Edinburgh Napier University

Industrial Automation

MEC10112

Liquid Processing and Bottling PLC Controlled Station.

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Introduction

This project required to deliver a system which produces a liquid product from two products mixed and heated to a recipe specification. The liquid then bottled using a conditioning line. This technical files provides an account of the manufacturing and design undertaken, as well as a description of the application programme (Functional Design Specifications) and account of the test realised to ensure the project delivers a functional control panel and software (Functional Testing Specification).

I. Control System Hardware Build.

This section details the manufacturing activities undertaken to design and manufacture the physical control panel.

A. Mechanical Build Description.

1. Temporary Component Layout.

This is the temporary component placement realised as a starting point. Components and connections will have been rearranged as manufacturing and electrical wiring was accomplished.

Parts footprint (mm):

PLC: 110 X 100.

Network Box: 100 X 45.

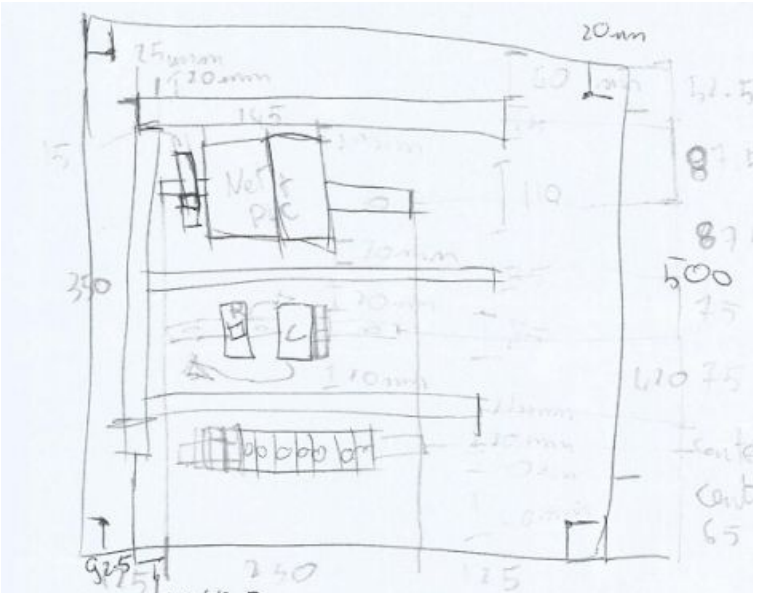
Overload Trip: 80 X 15.

Contactor: 58 X 45.

Relay: 85 X 36

Trunking: 35.

DIN Rail: 25



2. Panel Manufacturing Diagram.

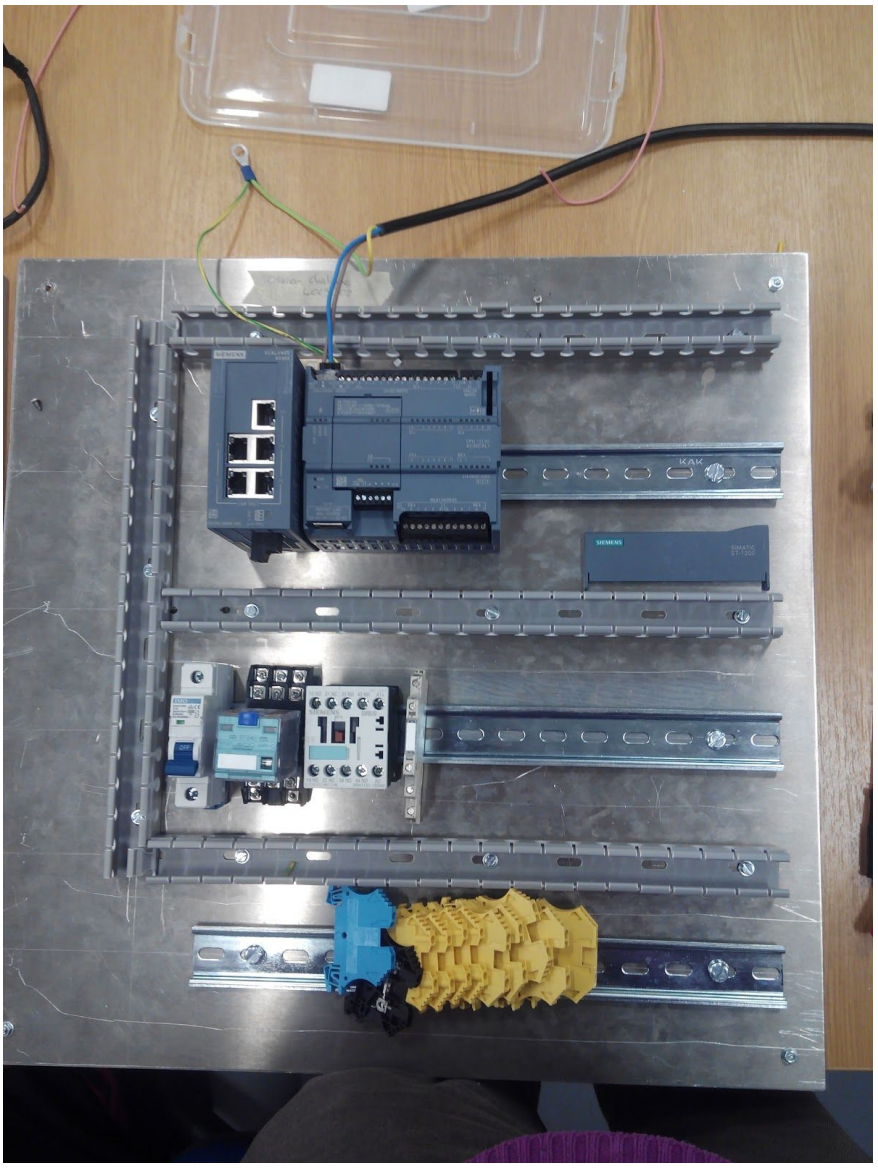
The panel manufacturing diagram is available in appendices. Here again modifications were realised whilst the manufacturing activities were undergo to facilitate and speed the process. The diagram shows consideration that have been made to place the trunking and DIN rail and panel feet.

