AENT4295
Emerson Process Controls
Phase 2

Bret Dohmen, Brenden Groff, Andy Rose

E.J. Daigle – Faculty Advisor

DUNWOODY
COLLEGE OF TECHNOLOGY

AENT - Program Outcomes

(1) Ability to apply knowledge, techniques, use skills and modern tools of mathematics, science, engineering, and technology to solve broadly-defined engineering problems appropriate to our discipline.

(2) We design systems, components, or processes meeting specified needs for broadly-defined engineering problems appropriate to our discipline.

(3) The ability to apply written, oral, and graphical communication in broadly-defined technical and non-technical environments; and an ability to identify and use appropriate technical literature.

(4) Ability to conduct standard tests, gather measurements, and conduct experiments, which allowed us to analyze and then interpret the results to improve processes.

(5) Ability to function effectively as a member as well as a leader on the team.

Abstract

Last year a team of Dunwoody students started assembling two tanks, and added pumps and a few sensors donated from Emerson. This year, we continued integrating sensors to allow more control over how and when water gets moved between tanks. The sensors that we integrated include a DP level sensor to accurately tell us the current tank level, a temperature sensor to tell us the temperature of the water, a water heater to allow us to increase the temperature of the water, a flow sensor to give us a gallons per minute flow reading, and vibratory fork sensors as safety devices to prevent over-filling the tanks. In addition to integrating these sensors we wrote the necessary PLC and HMI software to demonstrate these various sensors. Along the way we made a few more minor adjustments that we felt were necessary to push the project more towards a finalized state. Although this project itself may not provide a direct benefit to the industry, this project can be used as a proof of concept in which the skills and experience learned along the way can be used on future large-scale projects.

Team Composition

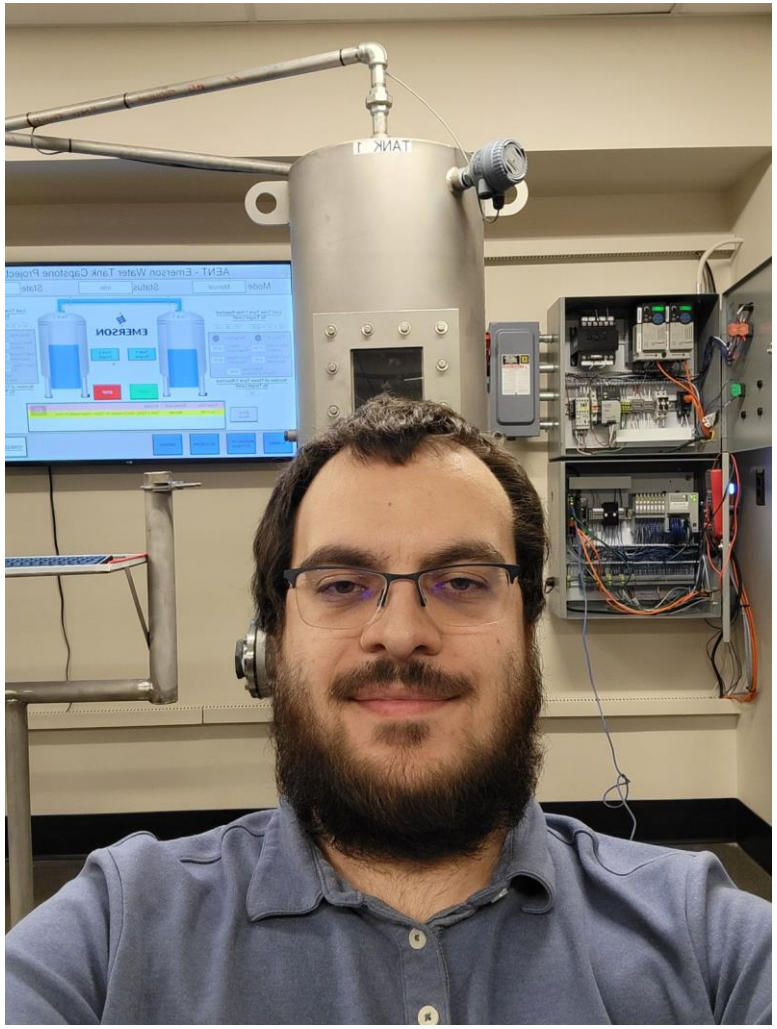
Bret Dohmen:

- I graduated with an AAS in Automated System and Robotics in 2020 and returned to Dunwoody in 2021 to start the Automation & Controls Engineering Technology program.
- I am currently employed by Andersen Windows as Controls / Electrical and Robotic Engineer. For the purpose of this project
- I did some wire labeling, cable management, installation of instruments, and assist wherever it was needed.

Team Composition

Brenden Groff

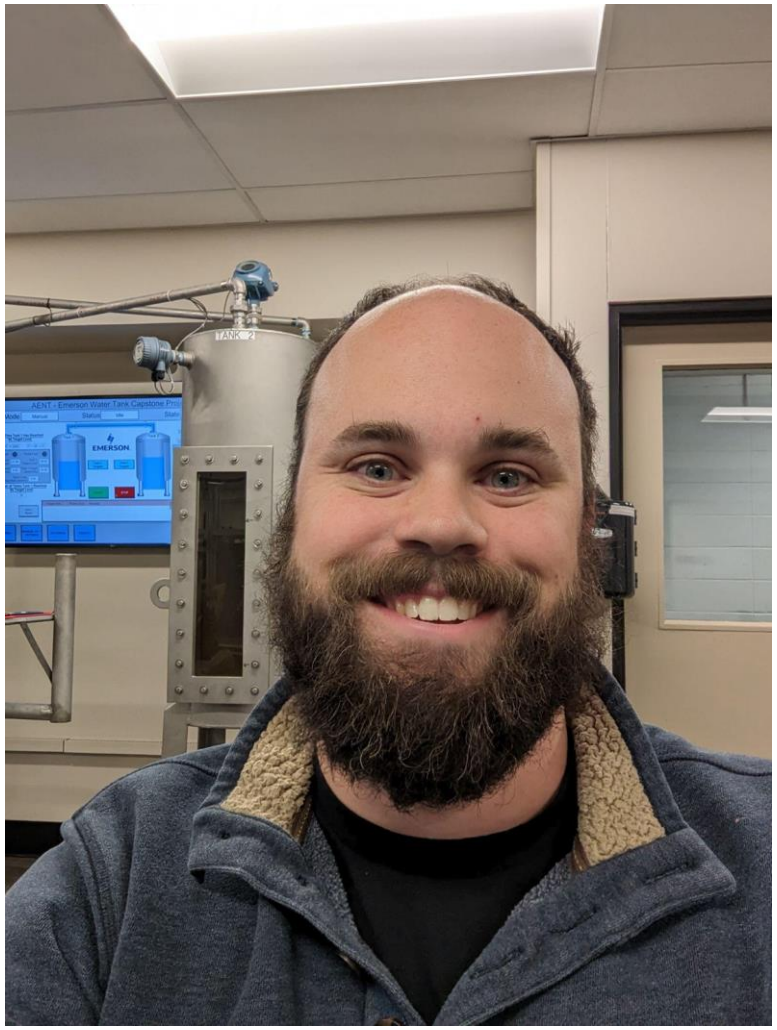
- Graduated with an A.A.S degree in Electronics Engineering Technology in Fall 2020, started the Automation and Controls Engineering Technology program in spring 2021.
- Currently working as an Associates Controls Engineer at Aspect Automation.
- My role in this project was being responsible for the ECAD schematics and P&ID, and the HMI and PLC code.



