OSIsoft Academic Hub to Advance the Techniques taught in Unit Operations

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WestVirginiaUniversity.

Outline

- Introduction
- Background – Unit Operations at WVU
- Problem – What was wrong with Unit Operations at WVU?
- Solution – Applying Arduinos for data collection, process automation, and data recording/visualization with OSIsoft Academic Hub
- Going Forward – Generalizing to other experiments

Introduction

- **Dr. Jeremy Hardinger**
- Teaching Instructor at WVU for 3 years
- B.S. and PhD at WVU in Chemical Engineering
- Research in biometrics, computation chemistry, numerical methods, electrochemistry, lab-scale reactor design
- Manage Unit Operations lab at WVU

Introduction

- **Jacob Douglas**
- **West Virginia University**
  - Bachelors of Science Chemical Engineering -2017
  - Masters of Science Chemical Engineering - Spring 2019
    - Focus: Application of Model Predictive Control
- **OSIsoft Academic Intern**
  - Arduino to PI
  - Dynamic Simulators to PI
  - Web API to MATLAB GUI

Unit Operations at WVU

- Senior level, year-long (2 x 16 week semesters) course
  - All major topics either taken prior or concurrently
- Class (approximately 30 students) divided into groups of 4
- Each group performs 4 different experiments over 32 weeks
  - Group meets once per week for up to 4 hours
  - Gives final presentation at end of 8 week cycle

Unit Operations at WVU

- Batch Distillation
- Dye Fade Kinetics
- Centrifugal Pump Operation
- Residence Time Distribution
- Thermal Conductivity in Spheres
- Enzyme Kinetics
- Convective Heat Transfer in Pipe
- Tank Drainage
- Process Controls
- Pressure Drop through Pipes/Valves

Unit Operations at WVU

- Example - Batch distillation - Using a 15 L, 6 stage column with reflux controller:
  - Determine tray efficiency
  - Determine heat loss to environment
  - Compare column performance to McCabe-Thiele and simulation
  - Force column to flood, compare flowrate to predicted flooding conditions from correlations

Unit Operations at WVU

- Learning Outcomes
  - Develop the ability to design and to perform laboratory experiments from a general problem statement and relevant literature suggested;
  - Become familiar with process equipment and instrumentation similar to that found in actual plant or research environments;
  - Integrate the principles learned in classes with laboratory operation and practice;
  - Learn how to document data and ideas appropriately in a laboratory notebook;
  - Analyze experimental data using basic chemical-engineering principles;
  - Communicate effectively in both written and oral formats;
  - Develop interpersonal skills necessary for team performance;
  - Practice standard laboratory safety procedures and follow good environmental practice.

Unit Operations at WVU

- Learning Outcomes
  - **Design and perform a physical experiment to determine some value using scaled-down versions of industrial hardware**
  - **Apply chemical engineering knowledge to non-ideal data (noise, systematic error, etc.)**
  - Write professional lab reports
  - Work in groups
  - Become accustomed to using Industrial software

The Problem(s) in the lab

- Equipment becoming dated and replacements were expensive
- Older experiments were not as safety-conscious as is now appropriate
- Lab Data from past semesters and years was getting lost
- **Students were getting frustrated/confused with old equipment/software.**
- **This prevented them from learning what working with real equipment is like**
- **Data was too coarse to compare to simulators (CHEMCAD) and quantify error.**

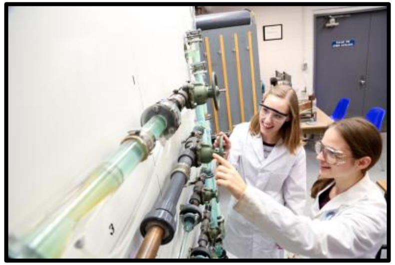
Solution - OSIsoft Academic Hub

- Academic Hub
  - Supports classroom activities and data sharing community across several universities

  - Allows for lab data to be
    - Securely stored
      - Data will not be lost in the case of internet or power outage
    - Easily accessed from either to Excel or directly to MATLAB
    - Easily shared across universities

