes at the Georgia Pacific plant.

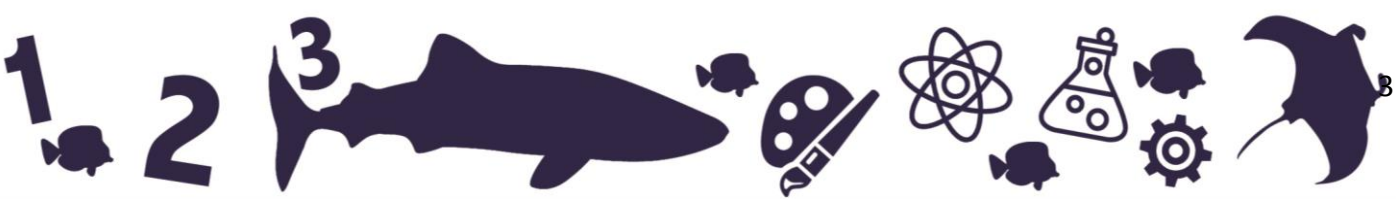
Pipe Number	Flow rate (% of maximum)
1	97
2	72
3	100
4	99
5	84
6	63
7	87
8	100
9	72
10	89

3. Draw a cross section of pipes 2, 4, 6, 8, and 10 that shows how much buildup you think is in the pipe. Label the pipe and the buildup.

Accept reasonable answers that show greater buildup for pipes with lower flow rates.

4. Based on the information in your graph, what are the pipes that need to be checked? Use your graph and the data in Table 1 to support your claim.

2,6,9 – the graph shows that between 70 and 80% flow the production efficiency starts to drop a lot.



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Extend the activity:

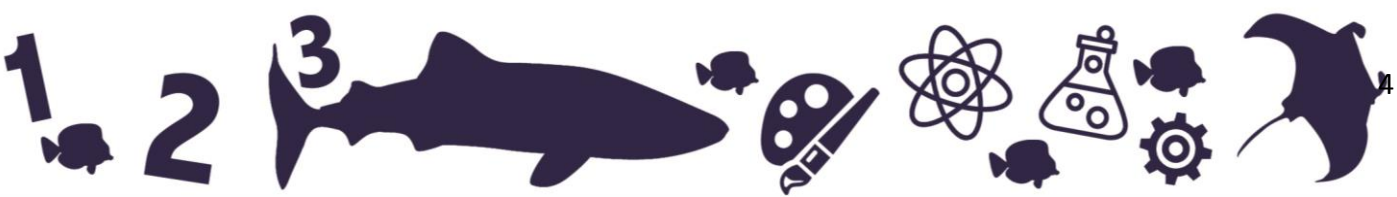
Have students explore the relationship between the buildup in pipe and the rate at which liquids flow through it. Encourage students to think about situations in their life where this might be relevant (for example, the pipes of an air conditioner, water pipes in the house, etc).

Materials

- Several lengths (maybe 12" long) of PVC pipe that are about 1-1.5" in diameter
- Modeling clay
- Measuring cups
- Funnel with diameter that almost fits that of PVC pipe (so it doesn't restrict flow too much
- Bucket to collect water
- Stopwatch

Procedure:

- Have students create a data table to collect their observations of how quickly water flows through a pipe. They will need to do three trials at each of three levels of buildup.
- Have students measure out 1 cup of water.
- Have students hold the PVC pipe over the bucket.
- Place the funnel in the PVC pipe.
- Have one student pour the water in the funnel so it stays mostly full (water speed is not limited by pouring speed).
- A second student starts the stopwatch when the pour starts and stops the stopwatch when the last water falls into the bucket.
- Record the data.
- Repeat two more times.
- Have students add modeling clay to restrict the flow a small amount at the end of the pipe by placing clay along the inside of the pipe.
- Have students draw a cross section of the pipe and diagram the amount of buildup. Have students estimate the proportion of the area that is blocked off.
- Repeat the water pour procedure three times.
- Have students add more buildup and repeat the above.
- Have students calculate average speeds per level of buildup and create a bar graph.
- Have students compare data and discuss any variation in their measurements within their group and among them. Have them draw conclusions from their tests and suggest improvements in the study design.