Team Composition

Andy Rose

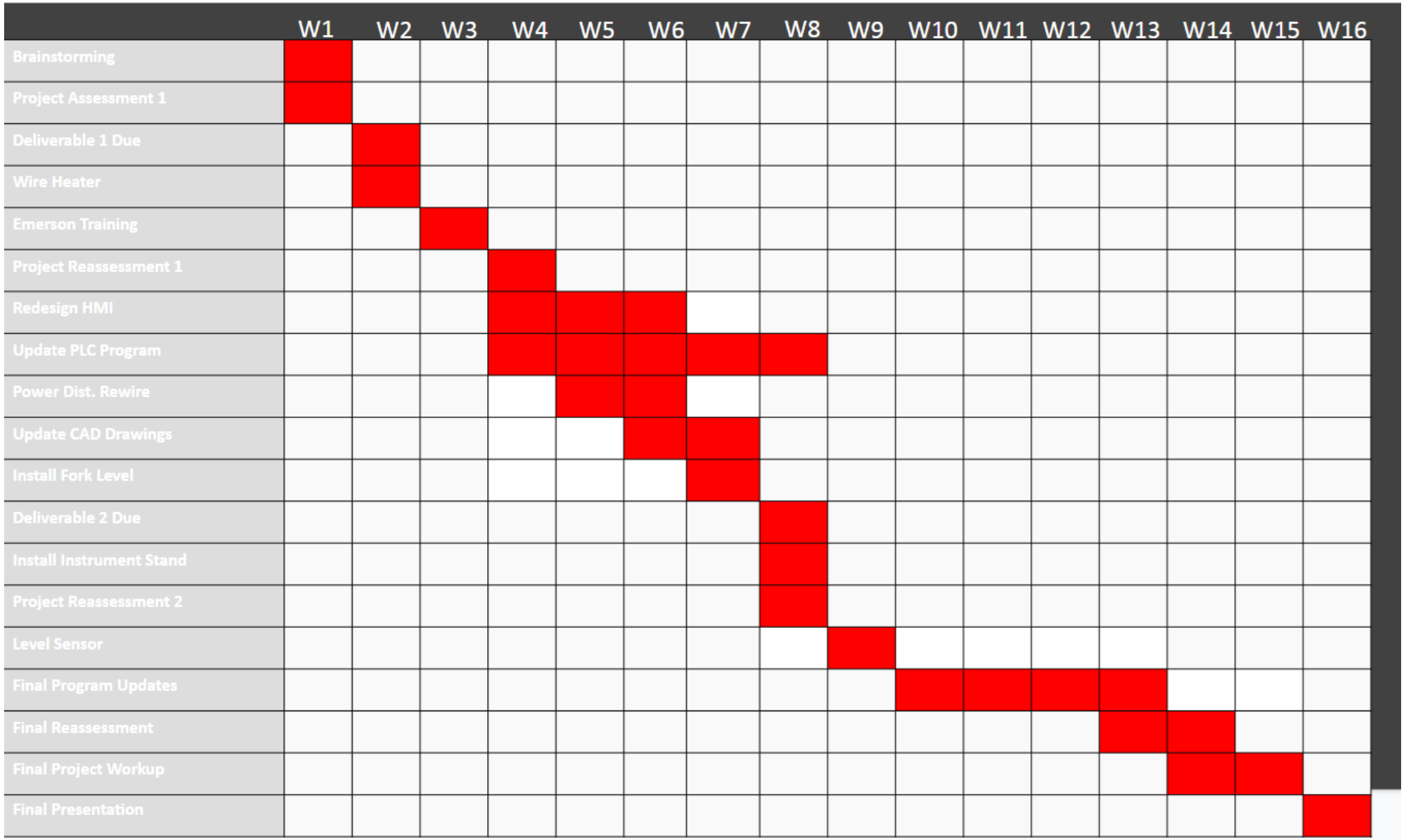
- Graduated with an AAS in Automated Systems and Robotics in fall of 2020. I started the Automation & Controls Engineering Technology program in spring of 2021
- Currently working for EasyDX, a small medical company out of Roseville. My official title is Automation Technician, but we are in an R&D phase and I have built, wired, and programmed a few small machines, taken over the documentation and safety programs, and am also the facilities manager
- For this project, I helped install, wire, and program the new sensors. I also assisted Brenden with HMI and PLC programing as needed



Top Level Requirements

Requirement	Assessment
Installation of new sensors/instruments. This includes two vibrating fork level switches, a heater, a temperature probe, and two DP sensors (one to measure flow rate, and one to measure tank level).	Everything was added, commissioned, and works properly (except for Tank 1 vibrating fork, it has a calibration error).
Update PLC code to interpret and use data from the new sensors.	PLC handles all incoming data, and uses it in meaningful ways.
Update HMI screen to show more information regarding the tanks, and offer more operator interactivity.	HMI now displays various information regarding the tanks, popups to change the target settings for each tank, and the ability to monitor and change the scaling of the sensors.
Update all ECAD schematics and P&ID in order to reflect all that was added this semester, while creating a labeling scheme for future teams that work on this project.	All ECAD schematics and P&ID have been updated to reflect the work that was done this semester. The high voltage cabinet has been labeled, but ran out of time to label the low voltage cabinet.
Run all electrical from one main power source.	All power comes from a 220V three phase power source. Added a disconnect so users can safely remove power.

