Pumping into the Future!

University of Florida AIChE Student Chapter

Kayla Kent, Melina Michel, Zoe Reddecliff

I. Objective	The purpose of this module is to demonstrate the process of building fluid pumps to contribute to pump efficiency. Our goal is to teach students how different piping networks can decrease energy consumption within chemical plants.
II. Materials	Materials listed below are for one person/group: a) 8-Liter Bucket with Spout b) 8-Liter Bucket c) 4 Liters of Water d) 3 of 3/8 inch PVC Tee e) 600 cm of ¼ inch PVC clear vinyl tubing f) Scissors g) Blue Food Coloring h) Tape i) Stir rod j) Tape measure k) Sharpie l) 250 mL cup m) 125 mL cup n) Stopwatch
III. Procedure	Preparation of Liquid: 1) Place 4 Liters of water into the 8 liter bucket with spout. 2) Add 10-20 drops of blue food coloring to the water and mix well with the stir rod. This will be the liquid that flows through the pump system you create. Making Pump System: 3) Take the tape measure and measure out 100 cm, 40 cm, and two 65 cm strips of the clear PVC piping from the 600 cm clear PVC vinyl piping. Use the sharpie to mark each of these measurements on the pipe. 4) Use your scissors to cut the piping at each of these marks. 5) Connect the 100 cm pipe to the spout on the bucket. Use tape to ensure the pipe is well connected and sealed onto the spout. 6) Place the end of the pump network into the second 8-liter bucket. This is to ensure easy cleanup once the water flows through the system and that no water spills onto the floor. Place the 250 mL cup at the bottom of the pipe inside the bucket.

	7) Now turn on the spout on the top bucket and watch the water flow through the pipes! Take your stopwatch and record how long it takes for the liquid to fill up the 250 mL cup at the bottom of the bucket. We can use this measurement to compare the velocity of liquid exiting the pipes for the different pump systems. 8) Pour the liquid from the bottom bucket back into the bucket with the spout. Changing the Pump System: 9) Now, we can change our pump to see how different design affect the velocity of the exiting liquid. One way you could do this is by attaching the 40 cm pipe to the spout using tape to secure it. Turn on the spout and use the stopwatch to determine if the velocity of the exiting liquid changes. 10) Now, we can try different designs using the PVC tees. Attach one PVC tee to the end of the 40 cm pipe, which is already connected to the spout, branch pipes into 2 separate pathways and attach the clear PVC pipe attached to the spout and another desired PVC pipe to each end of the tee. Continue to build off this network. Multiple tees and pipes can be used to create your desired pump network. 11) Use tape as needed to reenforce where the PVC tees and pipes connect. Wrapping tape around this junction may help prevent any leakage. 12) Now that the pump system is set up, turn on the spout from the top bucket and watch your fluid move throughout the pipes. Notice the velocity at which the water is exiting the tubes from. 13) Pour back any water in the bottom 2-liter bucket into the top bucket with a spout. Changing Pump Designs: 14) Take the tape off each junction and take apart each of the pipes and tees, except for the pipe attached to the spout. 15) Follow the same steps above and create different pathways with the pipes in any way you want. 16) Change the design a few times, noting the relative velocity that the water is flowing out of the pipe at. 17) Once you are finished creating various pump designs, dismantle the piping from the tees and spout. Dispose of the remaining liquid by pouring it into the nearest sink drain, and dispose of used piping, the stir rod, and any used tape into the nearest waste bin. 18) Wash the buckets that were used during the experiment with soap and water.
IV. Theory	In this module we will be teaching students the design process that engineers go through while trying to increase efficiency in pump systems. To truly understand our experiment on small scale pump systems, we must first understand how chemical engineers use pump systems in real life applications. Pumps located in chemical plant sites across the United States are used for a variety of tasks, one of which is for cooling fluids. During the process of cooling fluids, the fluid being worked on in sent to a pipe, which may branch into parallel pipe systems. This procedure can be beneficial to pump systems designed for energy conservation, as now there is less stress on each pipe and the longevity of these pipes lengthens. Within our module, we tasked students with the process of designing and building their own pump system to simulate this process. By branching the pipes, Bernoulli's Principle can be observed. There is less pressure acting on each of the pipes, so students are

	prompted to take note of the velocity exiting the pumps by using the stopwatch to record how long it takes each exit flow to fill either a 125 mL or 250 mL cup. Although the pressure did drop, there is still enough pressure to keep steady flow within the pipes. Observing this change can help student learn about the long-lasting effects of small pressure drops within pump systems. Designing pump systems efficiently is crucial for a chemical engineer, as conserving energy and increasing the longevity of the pipes can greatly decrease the energy consumption of the chemical plant. This benefits not only the company this pump system is within, but also contributes to a greener future.