Lab Data

Simulation Data



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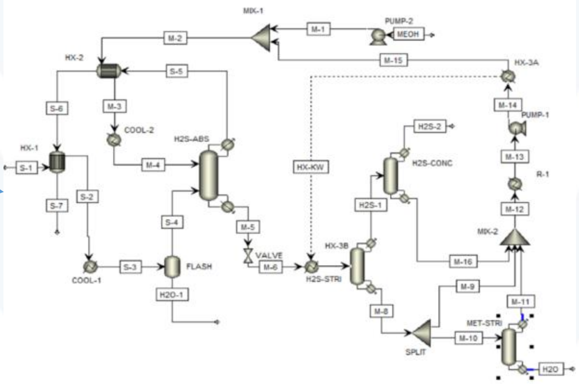
LabVIEW

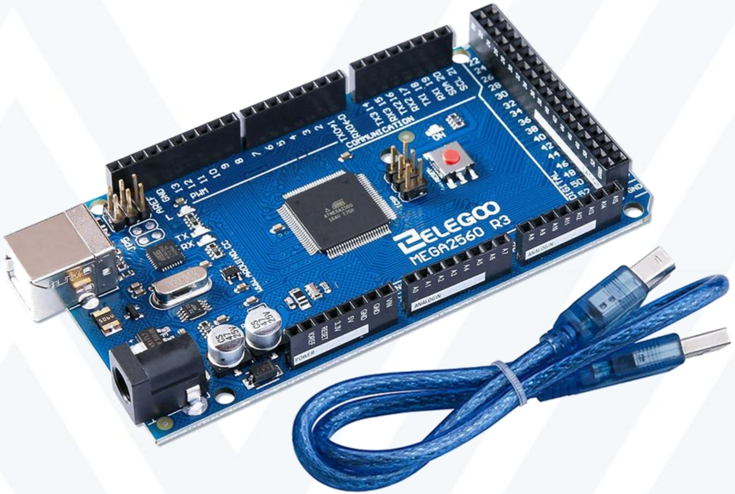
OPC FOUNDATION

OSIsoft Academic Hub



Solution

- What is an Arduino?
  - Programmable, open-source (hardware and software) microcontroller
  - Standard hardware (multiple Arduino forms)
  - Multiple digital and analog inputs and outputs (DC 0-5V, supports PWM)
  - Premade or custom modular “shields” mount using easily soldered headers
  - **Approximately $15 per unit**



Elegoo MEGA 2560 R3 Board

Batch Distillation Lab Problem(s)

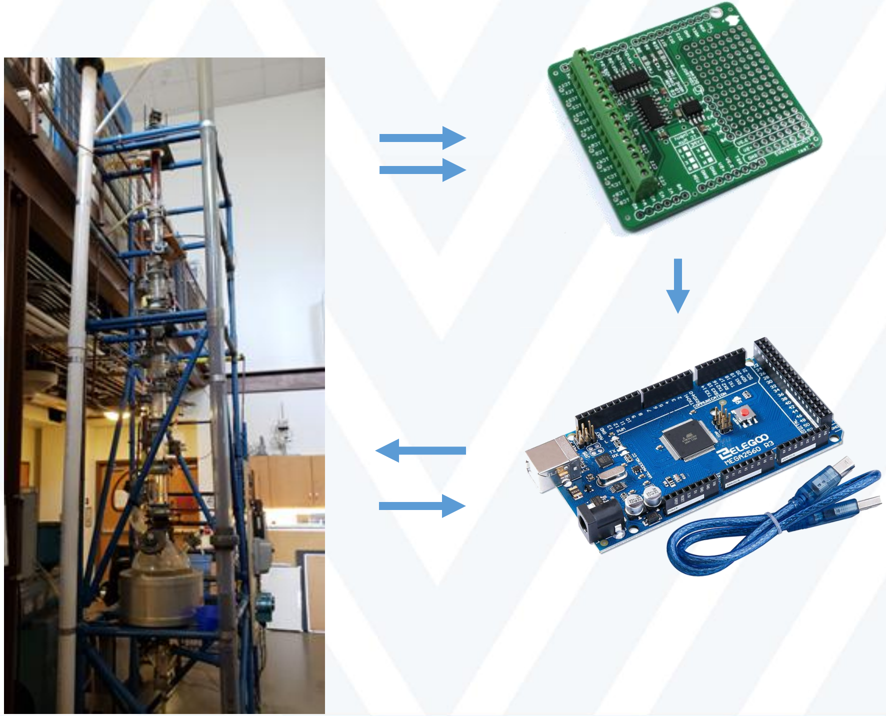
- Distillation example
  - Methanol product is volatile, flammable, and toxic. Product evaporates/absorbs atmospheric water as it is taken for analysis.
  - Temperature data acquisition done by one manual thermocouple reader with thermocouples on 3 stages and in the pot. Miss a data point and it’s gone.
  - Measure flowrates with bucket-and-clock method. If flowrate changes during process, there is no easy way to quantify.
  - Reflux controlled manually. Must be constant. No way to automate (PID controller).

