# Research Projects conducted under the Multiphase Flow Loop Facility
## at the National University of Singapore (NUS)


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## INTRODUCTION

The multiphase oil-water-air flow test loop facility is a three-phase oil-water-air integrated facility, designed to accommodate the complex flow of multiphase oil-water-gas mixtures, as well as to aid projects related to fundamental flow assurance issues currently faced by the offshore oil and gas industry. Additionally, subsea production equipment such as multiphase flow meters and pumps, compact separators, and wet-gas compressors can be tested in the facility. Multiphase flow, equipment applications, and ideas related to oil and gas transportation were investigated in this project.

## EXPERIMENTAL

### Instrumentation and Flow Visualization

Firstly, instrumentation within the lab were studied to understand respective purposes within the multiphase flow loop. Flow visualization exercises were also carried out by first recording with the high-speed camera (Photron FASTCAM) in the facility, followed by the monitoring of the flow on screen. Floodlights and elevation of surfaces, as well as adjustment of camera contrast and brightness were considered when recording the flow.

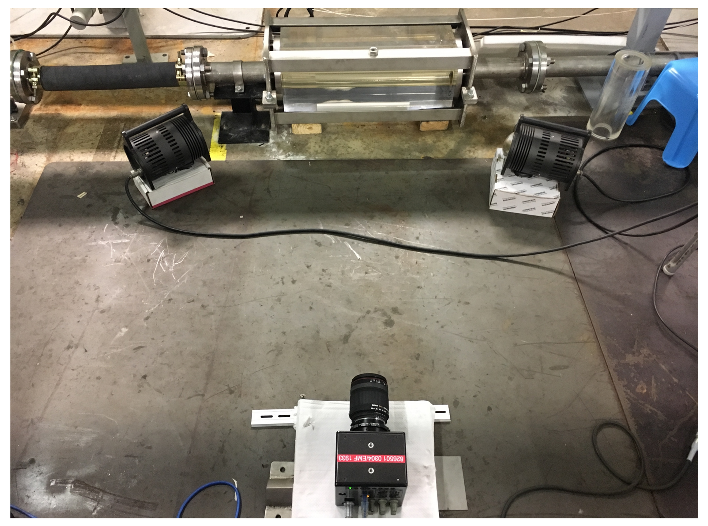

*Figure 1. High-speed camera setup for flow visualization*

### Water Quality Sensor Configuration

With water quality being a concern, multiple solutions were discussed and tested – one of which being the use of the Horiba ® Water Quality sensor. Troubleshooting was conducted on an ultrafiltration water filter and the sensor itself, thereby discovering the need for replacement of the dissolved oxygen sensor membrane. However, auto and manual calibration of the sensor led to the conclusion that it was not feasible for this experiment.

### Capacitance and Conductance

Thus, the project was directed toward the use of conductance and capacitance to monitor the purity and level of water, respectively. After thorough research of possible methods, open source code programmed onto Arduino UNO microcontroller boards were used to mimic conductivity and conductance probes. The circuitry of the respective probes are shown in figure [2] and [3].

## EXPERIMENTAL

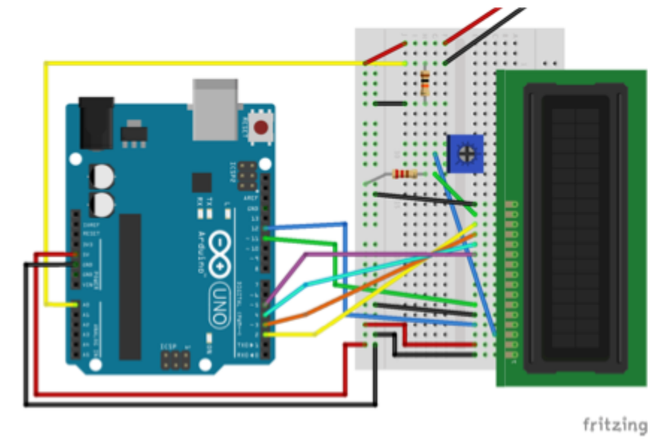

*Figure 2. Breadboard circuitry describing the setup of a conductivity probe to an Arduino Uno model*

