



# Analysis of Difference Variable Parameter Effect to Temperature Drop: Application of Cooling Tower

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## Abstract

This abstract presents a comprehensive overview of the piping system before entering cooling tower that has been specifically engineered to enhance the operational efficiency of a cooling tower. The piping system plays a vital role in connecting the cooling tower with different components, facilitating the continuous flow of water to efficiently dissipate heat. The piping system consists of a complex arrangement of interconnected pipes, heat exchangers and valves that facilitate the movement of water from the tower to the relevant equipment. The engineering of the piping system entails meticulous consideration of its design and layout to maximise cooling performance while simultaneously minimising pressure losses and energy consumption. In order to ensure the variable that gives better performance, the elevation of pipes and different temperature inlets are to be considered in this research. The 3D piping model involves a pipeline from the setpoint of the heat exchanger to the cooling tower. The model part includes the pipe and flange drawn using Solidworks. According to the parameter, the elevation of the pipe will change to get the optimum result for the data analysis. The simulation results show that the longer the elevation of the pipe, the lesser the velocity flow in the pipeline, which affects the pressure distribution in the pipeline, and the pressure decreases due to the elevation of the pipe. The simulation results show that higher velocity occurs on the inlet pipe rather than the outlet of the pipe when different temperature inlets are applied. However, different temperature inlets did not affect the pressure distribution along the pipeline as the results indicate no significant difference between the different temperature inlets for each model.

## 1. Introduction

Cooling towers play a pivotal role in industrial processes, efficiently dissipating heat and ensuring optimal operating conditions for equipment and systems. Cooling tower performance is critical for overall efficiency and reliability in industrial circulating water systems [1]. As academics delve into enhancing cooling tower effectiveness, research approaches vary, ranging from theoretical optimizations to experimental analyses [2]. This study specifically focuses on the impact of piping systems before entering the cooling tower, recognizing them as a major component influencing heat loss. By analyzing the elevation changes in the piping system, this research aims to unravel the relationship between temperature drop, elevation, and inlet temperature. Understanding these



dynamics is vital for optimizing cooling tower performance and reducing energy consumption [3] The study employs simulation-based analysis using SolidWorks and Ansys, with 3D modeling based on the UTHM Biodiesel Plant. By delving into three different pipe elevations and temperature inlets, this research seeks to provide valuable insights for designing and locating piping systems before cooling towers, ultimately contributing to the improvement of industrial cooling processes.

## 2. Methodology

This chapter will demonstrate the methodology of three parameters that affect the performance of cooling tower piping systems. In this chapter, the analysis of the temperature and elevation of the pipe will be included. The overall project approach will also be explained in detail and was designed to achieve this project's objective and scope.

### 2.1 3D model piping system

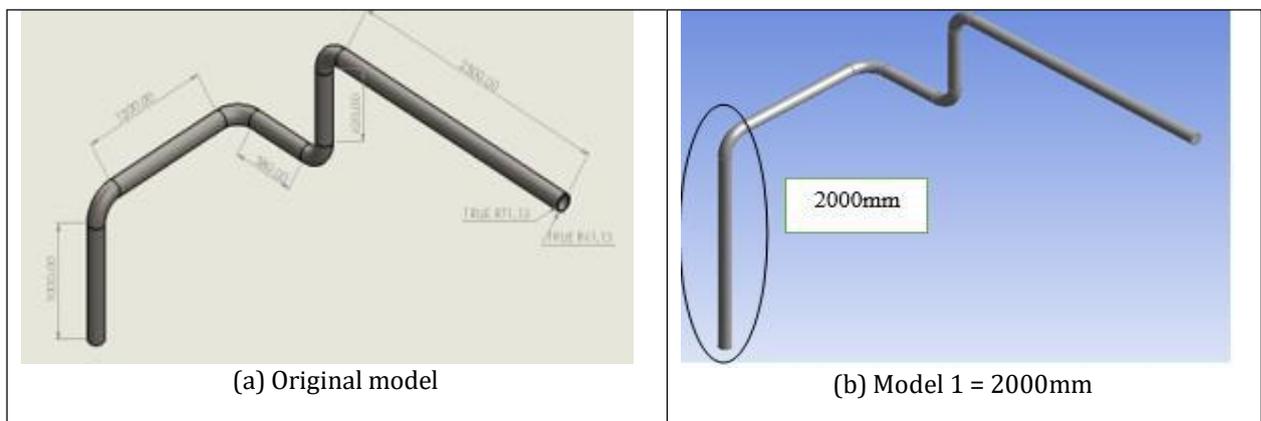
The SolidWorks software was utilized to visually represent the pipe model based on the UTHM power plant. All the dimensions are derived from the pipe utilized in the UTHM power plant (Fig. 1). The pipe model is constructed and subsequently analyzed using two software applications, namely SolidWorks and ANSYS. The application of SolidWorks as the primary tool for component remodelling and recreation, followed by the transfer of the model to ANSYS software for analysis, was employed in this study.



**Fig. 1** Pipeline system from the heat exchanger to a cooling tower at UTHM Biodiesel Plant

### 2.2 Pipe modelling

In this pipe modelling, it contains 4 detailed drawings of parts. There are 4 design pipes with different dimensions. All measurements are based on the UTHM Biodiesel Plant and have been drawn using SOLIDWORKS software, as shown in Fig. 2 and Fig. 3.