Pumping into the Future!

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Pump systems are an essential system used in almost all aspects of life. Anywhere from drain systems, to refrigeration, to air conditioning systems, we can see different types of pump systems in action. In chemical process industries, the most commonly used chemical process equipment is a centrifugal pump. This type of pump works by moving liquid through piping by means of rotational energy supplied by driven rotors. As the liquid passes through the rotors, it is pushed through by centripetal force, that also increases the fluids velocity and pressure. This type of pump is very effective for displacing fluids, however when these systems are used in chemical plants, they consume a vast majority of the electrical power supplied to the plant. Lifecycle costs of the pipes, maintenance, and electric power supplied to the pump system account for a large total cost for chemical plants. Chemical engineers are tasked with choosing a pump system based on high efficiency, easy maintenance, and reliability. These factors can greatly contribute to pump efficiency and help decrease energy consumption from these systems when used for chemical processes such as cooling. In this experiment, we will investigate ways to making pump systems more efficient in cooling systems. We demonstrate these concepts using a simplified pump system powered through gravity with easily interchangeable piping.

When a liquid enters a pump system to go through the process of cooling, heat transfer occurs between the liquid and the pipes. Heat is lost from the liquid and to the piping surrounding it. Pump systems that undergo this process must be built to withstand this heat transfer without fault. However, maintaining the cooling process at top performance within one pipe may affect the longevity of that pipe. Chemical engineers can combat this issue by designing the pump system for energy preservation. Cooling pump systems may be run in parallel pipes, which means that the system consists of one pipe that branches into multiple paths, lessening the amount of fluid that can flow through it at any one time. We demonstrate this in our experiment by adding the PVC tees at the end of the pipes, splitting the flow into 2 sperate ways. This process alleviates the stress building upon one pipe for so long, as now the pressure within each pipe is reduced. Branching the pipes lengthens the duration that the pipes can last for because there are now less forces pressing onto the pipe and wearing down the material it is made up of. Energy is also conserved from the parallel pipe system during the actual act of cooling the liquid inside. Since the liquid is now separated into branching pipes, there is less heat transferring into each pipe and thus less stress on the material that makes up the pipe. We are able to build different pump systems to see how the pressure and velocity are affected by these changes.

In the pump systems we created, principles from physics are clearly relevant. Bernoulli's Principle states that there is an inverse relationship between the pressure and velocity of a fluid and is given by the formula: $P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$. As the pressure inside the pipes decrease due to the branching of pipes, velocity is known to increase. We demonstrate this knowledge by taking the velocity of the fluid flowing from one pipe versus the velocity of the fluid flowing from a branched pump. The fluid flowing from the branched pump was found to take less than double the time it took for the single pump to fill the 250mL cup within the demonstration. This indicated that the flow was faster coming from the branched pump. Other factors can also alter the velocity at which the fluid flows from the pump. Friction is a main force acting against the fluid as it passes through the tees or curves in the piping. Friction is defined as the normal force multiplied by the coefficient of friction and is a force resisting the flow of the fluids in the system. Resistance forces such as this must also be considered when determining what forces act upon the fluids within pump systems.

Pump systems are truly crucial achievements of engineering, influencing everyday life as we know it. Finding ways to make systems such as these work more efficiently is such an important job for decreasing our environmental footprint. We are living in a time where change must happen now before it is too late to stop the decline of our planet. Even small changes within pump designs can drastically decrease energy consumption within chemical plants, helping to make these plants more environmentally friendly. In our experiment, we not only wished to demonstrate how pump systems worked, but also to show how small changes in design can create long lasting benefits.

Safety Assessment Form

Basic Information:

AIChE Community Affiliation: *Student Chapter Name, Local Section Name, Other AIChE Community Name (Technical Entities, Divisions, Forums, Committees, Operating Councils, etc)., Undergraduate Student Member(s), Graduate Student Member(s), Professional Member(s)*	University of Florida AIChE Student Chapter
Primary Contact Name:	Kayla Kent
Primary Contact Email Address:	kaylakent@ufl.edu
Name of Module:	Pumping into the Future!
Brief Description of Module:	Students will learn about making more efficient pump systems by creating their own small scale pump system.
Does your module have a demonstration or experiment component? *Indicate Yes or No*	Yes
Briefly describe any interactive portions of your module:	Students will be able to choose how to connect the pipes and tees on their own pump system to demonstrate how changes in design affect the velocity and pressure of the exiting liquid.