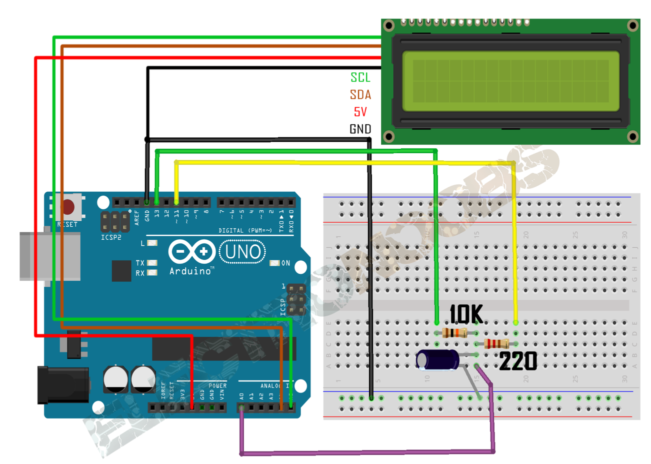

*Figure 3. Breadboard circuitry describing the setup of a capacitance meter using an Arduino Uno model*

### Piping and Instrumentation Diagram

As a side project, the process flow diagram of a three-phase flow system at NUS was reproduced as a piping and instrumentation diagram(P&ID), allowing for an understanding of the importance of schematic drawings, along with the opportunity to study the available instrumentation and control devices commonly used in the process industry.

## RESULTS

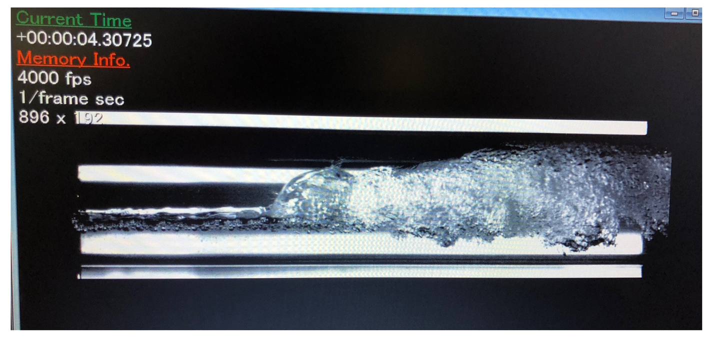

*Figure 4. Screen capture of flow taken by Photron FASTCAM*

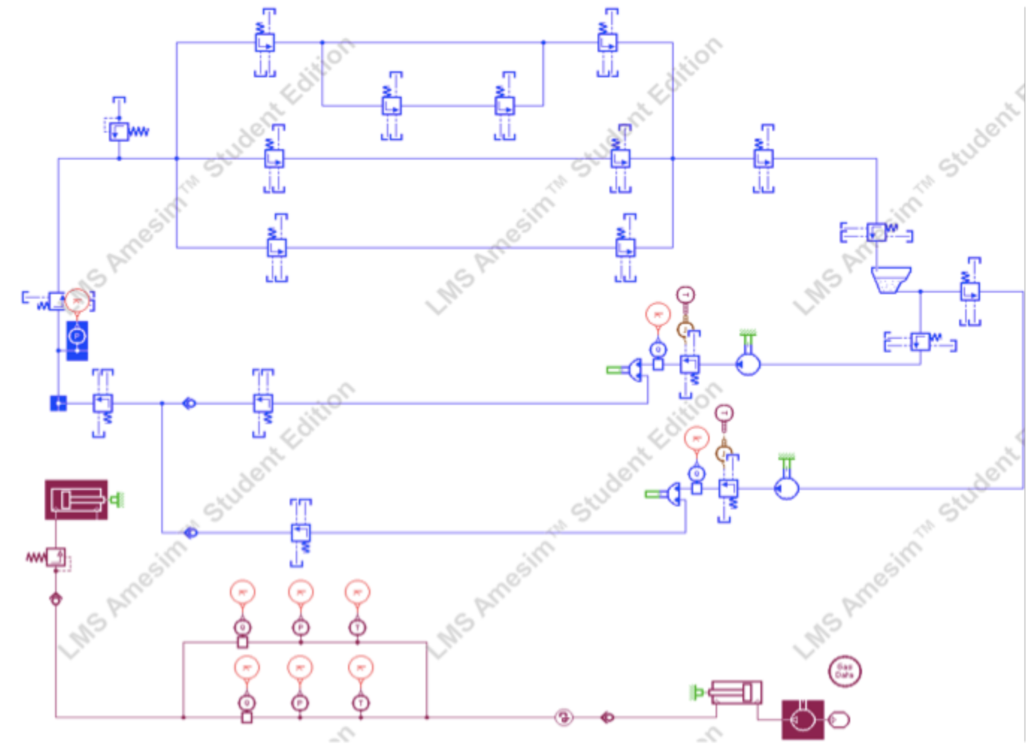

*Figure 5. Piping and Instrumentation Diagram of the Three Phase Flow System at NUS*