**Fig. 2** 3D model piping system (a) original model, (b) Model 1

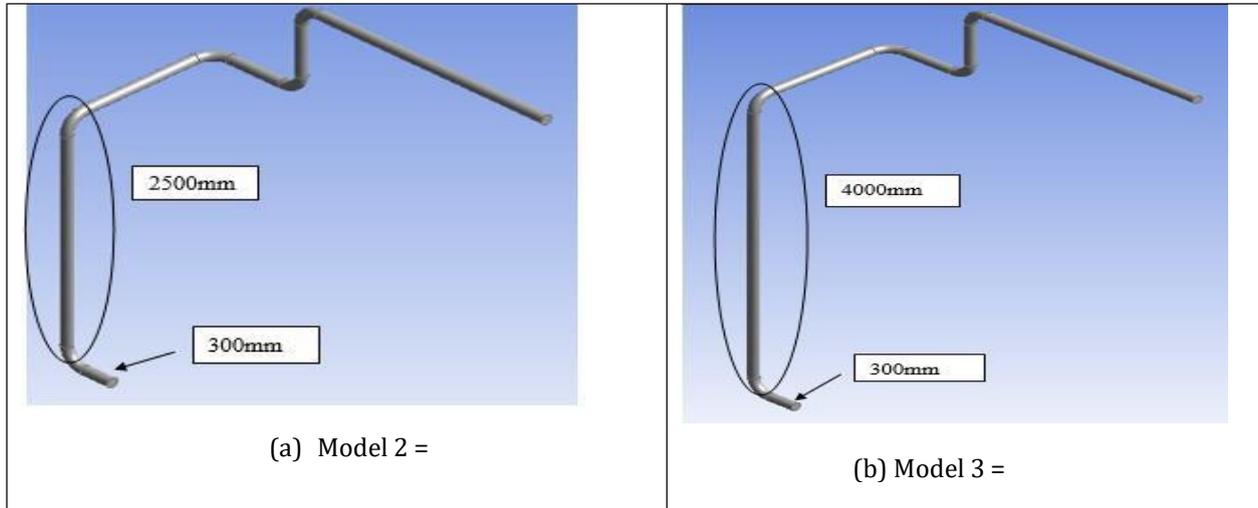


Fig. 3 3D model piping system (a) Model 2, (b) Model 3

The structural part of the piping model used in this study is a pipe. Types of pipe material used was carbon steel sheet. The outer diameter for the pipeline was 141.3 mm, and the inner diameter was 122.25 mm. The diameter chosen was based on Pipe Schedule 80, which is similar to the UTHM Biodiesel Plant cooling tower piping system. The original model was 1000mm long on the outlet elevation of the pipe. Meanwhile, Models 1, 2, and 3 have outlet elevations of 2000 mm, 2500 mm and 4000 mm, respectively.

### 2.3 Boundary condition for fluid

The boundary conditions addressed the conditions imposed by nature on physical boundaries [4]. Boundary conditions play an important part in ensuring the precision and significance of outcomes by specifying the fluid's conduct at the edges of the computational region [5]. Boundary conditions are utilized to establish the values of flow variables, including velocity, pressure, temperature, or concentration, at the boundaries [6]. Water liquid is the major part that is used in this research. The properties of the fluid are summarized in Table 1.

Table 1 List of boundary conditions used in the fluid domain

Parameter	2000 mm			2500 mm			4000 mm		
	15°C	45°C	75°C	15°C	45°C	75°C	15°C	45°C	75°C
Pressure inlet	551581 Pa								
Pressure outlet	101 325 Pa								
Size element	213280								

### 2.4 Boundary condition for pipe

The boundary condition includes a parameter variable: the pipe's elevation and temperature inlet to the cooling tower. The parameter of the simulation model was selected by the boundary conditions. The structural part of the piping model used in this study is the pipe. The diameter chosen was based on Pipe Schedule 80, which is similar to the UTHM Biodiesel Plant cooling tower piping system. Table 2 summarizes the boundary condition of the pipe.

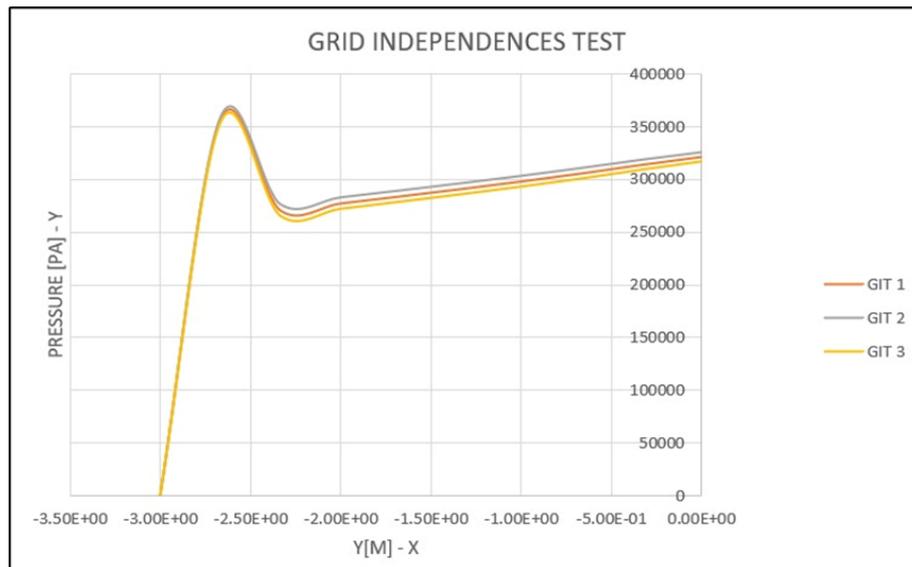


**Table 2** Summary of boundary condition for pipe

Type of pipe	Density (kg/m <sup>3</sup> )	Specific heat, Cp (J/kg K)	Thermal conductivity (W/mK)
Carbon Steel Sheet	7870	502.416	45

### 3. Procedure

A computational fluid dynamics (CFD) simulation was conducted to study the fluid flow behaviour in the 3D model piping system using ANSYS FLUENT. Three model designs with different elevations on the outlet pipe were tested with different inlet temperatures: temperature 1: 15°C, temperature 2: 45°C, and temperature 3: 75 °C.

**Fig. 4** Graph of Grid Independence Test (GIT)

A Grid Independence Test ensured the mesh quality. From the graph (Fig. 4), 213280 elements were used in this study. Thus, the graph at point  $-2.8 \times 10$  shows the different patterns of a line graph. GIT 1 was chosen because the number of elements is not too low or too high, which is the most suitable for conducting the simulations. This simulation employed the Energy Equation and k-epsilon viscosity model. The study focused on the flow patterns that affect outlet elevation and different temperature inlets to pressure distribution and velocity distribution. The simulation method employed the SIMPLEC scheme and Hybrid initialization. This method can lead to faster convergence and more accurate results of fluid flow[7].

### 4. Results and discussion

This topic will clarify the present study outcome. Solidwork and Ansys software was being used to draw the 3D model of piping system and all result were based on Ansys simulation analysis. Thus, the expected result is to know the effect of different elevation of pipe and difference temperature inlet to the temperature drop before entering cooling tower. By using Ansys Fluent simulation, the outcome result will be validated.

#### 4.1 Analysis of fluid behaviour

In this study, we analysed the pressure distribution and velocity distribution effect to the different elevation different temperature inlet and on the outlet pipe to the piping system before entering cooling tower. Based on the boundary condition, the pressure inlet for all models was 551581 Pa and the pressure outlet was 441264.8 Pa. The parameter to be analysed was different temperature inlets to different elevations of pipe. Three different temperatures to be analysed are temperature 1: 15°C, temperature 2: 45°C, and temperature 3: 75°C. While, for elevation on the outlet pipe for model 1: 2000mm, model 2: 2500mm, and model 3: 4000mm. On the pipe wall temperature, we used room temperature which is 20°C for all models.