3. Panel Manufacturing Activities.

In this section can be found pictures of the panel at different stages of the manufacturing and wiring process:

Manufactured Panel Ready for Component Mounting.

Electrical Components placed on the Panel.



Wired and Tested PLC Control Panel.

B. Electrical Wiring Description.

This section gives a description of the inputs and outputs of the PLC as well as the colour coding of the wires. Wiring diagrams can be found in the appendices.

The first tables lists the input.

PLC Input	**Description (Wiring Reference).**
I0.0	Valve 101 Sensor Opened (R101).
I0.1	Valve 101 Sensor Closed (RX101).
I0.2	Valve 102 Sensor Opened (R102).
I0.3	Valve 102 Sensor Closed (RX102).
I0.4	Valve 103 Sensor Opened (R103).
I0.5	Valve 103 Sensor Closed (RX103).
I0.6	Valve 104 Sensor Opened (R104).
I0.7	Valve 104 Sensor Closed (RX104).
I1.0	Product A minimum Level (RX - Orange)
I1.1	Product B minimum Level (RX - Green).
I1.2	Bottle Presence (RX - Purple).
I1.3	Mixer On - KM1 (RX - Blue) .
I1.4	Heat Tank Level (RX - Grey).
I1.5	Emergency Stop (+EMS+).
A0	Temperature Sensor (AT).
A1	Ultrasonic level sensor (AS).
M, 1M	Grounds for Inputs. (0)
L1, N, E	Connections to 240v Plug.

The second table lists the outputs.

PLC Output	Description (Wiring Reference).
Q0.0	Valve V101 ON (S101).
Q0.1	Valve V102 ON (S102).
Q0.2	Valve V103 ON (S103).
Q0.3	Valve V104 ON (S104).
Q0.4	Mixer ON - KM1 (Y+1).
Q0.5	Heater On (Y+2).
Q0.6	Fan On (Y+3).
Q1.0	Conveyor On (Y+4).
Q1.1	Conveyor Direction (Y+5).
AQ.0	Analogue output for Conveyor Speed (SY+).
AQ.0M, M	Grounds for outputs. (0)
1L, 2L	24v Supply for the outputs. (24v)

Colour Coding of the wires:

- Green and Yellow: Earth
- Black: Ground.
- Red: 24v.
- Yellow: Digital Outputs.
- Green: Analogue Output.
- White: Analogue Inputs.
- Pink: Emergency Stop.

II. Software Design.

This section is composed of the Functional Design Specifications and Functional Testing Specifications. The first will describe how the PLC programme fulfills the application and operations available. The second will explain how the functions of the PLC programme and physical actuators can be tested.

A. Functional Design Specifications.

This section will describe the different functions of the Control Panel programme. Essentially, the application can be broken down into four main sections described below:

1. System Control Operations.

The System Process Control is a function present in OB1 the main loop of the PLC programme in manages the tasks below:

- 1.a Mode Selection - RunMode Function Block.

This function allows an interlock between the different modes. There are three modes automatic, manual (triggered when system at rest or when manual mode selected) and forced manual (trigger when an error is detected). The Mode Selection is accompanied by a system enable function allowing for the system to be fully shutdown.

- 1.b Recipe Programming/Selection - Recipe Selection Function Block.

Using the recipe management screen available from the root menu of the HMI or from the relevant section in the SCADA it is possible to enter the recipe specifications. The Recipe Selection FB allows to select one recipe at the time with the necessity for the operator to press reset before selecting another recipe.