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Activity 2

Video segment: 2:26–4:10

OBJECTIVES: Why am I learning this?
At the end of this lesson, you will be able to:

- Use chemical test results to suggest a way to fix a mechanical system.

Introduction
Now that you understand flow rate and why it's important, we need to figure out what's disrupting the flow rate of the pipes. That's where you're bringing in your chemistry. You have been given samples of buildup from three pipes. Fill in the table below based on what you remember from the video, then use that to figure out what each sample has in it.

Table 1. Suggested cleaning methods for different potential buildup products.

Test for:	How to clean
Carbonate (anion)	Hydrochloric Acid Wash
Iron (cation)	Oxalic Acid Wash
Calcium (cation)	EDTA Wash
Sulfate (anion)	Mechanical Cleaning

Table 4. Results of chemical tests for buildups detected in pipes

Test for:	Pipe 1	Pipe 2	Pipe 6	Pipe 9
Carbonate	Positive	Negative	Positive	Negative
Iron	Negative	Negative	Negative	Positive
Calcium	Negative	Positive	Negative	Negative
Sulfate	Negative	Negative	Positive	Negative

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5. Use the information in Tables 2, 3 and 4 to fill out your suggested way to clean the buildup in each pipe in Table 5!

Table 5. Suggested maintenance of Pipes 1, 2, 6 and 9.

Pipe	Suggested cleaning and reason for this suggestion
1	Based on the data in Table 2, there is no need to clean Pipe 1.
2	Pipe 2 tested positive for calcium. It needs to be cleaned with EDTA. It needs to be cleaned because its flow rate is 72 and that leads to a reduction in production efficiency to about 60%.
6	Pipe 6 tested positive for carbonate and sulfate. It needs to be cleaned with hydrochloric acid to get rid of the carbonate and mechanically cleaned to get rid of the sulfate. It needs to be cleaned because its flow rate is 63 and that leads to a reduction in production efficiency to about 55%.
9	Pipe 6 tested positive for iron. It needs to be cleaned with oxalic acid to get rid of the iron deposits. It needs to be cleaned because its flow rate is 72 and that leads to a reduction in production efficiency to about 60%.

A possible way to extend the lesson: Ask students to discuss situations in which flow rates are important in their lives. Ask them what are different devices you use where flow rate may be a factor? They might consider a garden hose, shower, gas pump, or toilet. Have students share their ideas with the class through a presentation or a poster. Have them discuss why this type of engineering is critical even in simple devices, like a garden hose.

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In The Field

What better way to bring STEAM FORWARD alive than to meet an expert at Georgia Pacific? Here, you will learn more about the background and experience it takes to be a member of the STEAM TEAM. Let's get up close and personal!

MEET AN EXPERT
Meet: Brian Tish, Chemical Engineer at Foley Cellulose
University Of Central Florida
Major: Chemistry

What is the most exciting part of your job at Georgia Pacific?

The most exciting part of my job is when I get a to help solve a problem that improves the performance of the mill.

What advice do you have for students interested in doing what you do?

There are two pieces of advice I would give to students who want to pursue chemistry. The first is to get as much laboratory experience that you can get. I would also like to stress the importance of the ability to communicate effectively. Communication is a key part of any scientific career.

What is something surprising or unexpected about your career path?

My career path is full of suprises, every day poses a new and different challenge. I am fortunate that no two days of work are the same. Having new and challenging problems to solve every day keeps my job extremely exciting and fulfilling.

What do you say to students who ask "Why am I learning this?"

Chemistry is literally everywhere. It occurs inside the body and in space. Anything from volcanoes to smartphones can be understood in chemical terms. Chemisty is fundamental in determining how things work and how to make them better, which is why it is important to learn.