### 4.1.1 Effect from different outlet elevation

Fig. 5 displays the different elevations at the outlet pipe which have been analysed. The reference point to examine the impact of velocity and pressure distribution at the outlet pipe was established at this location. The elevation on the outlet pipe for model 1 is 2000 mm, model 2 is 2500 mm, and model 3 is 4000 mm.

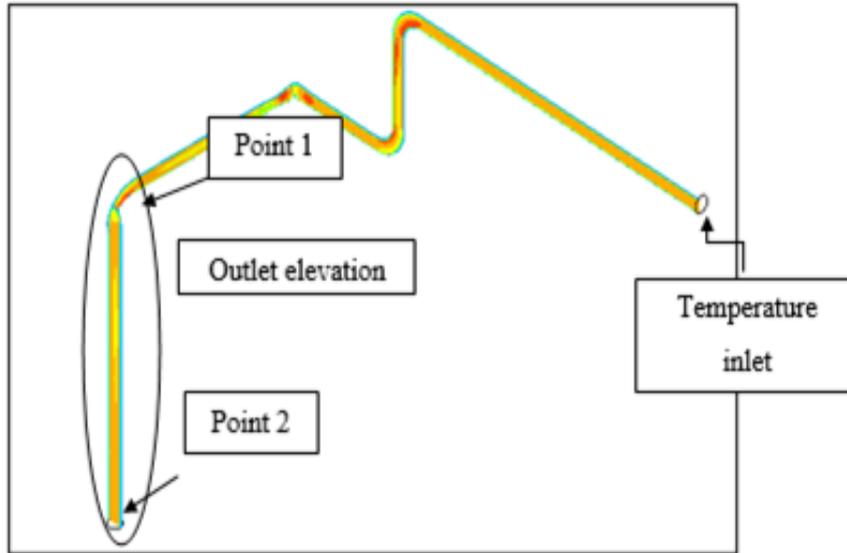


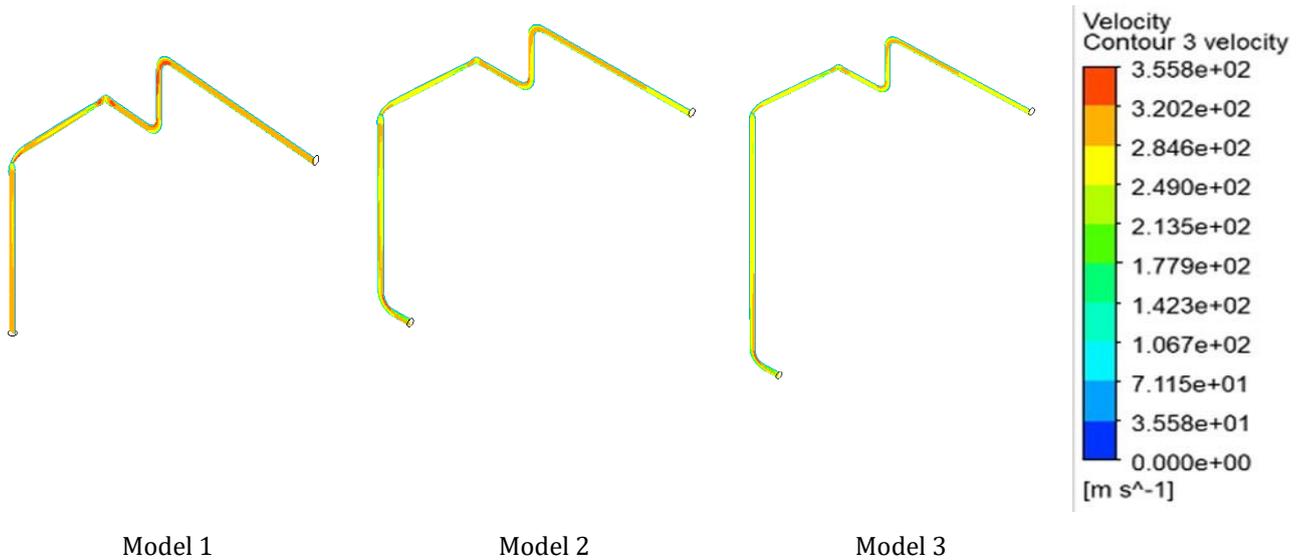
Fig. 5 Location of pipe analysed as references

#### 4.1.1.1 Velocity distribution

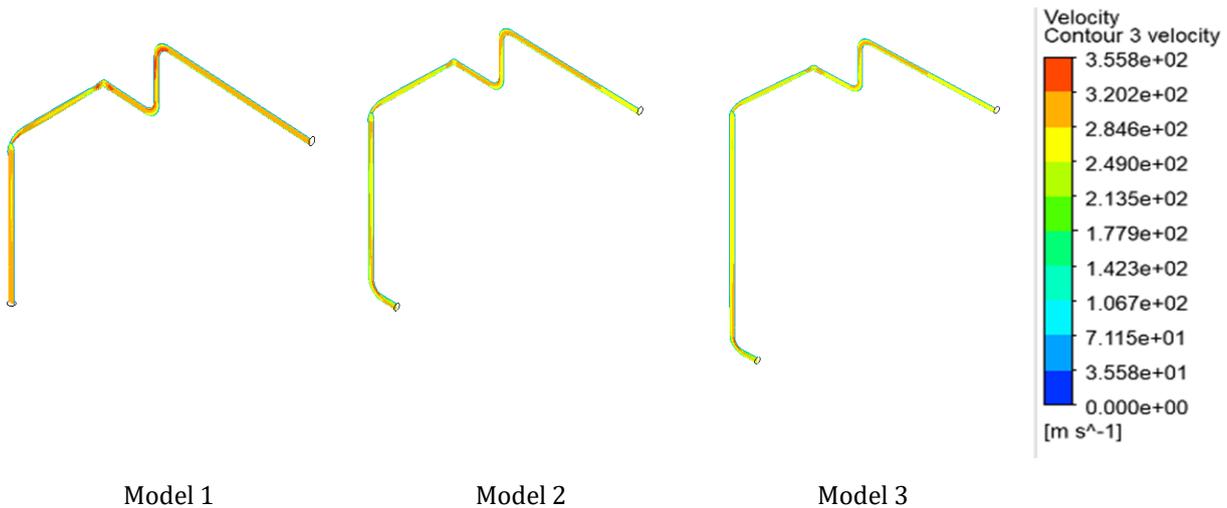
The analysis of velocity distribution of different temperature inlets to the different elevations on the outlet pipe was analysed. Three different temperatures are to be analyzed: temperature 1: 15°C (Fig. 6), temperature 2: 45°C (Fig. 7), and temperature 3: 75°C (Fig. 8).