- 1.c Sequential Function Chart:

The Sequential Function Chart offers an overview of the automatic process. It allows to keep track of the conditions necessary for the application to progress onto the next step hence allowing to fault find if the system was interrupted or missing a conditions to validate a step.

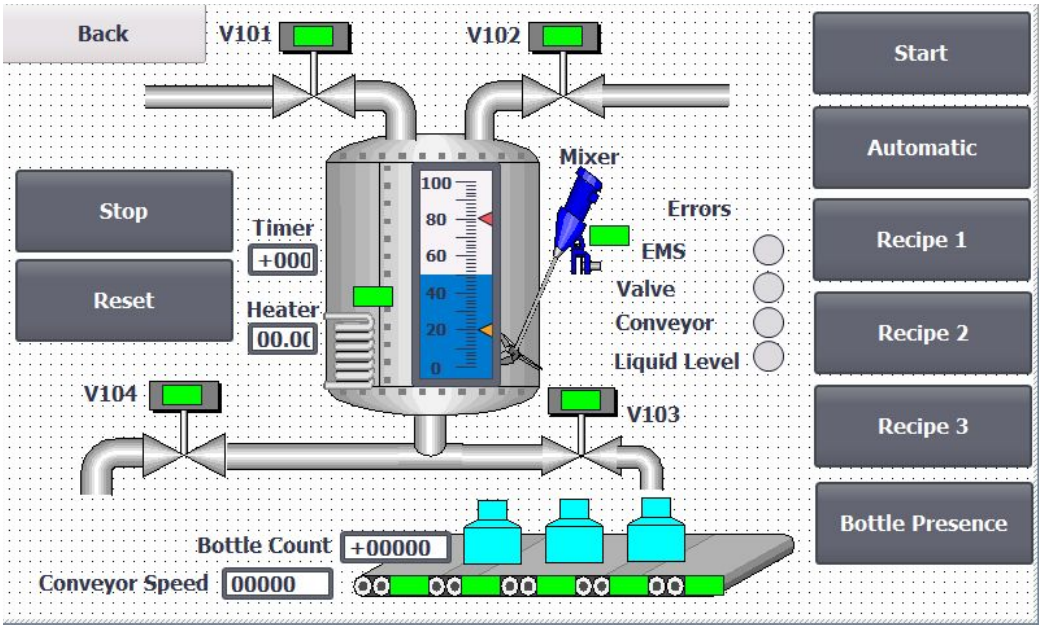
- 1.d Control Screens (HMI/SCADA):

The control screens are not exactly part of the System Process Control function but they allow the users to interact with the programme and gain insights about the running process of the station and display errors.

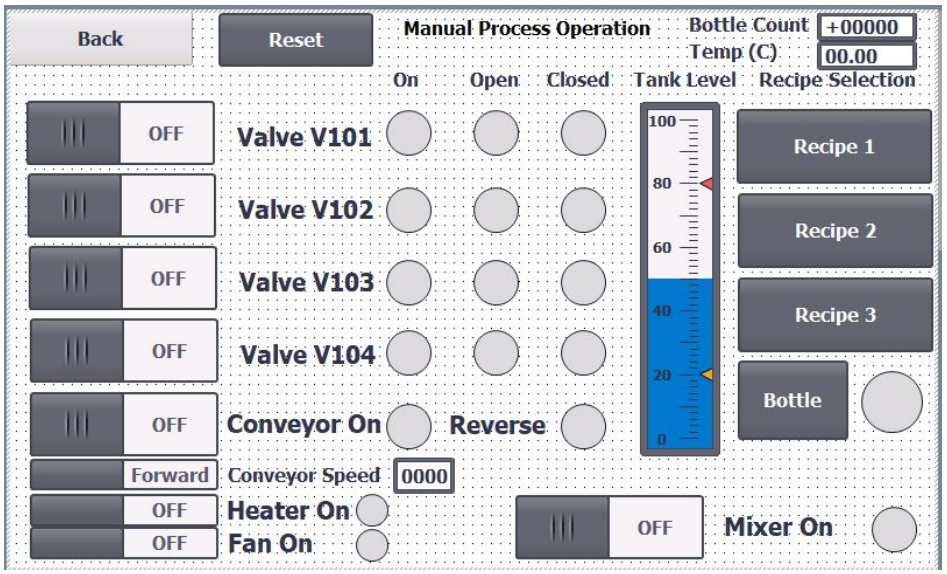
The HMI Control screens (examples below) provide the basics for an operator to interact with: Mode Selection (automatic and manual), Recipe entering and Recipe selection, Manual control to operate the hardware. The automatic mode also provides an overview of the process running and basic errors.

The SCADA screen (example below) provides an overview of the running process with more detailed information on the errors. It offers the possibility to launch the automatic sequence as well as modifying the recipe details.