Project GANTT Chart



Mechanical

- Most sensors installed by screwing into the tank, and using a sealant.
- New power distribution box added & holes pre drilled for the disconnect, which was located right where we needed them for fast install.
- Flow and level sensors provided the most challenge.
- Homemade instrument stand with welded on keyboard shelf for the operator.

Flow Sensor

- There were two pipes originally, last year's team knew the flow sensor was going in, they just didn't know the size
- We ordered extra pipe flanges, removed one pipe, and had the machine shop cut and thread the second pipe
- Temp Sensor (on the side) was preinstalled

Level Sensor

- Sensor mounts to the bottom of tank
- Sensor body and valves prevented it from mounting to the bottom
- We had some small pipe, and used it to route the block behind the tank
- It was challenging working in that small space, but after we installed it, no leaks!

Rust

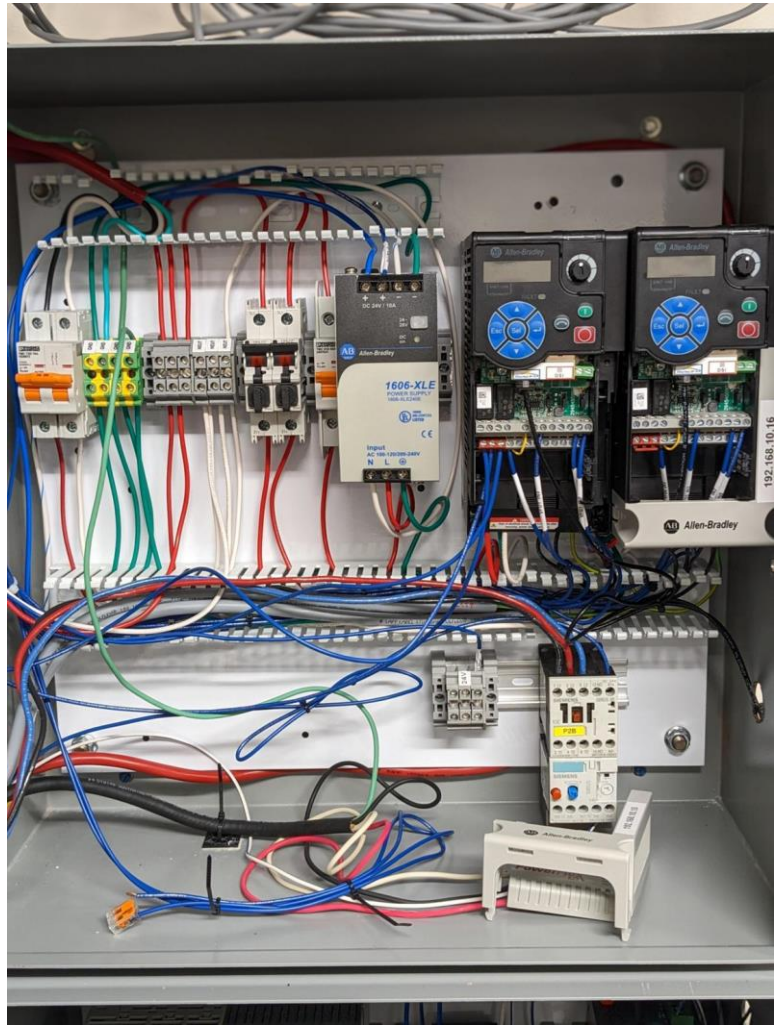
- We are having ongoing issues with rust in the tank
- Sacrificial zinc anodes started rapidly breaking down, causing grit to clog the inlet ports from the tanks to the pumps
- Using Rust Out (water softener cleaner) helps knock the rust down, but this is not a permanent solution

Electrical

- Most of the new sensors are using three wires, power, return/neutral, and ground
- Tank two vibrating fork has two lines, one for power, and one for a switch
- Heater is three phase, it is run via a motor starter
- New power distribution box, from three power sources to one