Batch Distillation Lab Solution(s)

- Distillation example
  - Switched to propylene glycol/water system. Non-flammable, less toxic, less volatile, but higher temperature bubble point.
  - Temperature measured using Arduino shield (more on this later), logged using OSIsoft Academic Hub.
  - Measure cooling water flowrates with DC 3-18V flowmeter.
  - Reflux control via Arduino.
  - Comparison between lab equipment and simulators (CHEMCAD or Aspen)

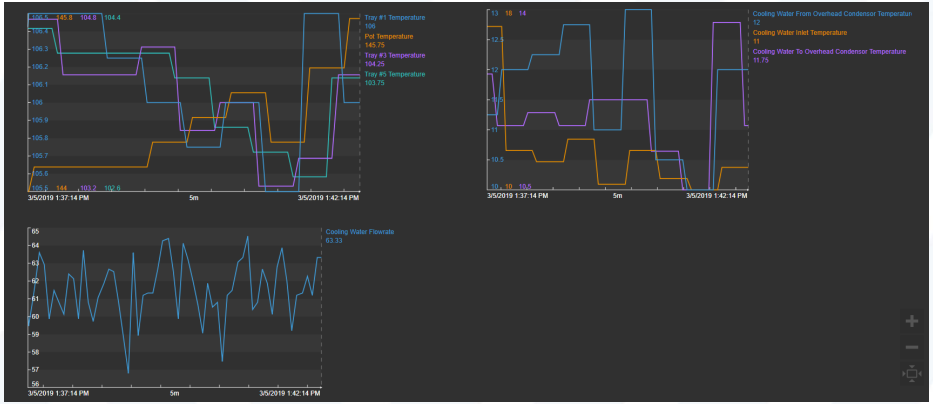
Batch Distillation Lab Solution(s)

- Thermocouple interfaces with shield
  - Thermocouples directly connect to the shield
- Shield is connected to Arduino
  - This interface is handled automatically by software accompanying shield
- Arduino is connected to PC
  - This interface must be manually programmed using Arduino language.
  - This language is essentially C.
- PC connects to Academic Hub
  - This interface is handled by MATLAB
- Arduino controls reflux ratio