Fig. 6 Velocity distribution for temperature 1= 15°C



**Fig. 7** Velocity distribution for temperature 2= 45°C

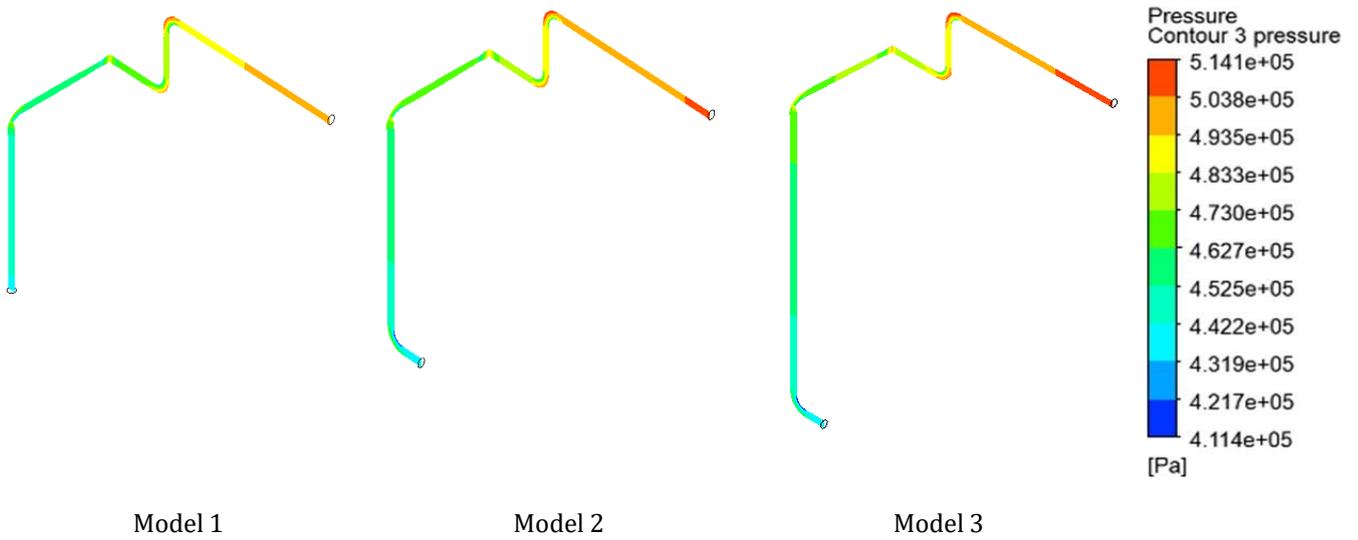


**Fig. 8** Velocity distribution for temperature 3= 75°C

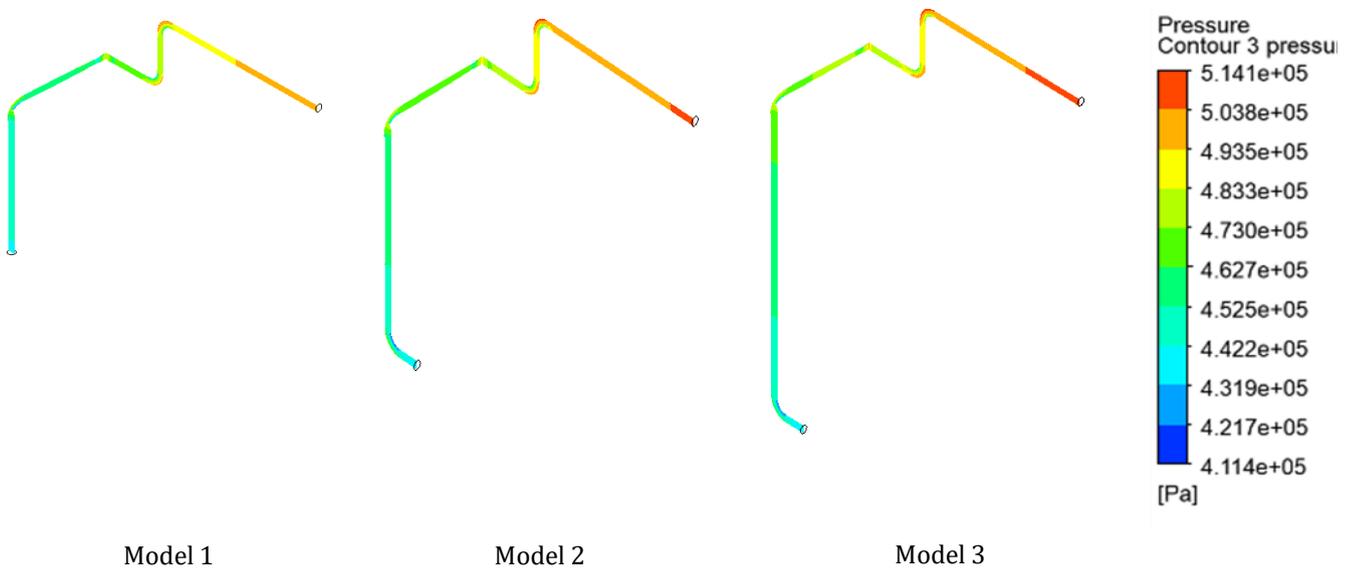
In conclusion, the velocity distribution in the pipeline is affected by the elevation of the pipe. As shown in the comparison between the three models, the outlet pipe of model 1 has a higher flow on the outlet pipe compared to model 2 and model 3. Meanwhile, model 3 shows the lowest flow of velocity from the outlet pipe. This is due to the longer vertical pipe, which increases gravitational potential energy at higher elevations and a corresponding increase in kinetic energy to maintain the balance dictated by the Bernoulli equation. According to Bernoulli's principle, an increase in elevation corresponds to an increase in potential energy, and this energy is converted into kinetic energy as the fluid flows downward [8]. As the fluid gains velocity due to the elevation change, the velocity distribution within the pipe is affected [9].

