assignment 1

by Gareth Wilkins

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1. Executive Summary

This report investigates control engineering philosophies and practical application. Flow, level, and temperature control techniques was explored where the system characteristics was detrimental for the classification of response being either a pure integrator, first order or multiple order systems. A system investigation was performed which observed a segment of the process station; the subject of this report contains a cascaded control loop arrangement. The inner loop controlled the flow where the outer loops controlled the level and temperature, respectively. The main components and instrumentation were discussed.

A process reaction curve was produced for the flow and it was apparent that the flow control system was of a first order. The Caldwell and the Ziegler and Nicholls tuning methods were used to provide PID values to test practically. The Caldwell method provided the best approximation for the optimal PID values. The process reaction curve for level was obtained from the HMI of the process station. This system behaved as a pure integrator with a ramp response. The gradient was calculated which enabled a mathematical model of the control system to be constructed. On Matlab the autotune feature was utilised and provided the proportional and derivative value. When testing it was found that these values were not as representative as the previous flow control loop. Followed by this the temperature process reaction curve was obtained from the HMI station. The same procedure for acquiring controller parameters was followed as this behaved as a pure integrator. The autotune feature instructed that derivative control was not required so the temperature only required proportional control. The proportional auto tune value was doubled to produce the optimal control system performance.

A conclusion was composed observing the significant outcomes. The tuning methods provide an adequate estimation for the control systems parameters, but system tuning must be performed to provide optimal control system performance.

Incorrect, flow is second order

Caldwell is used for second order systems as an approximation of two first order systems in cascade

Caldwell only gives a transfer function not PID values

2. Research and System Investigation

2.1 Research

A control system performs a function, verifies its success, and takes appropriate action to attain the set objective. (Hughes, 2016) A control system comprises interconnected modules to attain the required objective. The term regulator is used to describe a control system which holds an output steadily against any unknown disturbances, while tracking or servo systems are designed to follow the reference signal (Gene F. Franklin, 2015) . The origin for evaluating of a system is the property conveyed by linear system theory which assumes a cause-effect relationship for the element of a system. An open loop control system has no feedback where the actuating device directly controls the process. The closed loop control system uses feedback where the output value enables comparison of the actual output with the desired value. (Richard C. Dorf, 2017)

The dynamic response of a system can be expressed by a mathematical model to aid the design of the controller. However due to the nature of physical systems being complex they habitually produce nonlinear response. Consequently, the design is established on a simplified model that must meet the performance requirements when functionally implemented to the system. Additionally, the system dynamics can change due to environmental change so even the best models will be in some degree of error. To conclude the model must be robust to acquire performance and not too delicate too the foreseeable future alterations and it must perform satisfactorily, nonetheless. (Gene F. Franklin, 2015)

2.1.1 Flow Control

A fluid flow control system can comprise a pump, an actuating valve, and pipeline. The fluid flow equations defining motion and energy are complex, administered by coupled non-linear partial differential equations. The significant variables that must be considered are the fluid velocity, height of reservoir (if applicable) and pressure (Richard C. Dorf, 2017). The Flow control system behaves as a second order system where a change incurs a delay in response. The response of the system is defined by its damping factor. System performance can be optimized by the employment of a PID controller (Bolton, 2015).

2.1.2 Level Control

A level control system controls the liquid level in a tank. The level is measured by either an analogue or digital transducer. A significant attribute to a liquid level control system is capacitance. The surface area of the water affects the response time which delivers the control variable (Bolton, 2015). A tank

with a flow in and flow out behaves as a first order system where the input-output relationship produces an exponential transient response before reaching steady state. A tank with no flow out would simply behave as an integrator with a linear response.

2.1.3 Temperature Control

A temperature control system contains a temperature transducer and a control variable being a heating element. A system with no heat dissipation would behave as a pure integrator. If the temperature control system were continually pumping fluid a controller would be required to maintain the desired temperature. *It would then acts as a first order system*

2.2 Tuning

To produce the best system performance deliberation must be taken on selecting the appropriate control mode and control mode setting. Understanding of the system to be controlled aids in the selection of controller being a P, PI, PD or PID controller followed by selecting the values of Ki, Kp and Kd. These selections define the system behaviour by how it responds to disturbances or setpoint changes, response time, settling time or whether there will be a steady state error controller (Bolton, 2015).

The auto tune feature on modern controllers enables optimal tuning values to be obtained. However, there is still a need to understand manual methods of tuning to appreciate system dynamics. The methods extensively used produced by Ziegler and Nicholls are the process reaction method and the ultimate cycle method (Richard C. Dorf, 2017).

Improper Citation

2.2.1 Ziegler and Nicholls - Process reaction method

This method involves obtaining the process reaction curve. On this graph a tangent is drawn to attain the maximum gradient of the curve. The lag L is the term used to describe the time taken for the start of the test to the the point where the tangent intersects the curve. The Ziegler and Nicholls table using the gradient value of the tangent determines the controller setting. The foundation of this principle is to provide a closed loop response for the system which reveals a quarter amplitude decay resulting in the oscillations to subside with time resulting in the reduction of oscillation amplitude by a quarter per oscillation (Bolton, 2015).

2.2.2 Ultimate Cycle Tuning method

To perform this method the integral and derivative values are reduced to their minimum operational values in a closed loop system. The Kp value is set at its minimal value and steadily increased until oscillations begin in the controlled variable. The value of proportional constant when this occurred is observed and the time period of oscillations is measured (Bolton, 2015).

2.2.3 Caldwell method

The Caldwell method is established on an estimation of a system of higher order via a second order transfer function being the product of a series of two first order systems having two series lags being T1 and T2 constants. The open loop step response is the method of obtaining the values of T1 and T2. The Caldwell reference graph is utilised to find the value of $\frac{\tau}{\tau_1+\tau_2}$ and τ_2 and subsequently calculating τ_1. The basis of the Caldwell method is when the ratio of $\frac{\tau}{\tau_1+\tau_2}$ is adjusted from zero to 1, the response curve of respective models to a step input will intersect identical location at 1.32 at a reaction of 73% output final value (William Isaac Caldwell, 2012).

Improper Citation

2.3 System investigation

The piping and instrumentation diagram (P&ID) provides a schematic illustration of a system presenting an operational relationship concerning the pipework, instrumentation, and system components (The Engineering Toolbox, 2021). The ANSI/ISA-5.1-2009 standard provides standardisation to support various procedures for a diverse group of operators who are required to identify and graphically depict measurement and process control equipment and systems (ISA , 2009). The P&ID of the Process Rig System situated in G8 is shown in Appendix A

The Process Rig System investigation concerns the flow, level, and temperature control loops. This is a cascaded control system where flow is the inner loop with level and temperature being outer loops. The programmed logic and desired setpoint determines the control variable to achieve the desired setpoint. As this is a cascaded system in the instance of level and temperature control being the outer loops the pump duty cycle can be varied to achieve optimal performance. Note that the pump may start at 100% duty cycle and gradually reduce until the desired setpoint is achieved.

The direction of liquid flow is governed by solenoid valves which are controlled via the PLC logic. The flow control (FC535) regulates the flow rate by comparing the measured flow FT535 with the desired setpoint and controlling the DC pump duty cycle via amplifier (LY541) to achieve the desired setpoint. The fluid level of the cleaning chamber is provided via pressure transducer LT541. This transducer provides the plant data to allow the level controller LC541 to compute the required actions to achieve the desired setpoint. Draining the tank is achieved by solenoid valve (V500). The heating of the cleaning chamber is controlled by temperature controller (TC511). The plant data is provided via temperature transducer (TT511). The plant measurement is compared with the desired setpoint and the route of fluid is determined by the programmed logic. The Fluid can be cooled by opening solenoid valve V515 where the fluid travels through the condensor coil which is cooled by the fan. If cooling is not required, the condenser can be bypassed by solenoid valve V516 and proceed to fill the tank for heating. Heating is provided by and electric heating element which is controlled via PWM which is outputted via a solid-state relay. Two safety interlocks are in place being LS543-High Level and LS542-Low Level sensors. In the event LS543 is high the safety interlock activates, and the DC pump is disabled to prevent the tank overflowing. Conversely, if LS542 is activated in the event of low fluid level the safety interlock will be employed to disable the heating element that could damage itself and cause possible fire when not submerged.

3 Flow control system

3.1 Modelling flow control system

To obtain the process reaction curve for the flow loop the pump was run at full duty with the drain valve open. The flow data was attained from the PLC datalogger data block and placed into a spreadsheet. Using MatLab this array was plotted to produce the process reaction curve. The Matlab code and resultant process reaction curve is shown in Figure 1. The process experiences a significant dead time at the start of the test and then presents a second order response.

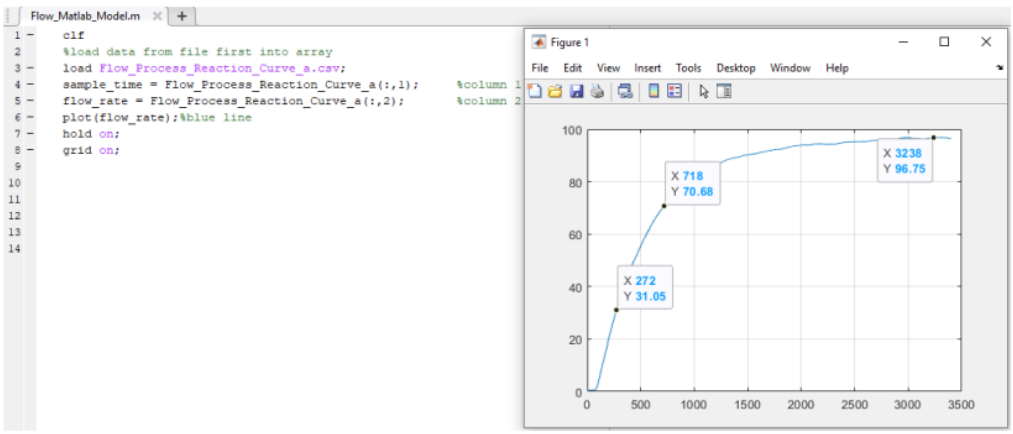


Figure 1: Process reaction curve of flow obtained from the Process Rig with data values.