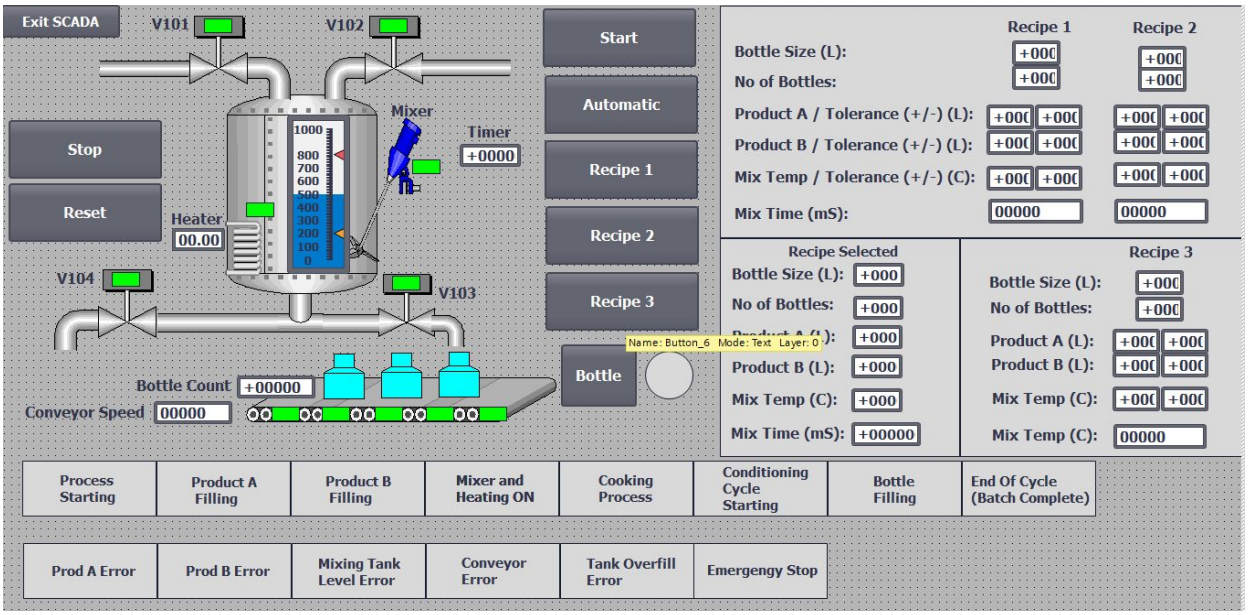
Operator Control Overview Screen.



Manual Operation Screen.



SCADA System Screen.



2. Temperature Management.

This function incorporates the reading and scaling of the analogue readings coming from the temperature sensor and the calculation of the upper and lower limits. Those are used to control the heater using the in range and not in range functions. If the Temperature reading is not in range the heater will be ON if the temperature reaches the range the heater will be turned OFF (This control is realised in the OB30 Cyclic Interrupt).

3. Solution Mixing Tank Operations.

The mixing tank process function englobes all the activities linked to liquids processing (aside from temperature reading). The function starts by obtaining the analogue reading from the ultrasonic passed through a filter to limit noise on the signal. The read value is then scaled between 0 and 1000.

Then, the valves V104 (to purge the tank), V101 (to fill product A to the desired level) and V102 (to fill product B to the desired level) are triggered sequentially following the process required by the user specifications. These valves function blocks also offer integrated error detection and safety features (i.e cannot be triggered if the tank attached is below minimum level).

Finally, the function shows how the heating and mixing are triggered. Once the temperature in range the Mixing timer will be triggered for the time defined by the operator, returning mixing done once the time elapsed.

4. Conditioning line Operations.

Once the mixing time achieved the following function englobes the bottling activities of the station. Once activated the conveyor is set on with the speed being outputted by an analogue out FB. This function scales the conveyor speed to deliver a signal between 0 and 10v.

Once a bottle detected in position, the conveyor stops and the Filling Control FB calculates the target liquid level required in the mixing following the bottle filling using the bottle size value. This value is then used to control the valve open request as long as the level reading and target level do not match.

Following the filling the conveyor is set back ON and the bottle counter ads a unit to the bottle counter. Once the bottle counter reaches the batch size the process will stop and the station will reset to await for further instructions.

5. Error Management.

This function regroups the conditions necessary for each error to be trigger. Error groups have also been created to facilitate display on the HMI.

The first group manages the valve errors. If one or more of them return an error the valve error and general error (error status) will be triggered.

The second group shows how triggering the emergency stop will trigger a light on the various displays.

The third group takes care of the potential liquid level errors taking into account liquid level tolerances.

The groups 4, 5, 6 are linked to level switches being triggered in the various tanks when at minimum level. Those are summed up in the 7th group to create a general liquid error.

