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by Thomas Grennan

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1. Executive Summary

The report details the design, implementation and testing of the proposed 'Ingredient Dosing System' for an SME customer within the baking industry requiring an increase in production due to new contracts, with the aim of replacing a time-consuming labour-intensive process with a fully automated dosing system with traceability. Issues uncovered with the hoppers in the testing stage has prevented the project completion within the timing plan. Therefore, the report details the process and evaluation of the current state of the project at 83% completion where £85,609.19 of the £110,000 (77.8%) budget has been spent.

The design aspect was efficiently completed within the time-frame dictated by the Gantt chart, with the systems safety-related parts of the control system (SRP/CS) developed, verified and validated before the build was implemented ensuring compliance with EN ISO-13849-1, 13849-2 & 13850 ensuring the machine safety constraints were covered. The majority of parts were delivered on time, allowing the panel to be 90% completed in line with the timing plan. Software was developed efficiently in TIA Portal, utilising Profinet devices enabled quick design and configuration of the automation network.

Increased workload and changes to company priorities resulted in the author not completing the build stage as planned, discussions with the workshop supervisor allowed for an electrician to complete these tasks. Delivery delays of the frame from powder coating resulted in the timing plan slipping by 8 days. Contingencies were implemented to recover the timing plan by bringing two days commissioning forward to reduce the time lost. The Gantt Chart, WBS & Costing Spreadsheet were essential in keeping track of the projects progress, tasks and finances as the timing plan slipped.

Upon manufacturing completion, the system was commissioned. During commissioning "Cohesive Bridging" issues in 4 of 6 hoppers prevented the system from being completely commissioned. Discussions between the authors company and suppliers resulted in an outcome to install High Frequency Impact Vibrators (HFIV). The time frame to receive & implement the HFIVs did not fall in line with the project plan, therefore the system was tested with only two hoppers.

The system was tested against the FDS test plan developed in the research phase, successfully achieving 32 of 38 requirements. The aspects not achieved are due to supply-chain issues or incompletion due to the requirement for HVIV installation.

In evaluation, the main constraints outlined at the start of the project have been successfully addressed. The machine has been designed safely in compliance with BS EN 60204-1, EN

ISO 13849-1, EN ISO 13849-2 and EN ISO 13850 ensuring the system is safe for the wider community. The ATEX constraints are alleviated utilising adequate equipment to ensure high power equipment with the potential to ignite dust clouds is not possible, through the use of Intrinsic Barriers achieving compliance with The Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 2016. Checklists completed confirm compliance with BS EN 60204-1 & Electromagnetic Compatibility Regulations 2016 ensuring the requirements of the Machinery Directive are met for CE/UKCA marking. Food hygiene constraints have been solved, implementing traceability of the recipe to maintain the “One Step Forward, One Step Back” supply chain rule 178/2002.

Recommendations were made for future improvement, including implementation of PD control to replace the Ramp Function for the first-stage of dispensing to remove the requirement for the second-stage valve, and to better use the MindConnect IOT2050 to benefit the company.

Very detailed but far too long for a summary

The brief asked you to write this in 300 words

2. Introduction

The report outlines the design, implementation, management and testing of the Ingredient Dosing System for a customer within the baking industry requiring a production increase to meet new contracts, with the aim of replacing a time-consuming labour-intensive process with a system that accurately dispenses, weighs and stores data on bake mix recipes.

The report will outline the design of the systems electrical, functional safety and software requirements to meet aspects of the Functional Design Specification (FDS) and Machinery Directive requisites, ensuring that all constraints uncovered in the research phase are accounted for, enabling the system to achieve CE/UKCA conformity, as well as customer & manufacturer requirements.

The design will be implemented and managed, utilising management tools & techniques developed. All aspects of the project's implementation lifecycle will be managed, ensuring that components, labour and information is available in the stringent timing plan to ensure the project is delivered within the budget of £110,000.

The testing phase will outline the success of the project, this will be gauged in terms of the projects ability to meet the requirements of the FDS. The qualitative test plan produced in the research phase will provide a benchmark to measure actual project outcomes compared to the requirements.

Evaluation of the project outcomes, and a conclusion will be derived including recommendations on how the project performed, along with reasons for successes, failures, and what engineering modifications & management techniques could have been implemented to improve the project.