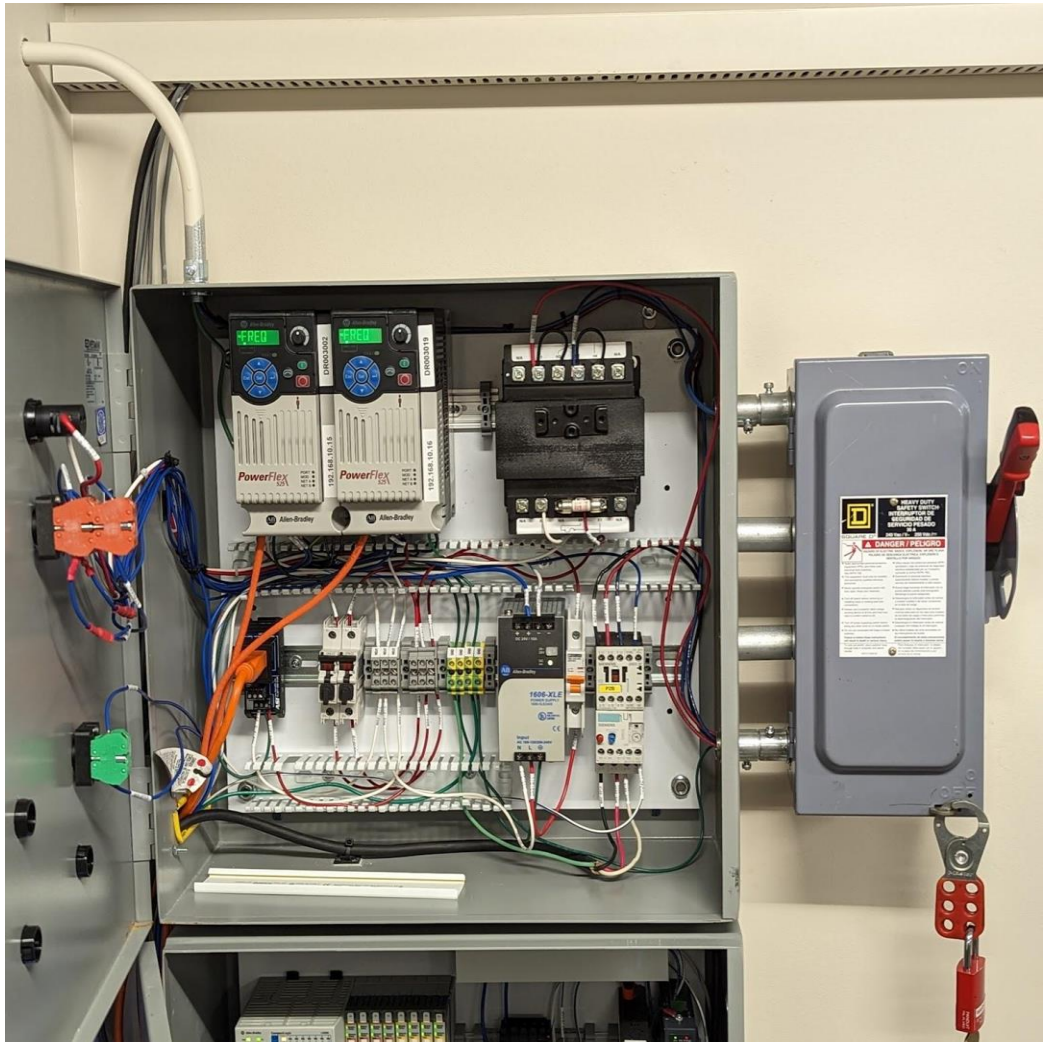
Old Power Distribution Box

- Old power distribution had multiple sources.
  - One for the TV
  - One for 120V
  - One for the 220V three phase power.
- The three phase breaker is in a janitorial closet below the classroom



New Power Distribution Box

- We added a transformer to step down the 220v to 120v
- Added a plug for the TV into the power dist. box.
- Added in a disconnect for the 220



PLC - Flow and Level Readings

- Added logic so that both tanks can display equal amounts of information

Level Readings:

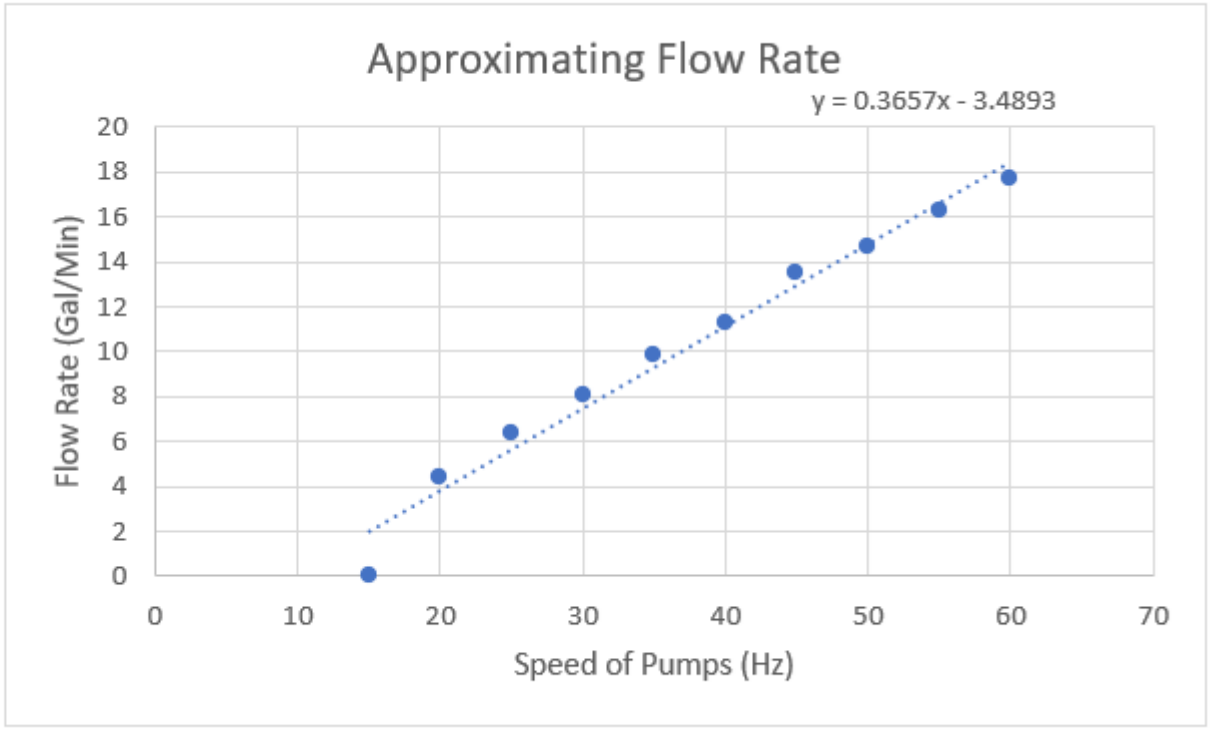
- Once Tank 2 level falls below what the probe can read, Tank 2 references the DP level sensor on Tank 1 for an approximate level of Tank 2 (total level - Tank 1 level)
  - Warnings are triggered indicating that the probe level sensor isn't being used for the current Tank 2 level

Flow Readings:

- By using excel, we were able to extract a nearly linear formula that can be used to calculate the flow rate for Tank 1 based on data from the flow sensor on Tank 2

PLC - Flow and Level Readings

Pump Speed	Flow Rate
15	0
20	4.45
25	6.35
30	8.1
35	9.83
40	11.3
45	13.5
50	14.7
55	16.3
60	17.7



*The pumps still move water at 15 Hz. 15 Hz is the slowest the pumps can go before water isn't being moved

PLC - Temperature Control

- Once the temp of Tank 2 exceeds its target level, the system gets placed in an “Overheated” state.
- In this state, the heater cannot be turned on but the system will remain functional in moving water.
- Once the water temp has fallen below a hardcoded temp, the system leaves the “Overheated” state and the heater is able to turn on.