#### 4.1.1.2 Pressure distribution

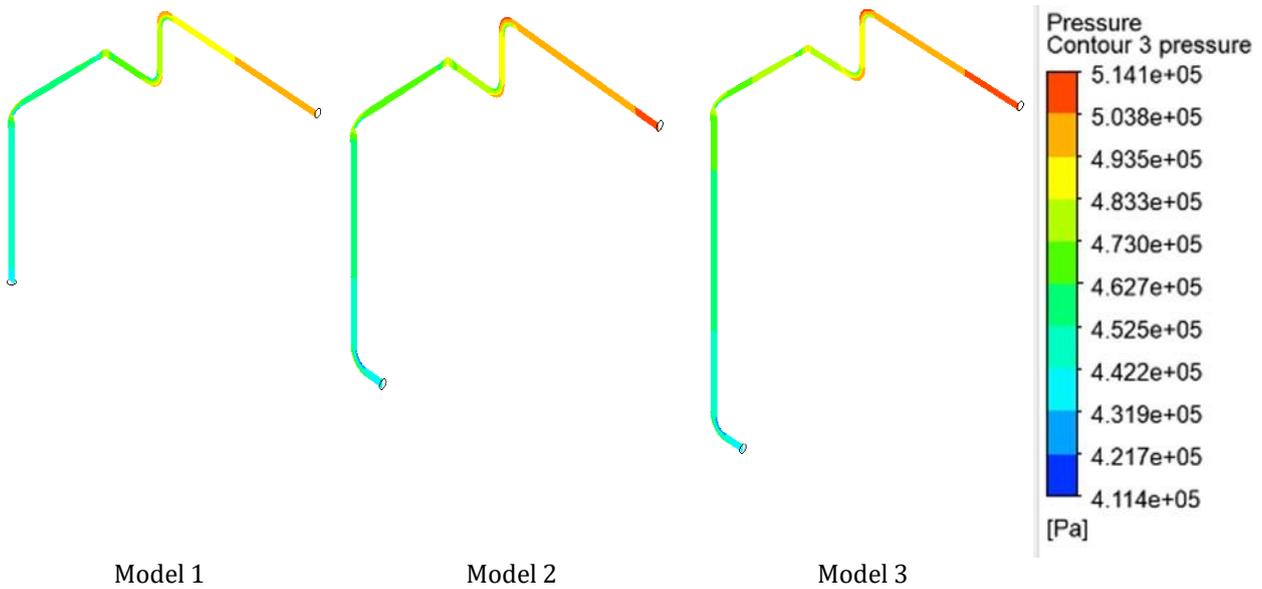
The analysis of pressure distribution in the outlet pipe, considering the different elevations has been conducted. Three distinct temperatures were selected for analysis of temperature 1 at 15°C (Fig. 9), temperature 2 at 45°C (Fig. 10), and temperature 3 at 75°C (Fig. 11). This analysis aims to investigate how the changes in outlet elevations influence the pressure distribution within the pipeline system.



**Fig. 9** Pressure distribution for temperature 1=15°C



**Fig.10** Pressure distribution for temperature 2= 45°C



**Fig. 11** Pressure distribution for temperature 3= 75°C

In conclusion, we can conclude that the elevation of the pipe affects the pressure distribution in the pipeline. This can be shown in each of pressure distribution where at longer elevations at point 2, the pressure distribution within the pipe is lower, while at Point 1 elevations, the pressure is higher. Model 1 shows a lower pressure distribution, marked by the orange colour on the inlet pipe. In contrast, Model 2 and Model 3 demonstrate a higher-pressure distribution, marked by reddish colouring on the inlet pipe. However, the outlet pressure decreases due to the elevation of the pipe, leading to a loss of pressure in the fluid flow.

#### 4.1.2 Analysis of Pressure Drop Distribution

Table 3 presents the findings regarding pressure drop occurring within the pipeline. The data on pressure drop was derived by computing the difference between the results obtained at point 1 and point 2, corresponding to each elevation at the outlet of the pipe. The tabulated data is a reference for the analysis of pressure variations at different points, showing detailed results of the performance at different elevation outlets of the pipe.

**Table 3** Pressure Drop Distribution value

Temperature inlet	Model 1 = 2000mm	Model 2 = 2500mm	Model 3 = 4000mm
	Pressure drop, Pa		
15°C = 288.15K	0.0196	0.0177	0.0165
45°C = 318.15K	0.0196	0.0176	0.0164
75°C = 348.15K	0.0196	0.0177	0.0165

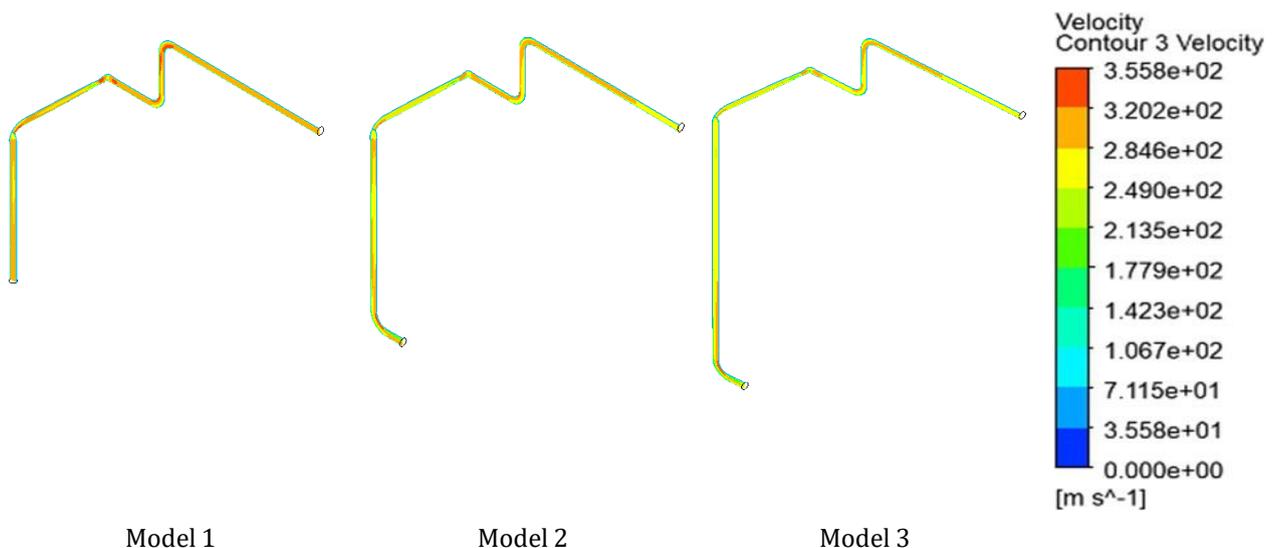
Table 3 shows Model 1 has the highest value for pressure drop in the pipeline. Therefore, Model 1, with an outlet elevation of 2000mm, is most effective at increasing pressure drop in the pipeline. A pressure drop can result in a decrease in temperature. As the fluid experiences a higher pressure drop, it may cool down, potentially leading to increased heat loss to the surroundings. The elevation at a pipe's outlet significantly impacts the pressure distribution throughout the pipeline. As the length of the pipe increases, there is a corresponding decrease in the amount of pressure drop within the pipeline. This correlation between outlet elevation and pressure drop emphasizes that longer pipelines tend to show lower pressure drops [10].