To produce a mathematical model of the system the Caldwell method is used. The required data point values are shown in Figure 1.

Final value = 96.75

t_y @ 73% of final value = 70.6275

t_y value from the graph = 718.6

Calculating $t_1 + t_2$

$$t_1 + t_2 = \frac{t_y}{1.32} = \frac{718.6}{1.32} = 544.394mS$$

$$t_x = \frac{t_1 + t_2}{2} = \frac{544.394}{2} = 272.197$$

$$\therefore \mathrm{X} = 31.85$$

As a fraction

$$\frac{31.05}{96.75} = 0.321$$

From the Caldwell chart reference Appendix B @ 0.321

$$\frac{t_2}{t_1 + t_2} = 0.84$$

$\therefore \ t_2 = 0.84 \times (t_1 + t_2)$

$t_2 = 0.84 \times 0.546 = 0.45864$

$\therefore \ t_1 = 0.546 - 0.45864 = 0.08736$

The standard transform function is of the form

$$H(s) = \frac{\frac{1}{t_1 t_2}}{s^2 + \frac{t_1 + t_2}{t_1 t_2} s + \frac{1}{t_1 t_2}}$$

Obtaining the values to be substituted

$$\frac{1}{t_1 t_2} = \frac{1}{0.0874 \times 0.459} = 24.927$$

$$\frac{t_1 + t_2}{t_1 t_2} = \frac{0.08736 + 0.45864}{0.08736 \times 0.45864} = 13.627$$

Substituted values into transfer function

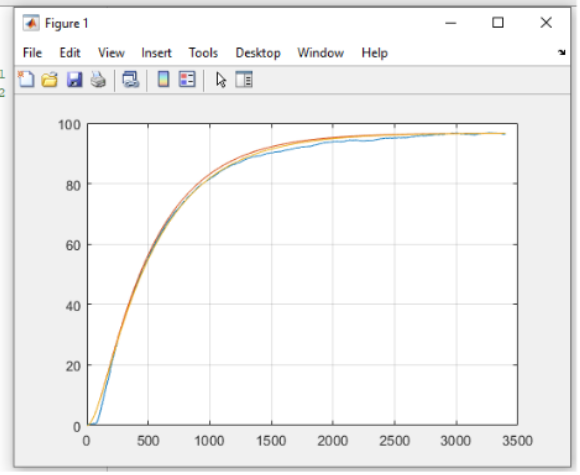
$$H(s) = \frac{24.927}{1 + 13.627s + 24.927}$$

3.2 Analysis of modelled transfer function

The mathematical model produced an accurate process reaction curve of the system. However the reaction curve does contain an offset which will be improved by fine tuning the transfer function to yield an improved representation. The yellow line is the most accurate representation of the process reaction curve which is shown in Figure 2Figure 2: Process reaction curve comparing system data with

Flow_Matlab_Model.m

```
clf
%load data from file first into array
load Flow_Process_Reaction_Curve_a.csv;
sample_time = Flow_Process_Reaction_Curve_a(:,1);      %column 1
flow_rate = Flow_Process_Reaction_Curve_a(:,2);        %column 2
plot(flow_rate);%blue line
hold on;
grid on;
%check time column to get sample time and data length
t=(0:0.001:3.399);
num1=[24.927];
den1=[1 13.627 24.927];
model_1 = step(96.79*num1,den1,t);
plot(model_1);%red line
%adjust to make improvements
num2=[24.8];
den2=[1 14.1 24.8];
model_2 = step(96.79*num2,den2,t);%yellow line
plot(model_2);
```



mathematical model and tweaked mathematical model.

To establish the natural frequency and damping factor the modelled transfer function will be compared with the standard transfer function formula shown below.

$$H(s) = \frac{K{w_n}^2}{s^2 + 2\zeta w_n s + {w_n}^2}$$

$$H(s) = \frac{24.8}{s^2 + 14.1 + 24.8}$$

${w_n}^2 = 24.8 \qquad w_n = \sqrt{24.8} = 4.980 rads/s$

Figure 2: Process reaction curve comparing system data with mathematical model and tweaked mathematical model.

$K{w_n}^2 = 24.8\ k = \frac{24.8}{{w_n}^2} = \frac{24.8}{24.8} = 1$

$2\zeta w_n = 14.1\ \zeta = \frac{14.8}{2\zeta w_n} = \frac{14.8}{2 \times 4.98} = 1.486$

Evaluating the calculations above it shows that the natural frequency of the system is 4.980rad/s with a gain of 1 with a damping factor 1.486. With a damping factor greater than 1 the system is overdamped providing a slower response compared with the optimal critically damped value of 1. The system performance is predicted to be stable as it is overdamped. A root locus has been plotted on Matlab to evaluate if the system can become unstable and can be seen in Appendix C. The two poles on the diagram stay in the left-hand plane. This concludes the system is stable and cannot develop to an unstable state with additional gain however system oscillation may occur.

3.3 PID tuning

3.3.1 Auto-tune method using Simulink

A Simulink model is constructed from the derived mathematical model. The model contains a limiter which prevents the output exceeding 1 which is fully duty. The Simulink model is shown in Figure 3.

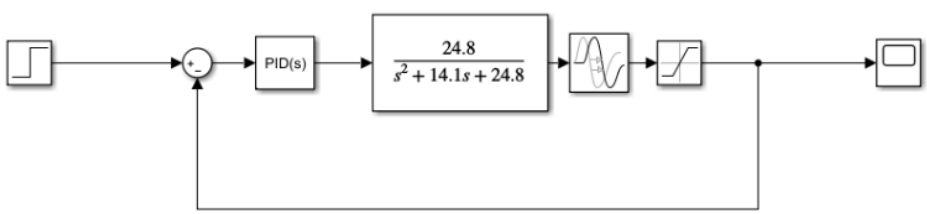


Figure 3: Simulink model of flow.

Utilizing the autotune feature the optimal values of k_P, k_I, and k_D are obtained shown in Figure 4. The results are scaled and tabulated in Table 1

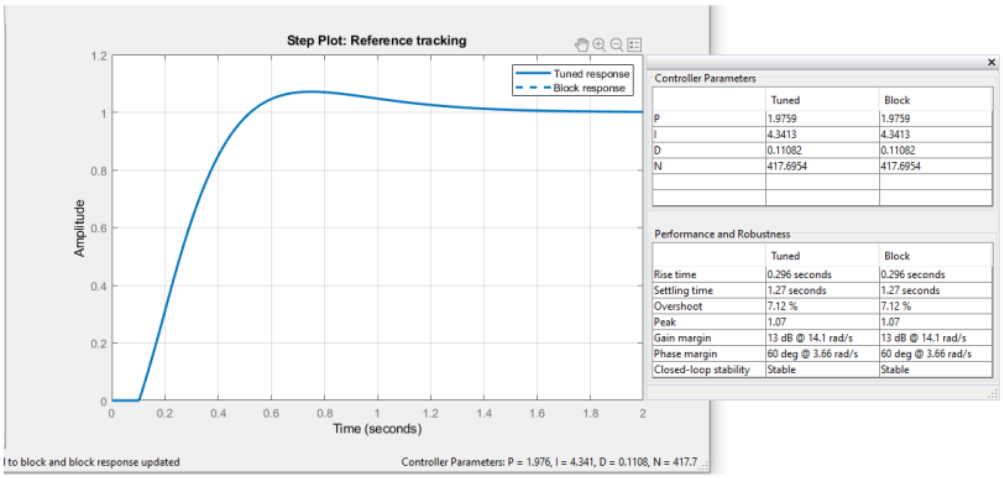


Figure 4: Result of autotune PID block for flow

Table 1: Autotune values for PID block obtained and scaled from Simulink

	Unscaled	Scaled
k_P	1.9759	1.9759
k_I	4.3413	0.0043413
k_D	0.11082	110.82

The results are simulated with a setpoint of 1 and a setpoint of 0.5 shown in Figure 5 and Figure 6.