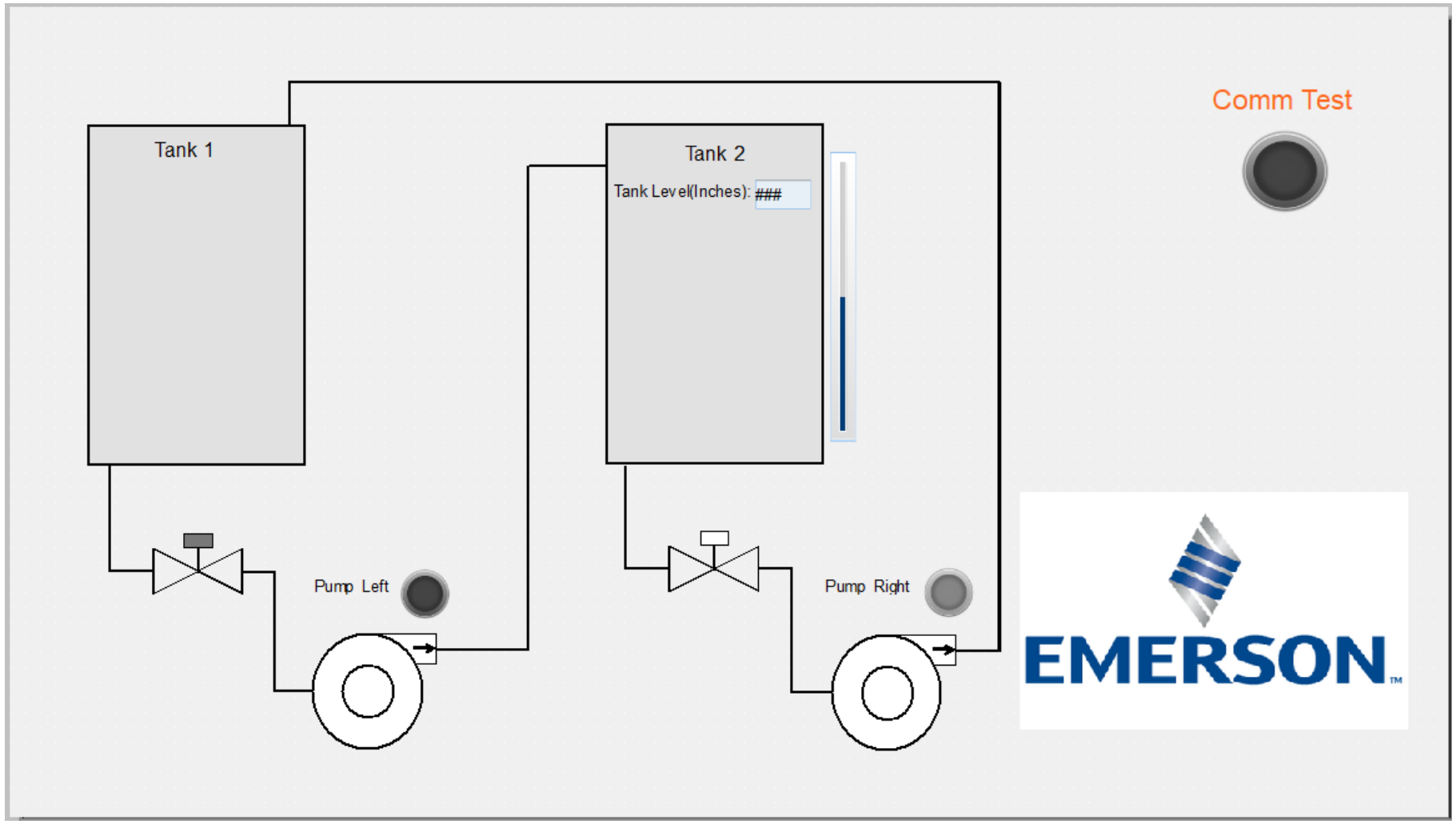
PLC - Minor Changes

- Added a counter to count the number of times the tanks reached their target level
- Added a way to time stamp the last time the tanks reached their target level
- Added various status tags for indicators on HMI
  - Machine Mode - Auto or Manual
  - Machine State - Idle, Running, Faulted
  - Machine Status - Idle, Filling Left, Filling Right
- Added various alarm logic to display on the HMI
- Wired the E-Stop to the safety inputs on both VFDs
  - This helps us achieve a SIL2 for controlling our motors
- Improved the organization of the code

