Optimizing Pipeline Operation through a Centralized Controller

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Category: Multi-Disciplinary Engineering Capstone – Team #12

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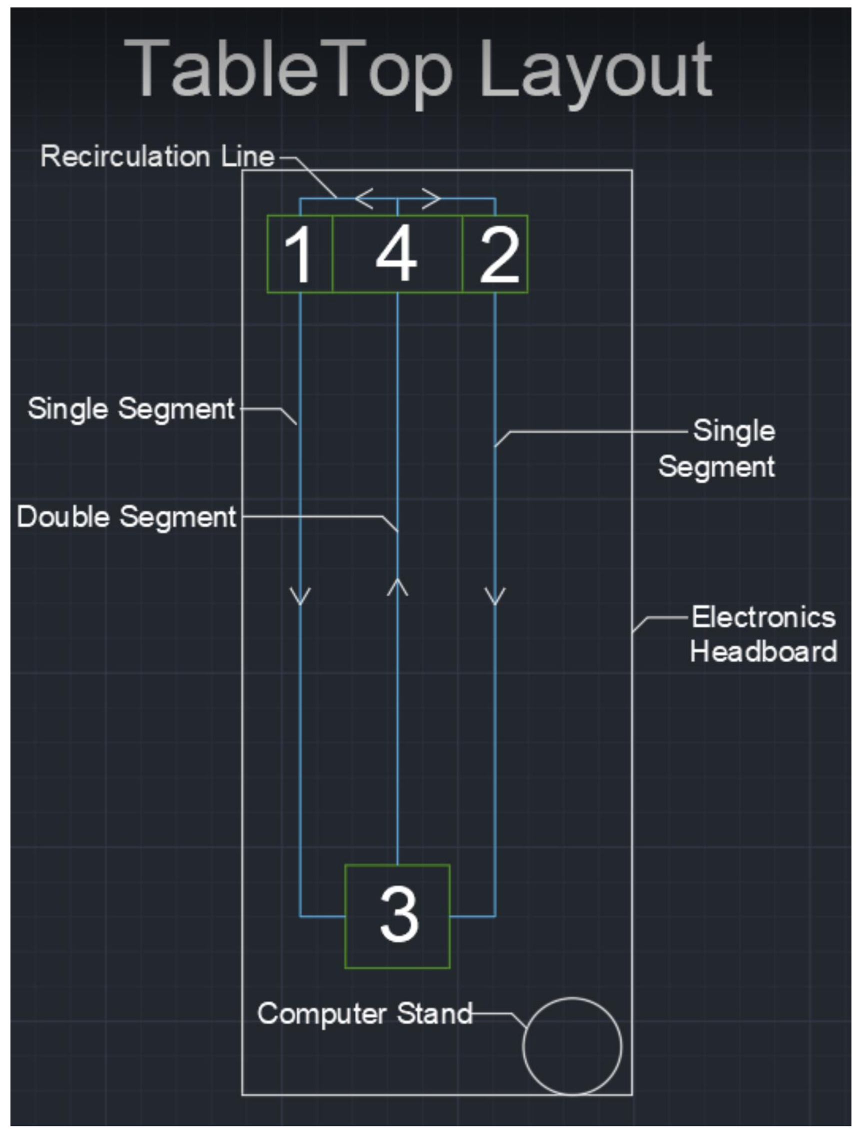
INTRODUCTION

The goal of this project was to build a functional tabletop model pipeline system with a centralized controller to demonstrate key concepts in pipeline system control and optimization.

The system will be used to showcase the differences between human and computer pipeline operation based on the time taken to empty the inlet tanks. Pipeline components (control valves and pump flow) are operated by the centralized controller and are compared to human operation to highlight optimization. Pipeline systems provide a wide array of services within society, primarily to transport fluids from one location to another for energy services. Society and engineers must uphold the responsibility to engage in practices that prevent harm to the environment and reduce the resulting energy footprint. A key pillar of energy engineering and this project is the optimization of existing technologies to make them more sustainable and reduce the energy footprint on the environment.