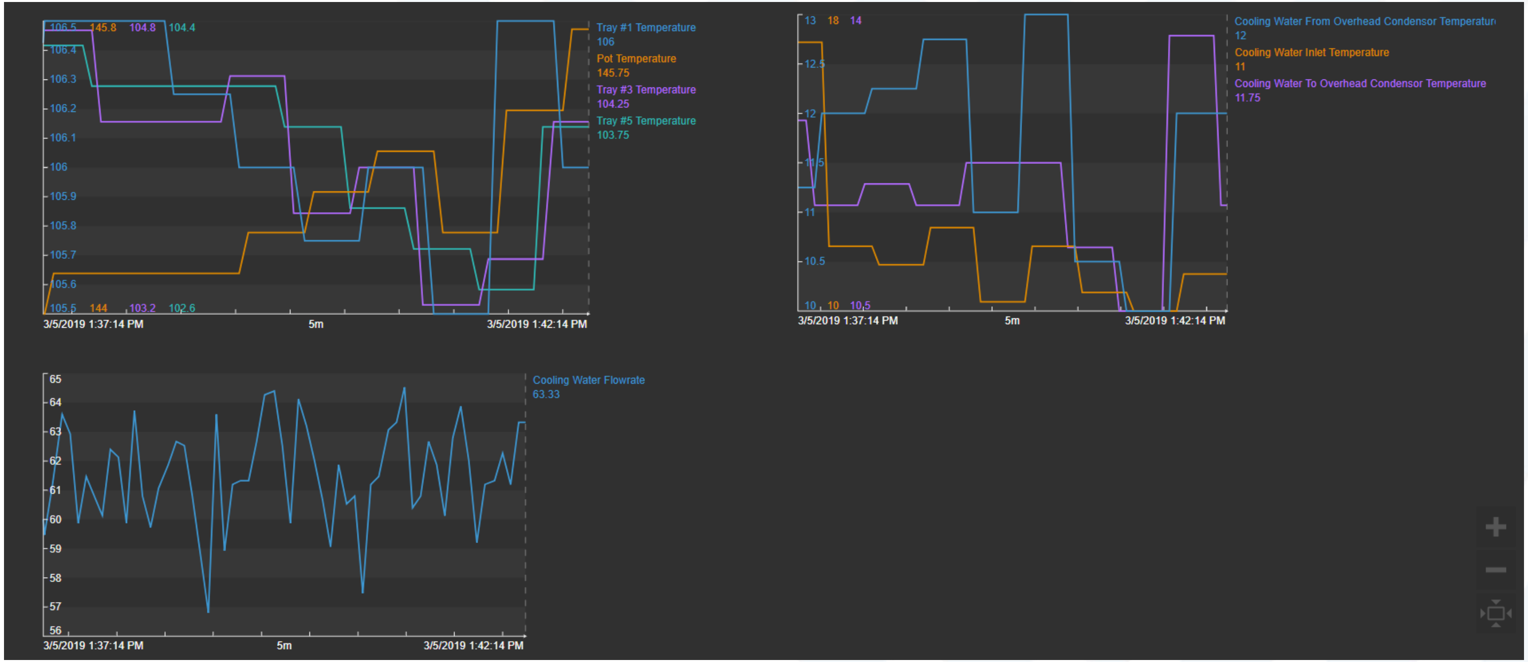


Batch Distillation Lab Solution(s)

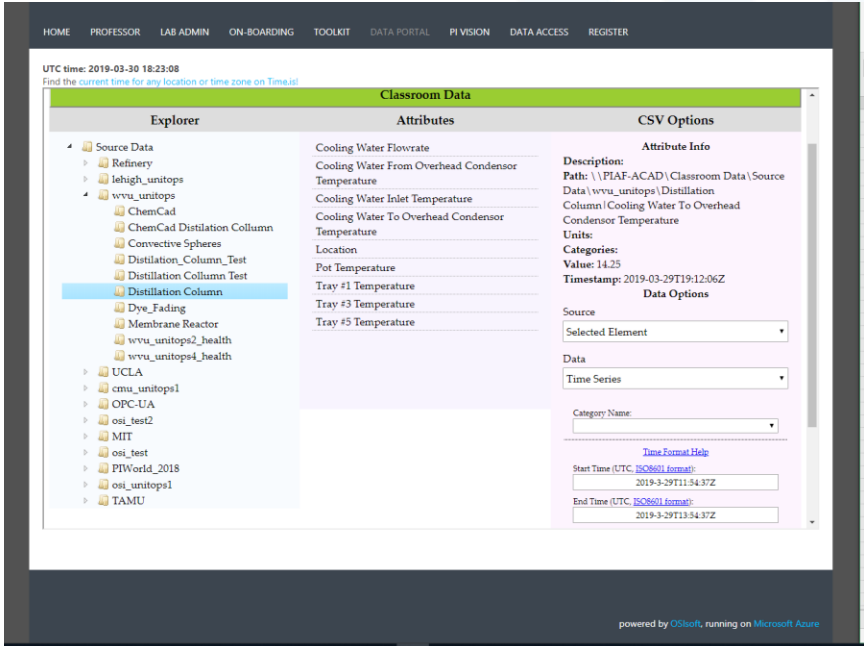
- What this allows
  - Hardware is very low-level and reliable
  - students get reliable data acquisition and have instantaneous control of reflux ratio.
  - All data is logged instantly to the Academic Hub.
  - Students can retrieve this at will, view in real-time directly from computer or online, compare to previous group’s data
  - Data and easily be exported from Academic Hub to Excel/Matlab/etc.
  - Data is not lost, even in event of power or internet outage.