3. Design

Solution 1 was chosen as the most suitable solution achievable within the time frame and budget. Utilising a Siemens S7-1511 PLC to control 6-off ATEX rated two-stage valves for the dosing of 6 common traybake ingredients. Profinet communications will be implemented where possible and practical to allow ease of communication with field equipment. Appendix 9.1.1 outlines an explanation about the components used in the solution.

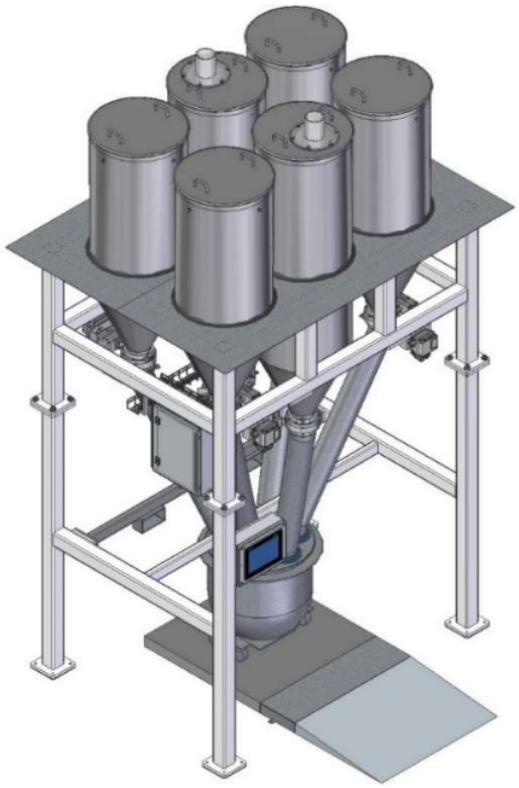


Figure 1 – Ingredient Dosing System Model

As the design stage commenced, the functional design specification (FDS) created in the research phase was continually referenced to ensure the design met all requirements (Grennan, 2023). Aspects of the FDS are no longer plausible within the time constraints of the project due to extended lead-times as a result of the global-chip shortage. Consequently, P.11 is no longer achievable within the timeframe and will be replaced by standard MCBs & Auxiliaries.

An internal concept review was held with the engineering department, it was outlined that there is no safety function to minimise the potential risk of compressed air. As the panel & main air shut-off valve will be situated on a mezzanine floor, an emergency stop is required to quickly remove the system air in an emergency situation. The second addition is to implement an alarm screen to display system alarms to aid fault finding. Figure 2 displays the updated hardware overview for solution 1.