Group 8 shows how if the system will shut if it does not receive a feed of empty bottles within 60 seconds.

Group 9 shows how the EMS, an Error, Stop push button or end of bottling cycle trigger a reset of the system.

Group 10 demonstrates how pressing reset will clear the errors allowing for the system to launch a new cycle.

B. Functional Test Specifications.

This section will describe the various tests (software and physical) realised to ensure the system is functional. The tests were realised using a hardware in the loop simulation namely a PLC running a simulation of the tanks and valves.

Required tasks for test: The Control and Simulation programmes need to be uploaded to their respective PLCs. The SCADA needs to be loaded. It is then "exited" using the on-screen button. Finally it is reloaded.

Purpose of the test: the purpose is to test is the SCADA system can be rebooted.

Test 1	Pass/Fail	Comments	Student	ENU
SCADA Reboot.				

Required tasks for test: The Control Panel programme needs to be uploaded to the relevant PLC. On the HMI, the relevant programme mode can be selected. The RunMode_Selection Function Block (FB) will output the correct mode.

Purpose of the test: Test the FB capacity to select a run mode.

Test 2	Pass/Fail	Comments	Student	ENU
Programme Selection				

Required tasks for test: Control Panel PLC programme loaded. HMI and/or SCADA activated.

Purpose of the test: When entered the recipes specifications should be saved.

Test 3	Pass/Fail	Comments	Student	ENU
Recipe requirements entering.				

Required tasks for test: Recipes should be entered into the HMI or SCADA. Select one of the recipes to test the selection.

Purpose of the test: Checking if the “Recipe Selection” FB is functional with one outputed recipe.

Test 4	Pass/Fail	Comments	Student	ENU
Recipe Selection.				

Required tasks for test: The Control Panel and Simulation programmes should be loaded on their relevant PLC. Wire connections should have been established between the Control Panel PLC, Simulation PLC, Heater and Fan, VSD (Conveyor).
A watch table of the process is available. Relevant actuators and measuring devices can also be physically monitored using a voltmeter with their reading being checked against the scaling in the programme. The SCADA and HMI also provide some process monitoring indications.

Purpose of the test: Checking the Automatic Mode runs through the process of filling product A and B into the Mixing Tank to be heated. Finally, the product will be conditioned using the bottling line and stop when required.

Test 5	Pass/Fail	Comments	Student	ENU
System Enabled.				
Automatic Mode Engaged.				
Tank Purging.				
Product A Filling.				
Product B Filling.				
Mixer and Heater ON.				
Cooking Time.				
Conditioning Process triggered (Conveyor ON).				
Bottle Filling.				
Bottle filled (Conveyor ON, Bottle count +1)				
Automatic Mode reset when the bottle counter reaches the bath count (Batch finished).				

Required tasks for test: The Control Panel and Simulation programmes should be loaded on their relevant PLC. Wire connections should have been established between the Control Panel PLC, Simulation PLC, Heater and Fan, VSD (Conveyor).
A watch table of the process is available. Relevant actuators and measuring devices can also be physically monitored using a voltmeter with their reading being checked against the scaling in the programme. The SCADA and HMI also provide some process monitoring indications.

Purpose of the test: Checking the manual mode allows for the actuation of the different hardware elements of the system with indications from the sensors.

Test 6	Pass/Fail	Comments	Student	ENU
Manual Mode Selected.				
V101 ON.				
V102 ON.				
V103 ON.				
V104 ON.				
Speed Entering				
Conveyor ON.				
Conveyor Reverse.				
Heating ON.				
Fan ON.				
Mixer ON.				

Required tasks for test: The Control Panel and Simulation programmes should be loaded on their relevant PLC. Wire connections should have been established between the Control Panel PLC, Simulation PLC, Heater and Fan, VSD (Conveyor).

Level switches will be unplugged to simulate the contact opening.

Emergency Stop will be pressed.

The step triggering the conveyor will be triggered and the timer will be left to run until the error appears.

For the Mixing tank overflow, the automatic sequence will be launched with levels of Product A and B amounting to an overflow.

Pressing the Reset push button will reset the error status.

Valve Errors can be triggered by plugging the sensor to 24v when it should be off, or by unplugging it when it should be on.

Purpose of the test: Checking the various errors defined in programme are functioning.

Test 7	Pass/Fail	Comments	Student	ENU
Emergency Stop				
Product A Level Error				
Product B Level Error				
Mixing Tank Level Error				
Conveyor bottle feed Error.				
Tank Overflow Liquid Level				
Valve Errors: V101 V102 V103 V104				
Error Reset				

III. Conclusion.

This technical file details the steps taken to provide a liquid processing and bottling unit from the construction of the control panel to the potential basic PLC control programme. It also demonstrates how the programme can be tested to ensure it is functional and reactive.