#### 4.1.3 Effect from different temperature inlet

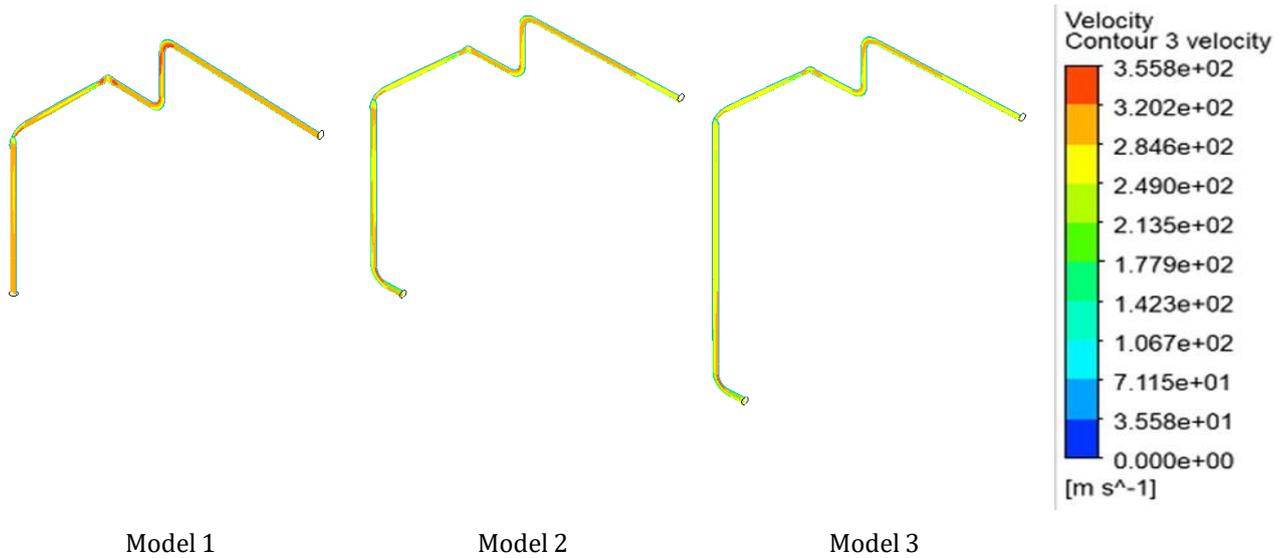
There are 2 effects to be analysed: velocity distribution and pressure distribution effect to difference temperature inlet.

##### 4.1.3.1 Velocity distribution

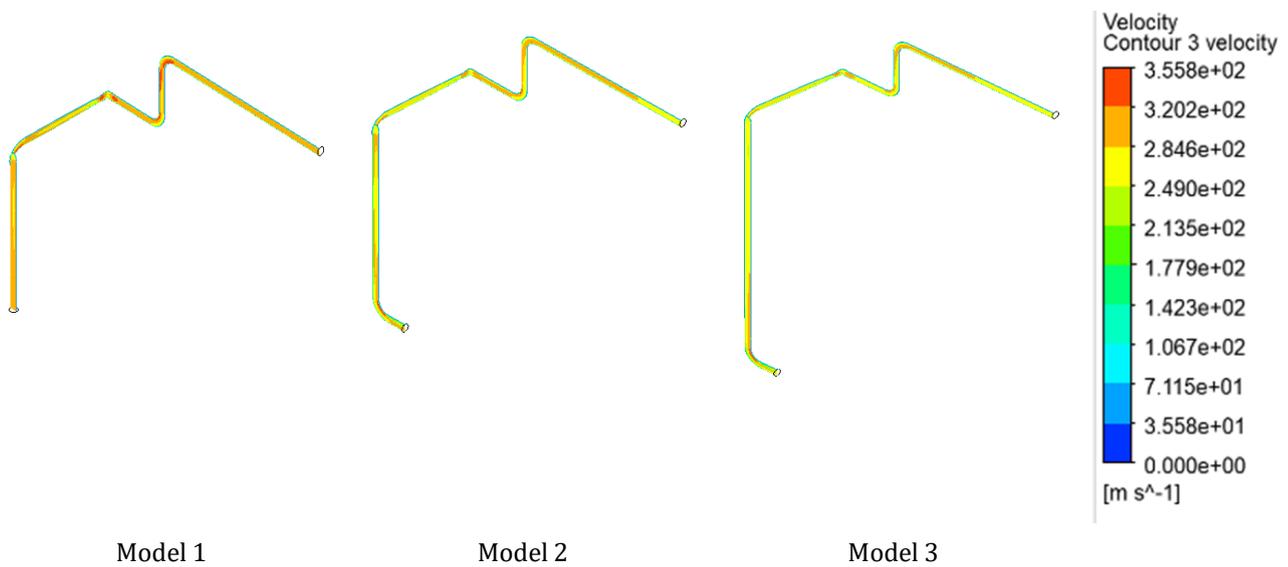
The velocity distribution at different temperature inlets was analysed for 3 types of models. Three different temperatures are to be analysed: temperature 1: 15°C, temperature 2: 45°C, and temperature 3: 75°C.