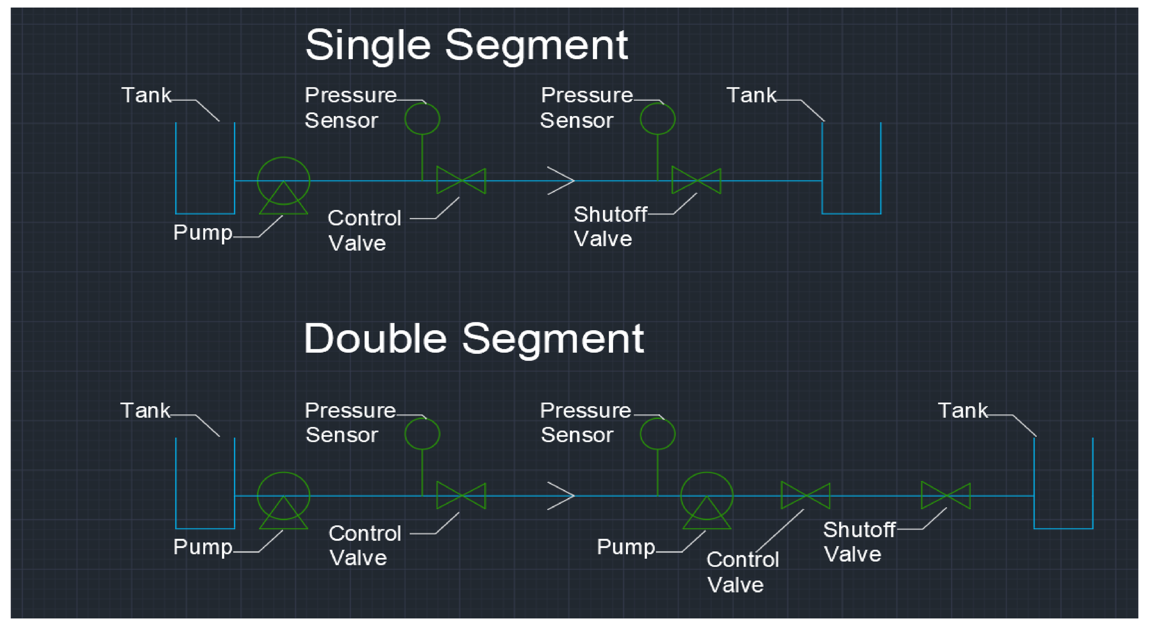
OBJECTIVES

The primary design requirement is to maintain an effective length-diameter ratio of about 10,000 on each piping segment. This ensures that the majority of the head loss is due to friction and not from a static pressure difference in the inlet and outlet tanks. Additionally, the flow through the majority of the effective length must be turbulent.

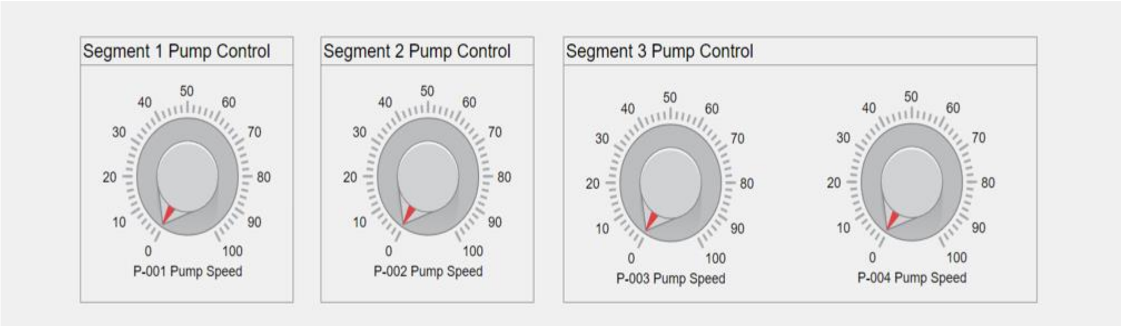
Historically, it has been difficult to implement a large-scale network with a centralized control system due to connectivity issues, but this is now possible using low latency broadband internet through technologies like fiber-optics and satellite internet. This project will demonstrate the optimization initiatives that are possible with new technologies by simulating and optimizing a control scheme using MATLAB and Simulink.