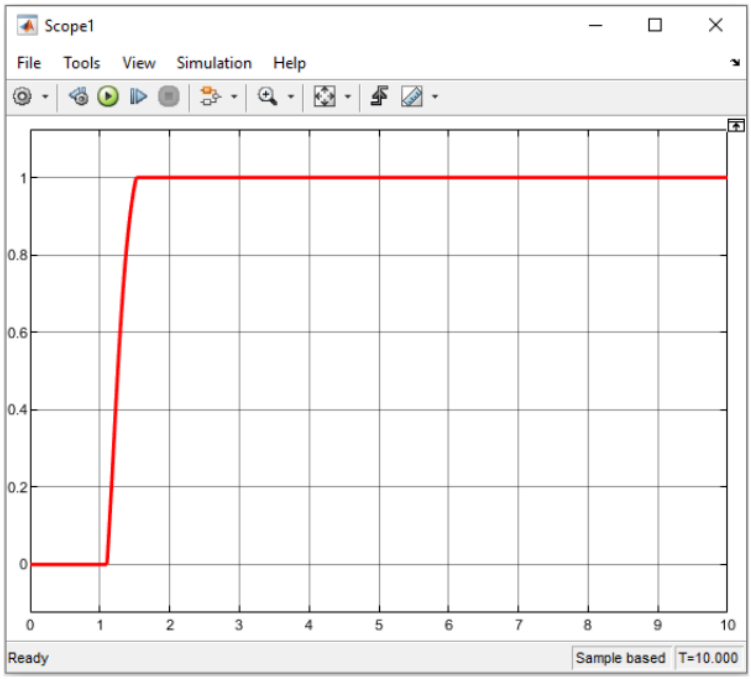


Figure 5: Simulation result with setpoint of 1.

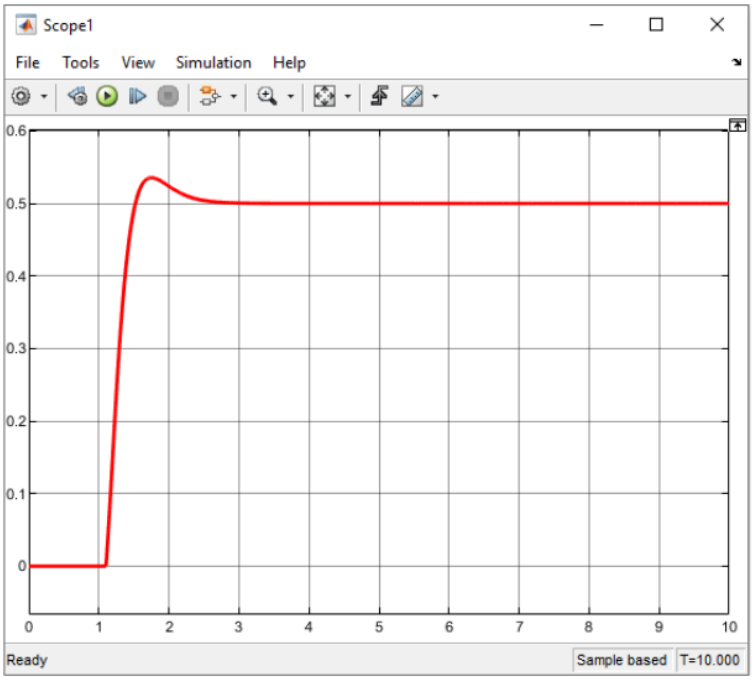


Figure 6: Simulation result with setpoint of 0.5.

3.3.2 Ziegler and Nichols method

The process reaction curve was utilized again for the Ziegler and Nichols tuning method. The change in setpoint ΔC and the change in output ΔY are the relationship values needed to obtain the PID values. In this example ΔC = 100% and ΔY = 96.75. A tangent line is illustrated on the process reaction curve and on the occasion it intersects the zero and 100% thresholds of the Y axes governs the L and T values of time presented in Figure 7.

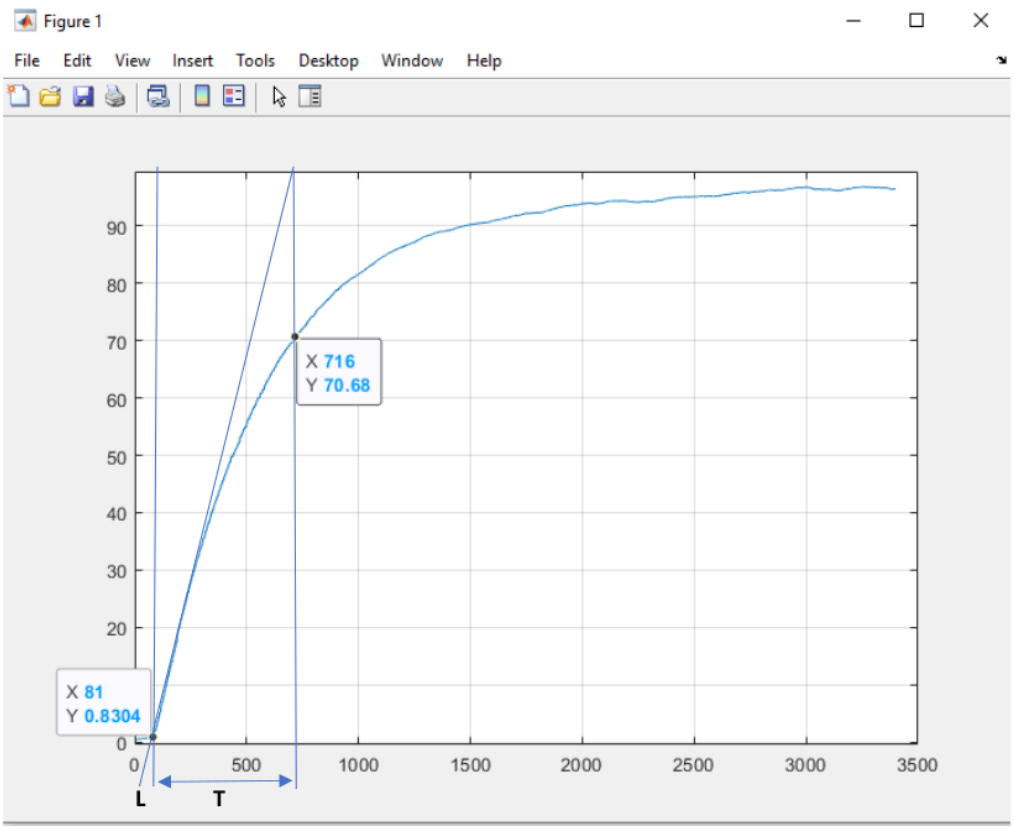


Figure 7: Obtaining values from the process reaction curve for the Ziegler and Nichols method.

The calculation to obtain the PID values are as follows.

$$L = 81ms = 0.081s$$

$$T = 716 - 81 = 635$$

$$R = \frac{\Delta y}{T} = \frac{96.75}{635mS} = 152.362$$

$$k_p = 1.2\frac{\Delta C}{RL} = 1.2\left(\frac{100}{152.362 \times 0.081}\right) = 9.723$$

$$k_i = \frac{k_p}{2L} = \frac{9.723}{2 \times 0.081} = 60.019$$

$$k_d = 0.5k_pL = 0.5 \times 9.723 \times 0.081 = 0.394$$

3.4 Analysis and evaluation

Table 2: Comparison table of tuned values produced by tunings methods

Comparison table of tuned values produced by tunings methods			
	k_p	k_i	k_d
Caldwell and autotuning	1.885	0.004062	85
Ziegler and Nichols	9.723	0.060019	394
Manual adjustment	0.900	0.002	8.4

It is noticeable from the comparison table that the Ziegler Nicolls method produced the closest PID values to the manually tuned values which produced the best performance.

4 Level Control System

4.1 Modelling the Level Control System

The process reaction curve was obtained from the graph produced by the HMI screen which is shown in Figure 8. With the reaction curve behaving as a ramp the mathematical model can simply be produced by calculating the gradient. On the ramp two data point are sampled which is shown in belowAppendix D. The values are shown in Table 3.

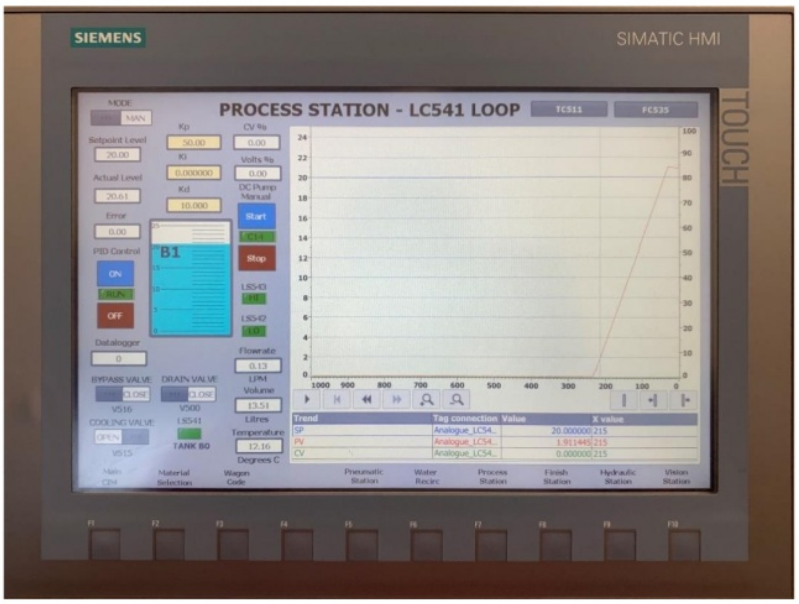


Figure 8: Level process reaction curve

Table 3: Data points required for level gradient calculation.

X Values	Y Values
$X_2 = 215$	$Y_2 = 19.526$
$X_1 = 44$	$Y_1 = 1.911$

The calculations to obtain the mathematical model are as follows.

$$\Delta X = X_2 - X_1 = 215 - 44 = 171$$

$$\Delta Y = Y_2 - Y_1 = 19.526 - 1.911 = 17.615$$

$$M = \frac{\Delta Y}{\Delta X} = \frac{17.615}{171} = 0.1030117$$

$$H(s) = \left\{ \int_0^{\infty} 0.1030117 dt \right\} = \frac{0.1030117}{s}$$

4.2 Analysis and evaluation of modelled transfer function

A cascaded Simulink model is produced where the inner loop is flow and the outer loop is level. A ramp response is produced by the level control therefore a PD controller is utilised. Utilizing the auto tune feature in Simulink the optimal values for Kp and Kd are provides and are shown in Figure 9.