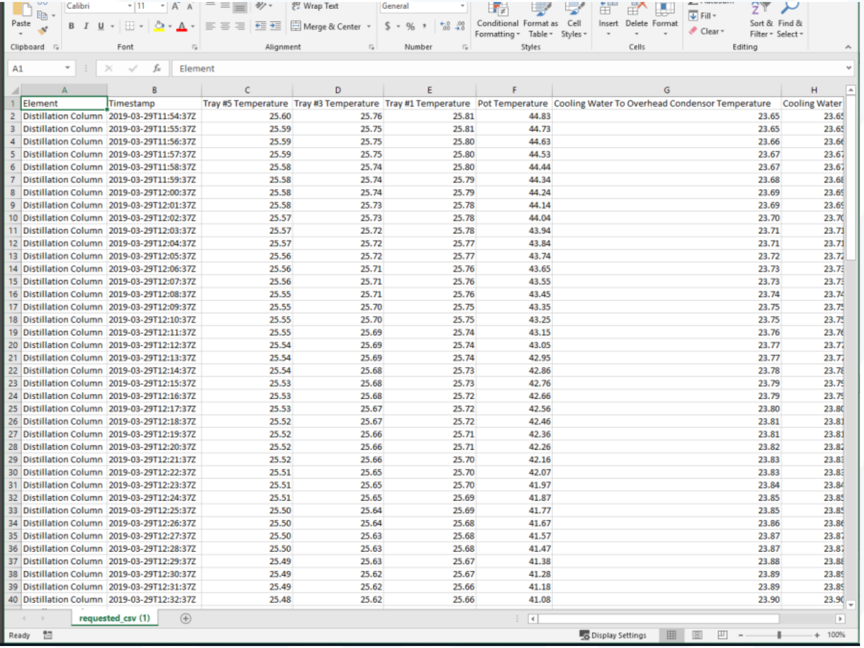


Batch Distillation Lab Solution(s)



Batch Distillation Lab Solution(s)