## RESULTS

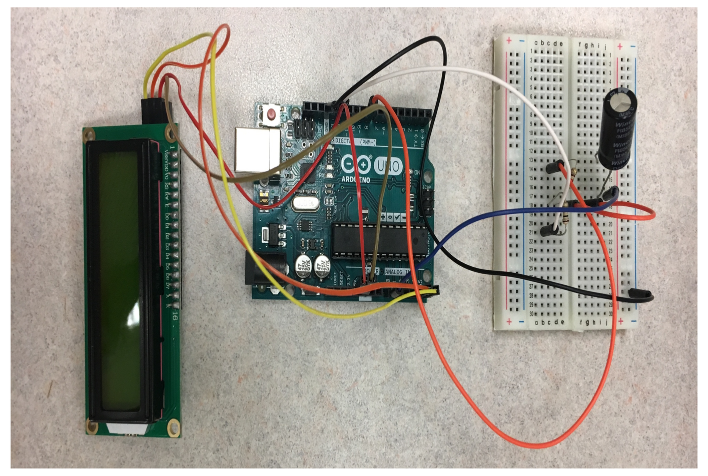

Figure 6. Physical setup of Arduino Uno capacitance meter

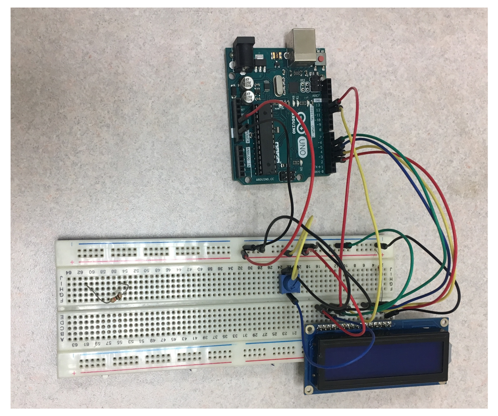

Figure 7. Physical setup of Arduino Uno prior to connecting to a conductivity probe

## DISCUSSION

The use of high-speed camera videos in the facility proves useful, such as when validating measurements from sensors or other equipment. This brief experimentation with the setup provided the opportunity to improve the clarity, and thus accuracy, of the video evidence captured.

AMESim (Advanced Modeling Environment for performing Simulations of engineering systems) operates in a 1D lumped parameter time domain. Common components of P&ID diagrams include process piping, wherein their sizes and identification are specified, such as pipe classes or piping line numbers, flow directions, interconnections references, and permanent start-up, flush and bypass lines. Additionally, mechanical equipment and process control instrumentation are primary components of the diagram, with unique tag identifiers to differentiate between valves, control inputs and outputs, as well as miscellaneous equipment. The diagram is normally completed with interfaces for class changes, information regarding the computer control system, and identification of components and subsystems. Aside from designing, P&IDs allow for the development of system control schemes, wherein safety and operational investigations can be conducted, while start-up sequences and control and shutdown schemes can be practiced. This way, the diagram simplifies the process of maintenance and modification of the design after initial build.

Setting up a capacitance meter allows for the measurement of capacitance of unknown capacitors.

## DISCUSSION

The working principle behind this derives from the time constant, which represents the time taken to charge a capacitor through a resistor to reach 63.2% of the maximum supply voltage. Alternatively, this can also be viewed as the time taken by a fully charged capacitor to discharge to 36.8% of its maximum voltage through a resistor. Smaller capacitors have a lower time constant, while larger ones have a higher time constant.

In this experiment, a pin on the Arduino UNO board charges the capacitor through the 10kW resistor. By knowing the resistance value of the resistor, the time constant of the capacitor, and using the ADC of the Arduino, the voltage the capacitor reaches can be determined. On the other hand, the purpose of the conductivity probe is to measure resistance and translate it as an indicator of conductivity. The probe measures the current and applies Ohm's law to calculate the resistance of the solution. From there, conductance is determined as the reciprocal of the resistance.

## CONCLUSION

The projects carried out revolved around gaining insight and contributing to existing ideas solving major problems. Developing these ideas required heavy research, thus emphasizing on efficient research techniques when studying tutorials, articles, and publications. A main example of this is the capacitance and conductance project, wherein existing sensors were experimented with for improvement at a low cost, due to the nature of open source code. Additionally, the project was feasible due to the durability of the sensors, which simultaneously explains its popularity in both research and industry. While honing previous knowledge, new skills in programming and electrical circuits were tested too, alongside learning the functionality of schematic drawings and studying issues linked to oil and gas transportation.

## ACKNOWLEDGMENTS


I would like to thank Professor Loh Wai Lam for the invaluable opportunity to experience learning about multiphase oil-water-air flow and to gain insight into a prospective career. Additionally, I gratefully acknowledge the time and guidance provided by Dr. Nguyen, Dr. Wan, and Vivek Premanadhan.


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