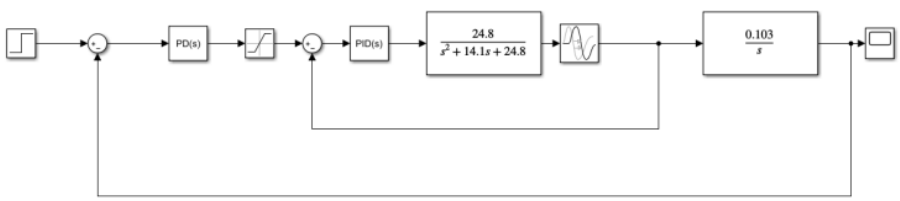
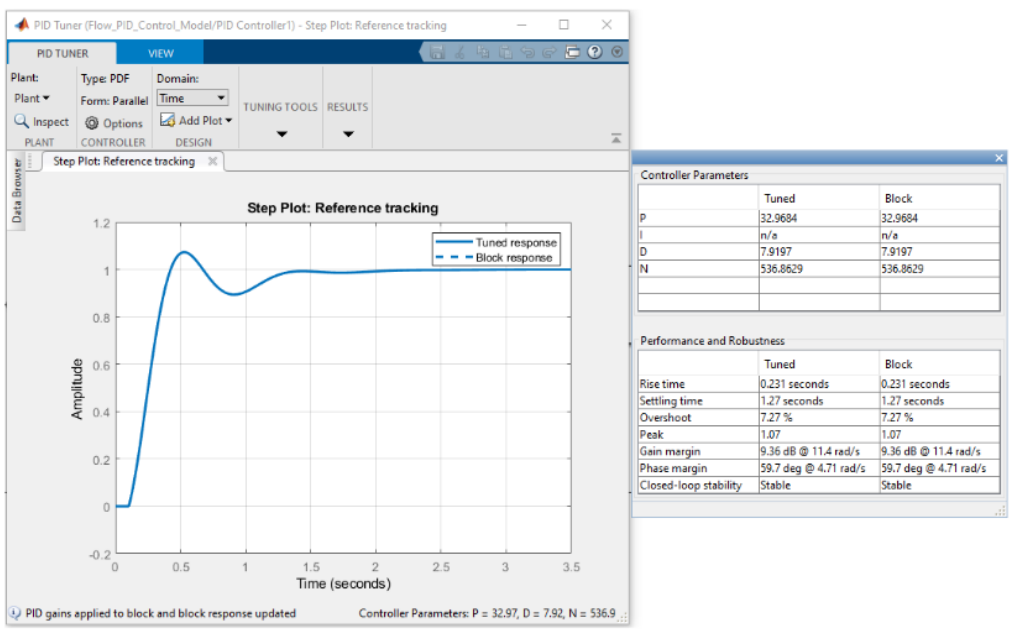


Figure 10: Cascaded model of level control.



	Tuned	Block
P	32.9684	32.9684
I	n/a	n/a
D	7.9197	7.9197
N	536.8629	536.8629

	Tuned	Block
Rise time	0.231 seconds	0.231 seconds
Settling time	1.27 seconds	1.27 seconds
Overshoot	7.27 %	7.27 %
Peak	1.07	1.07
Gain margin	9.36 dB @ 11.4 rad/s	9.36 dB @ 11.4 rad/s
Phase margin	59.7 deg @ 4.71 rad/s	59.7 deg @ 4.71 rad/s
Closed-loop stability	Stable	Stable

Figure 9: Autotuned values for level PD controller

A simulation was run with the desired setpoint of 20cm³ and is shown in **Error! Reference source not found.**. The tuning values provide a reasonable approximation which will be inputted into the actual plant.

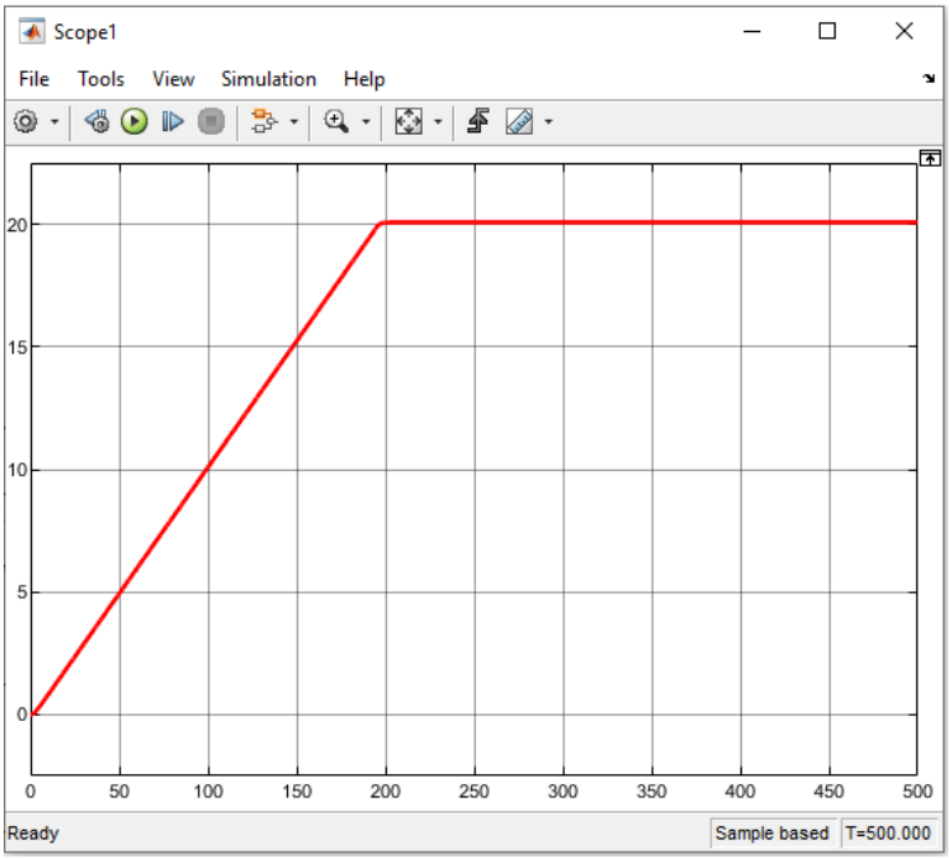


Figure 11: Simulation of level control.

Table 4: Table of autotune and manual adjustment carried out.

	Kp	Kd
Autotune	32.9684	7.9197
Manual adjustment 1	38	3.8
Manual adjustment 2	76	3.8
Manual adjustment	140	20

The process reaction curve results can be found in Appendix F which will be the subject of the analysis.

4.3 Analysis and Evaluation

The auto tune value provided a useful starting point where the manual tuning could commence. With manual adjustment 1 it was found that there was an error of 0.368 from the plant and the desired setpoint. To reduce this the Kp was doubled which reduced the error down to 0.2. As there was still an error present it was decided to increase Kp and Kd. This produced a reduced error of 0.079 comparing the setpoint with the plant.

5. Temperature Control System

5.1 Modelling the Temperature Control System

Identical to the previous task the temperature process response curve was obtained from the process stations HMI screen which is shown in Figure 12. Again, the response was of a pure integrator with a steady ramp response. Two samples were obtained from the HMI shown in Appendix G to calculate the gradient. The values are tabulated in

Table 5.

Figure 12: Process reaction curve for temperature

Table 5: Temperature gradient samples

X Values	Y Values
$X_2 = 788$	$Y_2 = 19.526$
$X_1 = 157$	$Y_1 = 43.549$

The calculation to obtain the temperature control loop are shown below.

$$\Delta X = X_2 - X_1 = 788 - 157 = 631$$

$$\Delta Y = Y_2 - Y_1 = 43.549 - 18.265 = 25.284$$

$$m = \frac{\Delta Y}{\Delta X} = \frac{25.284}{631} = 0.04006973$$

$$H(s) = \left\{ \int_0^{\infty} 0.04006973 dt \right\} = \frac{0.04006973}{s}$$

5.2 Analysis and evaluation of modelled transfer function

The mathematical model was entered into a Simulink model and is shown in Figure 13. A disturbance of 16 has been included to consider the ambient temperature of the environment.

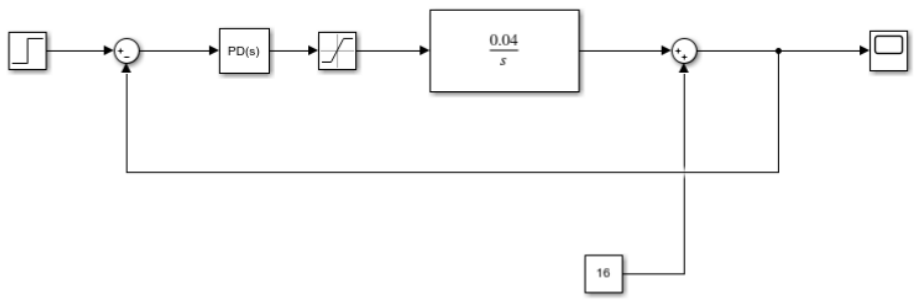


Figure 13: Temperature loop model produced in Simulink

To obtain the optimal value of Kp and Kd the autotune feature of Simulink was utilised and is shown in Figure 14.