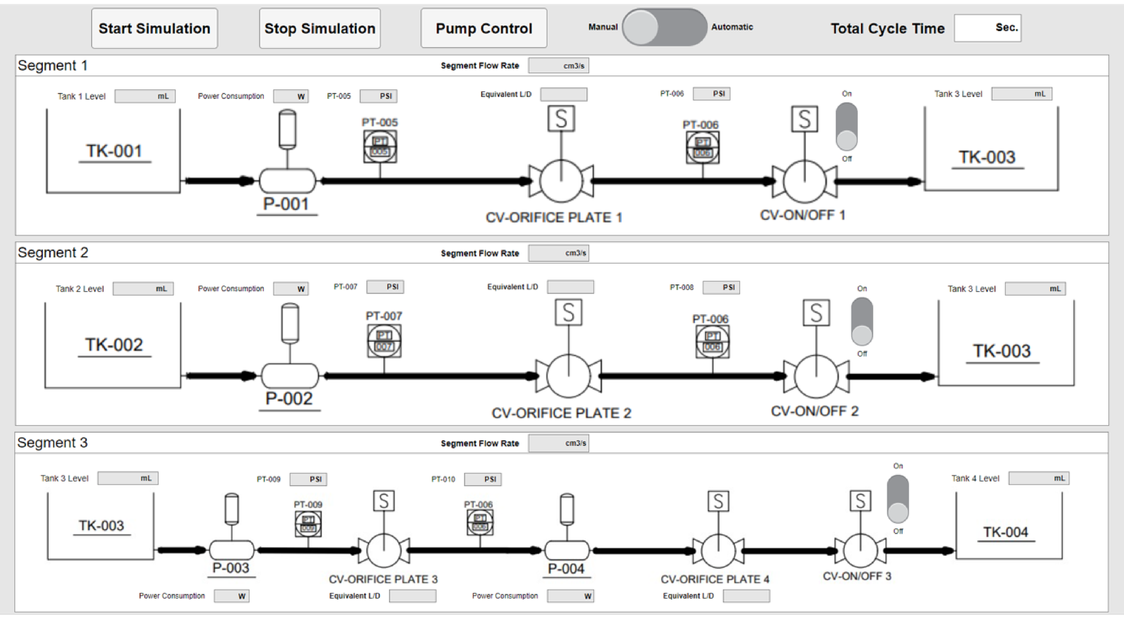
MATERIALS & METHODS

The fluid properties and instrument calibrations of the system's components were determined through the testing of a single-segment design. From this testing apparatus, the characteristics of the orifice-plate valve, control valves, and pumps were calculated using timed flow tests, and water columns.



The model has been scaled to match the parameters of one of Pembina's gathering laterals. The Controller and HMI (Human Machine Interface) are designed and operated within MATLAB and Simulink.