**Fig. 12** Velocity distribution for inlet temperature 1= 15°C



**Fig. 13** Velocity distribution for inlet temperature 2= 45°C

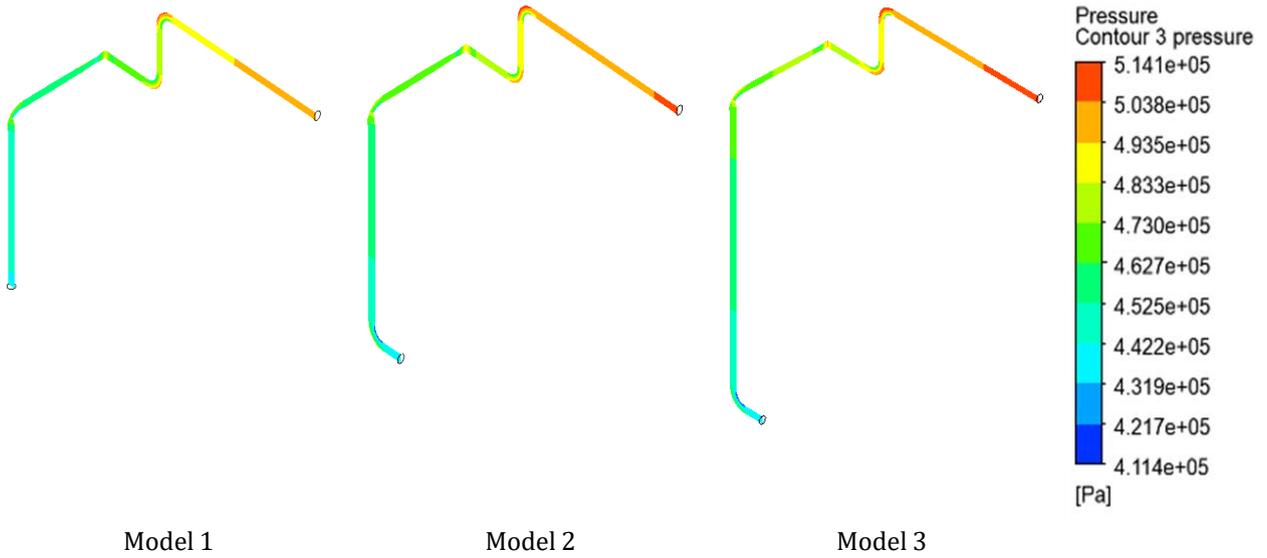


**Fig. 14** Velocity distribution for temperature 3= 75°C

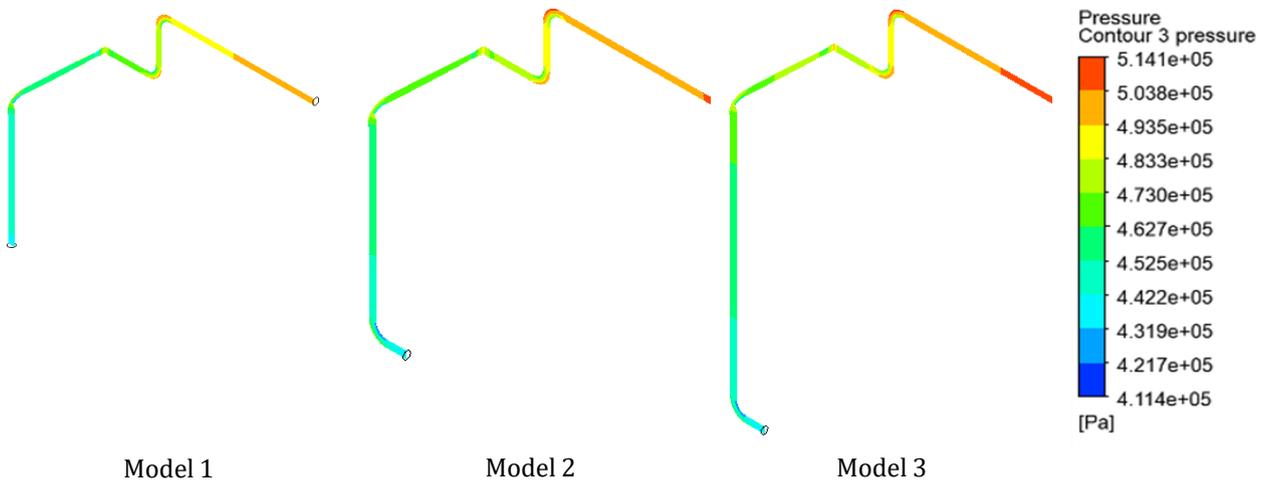
In summary, the velocity of the fluid in the pipeline is influenced by the difference in temperature. Model 1 has a higher inlet velocity than models 2 and 3. This results in larger convective heat transfer coefficients and higher heat transfer rates at the inlet. In high-velocity zones, the temperature difference between the fluid and the surrounding environment may decrease faster, resulting in more heat loss to the surroundings. This causes the temperature of the fluid entering the cooling tower to decrease, improving the cooling tower's performance.

#### 4.1.3.2 Pressure distribution

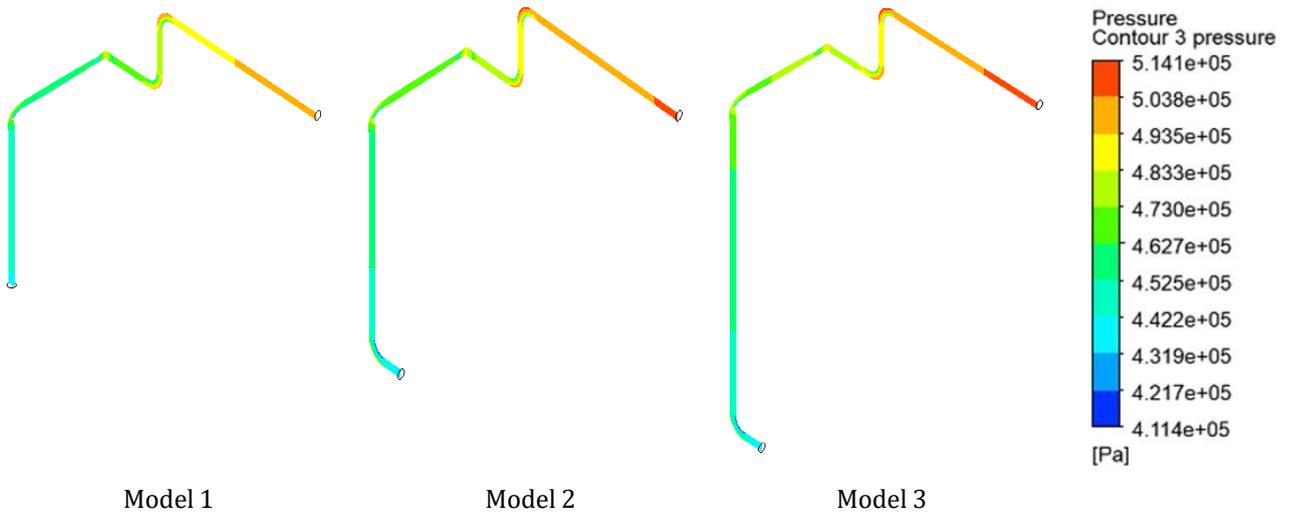
Considering the different inlet temperatures, an analysis of pressure distribution in the outlet pipe was conducted. Three distinct temperatures were selected for analysis temperature 1 at 15°C (Fig. 15), temperature 2 at 45°C (Fig. 16), and temperature 3 at 75°C (Fig. 17). This analysis aims to investigate how the changes in inlet temperature influence the pressure distribution within the pipeline system.