From there further addition can be made. It would be conceivable to add a bottle level checking position at the end of the filling stations with defects being rejected. The processing unit could also be completed with a capping and boxing stations.

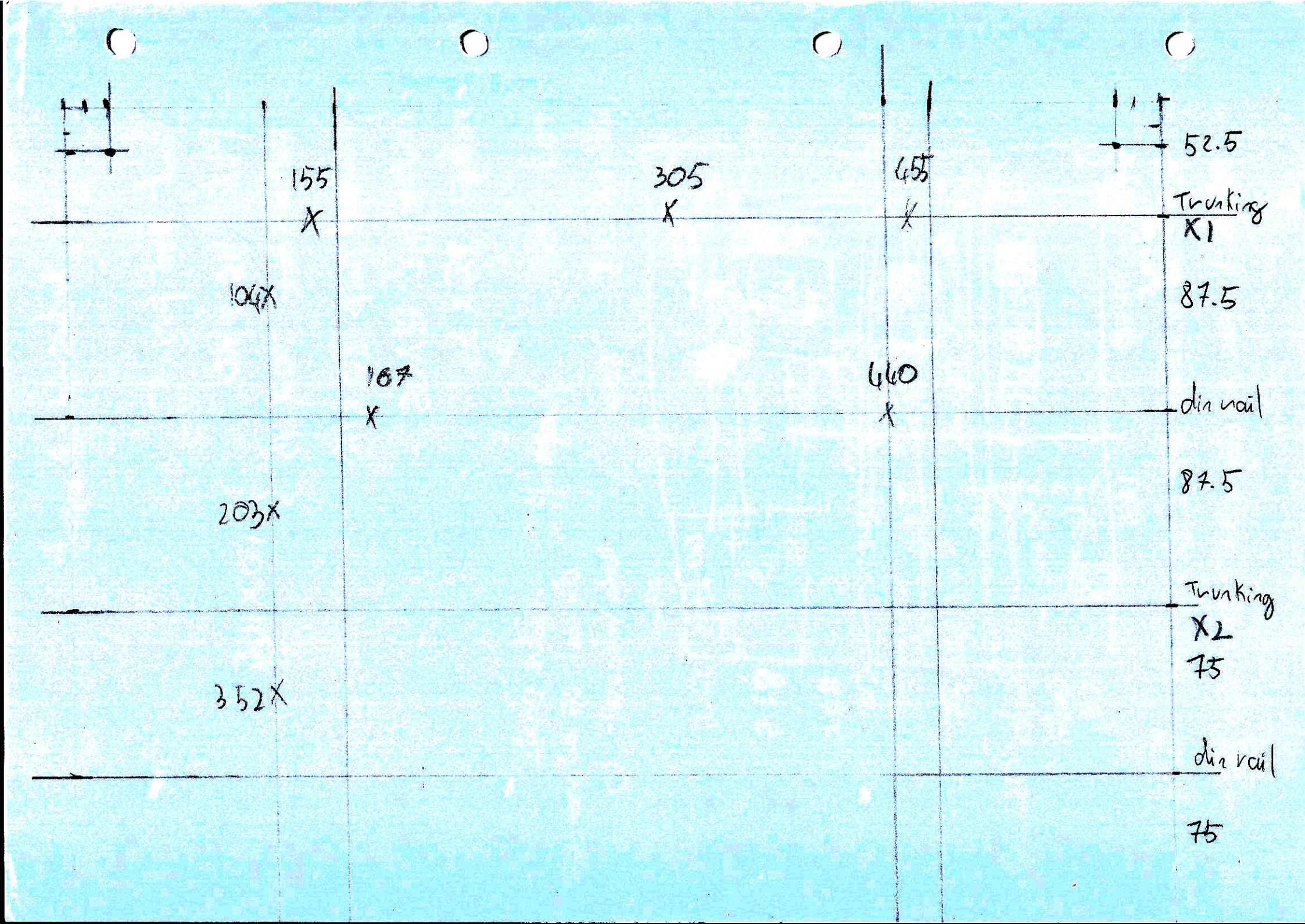
The programme could also allow the operator to plan the filling cycles with a cleaning phase between recipe changes to allow for setting up times to be minimised. More safety features could be added, for example to take into account the risk of the element overheating. These would have to be put to the client in an FDS to be agreed, implemented and tested again with an FTS.