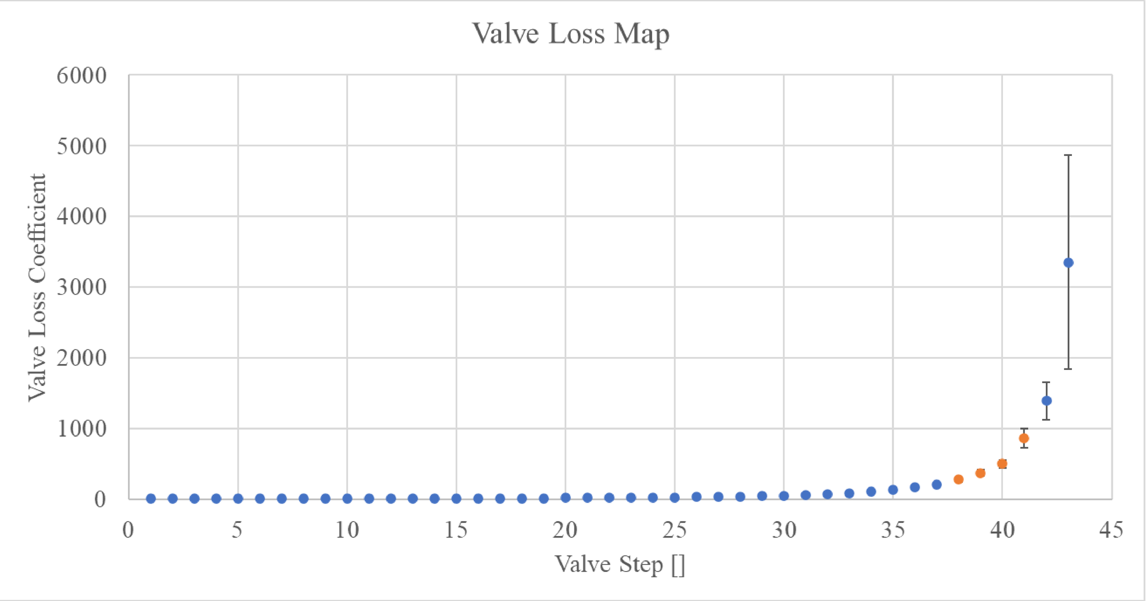


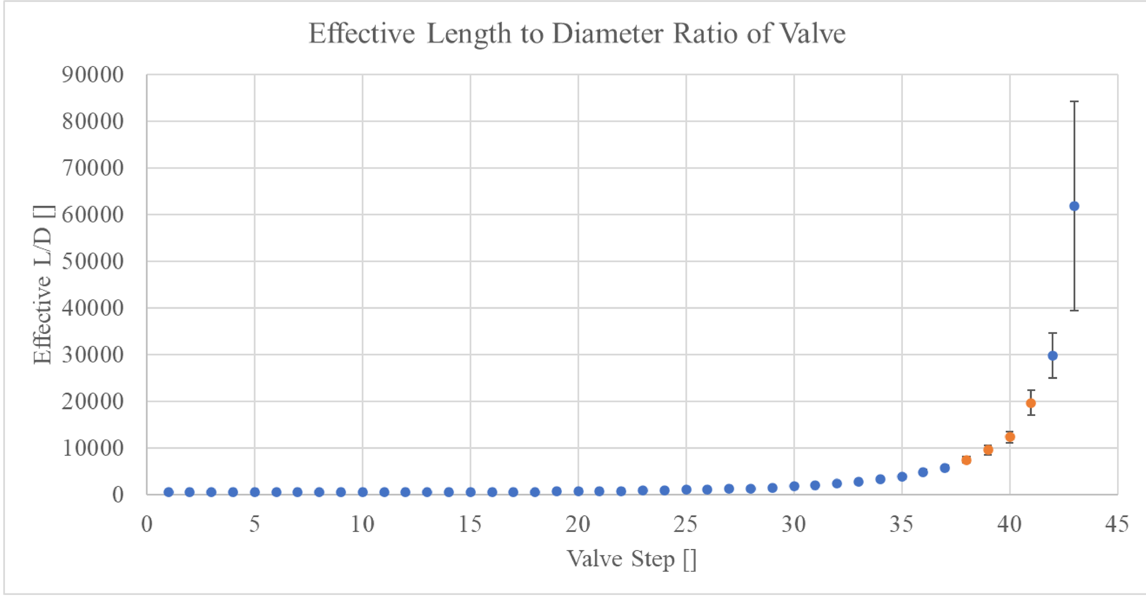
OPC-UA (Open Platform Communications – Unified Architecture) is an open-source, cross-platform communication platform defined by IEC 61541 and developed by the OPC Foundation. The primary purpose is to allow for data exchange between low-level sensors and actuators and high-level applications.

Each microcontroller runs on identical code, allowing them to independently communicate with a program on the PC via an OPC library. The program acts as the OPC server, which the Simulink model then connects to in order to send and receive data to each microcontroller.