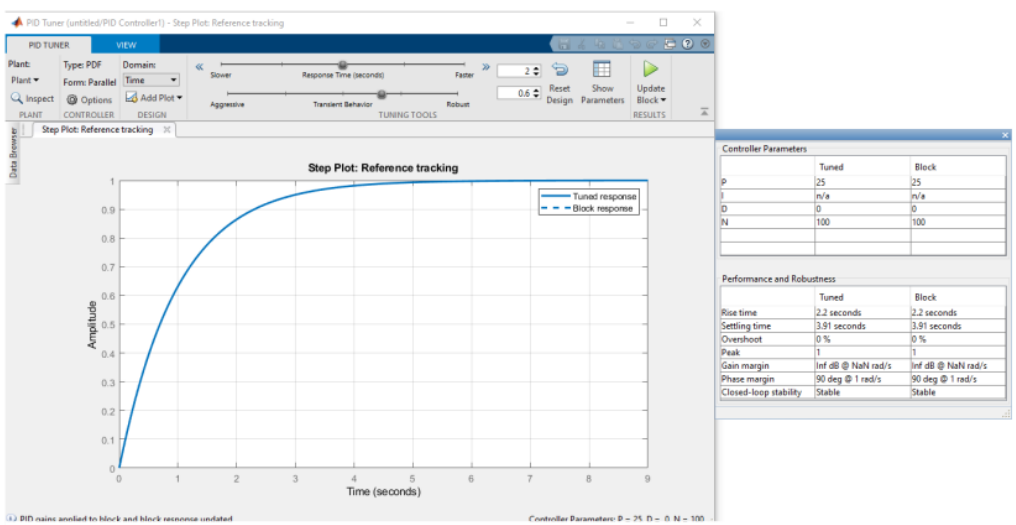


Figure 14: Temperature autotune results from SimuLink.

A simulation was run with the desired setpoint of 50C and is shown in Figure 15. The tuning values provide a practicable approximation which will provide a guideline for the values to be tested. The manual adjustment HMI results can be found in Appendix H. The results are tabulated in Table 6.

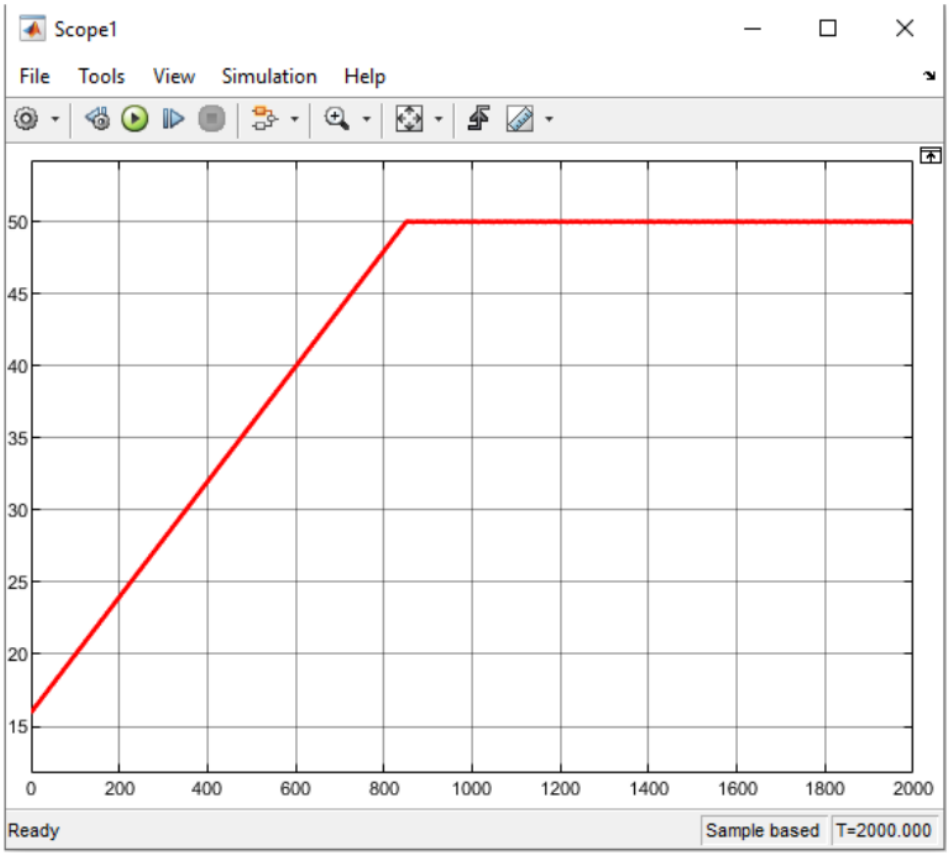


Figure 15: Simulation of temperature control.

Table 6: Table of autotune and manual adjustment carried out on temperature

	K_p
Run 1	13.344
Run 2	35
Run 3	50

5.3 Analysis and Evaluation

The temperature control system only required proportional control. By increasing the value of Kp the process reaction curve reached its setpoint quicker. Increasing Kp to much would result in oscillations before reaching steady state.

6. Conclusion and Recommendations

The calculated, simulation and practical investigation and tuning has provided an understanding into process control theory. By initially running the process under open loop conditions the raw data captured provided the plant information that permitted the tuning process to be carried out. The datalogger facility using a data block array in the PLC provided invaluable real time raw data to produce the process reaction curve. It was found that the Caldwell and auto tune method provided superior accuracy compared to the Nichols and Ziegler method. It is however worth noting that these methods only provide an approximation with manual tuning providing optimal performance. Both tuning methods are advantageous to control engineers as an approximation is provided which eliminates multiple process runs which incur cost and downtime. The tuning methods explored provided a more accurate value for the second order system compared with the pure integrator systems. The flow being a second order systems proportional, integral, and derivative control is required for optimal performance as it provides faster response to changing errors caused by disturbances and restricts oscillations. The level and temperature being purely integrator control systems only require proportional, derivative control.

The system would benefit from an improved pump as the current pump does not provide linear performance which significantly affects the control loop performance. From an academic perspective the control system would benefit from control systems of a higher order.

7. Team working

In the laboratory social distancing, appropriate P.P.E and good personal hygiene allowed the experimental data to be obtained. As a group calculation were performed and compared to predict system performance and author was tasked with capturing images of the HMI to obtain process reaction curves. Unfortunately, due to college closure critical evaluation of the system could not be performed. As a team the information gathered was collated and interaction via Google Meets allowed a satisfactory outcome with the main objectives achieved.

8. Citation List

Correctly cited

Bolton, W., 2015. *Instrumentation and Control Systems.* Second ed. Oxford: Joe Hayton.

Gene F. Franklin, J. D. P. A. E.-N., 2015. *Feedback Control of Dynamic Systems.* Seventh Edition ed. Essex: Pearson Education Limited.

Hughes, E., 2016. *Electrical & Electronic Technology.* Twelfth Edition ed. Harlow: Pearson Education Limited.

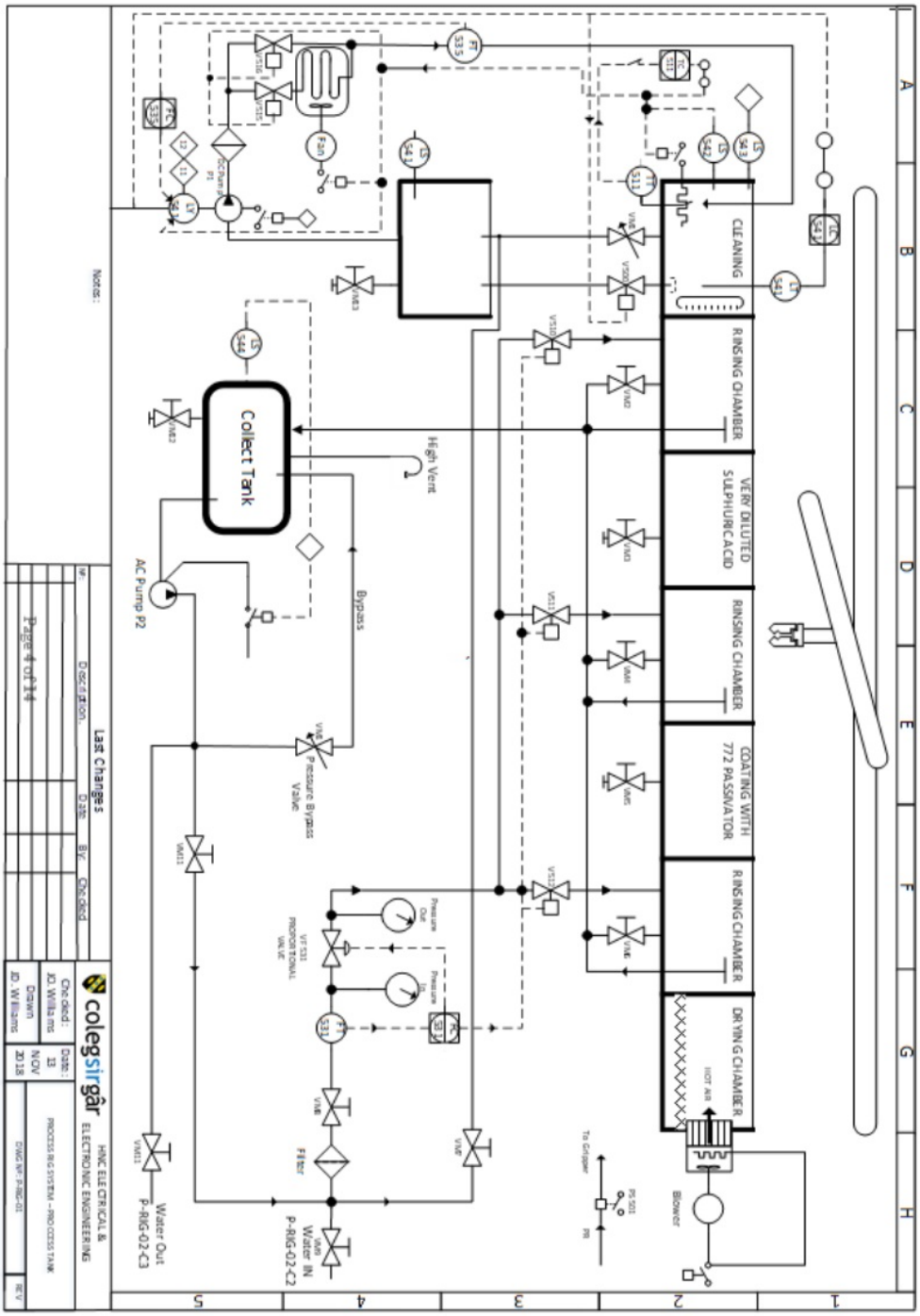
ISA , 2009. *ANSI/ISA-5.1-2009, Instrumentation Symbols and Identification ,* North Carolina,: ISA.