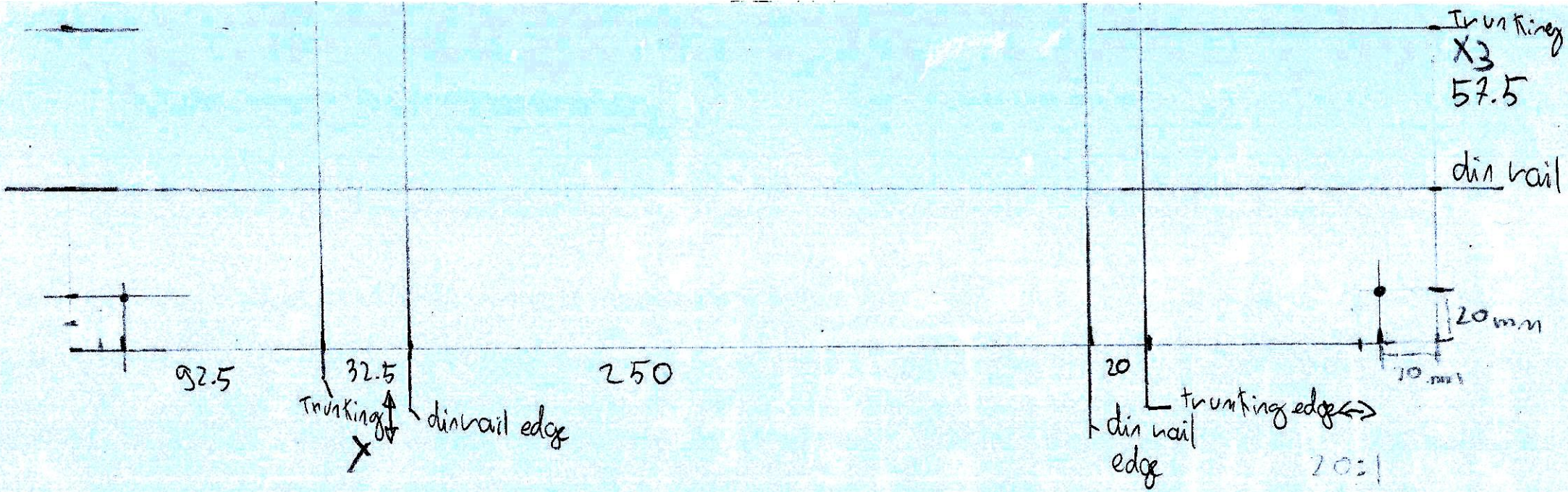
IV. Appendices.

Appendix 1 - Panel Manufacturing Diagram.

Appendix 2 - Electrical Panel Inputs Wiring Diagram.

Appendix 3 - Electrical Panel Outputs Wiring Diagram.


155
305
455
52.5
Trunking
X1
87.5
104
167
460
din rail
87.5
203
Trunking
X2
75
352
din rail
75