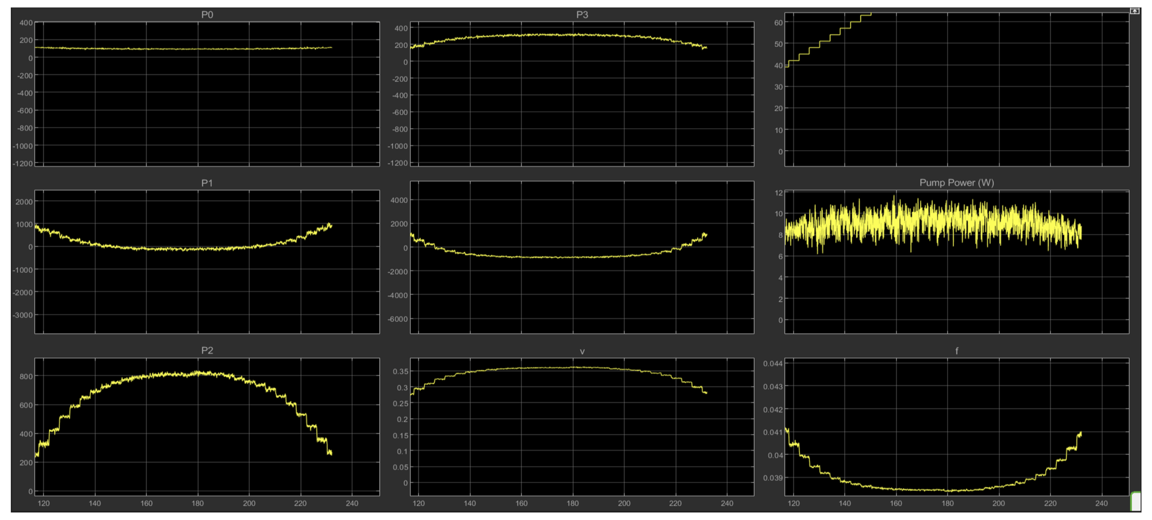
RESULTS & ANALYSIS

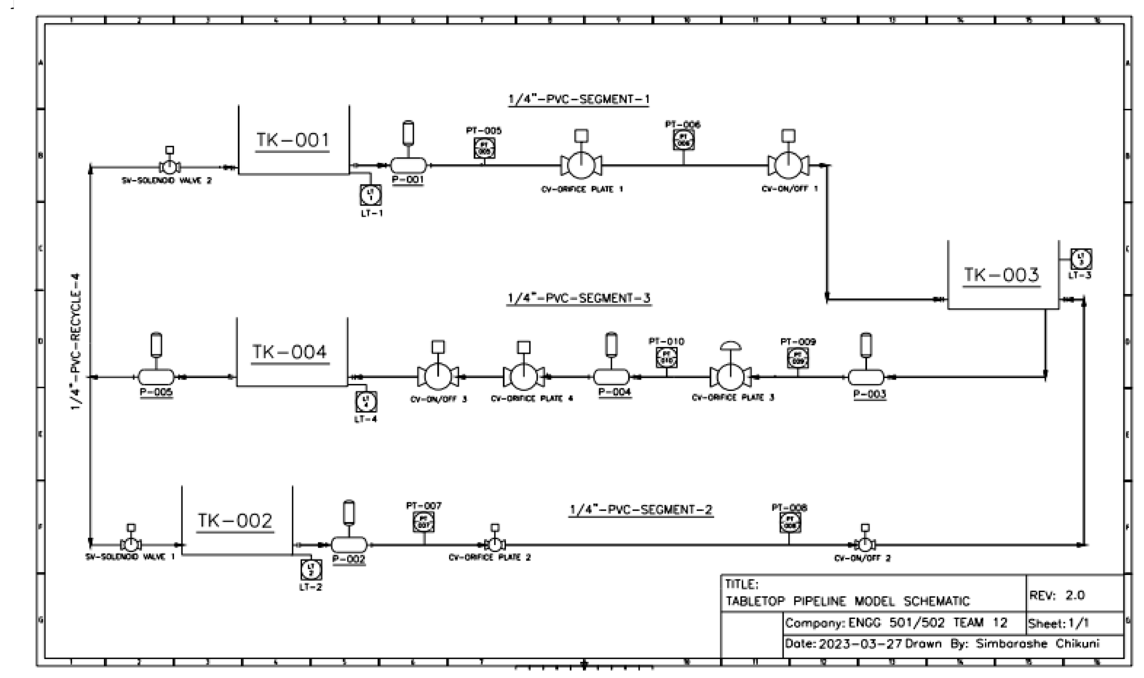
Establishing that the orifice-control valve can be used to emulate an effective length-diameter ratio given similar loss coefficient curves.