Richard C. Dorf, R. H. B., 2017. *Modern Control Engineering.* Thirteenth Edition ed. Essex: Pearson Education Limited.

The Engineering Toolbox, 2021. *The Engineering ToolBox.* [Online]
Available at: https://www.engineeringtoolbox.com/p-id-piping-instrumentation-diagram-d_466.html#:~:text=P&ID%20is%20a%20schematic%20illustration%20of%20a%20functional,The%20P&ID's%20are%20used%20to%20operate%20process%20systems.
[Accessed 15 02 2021].

William Isaac Caldwell, G. A. C. L. M. Z., 2012. *Frequency Response of Process Control.* First Edition ed. LLC: Literary Licensing.

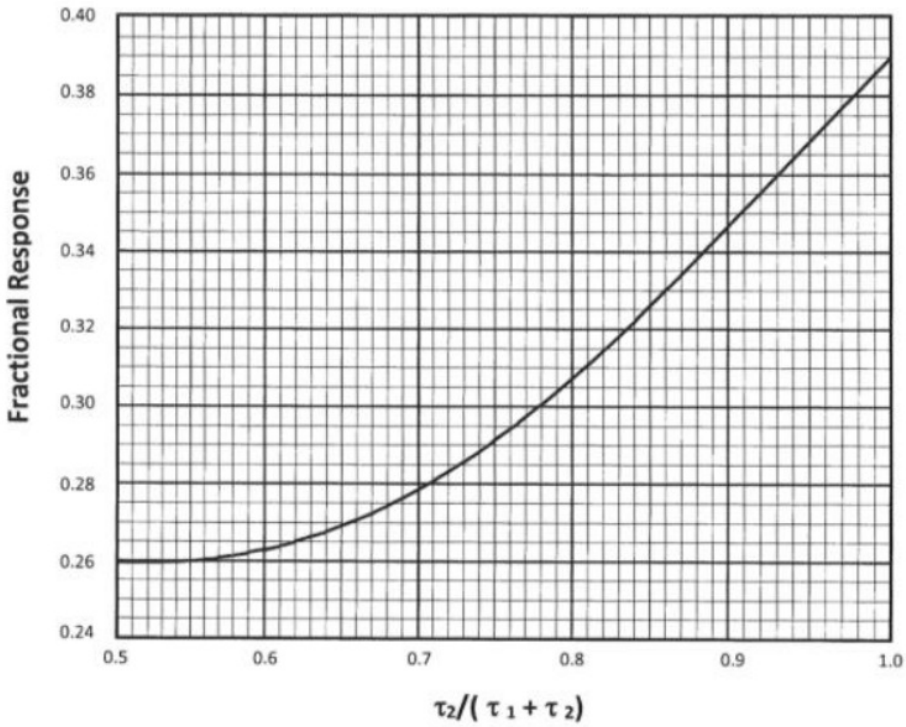
Appendix A



CLEANING
RINSING CHAMBER
VERY DILUTED SULPHURIC ACID
RINSING CHAMBER
COATING WITH 772 PASSIVATOR
RINSING CHAMBER
DRYING CHAMBER
HOT AIR
Blower
Collect Tank
High Vent
Bypass
AC Pump P2
Pressure Bypass Valve
Filter
Water Out P-RIG-02-C3
Water IN P-RIG-02-C2
Fan
Notes:
Last Changes
Description
Date
By
Checked
Checked: JD. Williams
Drawn: JD. Williams
Date: 13 NOV 2018
colegsirgâr
HNC ELECTRICAL & ELECTRONIC ENGINEERING
PROCESS RIG SYSTEM - PROCESS TANK
Page 4 of 14

Appendix B

Caldwell Reference Graph



Appendix C

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den = [ 1 14.1 24.8];
rlocus(num,den);
grid on
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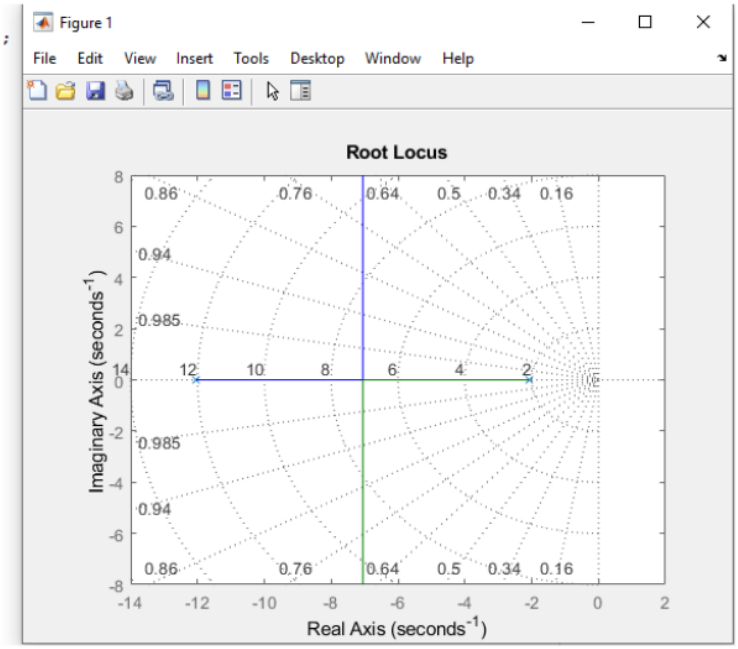
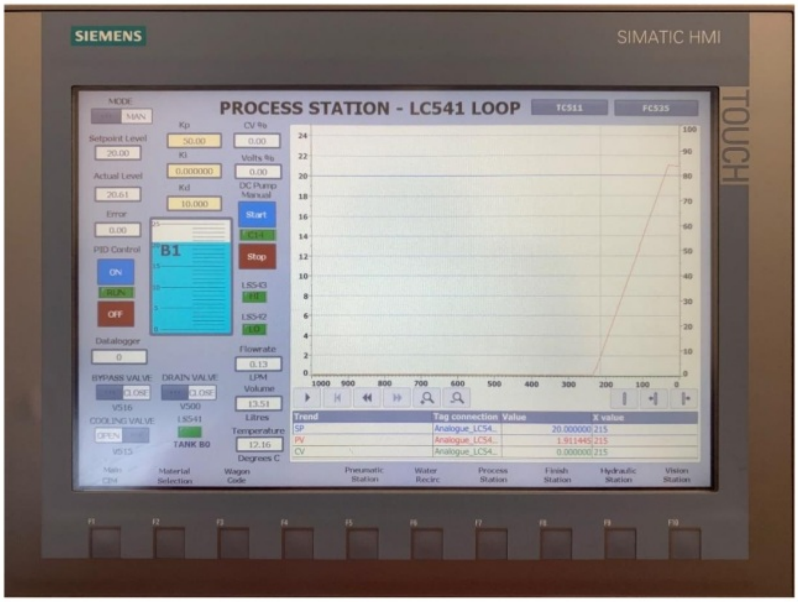