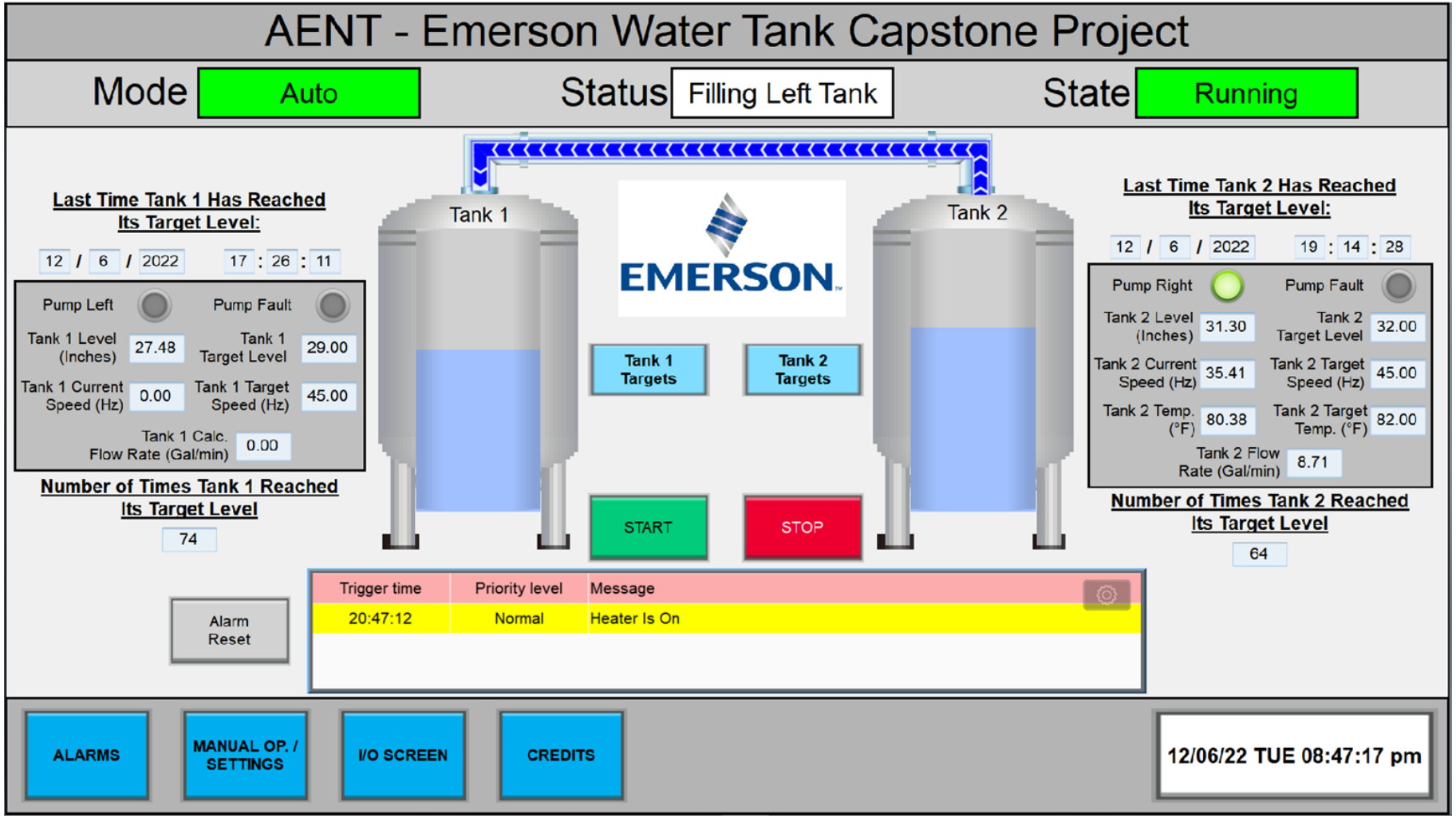
HMI - Changes

- Updated the screens to include more indicators
- Added alarms to tell the operator if something is wrong with the system or if they need to be aware of something (warnings)
- Added buttons to control various functions (sequence control, manual filling, turning heater on)
- Added parameter popups to change various tank/sensor parameters through the HMI.
- Added I/O screens to monitor the status of all of our I/O