Materials Used/Waste Generated:

If you need additional space, please insert additional rows and continue numbering sequence.

	Item *Include concentration where applicable*	**Chemical State** *Where applicable, specify solid, liquid, or gas. Otherwise write "N/A"*	**Estimated quantity used** *include units where applicable*	**Estimated amount of waste generated** *Include units where applicable*	**Waste Classification** *Where applicable, specify Acid, Base, Organic, Metal, Oxidizer, Other (include explanation if other), or Regular trash*
1	8-Liter Bucket with Spout	N/A	1	None	N/A
2	8-Liter Bucket	N/A	1	None	N/A
3	4 Liters Water	Liquid	4 liters	4 Liters	Regular Trash
4	3/8-inch PVC Tee	N/A	3	None	N/A
5	¼ inch PVC clear vinyl tubing	N/A	600 cm	600 cm	Regular Trash
6	Scissors	N/A	1	None	N/A
7	Blue Food Coloring	Liquid	10-20 drops	10-20 drops	Regular Trash
8	Tape	N/A	1 meter	1 meter	Regular Trash
9	Stir Rod	N/A	1	1 unit	Regular Trash
10	Tape measure	N/A	1	None	N/A
11	Sharpie	N/A	1	None	N/A
12	250 mL cup	N/A	1	None	N/A
13	125 mL cup	N/A	1	None	N/A
14	Stopwatch	N/A	1	None	N/A
15					

Access to 120V power outlet:

Access required? *Respond Yes/No in the space provided*	No
If yes, specify reasoning/any equipment it will be used for: *Please note that outlets requested to plug in laptops/monitors will not be granted*	

Hazard Identification & Mitigation:

Please ask yourself the following questions prior to completing the below table. ***1) What can go wrong?*** *(Identification of Hazards);* ***2) How bad can it be?*** *(Severity of Hazards);* ***3) How easily or often can it happen?*** *(Frequency or Likelihood);* ***4) How is the risk managed?*** *(Both preventive & mitigation safety measures)*

Hazards: *Describe any hazards associated with the above list of materials used and waste generated and any other hazards associated with the execution of the module*	1) Breakage of Buckets: (1) Dropping or hitting either the bucket with the spout or the regular bucket may result in cracks on the buckets. (2) These cracks may look dull, but there is a possibility that they may be sharp. These cracks may be dangerous to touch as they may be able to cut through skin. (3) This is unlikely to happen if buckets are handled with care. (4) If broken, carefully dispose of the broken bucket. 2) Stains: (1) Getting some of the food coloring on your hands or clothes may stain them. (2) These stains are not harmful but may take time to clean. (3) This is unlikely to happen if food coloring tubes are handled responsibly. (4) If staining does occur, immediately go to the nearest sink and wash affected area. 3) Cuts: (1) Dropping scissors or accidentally cutting yourself with the scissors. (2) This can be dangerous if sharp objects pierce the skin. (3) Unlikely to happen if scissors are handled responsibly. (4) If cut, immediately wash the affected area and locate the nearest first aid kit to bandage the wound.
Safety Measures: *Describe any safety measures that will be taken to mitigate hazards identified above*	1) Breakage of Buckets: Place all buckets in the center of table and away from the edge of the workstation when not in use. 2) Stains: Secure the cap on the food coloring when not in use. Only pour the food coloring into the designated area. 3) Cuts: Leave the scissors on the table when not in use. Use caution when handling the scissors and keeps other members hands away from the scissors when in use.
Required PPE: *Specify required PPE, who is required to use it, and within what proximity*	1) Closed Toe Shoes: Anyone using or within 1 meter of the scissors should wear closed toe shoes to protect their feet if the scissors were to fall.

Certification:

I certify that this module is safe for presentation <u>to</u> K-12 community members (including students, parents, and educators) and to AIChE volunteers and community members. I additionally certify that this module is safe for presentation <u>by</u> K-12 community members (such as parents & educators) and by AIChE volunteers and community members.

Kayla Kent		8/30/2021
Primary Contact Name	**Primary Contact Signature**	**Date**