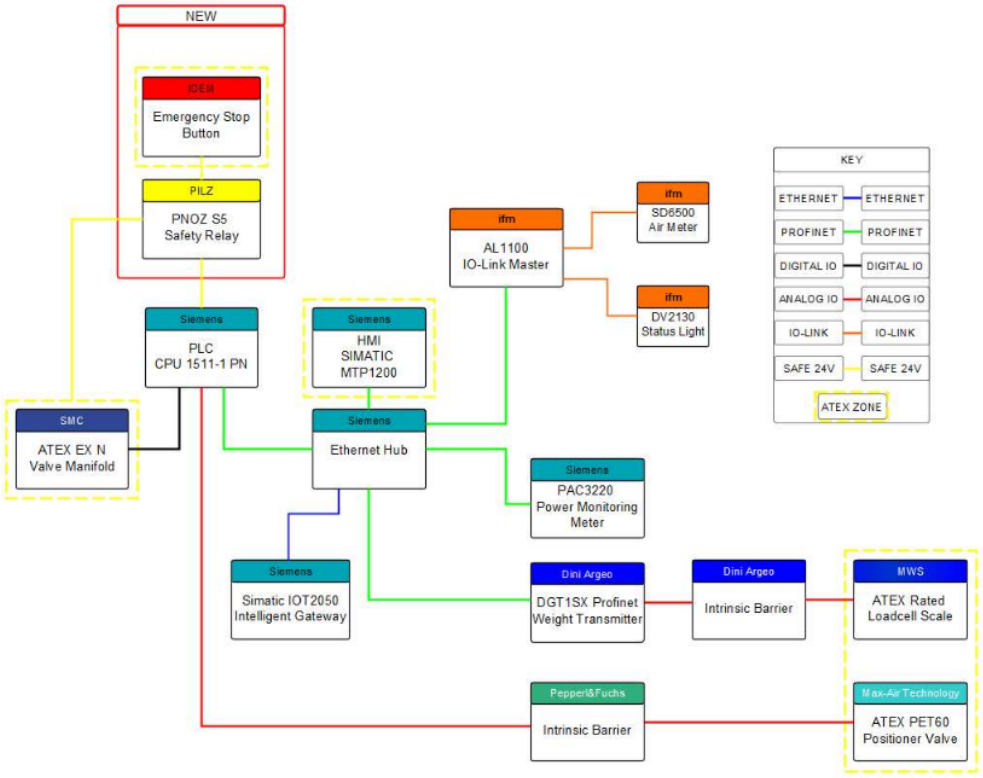


Figure 2 – Ingredient Dosing System Updated Hardware Network

Table 1 displays the original FDS requirements table adapted to include the two new additions.

Functional Design Specification – Original vs. Deliverable		
Ref.	Original Requirement	Current Requirement
P.0	4-off 375 Litre capacity stainless steel hopper for Caster Sugar, Light Brown Sugar, Buttery Scone Mix and Rolled Jumbo Oats	Required
P.1	2-off 500 Litre capacity stainless steel hopper for Plain & Self-Raising Flour	Required
P.2	System must detect if a hopper is empty	Required
P.3	System must allow for 'Recipes' to be added	Required
P.4	System includes function to add external product to mixing bowl	Required
P.5	System includes function to empty each hopper for cleaning	Required
P.6	Weigh Scale must allow for weights up to 300Kg	Required
P.7	Weigh Scale must be accurate to 20g (0.02Kg)	Required
P.8	GUI must have 12" Display	Required
P.9	System must be supplied by Single Phase 230V 50Hz	Required
P.10	System must include connection to a Siemens IOT2050	Required
P.11	System must include IFM DF2101 IO-Link fuse modules	No longer deliverable due to the global chip shortages.
P.12	Must Include an Alarms Screen	New Requirement
S.0	System Performance Level (PL) must be greater than or equal to the Performance Level Required (PLr)	Required
S.1	All protective conductor connecting points must be marked or labelled with IEC 60417-5019:2006-08 symbol.	Required
S.2	All equipment within the ATEX zone must be adequately rated i.e., Equipment in Zone 22 must be rated to minimum Zone 22	Required
S.3	Air Service unit must have a shut-off valve of the lockable type	Required
S.4	Main Electrical Panel must have an isolator of the lockable type	Required
S.5	Signals between the safe and ATEX zone must be connected through barriers	Required
S.6	The system must be designed following the best EMC practices	Required
S.7	Live parts shall be located inside enclosures that provide protection against contact with live parts, and can only be opened with a proprietary key	Required

S.8	The system must implement an emergency stop button	New Requirement
S.9	The system must conform to the Safety of machinery. Electrical equipment of machines General requirements BS EN 60204-1:2018	Required
D.0	The system must display the status of Inputs, Outputs and Alarms	Required
D.1	The system must display information on the current sequence step	Required
D.2	The system must detect a loss of air pressure	Required
A.0	Machine Frame Powder coated to RAL9003	Required
A.1	Control Panels outside of ATEX zone to be Mild Steel minimum IP54, finished in RAL7035	Required
A.2	Control Panels in ATEX zone to be Stainless Steel minimum IP66, unfinished	Required
A.3	Actuator colours will be designed in accordance with BS EN 60204-1	Required
T.0	Technical File must be compiled including System Overview, Drawings, Calculations, Risk Assessment, Conformity Documentation, Instructions and Manufacturers declaration	Required
F.0	Project must be delivered within budget	Required
E.0	Must incorporate “Air-Saver” mode after 15 minutes of inactivity	Required
E.1	System must monitor Electricity consumption	Required
E.2	System must monitor Air consumption	Required
G.0	GUI must be mounted 1.5m from the floor to the centre	Required
G.1	Main electrical isolator must be mounted between 0.6m and 1.7m	Required
G.2	The system and equipment must be ergonomically designed to allow maintenance to be performed easily	Required