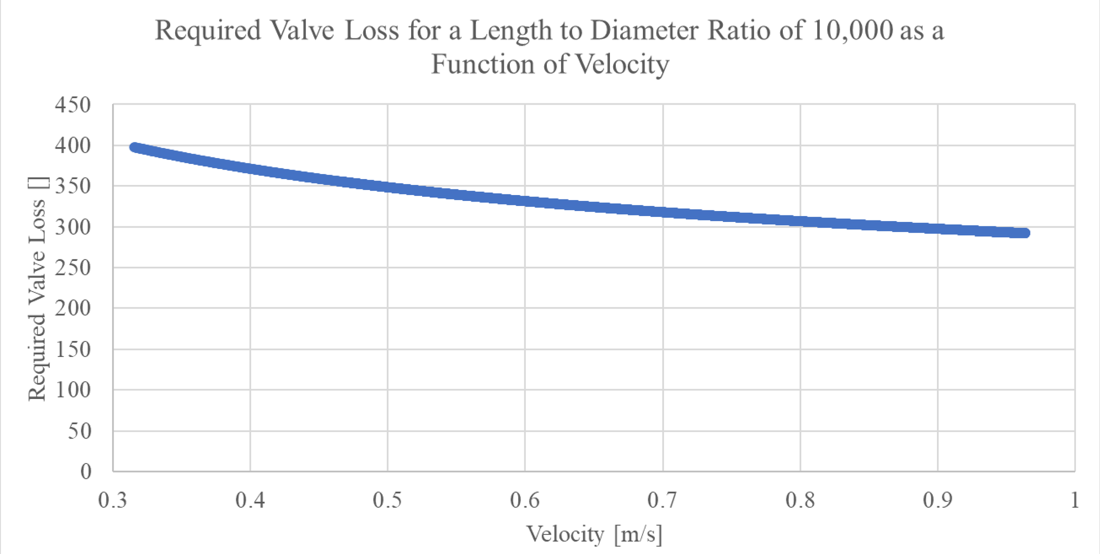
Continuous readings from various instrumentation and calculated values during testing operation. Plots contain (from top left to bottom right going down each column): Tank Pressure [Pa], PT-001 reading (Pressure Transducer) reading [Pa], PT-002 reading [Pa], PT-003 reading [Pa] , Effective L/D [], Velocity [m/s], Valve Step [], Pump Power [W], Friction Factor [].



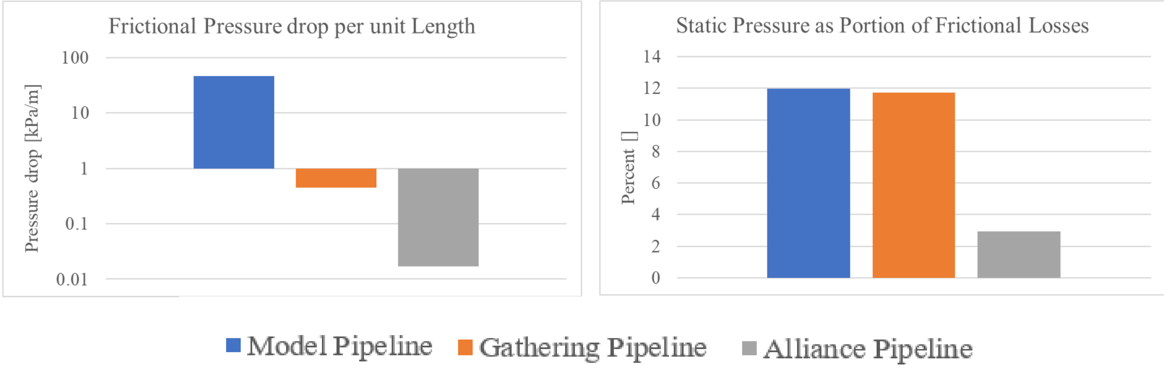


VERIFICATION & VALIDATION

A consequence of a tabletop model pipeline is the inability to reach large Reynold's Numbers (in the order of 10^8) where the friction factor is independent of the velocity. As a result, the effective length of the valve will increase as the velocity increases, which is not the case in real pipeline systems.



Since the goal of the project was to emulate the frictional losses in a real pipeline system, the frictional pressure drop per unit length and the portion of frictional pressure loss compared to maximum static pressure from inlet tanks were compared to multiple pipeline systems shown in the plots below:



While the model does not accurately emulate pipelines in the range of 100 km, it is a close model of smaller gathering pipelines on drilling sites.

CONCLUSION

The goal of this project was to physically replicate a real world pipeline system and perform autonomous operation of the system using a controller. The operation of said controller showcases a reduction in certain parameters such as time, power consumption and costs as compared to human operation. Through testing, and utilizing appropriate engineering methodologies, the effective design parameters were met, and the system has been optimized to represent real world pipeline systems.

REFERENCES

Munson, B. R., Okiishi, T. H., Huebesch, W. W., & Rothmayer, A. P. (2013). *Fundamentals of Fluid Mechanics*. John Wiley & Sons, Inc.

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