Appendix D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OFF
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Ki
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Kd
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CV %
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Volts %
0.00
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Start
Stop
B1
LS543
LS542
Flowrate
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LPM
Volume
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Litres
Temperature
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Degrees C
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DRAIN VALVE
CLOSE
V516
V500
COOLING VALVE
LS541
OPEN
V515
TANK B0
Trend
Tag connection
Value
X value
SP
PV
CV
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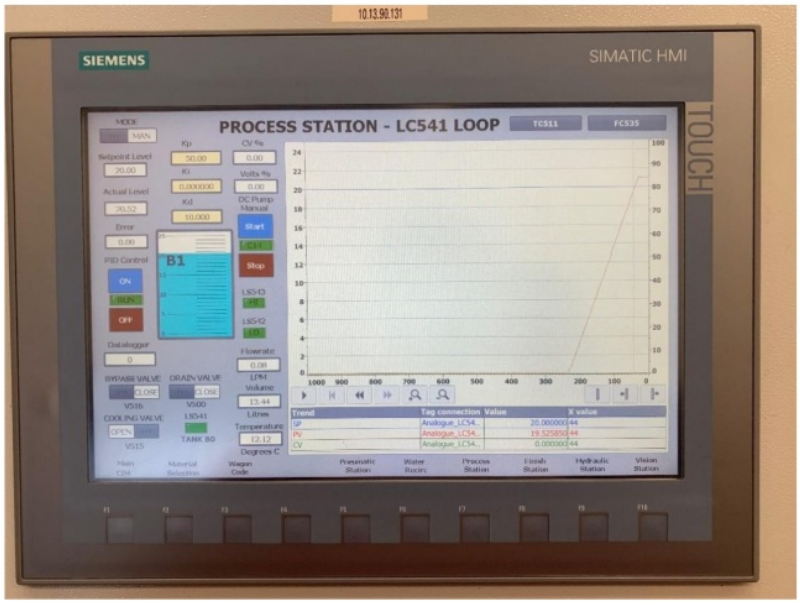
Water Recirc
Process Station
Finish Station
Hydraulic Station
Vision Station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Ki
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Kd
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Volts %
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Stop
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Degrees C
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DRAIN VALVE
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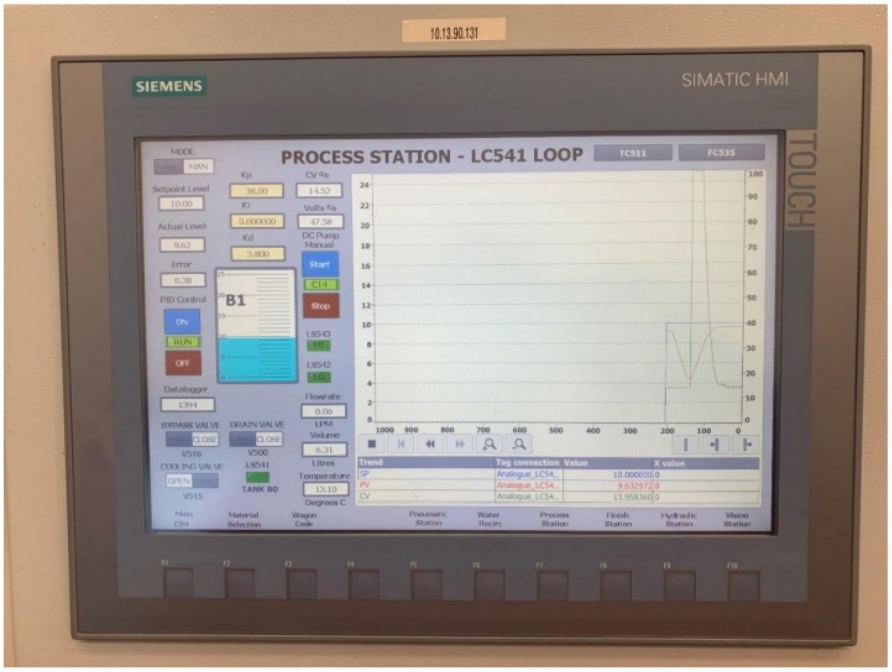
Appendix E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Kd
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Volts %
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HI
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Degrees C
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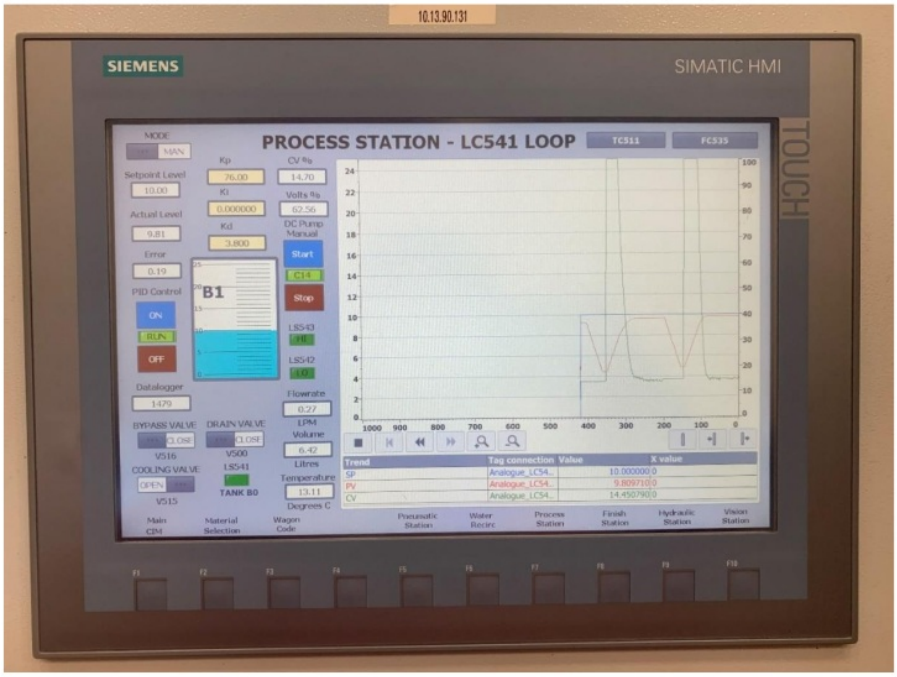
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Vision Station

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Kd
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Volts %
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Stop
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LS543
LS542
Flowrate
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LPM
Volume
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Litres
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Temperature
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Degrees C
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Water Recirc
Process Station
Finish Station
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Vision Station
Trend
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PV
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Appendix F

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D part
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G VALVE
CLOSE
COOLING FAN
OFF
C12
Material Selection
Wagon Code
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Water Recirc
Process Station
Finish Station
Hydraulic Station
Vision Station
Trend
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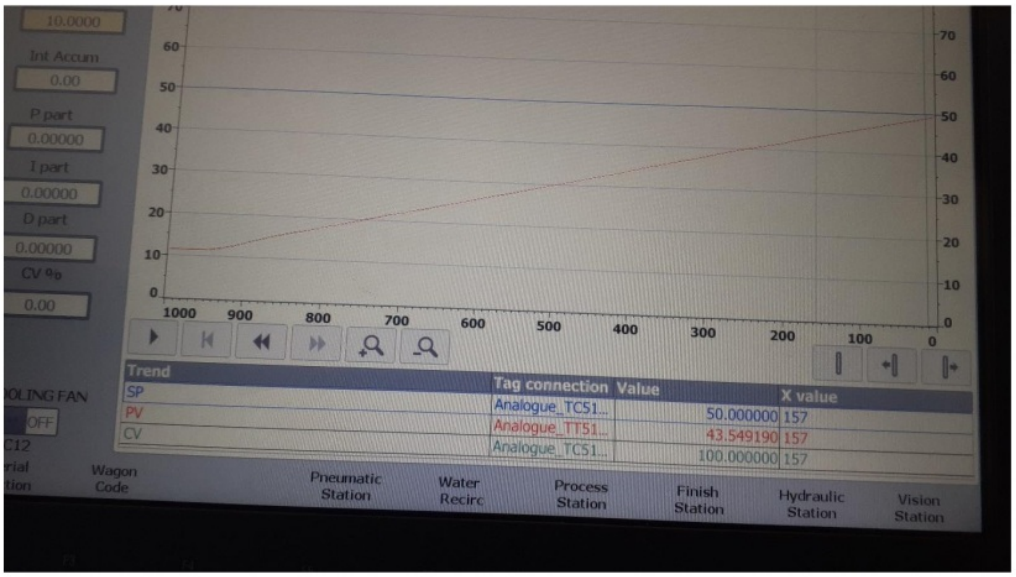
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Wagon Code
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Water Recirc
Process Station
Finish Station
Hydraulic Station
Vision Station
Trend
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Value
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PV
CV
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Analogue_TT51...
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Appendix G