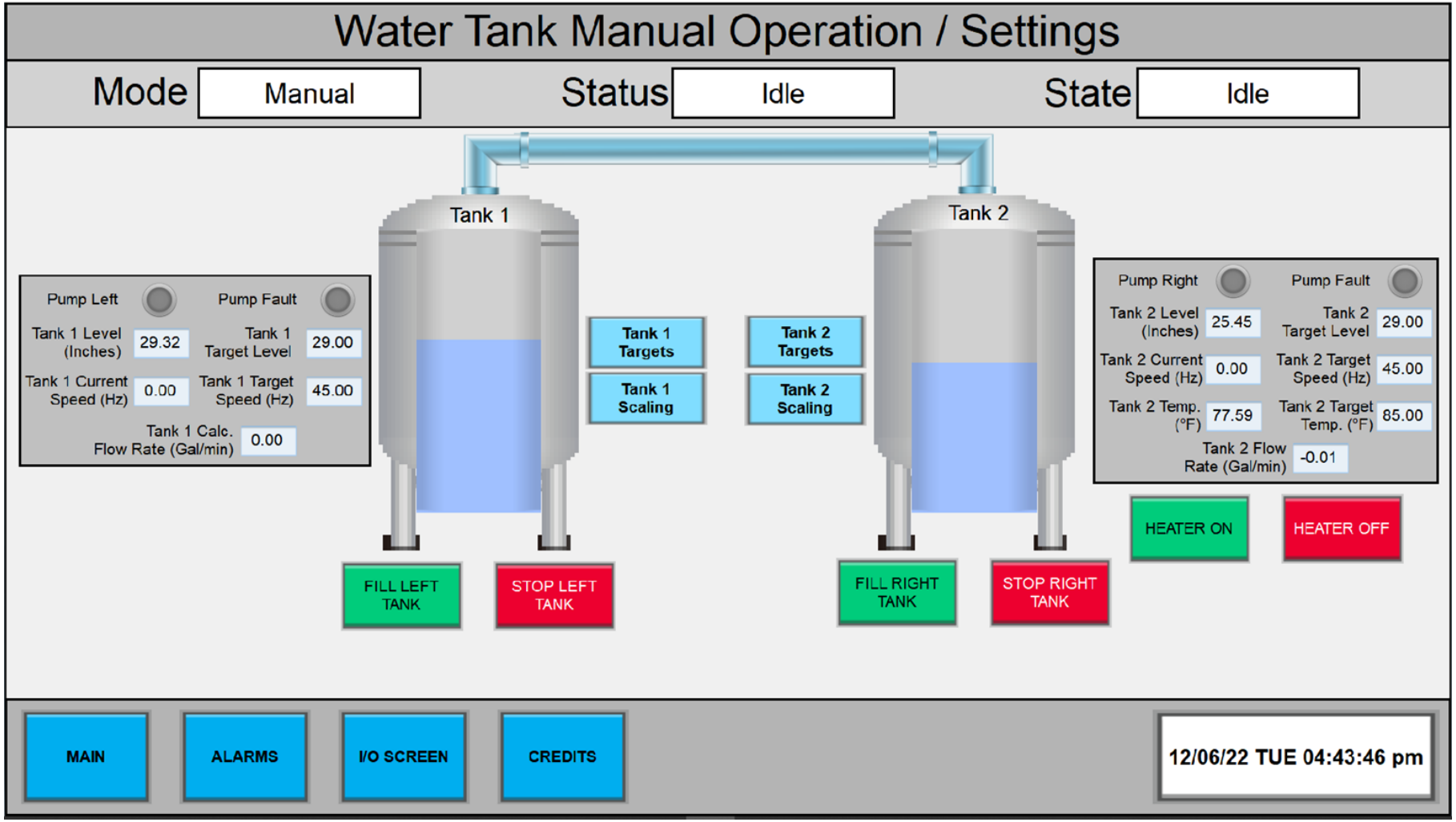
HMI - Before


Tank 1
Tank 2
Tank Level(Inches): ###
Comm Test
Pump Left
Pump Right
EMERSON

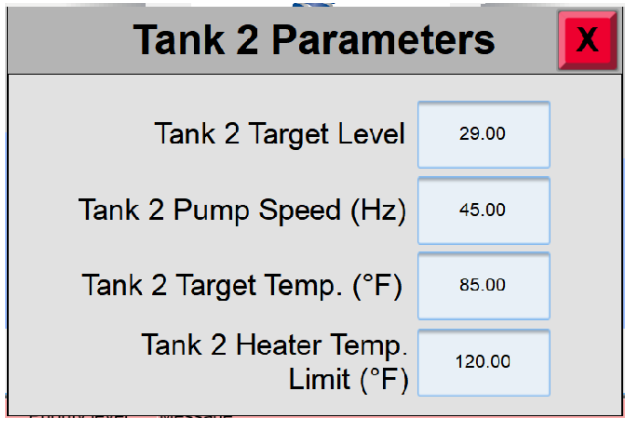
HMI - Updated Main Screen

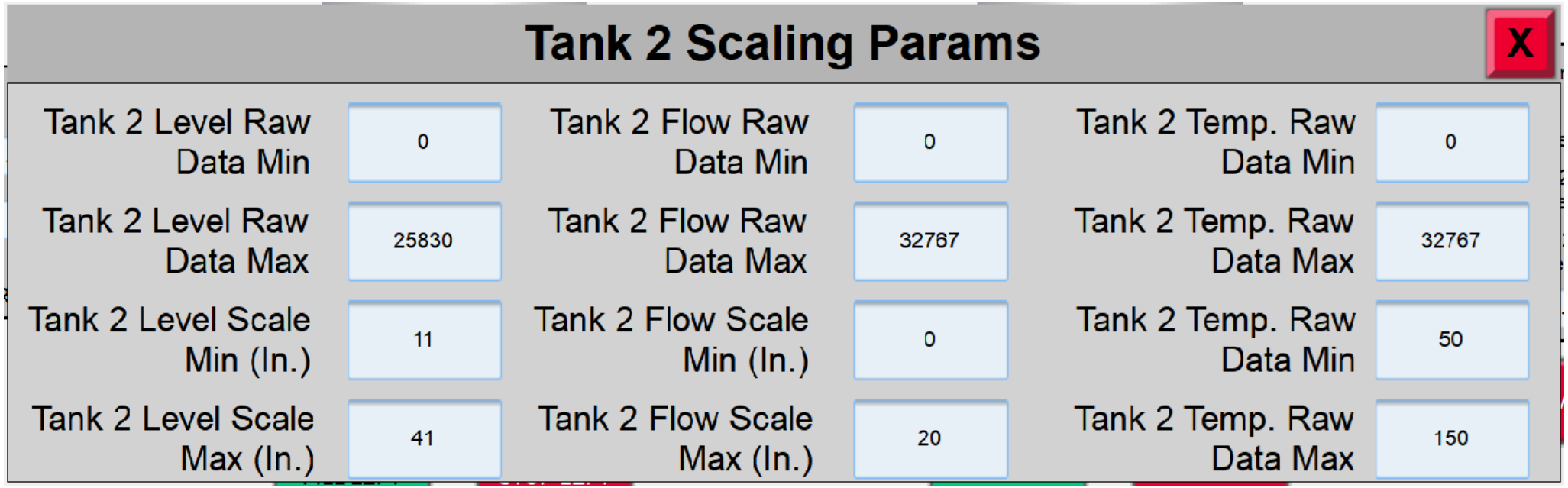


HMI - Manual Operation Screen

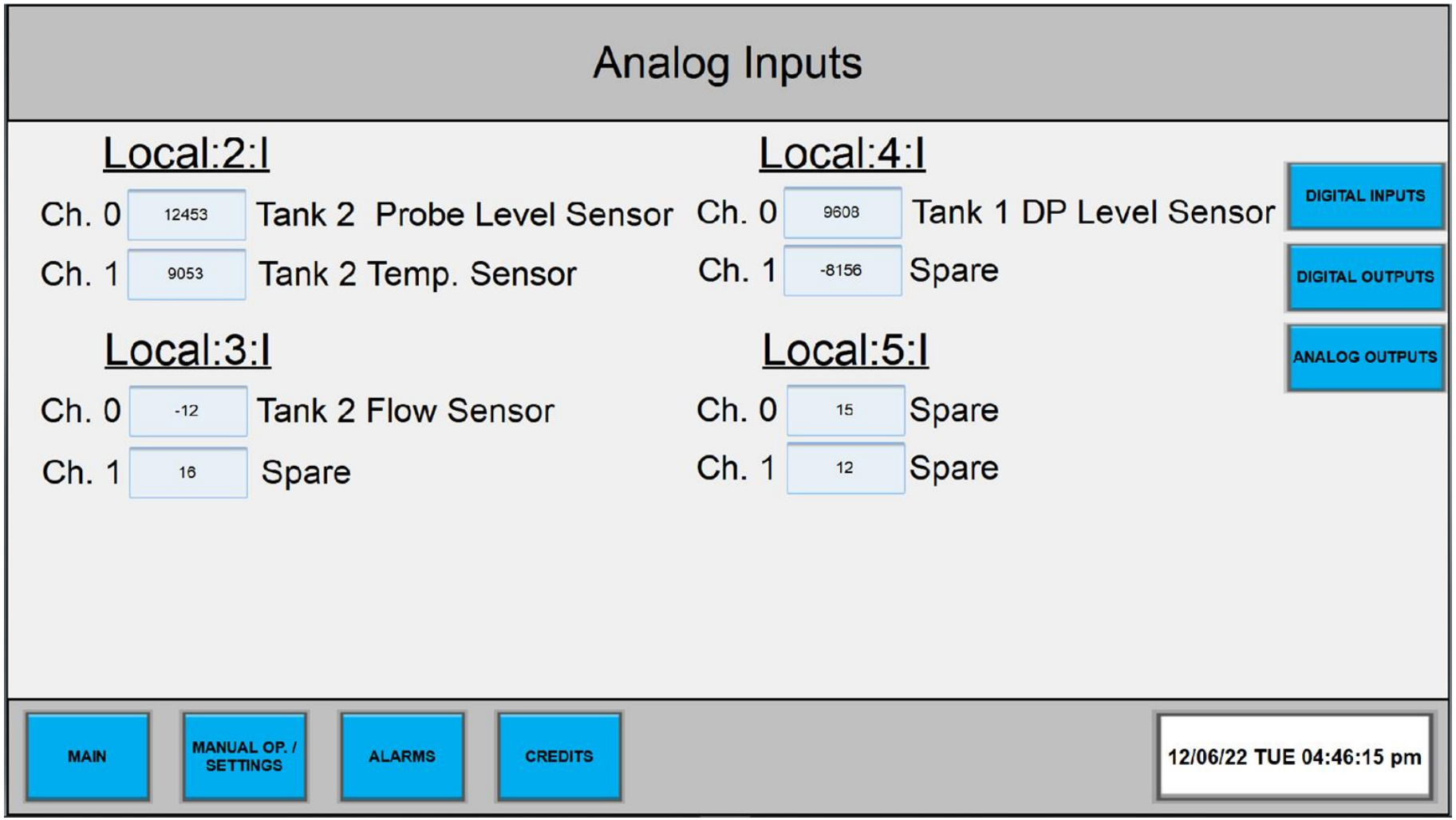


HMI - Targets/Scaling Popups





HMI - I/O Screen



Project Bill of Materials

Quantity	Part Number	Part Name	Vendor	Cost
2	25B-V4P8N104	PowerFlex VFD's	Allen Bradley	$768.50
1	1769-L18ERM-BB1B	MicroLogix 1769-L18ERM- BB1B PLC	Allen Bradley	$972.80
11	1734-TBS	1734-TBS point I/O bases	Allen Bradley	$76.89
4	1734-OE2C	1734-OE2C Two-Channel Analog Output Module	Allen Bradley	$376.92
4	1734-IE2C	1734-IE2C Two-Channel Analog Input Module	Allen Bradley	$361.80
2	H-107WLG305	Smart Lights	Amazon	$35.98
4	B09DYMRL2T	Conduit/Cable Trays	Amazon	$104.00
10	N/A	Plastic Knockout Plugs	Amazon	$5.75

