Outlet Temperature Control of High Flow Mixing Valve

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Design Project

Lab section: E
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Submitted towards partial fulfillment of the requirements for
EXPERIMENTAL METHODS IN THE THERMAL SCIENCES – 05/01/2020

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ABSTRACT
This experiment evaluates a mixing valve to maintain a temperature variance of one degree. The mixing valve provided by General Atomics handles approximately 125GPM and various temperatures and flow

rates. Therefore, an evaluation of the temperatures for inlets and outlets was conducted using platinum resistive thermometers (RTDs). From temperature readings and the experimental parameters, an evaluation of Reynolds number, kinematic viscosity, and temperature variation can be examined.

INTRODUCTION

The design experiment comes from the General Atomics capstone project of redesigning a lighter thermostatic mixing valve. The purpose of this experiment is to inquire the accuracy of temperature readings based on readings taken by platinum RTDs. The main goal is to make sure that the rate of energy loss through the mixing of different temperature fluids is at minimum. Platinum RTDs are connected to a hot water tank, cold water tank, the two inlets of the mixing valve and the path of the outlet of the mixing valve. The temperature at each of these points are recorded and analyzed.

Another factor that was being varied is the velocity of the fluid. The tanks will be using pumps so that the velocity can be altered as needed. A basic tank is used for the system to ensure the steady flow of hot and cold water. To calculate the flow rate, a bucket timer was used. The Reynolds Number theorem was a major aspect to get the best stimulation of the mixing valve.

The valve used is 4 inches in diameter and operates at 125 GPM. The flow rate of the valve is found to be $7.88\ x\ 10^{-3}\frac{m^3}{s}$. The Reynolds number of water is$1.36\ x\ 10^5$ at 35^oC.

OBJECTIVE

The objective of the experiment is to analyze the accuracy of different thermocouples. With the background to the General Atomics, the platinum RTDs are calibrated and checked if the platinum RTDs can handle the range needed by the General Atomics project. The primary objective of this experiment is to stimulate the actual mixing valve and determine how the accurate temperature measurements can be recorded and used to analyze the accuracy of the mixing valve.

THEORY

The main theory being analyzed is a modified Reynolds Number equation, (**Eqn 1**). In the equation, diameter and Reynolds number are constant by General Dynamic specifications, therefore kinematic viscosity and velocity will be the changing variable. Density and dynamic are a function of temperature and will be used in calculating the kinematic viscosity. The specified parameters will be tested to hold a one degree variation using the determined kinematic viscosity.

$$\nu = \frac{\rho}{\mu} \quad \& \quad Re = \frac{\rho U L}{\mu} \quad \Rightarrow \quad Re = \frac{UL}{\nu} \qquad \textbf{(1)}$$

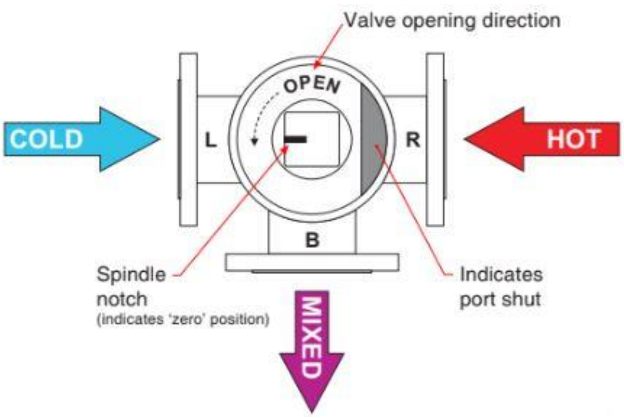
In Eqn (1):

$$\rho = density$$
$$\nu = kinematic\ viscosity$$
$$\mu = dynamic\ viscosity$$
$$L = characteristic\ length$$
$$U = velocity$$

After, kinematic viscosity can be compared to the temperature for a visual comparison at different temperatures. This can then be used to compare Reynolds of different temperatures to compare flow types.

EXPERIMENTAL APPARATUS

The experimental apparatus will be constructed around the mixing valve for inputs of different temperatures. The different temperature inputs will then mix within the valve to the exit. Inputs for the mixing valve will be fed by two water pumps from water tanks by PVC piping. The output of the mixing valve should be fed to the mixed tank by PVC piping as well. At both inlets and the outlet, a ball valve should be placed before the mixing valve to control the flow of water from the pumps. Also before each input and the output, a Platinum RTD will be used to measure temperatures being inputted and outputted to meet the one degree variance.