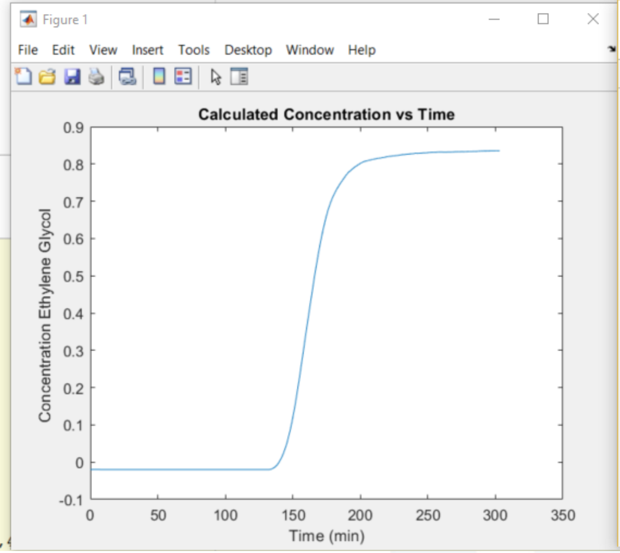


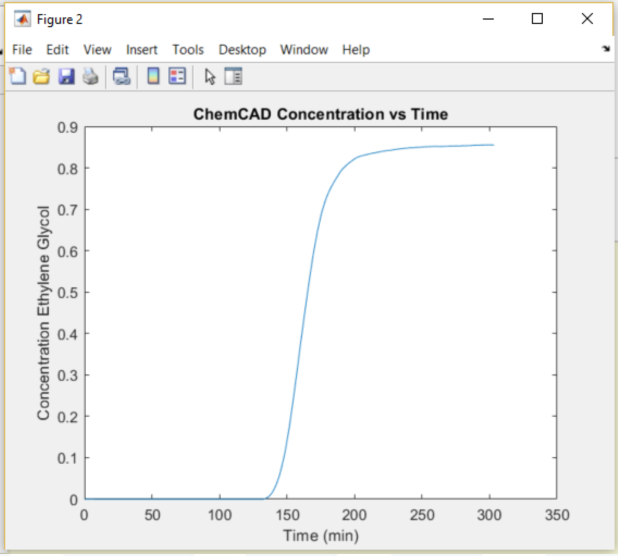
	A	B	C	D	E	F	G	H
1	Element	Timestamp	Tray #5 Temperature	Tray #3 Temperature	Tray #1 Temperature	Pot Temperature	Cooling Water To Overhead Condensor Temperature	Cooling Water
2	Distillation Column	2019-03-29T11:54:37Z	25.60	25.76	25.81	44.83	23.65	23.65
3	Distillation Column	2019-03-29T11:55:37Z	25.59	25.75	25.81	44.73	23.65	23.65
4	Distillation Column	2019-03-29T11:56:37Z	25.59	25.75	25.80	44.63	23.66	23.66
5	Distillation Column	2019-03-29T11:57:37Z	25.59	25.75	25.80	44.53	23.67	23.67
6	Distillation Column	2019-03-29T11:58:37Z	25.58	25.74	25.80	44.44	23.67	23.67
7	Distillation Column	2019-03-29T11:59:37Z	25.58	25.74	25.79	44.34	23.68	23.68
8	Distillation Column	2019-03-29T12:00:37Z	25.58	25.74	25.79	44.24	23.69	23.69
9	Distillation Column	2019-03-29T12:01:37Z	25.58	25.73	25.78	44.14	23.69	23.69
10	Distillation Column	2019-03-29T12:02:37Z	25.57	25.73	25.78	44.04	23.70	23.70
11	Distillation Column	2019-03-29T12:03:37Z	25.57	25.72	25.78	43.94	23.71	23.71
12	Distillation Column	2019-03-29T12:04:37Z	25.57	25.72	25.77	43.84	23.71	23.71
13	Distillation Column	2019-03-29T12:05:37Z	25.56	25.72	25.77	43.74	23.72	23.72
14	Distillation Column	2019-03-29T12:06:37Z	25.56	25.71	25.76	43.65	23.73	23.73
15	Distillation Column	2019-03-29T12:07:37Z	25.56	25.71	25.76	43.55	23.73	23.73
16	Distillation Column	2019-03-29T12:08:37Z	25.55	25.71	25.76	43.45	23.74	23.74
17	Distillation Column	2019-03-29T12:09:37Z	25.55	25.70	25.75	43.35	23.75	23.75
18	Distillation Column	2019-03-29T12:10:37Z	25.55	25.70	25.75	43.25	23.75	23.75
19	Distillation Column	2019-03-29T12:11:37Z	25.55	25.69	25.74	43.15	23.76	23.76
20	Distillation Column	2019-03-29T12:12:37Z	25.54	25.69	25.74	43.05	23.77	23.77
21	Distillation Column	2019-03-29T12:13:37Z	25.54	25.69	25.74	42.95	23.77	23.77
22	Distillation Column	2019-03-29T12:14:37Z	25.54	25.68	25.73	42.86	23.78	23.78
23	Distillation Column	2019-03-29T12:15:37Z	25.53	25.68	25.73	42.76	23.79	23.79
24	Distillation Column	2019-03-29T12:16:37Z	25.53	25.68	25.72	42.66	23.79	23.79
25	Distillation Column	2019-03-29T12:17:37Z	25.53	25.67	25.72	42.56	23.80	23.80
26	Distillation Column	2019-03-29T12:18:37Z	25.52	25.67	25.72	42.46	23.81	23.81
27	Distillation Column	2019-03-29T12:19:37Z	25.52	25.66	25.71	42.36	23.81	23.81
28	Distillation Column	2019-03-29T12:20:37Z	25.52	25.66	25.71	42.26	23.82	23.82
29	Distillation Column	2019-03-29T12:21:37Z	25.52	25.66	25.70	42.16	23.83	23.83
30	Distillation Column	2019-03-29T12:22:37Z	25.51	25.65	25.70	42.07	23.83	23.83
31	Distillation Column	2019-03-29T12:23:37Z	25.51	25.65	25.70	41.97	23.84	23.84
32	Distillation Column	2019-03-29T12:24:37Z	25.51	25.65	25.69	41.87	23.85	23.85
33	Distillation Column	2019-03-29T12:25:37Z	25.50	25.64	25.69	41.77	23.85	23.85
34	Distillation Column	2019-03-29T12:26:37Z	25.50	25.64	25.68	41.67	23.86	23.86
35	Distillation Column	2019-03-29T12:27:37Z	25.50	25.63	25.68	41.57	23.87	23.87
36	Distillation Column	2019-03-29T12:28:37Z	25.50	25.63	25.68	41.47	23.87	23.87
37	Distillation Column	2019-03-29T12:29:37Z	25.49	25.63	25.67	41.38	23.88	23.88
38	Distillation Column	2019-03-29T12:30:37Z	25.49	25.62	25.67	41.28	23.89	23.89
39	Distillation Column	2019-03-29T12:31:37Z	25.49	25.62	25.66	41.18	23.89	23.89
40	Distillation Column	2019-03-29T12:32:37Z	25.48	25.62	25.66	41.08	23.90	23.90

requested_csv (1)