Table 1 – Functional Design Specification: Original Vs. Current (Grennan, 2023)

3.1 Electrical Design

The first aspect of the design stage planned in the Gantt chart is electrical design, consisting of electrical schematics, panel layout, parts list and purchasing of equipment. The electrical schematics are designed in EPLAN P8, EPLAN is a computer-aided design (CAD) software used for electrical engineering design and documentation. EPLAN is widely used in electrical and automation industries, allowing users to produce electrical schematics, panel layouts, and parts lists (EPLAN, 2023). An explanation of the design and electrical schematics are seen in appendix 9.2.1 & 9.2.2 respectively.

Throughout the design, BS EN 60204-1:2018: Safety of machinery. Electrical equipment of machines - General requirements (BSI, 2021) was referred to, providing information on cable colours and minimum sizes in clauses 13.2.4 & 12.2 respectively. The system will consist of AC power circuits (Black Wiring) and DC control circuits (Blue Wiring), with circuit protective conductors in green & yellow, and earth bonding areas indicated by the IEC 60417 5019 symbol.

The pneumatic solenoid valves will be contained in a separate panel, due to the requirements of BS-EN 60204-1 11.2.2, which outlines the segregation of electrical equipment and non-electrical equipment. 11.2.2 also gives guidance on terminal segregation for power and control circuits applied to the project. Clause 13.3 requires all control wiring extending past the panel to be connected in terminals.

Due to the ATEX constraints, The Equipment and Protective Systems Intended for use in Potentially Explosive Atmospheres Regulations 2016 (Legislation, 2016) was referenced ensuring that guidelines are followed to ensure the system meets ATEX regulations. Guidance was received from Mucon, Pepperl+Fuchs & Micro Weighing Solutions (MWS) for selecting Intrinsic Barriers to isolate high power from the safe zone, preventing potential explosions seen in appendix 9.1.2. The Siemens MTP1200 Unified Comfort Panel is rated suitably for ATEX zone 22 (Siemens, 2021).

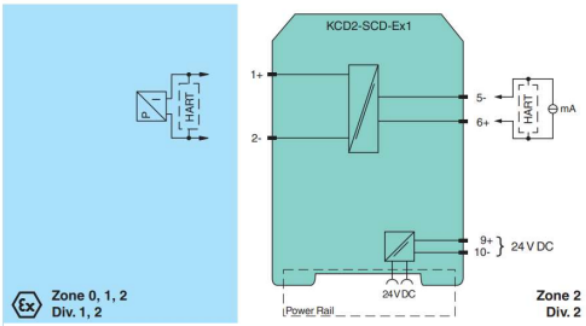


Figure 3 - KCD2-SCD-Ex1 Smart Current Driver (pepperl+fuchs, 2022)

The system has a single emergency stop safety function defined as a safety related stop function, initiated by a safeguard by DGUV (2017), to quickly stop the machine in an emergency situation to prevent injury to workers, or damage to equipment (HSE, 2020). The safety function must meet the Performance Level Required B (PLr B) determined in the risk assessment.

should be Harvard referenced

Category B architecture defined in ISO 13849-1:2015 is required as a minimum and is suitable for machines with medium levels of risk requiring a moderate level of safety. To achieve Category B, the safety-related parts of the control system must meet certain requirements outlined in appendix 9.2.3.

Punctuation Error

The authors company designs their emergency stop circuits to meet PL D requiring category 2 architecture. DGUV states "Category 2 SRP/CS must employ well-tried safety principles and be designed such that their safety functions are tested at reasonable intervals, for example by the machine control system. The safety function(s) must be tested:

- *"at start-up of the machine, and*
- *prior to initiation of any hazardous situation, e.g., the start of a new cycle, start of other movements, as soon as the safety function is required, and/or periodically during operation, where the risk assessment and the form of operation indicate that this is necessary. These tests can be initiated automatically. Each test of the safety function(s) must either:*
- *permit operation, if no faults have been detected, or*
- *should a fault have been detected, generate an output for the initiation of appropriate control action (OTE)" (2017).*

a long quotation

To detect a fault, two test channels are implemented. Mechanically interlocked "force-guided relays" are used as the final switching device, the contacts are mechanically interlocked in sets of three. When the coil is energised, the contacts all switch together through a common armature, ensuring all contacts move at the same time, regardless of the triggering signal. The normally-closed contact is connected in series with the safety relay reset chain as an External Device Monitoring (EDM) function to prevent the safety function resetting if the relay is welded in a non-safe position, detecting the fault on the next operation of the safety function either preventing actuator power, or the safety circuit reset.