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Water Recirc
Process Station
Finish Station
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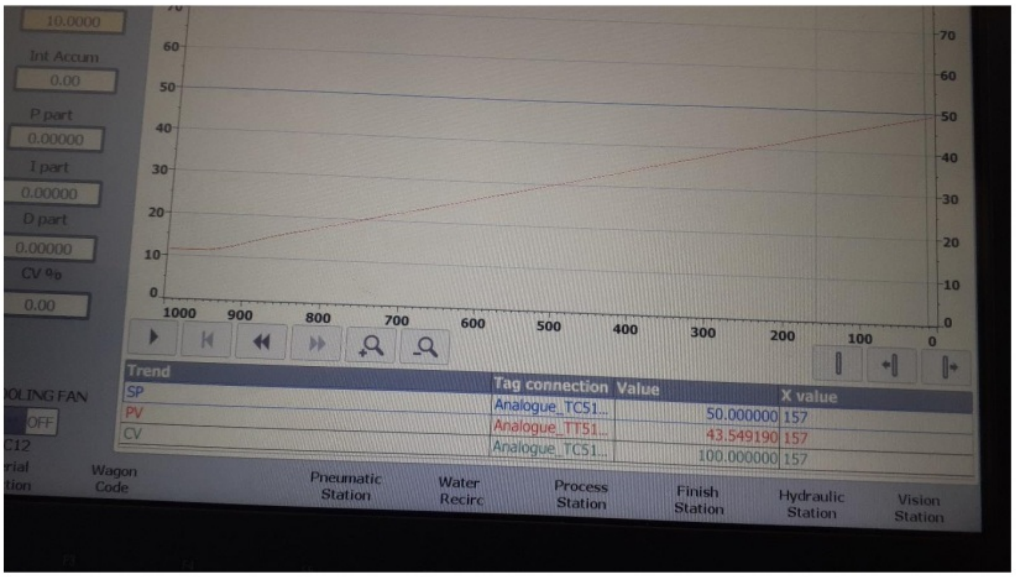
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Process Station
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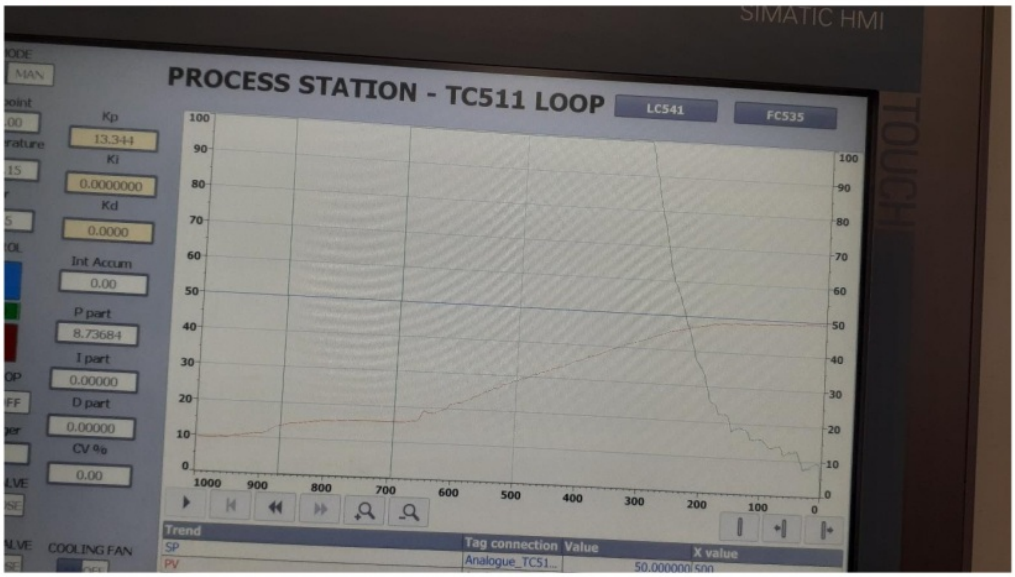
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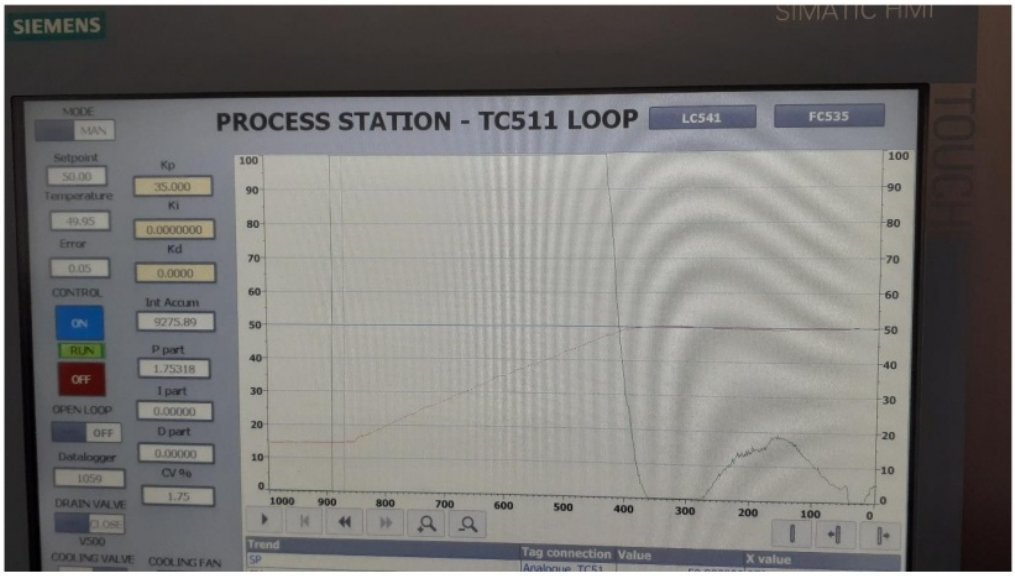
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RUN
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OPEN LOOP
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Datalogger
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COOLING FAN
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Kd
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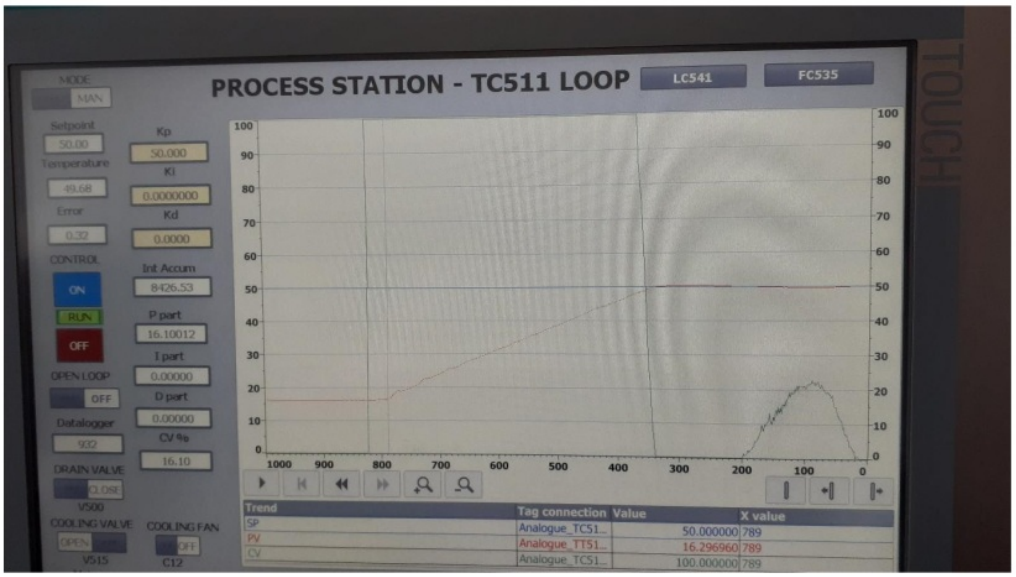
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OPEN
V515
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Kd
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789
CV
Analogue_TC51...
100.000000
789
TOUCH

assignment 1

GRADEMARK REPORT

FINAL GRADE

64/100

GENERAL COMMENTS

Instructor

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

Text Comment. Incorrect, flow is second order

Text Comment. Caldwell is used for second order systems as an approximation of two first order systems in cascade.

Text Comment. Caldwell only gives a transfer function not PID values

PAGE 6

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

QM

Improper Citation

Improper citation:
Improperly cited material. Please use the link below to find links to information regarding specific citation styles: http://www.plagiarism.org/plag_article_citation_styles.html

QM

Improper Citation

Improper citation:
Improperly cited material. Please use the link below to find links to information regarding specific citation styles: http://www.plagiarism.org/plag_article_citation_styles.html

Text Comment. Only the surname should appear in the citation

QM

Improper Citation

Improper citation:
Improperly cited material. Please use the link below to find links to information regarding specific citation styles: http://www.plagiarism.org/plag_article_citation_styles.html

QM

Improper Citation

Improper citation:
Improperly cited material. Please use the link below to find links to information regarding specific citation styles: http://www.plagiarism.org/plag_article_citation_styles.html

Text Comment. This is additional to the second order feature

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

PAGE 7

Text Comment. It would then acts as a first order system

QM

Improper Citation

Improper citation:
Improperly cited material. Please use the link below to find links to information regarding specific citation styles: http://www.plagiarism.org/plag_article_citation_styles.html

PAGE 8

QM

Improper Citation

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QM

Correctly cited

Citation method conforms to Harvard standard, well done.

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PAGE 36

PAGE 37

PAGE 38

GRADING FORM: NEW CSG-RUBRIC

GARETH WILKINS	64

1. ENGAGEMENT WITH LITERATURE

Engagement with an appropriate range of literature, including sources retrieved independently. Some over-reliance on texts. Referencing may show minor inaccuracies or inconsistencies. (10/20)	**10**

2. KNOWLEDGE AND UNDERSTANDING

Knowledge is reasonably extensive. Exhibits very competent critical understanding of the well-established concepts and principles of the subject and the main methods of enquiry. Breadth and depth of knowledge. (13/20)	**13**

3. COGNITIVE AND INTELLECTUAL

Sound critical evaluation and analysis of concepts. Is selective in the range of evidence used and	**13**

synthesises rather than describes. Ability to devise arguments that show awareness of different stances, and use evidence convincingly, to support appropriate and valid judgements. (13/20)

4. PRACTICAL APPLICATION

An advanced application of a range of established methods, materials, tools and/or techniques. The context of the application is well considered, and insightful. Consistent, accurate and logical application of theory to practice, making well-developed links between the two. Can identify problems and propose excellent, creative solutions outside the context in which they were first studied. (14/20)

14

5. TRANSFERABLE SKILLS

Can communicate professionally confidently and consistently in a suitable medium for the audience. Work is coherent, very fluent and is presented proficiently. Can work autonomously with initiative. Where relevant can work professionally within a team, showing leadership skills as appropriate, and meeting obligations. Demonstrates excellent skills for employment requiring the exercise of personal responsibility and decision-making and an appetite for further development. (14/20)

14