Batch Distillation Lab Solution(s)

```
%Distillation

% 3/28/2019
% Group 4

a0=fx1
a1=(fx2-fx1)/(x2-x1)
a2=(1/(x3-x2))*(((fx3-fx1)/(x3-x1))-a1)
%% step 4
fxmin=min(fx)
findxlocation=find(fx==fxmin)
xmin=x(findxlocation)
%% step5
xtil=((x1+x2)/2)-(a1/(2*a2))
fxnew=a0+a1*(xtil-x1)+a2*(xtil-x1)*(xtil-x2)

C0B=mean(cell2mat(data(660:760,6)))

C0C=1.17

ftB=(cell2mat(data(:,7)))/C0B

ftC=(cell2mat(data(:,14)))./C0C


figure(1)
plot(cell2mat(data(1:1111,1)),cell2mat(data(1:1111,
```





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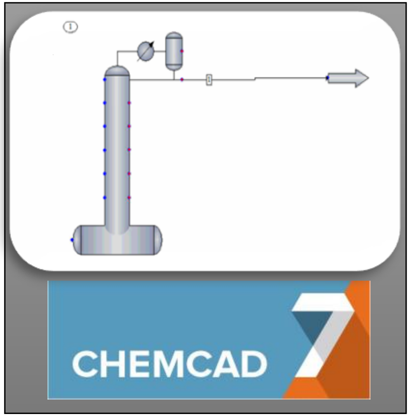
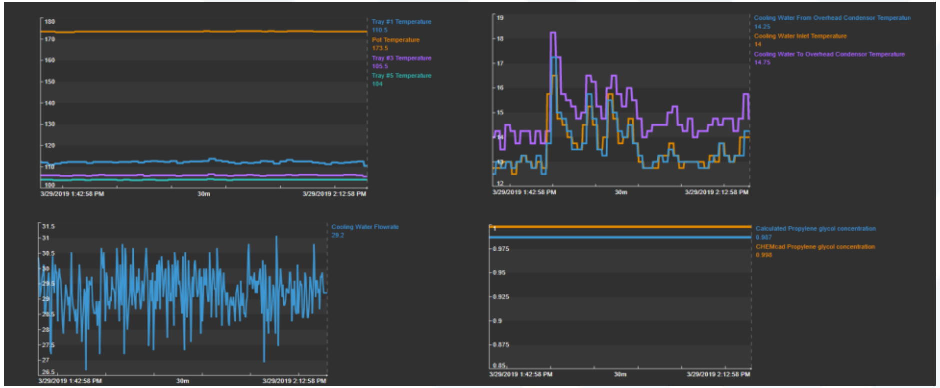
Batch Distillation Lab Solution(s)

- Improvements on Student Learning
  - Students learn how to build data acquisition systems from the ground up. They choose thermocouple types, attach to shields, solder headers.
  - Students learn how to program a micro-controller. The software is open-source and has numerous examples.
  - Students can get enough data to compare outcomes to a simulator (CHEMCAD, Aspen, etc.)
  - Students can control reflux ratio to maintain product purity. This requires them to tune the a PID controller. Input is distillate temperature. Output is reflux position. Arduinos support a PID library.

Batch Distillation Lab Solution(s)

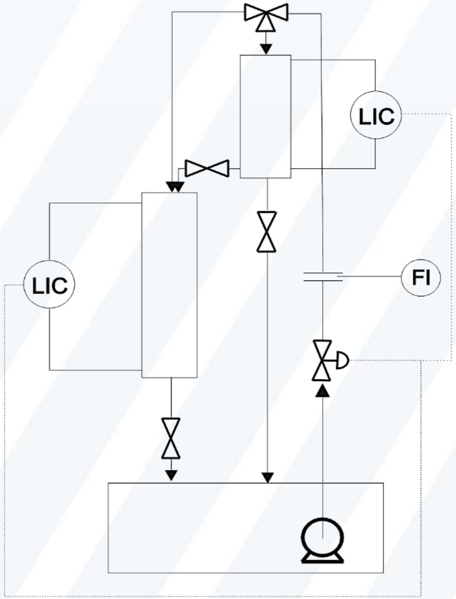
- Comparison between data gathered from lab and data from simulators
    - Most simulators used in the academia either include an OPCDA server or have the ability to export to an OPCDA server