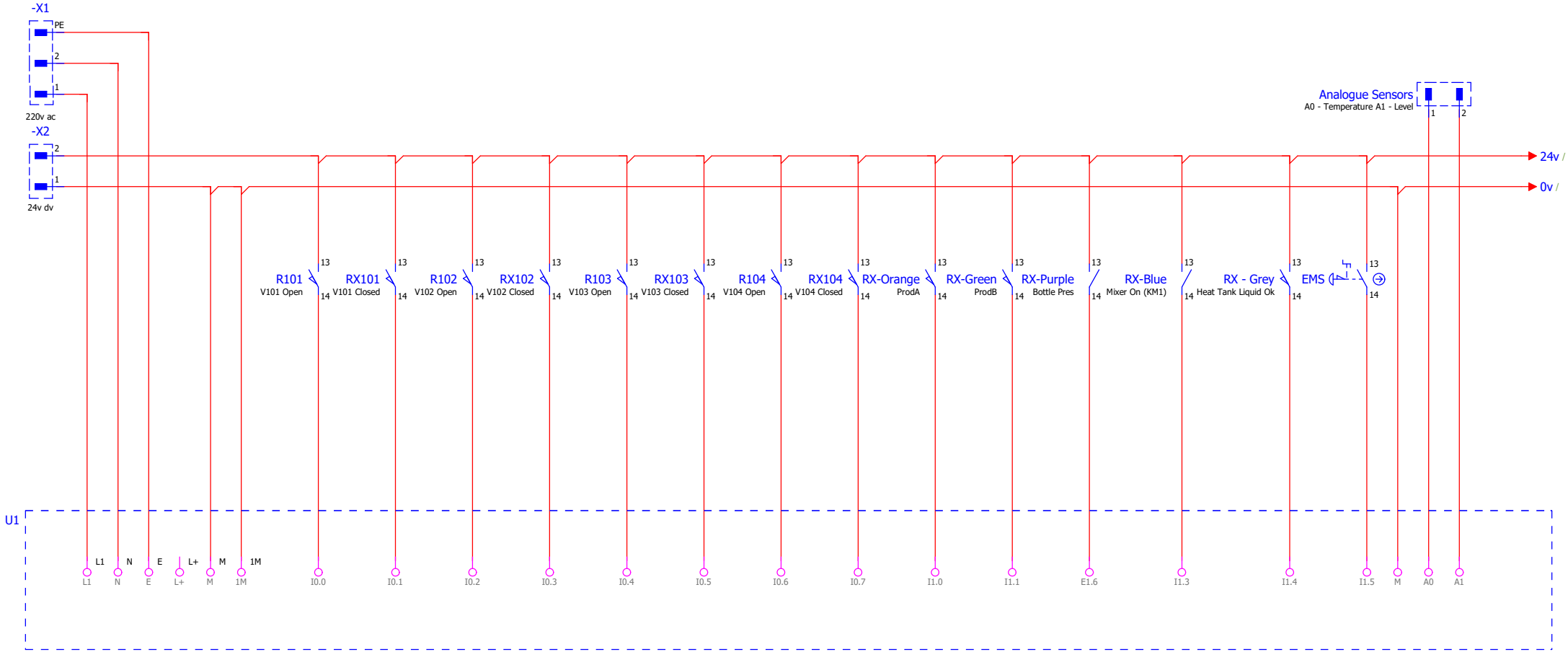


Top and bottom trunking = 315

Mid trunking = 302.5

Din rails = 250 mm

Vertical trunking = 350



Output

ENU

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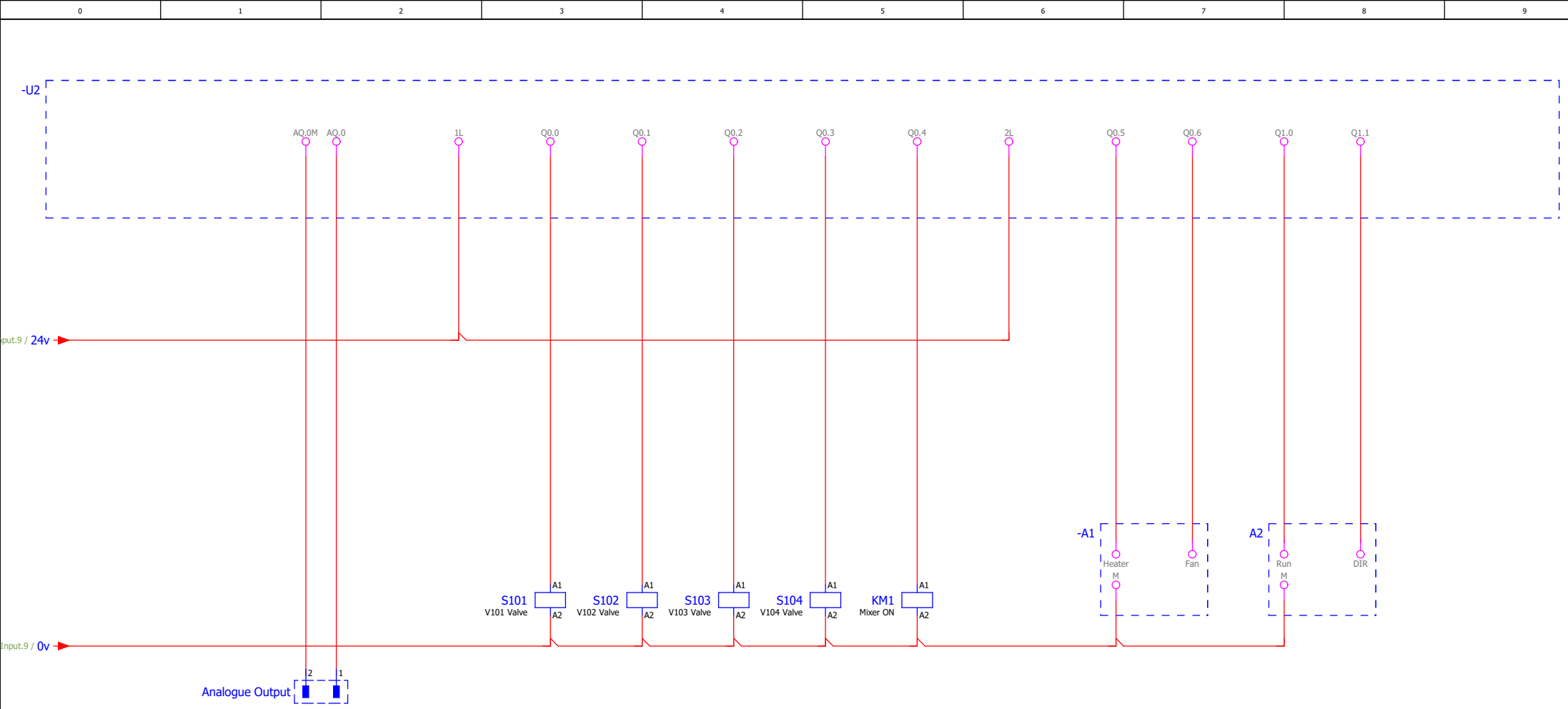

Input

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Modification	Date	Name	Original		Replacement of	Replaced by			Page 2 / 2