The second test channel is a pressure switch which monitors pressure after the dump valve. The signal from the pressure switch is also wired in series with the reset circuit to prevent the safety circuit resetting if air pressure is detected when the safety function is active, indicating

the dump valve has failed in the on position. Implementing two test channels enhances the diagnostic coverage of the architecture, ensuring that faults are quickly addressed.

The safety function will initiate stop category 1 defined by EN ISO 13850, stopping the system by immediate removal of power to the machine actuators, but delaying the removal of air by 5 seconds to ensure the valve is closed (ISO, 2020). EN ISO 13850 4.3.6 states “the emergency stop must be red in colour with a yellow legend with no text or symbols, the IEC-60417-5638 symbol is permitted” (2020).

don't instruct your reader

It is critical all relevant standards are continually referenced, ensuring that the system is designed in accordance with British standards and safeguarded to assure machinery safety constraints outlined in the research report are satisfied, ultimately resulting in achieving CE/UKCA conformity (gov.uk, 2022).

3.2 SISTEMA

SISTEMA is the "Safety Integrity Software Tool for the Evaluation of Machine Applications" to evaluate and verify the safety of safety-related control systems and safety components according to the requirements of EN ISO 13849-1 (DGUV, 2020).

SISTEMA is used to calculate and verify safety functions and performance levels (PL) based on the safety system components. The tool verifies the safety system by entering information about safety components, such as sensors, actuators, safety relays, and their performance characteristics, such as failure rates and diagnostic coverage (pepperl+fuchs, 2021).

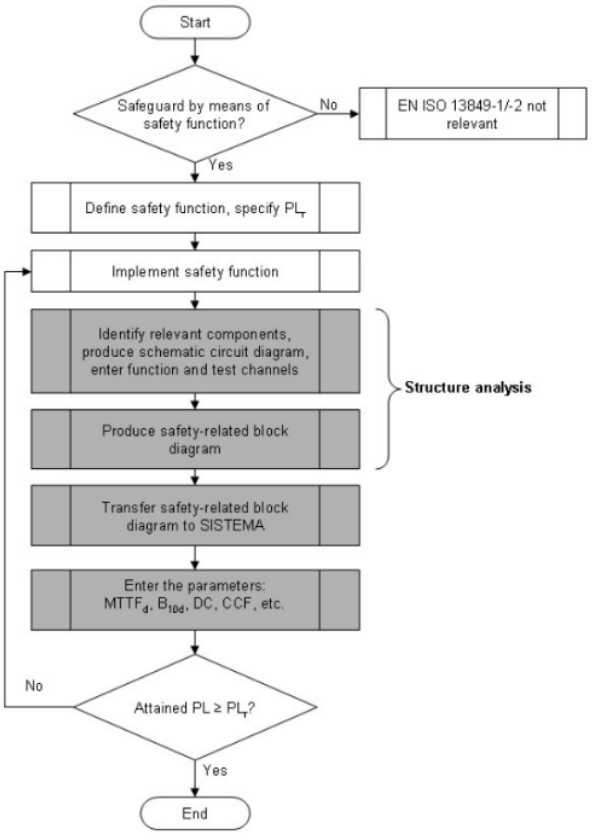


Figure 4 – Flow Chart SISTEMA Process (IFA, 2010)

A Sistema report was produced following the process seen in appendix 9.3, verifying and validating the Safety Related Parts of the Control Systems (SRP/CS) ability to perform its intended safety function under all foreseeable conditions ensuring the requirements of EN ISO 13849-2 Safety of machinery - Safety-related parts of control systems - Part 2: Validation is met. Following this process ensured that the system achieved a verified and validated performance level (D), greater than the performance level required (B).

The safety functions predicted yearly cycle is calculated to determine if the components Mean Time to Dangerous Failure (MTTFD) satisfies the systems mission time, using the n_{op} calculation from ISO 13849-1 (ISO, 2015), as seen in appendix 9.2.3 the yearly operation is calculated as 2400.