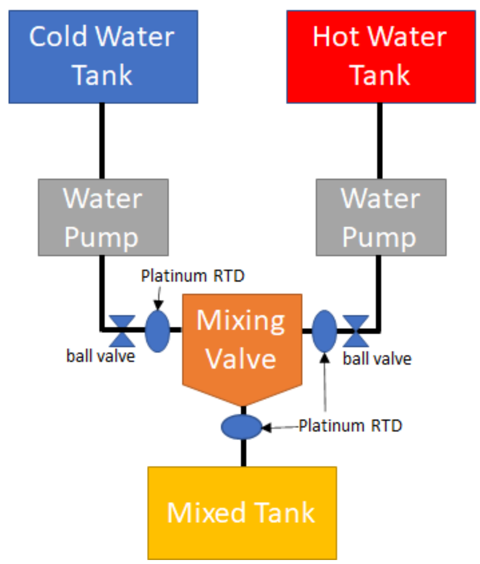


Figure 1: Valve Diagram

Figure 2: Apparatus Schematic

EXPERIMENTAL PROCEDURE

The mixing valve has three inlet/outlet ports. Two of the ports will be supplying water at different temperatures ranging from 15-50 degrees Celsius. The internal turret which restricts the flow from each inlet port will be fixed to maintain a specific ratio of water flow from each side. The temperature of the water in the storage tanks will be changed using a water heater. The temperature of the mixed water flow will be measured using a platinum RTD which is located downstream.

1) Check the ball valves near the mixing valve and make sure they are closed. Also check the mixing valve and ensure the turret is secured in the correct position.
2) Begin to fill up the water storage tanks close to the maximum capacity. Approximately 200 gallons of water for each.

3) Once the tanks have been filled, turn on the water heater and raise the temperature of the tank approximately 20 degrees Celsius.
4) Turn off the water heater once the water temperature is within the range of 40-50 degrees Celsius.
5) Using the calibrated platinum RTD at the tank, record the temperature of both tanks.
6) Now we will turn on the both of the pumps. Next completely open up the ball valves and allow the water to flow through the mixing valve.
7) Record the data from the platinum RTD downstream in intervals of 5 seconds between recording. Take 10 recordings.
8) Turn off the pumps and then close ball valves on each side.
9) Change the temperature of the cold tank by adding ice to the water. Allow the water to cool down until the temperature remains at steady state.
10) Record the new temperatures of the storage tanks and repeat steps 6-8.

DESIGN STATE UNCERTAINTY

The main object of this design project is to control the outlet temperature of a high flow mixing valve within $\pm 1^{\circ}C$. One of the biggest challenges for this project is having a temperature sensor that has a high accuracy and quick reaction time. A platinum RTD will be used to achieve the best results. The temperature the RTD records is dependent on a multitude of factors such as the accuracy of the sensor, accuracy of the incoming flows, accuracy of the water temperatures and accuracy of pump output. The RTD sensor used for the design has an accuracy of $\pm 0.15^{\circ}C\ at\ 0^{\circ}C$and $\pm 0.35^{\circ}C\ at\ 100^{\circ}C$[2]. The water temperature does not exceed $50^{\circ}C$so the inaccuracy will not exceed $\pm 0.35^{\circ}C$. Another consideration for the design state uncertainty is the position of the internal turret that controls flows from the inlets. The positioning will allow a higher flow rate from one side, thus increasing or decreasing the fluid temperature. In addition, the pumps could also be a cause of the uncertainty. If the pumps are outputting different amounts of water from the different storage tanks, a temperature will be seen downstream. Finally, if the initial temperature of the water at the storage tanks is inaccurate, the calculations of the outlet stream will be affected.

BILL OF MATERIALS

The total cost of this project is approximately $3700 before taxes (**Table 1**). The biggest cost of the project is the mixing valve, which accounts for roughly 66% of total cost. Other large expenses include the water storage system and water pumps. Due to the high flow rate the system operates at, large storage tanks are needed as well as pumps that can match the 125 GPM.

Table 1: Bill of Materials

Bill of Material				
Components	**Description**	**Price (Unit)**	**Quantity**	**Cost**
Armstrong F8T100 Mixng Valve	Hot/Cold mixing valve	2500	1	2500
NorthStar Water Pump	7920 GPH water pump	190	2	380
Norwesco Water Tank	210 gallon water tank	229	2	458
JM Eagle PVC pipe	Schedule 40 - 10ft	11	3	33
NIBCO PVC Reducer	4in to 2in PVC	6	2	12
Christy's PVC Cement	4 oz	5	1	5
Omega Platinum RTD	PT100	80	3	240
Homewerks Worldwide Valve	4 inch ball valve	44	2	88
			Total	3716

Most of these parts are readily available at stores such as Home Depot, parts such as the mixing valve would not be easily obtained.

CONCLUSION

In conclusion, setting up an experiment of this size is feasible under the right conditions and facilities. With that said, a design project of this proportion would not be feasible for ME 495 at NAU. The total cost of the design would nearly be $4000, which would be very hard to find funding. In addition, the experiment requires a large quantity of water to be stored and discharged.

If this was a reoccuring experiment each semester, the argument could be made that it is feasible and reasonable. In order to make this experiment very feasible, the overall size of the design would have to be reduced. A smaller mixing valve would have to be used, maybe a one inch valve. The Buckingham Pi Theorem would have to be applied in order to keep the same Reynolds Number within the pipes. Reducing the scale would decrease the overall cost and resources needed.

REFERENCES

[1] “Emech Digital Actuator - Model G1 Installation, Operations, and Maintenance Manual,” Armstrong International, 2019
[2] “Emech Hot/Cold Water Mixing Valve Model F8T100 Installation, Operation, & Maintenance Manual” Armstrong International, 2016
[3] “General Purpose RTD Probes”, Omega