Project Bill of Materials

Quantity	Part Number	Part Name	Vendor	Cost
1	IMACP01	ASI IMACP01 Single Three Prong Grounded AC Outlet Power Module	Amazon	$17.29
1	BMP41-KIT-VD	Brady BMP41 Printer DataComm Starter Kit	Amazon	$470.00
1	3473-MT0500A-ND	MT0500A Transformer	DigiKey	260.00
2	3144PD1A1NAM5XA	Temperature Transmitter	Emerson	$4,017.40
2	114CE0060TAA2SC017AXW	Thermowell	Emerson	$360.92
2	Unknown	PT100 RTD Sensor	Emerson	$426.90
1	2120D1DV1NADA0000	Vibratory Fork Level Switch	Emerson	$1,243.64
1	5408A1SHA1NA1NAZZCAD2	Non-Contact Radar Level Probe	Emerson	$4,360.97

Project Bill of Materials

Quantity	Part Number	Part Name	Vendor	Cost
1	405PS010T065D3	405P Compact Orifice Plate Primary Element	Emerson	$2,010.00
1	405PS010T065D3	RTD for Primary Element Orifice Plate	Emerson	$213.45
1	1195F010A1S0800C TBCG2	1195 Integral Orifice Assembly	Emerson	N/a
2	1BF40334	3-phase Variable Speed Electric Motor	Grainger	$2,360.00
12	409E111N010	1" NPT Pipe Elbows	Grainger	$288.00
1	CMT-FHDX-220	Headless HMI Module	Maple Systems	$729.38
1	49175K38	normally open float switch	McMaster Carr	$31.00
1	3656K136	3-Phase Electric Submersible Tank Heater	McMaster Carr	$460.00

Project Bill of Materials

Quantity	Part Number	Part Name	Vendor	Cost
2	43505K358	3" NPS -to- 3" NPT Female Adapter Flanges	McMaster Carr	$230.00
1	4464K178	3" NPT male -to- 2" NPT Female Reducer Bushing	McMaster Carr	$80.00
2	4596K81	3" NPT Male Plastic Plug	McMaster Carr	$46.00
2	4596K75	1" NPT Male Plastic Plug	McMaster Carr	$9.00
4	4596K73	1/2" NPT Male Plastic Plug	McMaster Carr	$14.00
2	1082N15	Gaskets for 3" Pipe Flanges	McMaster Carr	$7.56
1	4464K157	1.5" NPT Male -to- 1" NPT Female Adapter	McMaster Carr	$20.00
2	44685K13	1" NPS -to- 1" NPT Female Adapter Flanges	McMaster Carr	$92.00

Project Bill of Materials

Quantity	Part Number	Part Name	Vendor	Cost
2	1082N666	Gaskets for DN25 Pipe Flanges	McMaster Carr	$3.00
2	4464K151	1.25" NPT Male -to- 1" NPT Female Adapter	McMaster Carr	$37.00
2	4464K275	1" NPT Male -to- 1/2" NPT Female Reducer Bushing	McMaster Carr	$20.00
2	4813K69	1" NPT Schedule 40 Straight Pipe	McMaster Carr	$480.00
5	4464K488	1" NPT Pipe Unions	McMaster Carr	$170.00
7	46325K31	1" NPT 2-way Lockable Ball Valves	McMaster Carr	$371.00
3	48315K93	1" NPT Plastic Hose Barb Fittings	McMaster Carr	$6.00
18	4464K53	1" NPT Pipe T-Fittings	McMaster Carr	$396.00

Project Bill of Materials

Quantity	Part Number	Part Name	Vendor	Cost
46	4830K225	1" NPT Pipe Nipples 3" Long	McMaster Carr	$414.00
2	4830K223	1" NPT Pipe Nipples 2" Long	McMaster Carr	$14.00
2	4464K486	1/2" NPT Pipe Unions	McMaster Carr	$35.00
2	4464K14	1/2" NPT Pipe Elbows	McMaster Carr	$15.00
4	4830K175	1/2" NPT Pipe Nipples 3" Long	McMaster Carr	$24.00
1	4813K45	1/2" NPT Straight Pipe	McMaster Carr	$115.00
2	44685K13	1’’ NPT Stainless Steel Pipe Flange	McMaster Carr	$90.90
2	1082N11	1’’ Flange Gasket	McMaster Carr	$4.12

Project Bill of Materials

Quantity	Part Number	Part Name	Vendor	Cost
2	94368A110	Screw and Nut Kit	McMaster Carr	$16.76
1	90107A033	316 Stainless Steel Washer	McMaster Carr	$12.09
1	8634K64	Economical Abrasion-Resistant SBR Rubber	McMaster Carr	$26.97
4	97110A300	Galvanized Steel Stud Anchors	McMaster Carr	$10.16
1	TV	Monitor for HMI Display (LG TV 50in)	Micro Center	$349.99
2	P53390	55-gallon stainless steel tank	Midwest Tank	$12,910.00
			Last Year: **This Year:**	$35,057.00 $35,984.00

Conclusion

- We added all sensors we set out too
- Add more functionality to the HMI
- Project creep is real
- Instrument stand turned into keyboard stand
- Team worked well together

Recommendations for the Future

- Network the water tanks PLC with all of the PLC stations. Create produced and consumed tags.
- Heat exchanger so that the water can be cooled.
- Look into a safety PLC, or at least safety relays, for the vibrating fork switches
- Minor additions: water filtration, light stack(s), etc.

Questions

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EMERSON
Industrial Automation

Music Video

https://youtu.be/xyJgee7Tdvo