**Fig. 15** Pressure distribution for temperature 1=15°C



**Fig. 16** Pressure distribution for temperature 2=45°C



**Fig. 17** Pressure distribution for temperature 3=75°C

In conclusion, we can conclude that the difference in temperature does not affect the pressure distribution of the pipe. This can be shown in each of the tables of pressure distribution, where the pressure inlet and pressure outlet for the three models are the same even though the temperature increases. Model 1 shows a lower pressure distribution, marked by the orange colour on the inlet pipe. In contrast, Model 2 and Model 3 demonstrate a higher pressure distribution, marked by reddish colouring on the inlet pipe. However, the outlet pressure decreases due to the elevation of the pipe, leading to a loss of pressure in the fluid flow.

### 4.2 Analysis of temperature drop distribution

Table 4 provides detailed insights into the temperature drop within the pipeline. The information on temperature drop was obtained by calculating the variance between the results measured at point 1 and point 2, corresponding to each elevation at the outlet of the pipe. The tabulated data serves as a reference for analysing temperature drops at various inlet temperatures, offering a comprehensive depiction of the system's performance under different conditions.

This table thoroughly examines the temperature variations along the pipeline, specifically highlighting the differences in temperature between specific points. By comparing the results at different inlet temperatures, the table allows for a better understanding of how the pipeline system behaves under varying thermal conditions. This analysis contributes valuable information for assessing the performance and efficiency of the pipeline across a range of operating temperatures.

**Table 4** Analysis of Temperature Drop Distribution Value

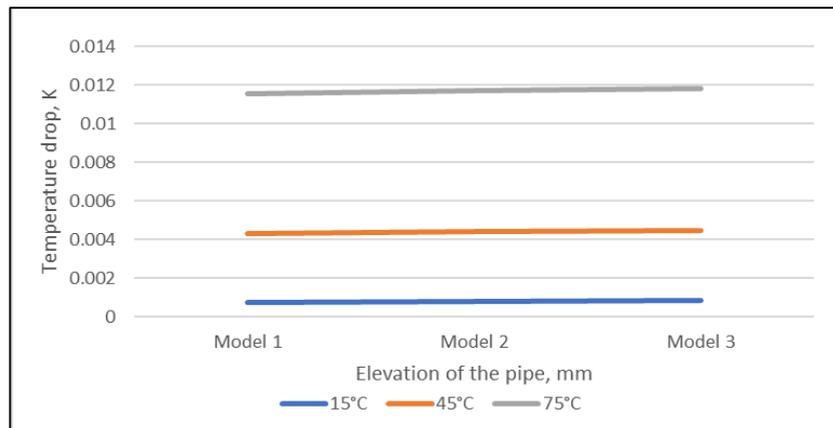
Temperature inlet	Model 1 = 2000mm	Model 2 = 2500mm	Model 3 = 4000mm
	Temperature drop, K		
15°C = 288.15K	0.00076	0.00083	0.00085
45°C = 318.15K	0.00353	0.00357	0.00361
75°C = 348.15K	0.00727	0.00734	0.00737

Table 4 shows Temperature 75°C has the highest temperature drop value for each pipeline model. Therefore, the Temperature 75°C with the outlet elevation of Model 3 is 4000 mm, which is most effective at increasing temperature drop in the pipeline. The preference for a higher temperature drop can be attributed to its significance in thermal systems, particularly those involving the transportation of steam. The temperature drop reflects the extent to which the steam is losing heat energy along the pipeline. In the context of a cooling tower, where the objective is often to dissipate heat from the system, a substantial temperature drop signifies efficient heat transfer.

Efficiency, in this case, can be associated with effective cooling of the steam, ensuring that it reaches the cooling tower at a lower temperature [11]. This is crucial for optimizing the overall performance of the thermal system. A higher temperature drop suggests that the steam is being appropriately cooled, which can enhance the cooling tower's efficiency in extracting and dissipating heat[12].

### 4.3 Summary

Fig. 18 shows the comparison between the temperature drop and the pipe's different elevations. From this graph, temperature 15C shows the lowest temperature drop, which is model 1, which is 0.00076K, model 2, 0.00083K, and model 3, 0.00085K.



**Fig.18** Graph for temperature drop analysis to the elevation of the pipe

Temperature 45C shows a moderate temperature drop: model 1 is 0.00353K, model 2 is 0.00357K, and model 3 is 0.00361K. While temperature 75C shows the highest temperature drop, which model 1 is 0.00727, model 2 is 0.00734 and model 3 is 0.00737. We can conclude that the temperature drop is proportional to the elevation of the pipe. This is because the higher the elevation of the pipe, the more heat loss in the pipeline, which affects a temperature drop. According to the principle of the cooling tower, the more temperature drops in the pipeline, the better the performance of the cooling tower. As the elevation of a pipe increases, it is exposed to more environmental factors that contribute to heat loss. Therefore, the proportional relationship between temperature drop and pipe elevation highlights the strategic importance of considering elevation in achieving superior cooling tower performance through increased heat dissipation [13].

## 5 Conclusion

The study, conducted using ANSYS software, analyzed fluid flow in a pipeline, focusing on temperature drop and its impact on cooling tower performance. Results revealed that higher pipe elevations led to decreased velocity, affecting pressure distribution. Different temperature inlets affected velocity but not pressure. The findings confirmed a direct relationship between temperature drop and pipe elevation, crucial for understanding cooling tower performance. The study's objectives were successfully achieved, emphasizing the significance of temperature drop in enhancing cooling tower efficiency.

In contrast, different elevations could be used depending on the design of the cooling tower and its location. In the future, this result can be used as a guideline for engineers and designers to conduct a new piping system for the cooling tower. Based on the result, engineers can predict the elevation of the pipe to the cooling tower, which can give better performance to the cooling tower. Different temperatures can also be used as they do not impact the performance of the cooling tower.

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## Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

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