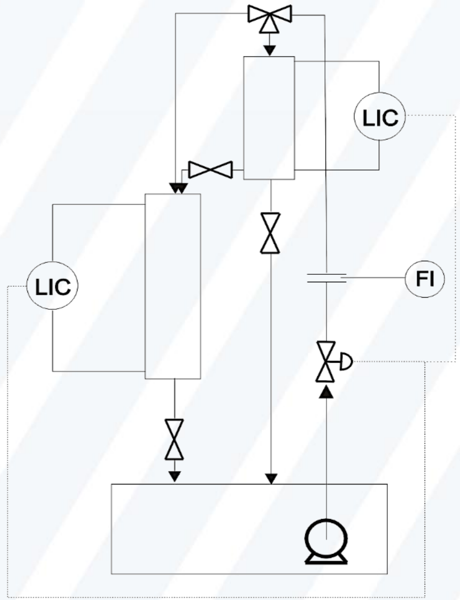
Process Control Lab

- Process Controls
  - A pump circulates water through a tank.
  - The tank has two hand-adjusted drainage valves. One leads to another tank, the other back to the water reservoir.
  - The flow from the pump is controlled via an electronic control valve. The valve is controlled by a DC 0-1V signal.
  - Students are to tune the controller to set the tank height to a specified value by controlling the valve.
  - Flowrate and tank levels are measured. Outputs are 4-20 mA signals.



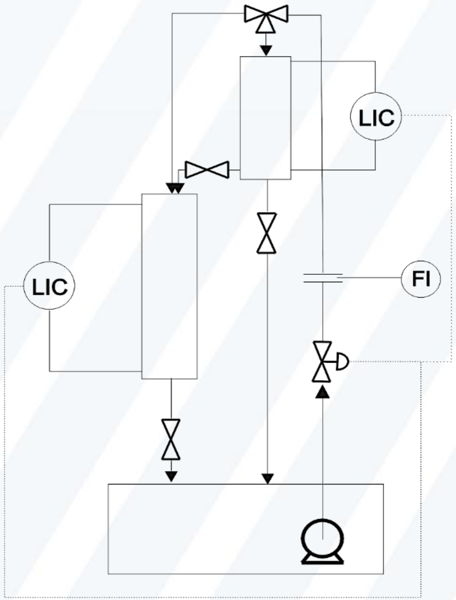
Process Control Lab Problems(s)

- Controller interface was VERY primitive
- Data acquisition was done by proprietary software. It is not easily configured. It does not cache data throughout experiments. The hardware shows drift in current measurements.
- Electronic valve did not open quickly. PID controller cannot account for this.



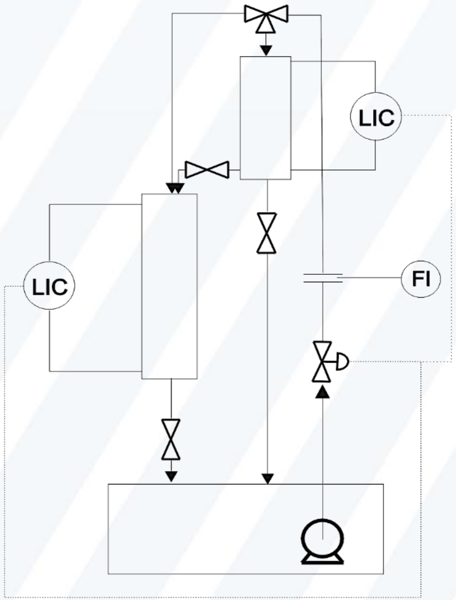
Process Control Lab Solution(s)

- Arduino can handle everything with very little modification.
- A custom shield can convert 4-20mA signal to DC 0-5V, which is read natively by Arduino.
- The valve is controlled natively by Arduino.
- All data is logged on the Academic Hub.



Process Control Lab Solution(s)

- Students learn to solder custom circuits.
- Students learn to tune a PID controller.
  - This is very easy using the PID library for the Arduino. Avoiding the clumsy interface relieves frustration, allowing students to try many combinations.
- Students learn to work with industry-standard 4-20mA signals.
- Students learn to create data displays in PI Vision.



Going Forward

- Upgrade other labs with similar hardware/software.
  - The next lab to be upgraded is a CSTR used to determine kinetic parameters.
  - More soft sensors will be added to the batch distillation column
- Begin teaching Arduino programming in Freshman engineering.

Thank you

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Questions ?