The low operation of the safety function has resulted in all components meeting the required mission time. The B10d value of all components is far greater than the mission time, ensuring the systems components are reliable for a 20-year mission time without replacement.

DGUV states that “as EN ISO 13849-1 is harmonized under the Machinery Directive as a Type B standard for machine controls. The Verification & Validation activities must demonstrate that each safety-related part and each of the safety functions that it performs satisfies the requirements of EN ISO 13849-1 & EN ISO 13849-2 ” (2017). To achieve Machinery Directive conformity to obtain UKCA/CE marking, the verification and validation of the SRP/CS is essential.

This is an excellent analysis for choice of safety related parts

3.3 Software Design

To meet the requirements of the FDS, three PLC automatic modes and a manual mode are required, these are:

- **Empty Mode**: Sequence to empty the ingredient in a selected hopper.
- **Dispense Mode**: Sequence to dispense a specified weight of an ingredient.
- **Recipe Mode**: Dispenses a user-defined recipe entered into the HMI, allowing for hopper ingredients or external ingredients to be used in up to 16 layers to aid the mixing process.
- **Manual Mode**: Allows engineers the ability to manually control the system actuators for fault finding.

Appendix 9.4 displays the flowcharts for the three sequences, and the HMI screen layout architecture.

The PLC & HMI software is developed in Siemens' TIA Portal integrated software tool for automation tasks. The hardware was configured consisting of a Siemens 1511 PLC with a 16-way digital input card, 16-way digital output card and 8 channel analog output card. The IO card addresses are configured to allow the processor to read or write to the field devices through an individual address, the analog outputs are configured for current output with a range of 4-20mA as required for the positioners.

Utilising Profinet field devices enabled quick network configuration, the Dini Argeo DGT1SX Weight Transmitter and AL1100 IO Link Master Profinet slaves were configured through General Station Description Markup Language (GSDML) files. The standardisation of GSDML files enables devices from different manufacturers to be integrated seamlessly into a single network, reducing the complexity and cost of automation projects (PROFINET, 2019). The PAC3220 energy meter and MTP1200 Unified Comfort HMI are also configured, with all devices being allocated IP addresses and Profinet Device Names.

Function calls were created for both Input and Output maps, to map the physical inputs and outputs (IO) to internal datablocks. If an IO channel becomes damaged, the IO only requires changing in one area of the PLC program, vastly reducing downtime. Scale_X and Norm_X functions were used to scale the analogue output 16-bit Integer value to a percentage that is user-friendly for the operator.

A Function call was created to monitor the system alarms to display on the HMI, the 'DeviceStates' function block was implemented to monitor the fieldbus status of the Profinet devices which are used as alarm flags. Each alarm is mapped to an individual element of

Array of Bools stored in a datablock, whereby element 0 of the array indicates if there is a current alarm.

3.3.1 Empty Sequence

The first sequence designed was the empty sequence, the least complex out of the automatic modes. 'Empty Sequence' will be used when there is a small amount of ingredient in the hopper that is not enough to be used in a recipe, the hopper can be emptied to avoid the complexity of mixing multiple batches of ingredients.

The operator selects a hopper to empty, once the presence of the mixing bowl is confirmed, the valve opens to its maximum position emptying the hopper. After 5 seconds of the valve opening, the weigh scale weight is stored in a variable "FirstRecordedWeight", after a further the weight is stored in a second variable "SecondRecordedWeight". The second weight is deducted from the first weight, if the weight difference is greater than 0.01Kg, the sequence is repeated until a difference of 0.01Kg or less is registered, deeming the hopper empty. A time delay of 5 seconds is implemented to allow for a substantial change in weight, and is implemented through "On-Delay (TON)" timers. Appendix 9.5.6 displays the empty sequence program.

3.3.2 Dispense Amount Sequence

The dispense amount sequence is more complex, requiring a control measure of the valves to ensure the weight dispensed meets the set-point with high accuracy, due to the accuracy required the second stage valves are implemented. The initial plan was to control the first-stage of the proportional valve through Proportional-Differential (PD) control. Time restrictions meant this was no longer viable due to the extra programming and commissioning time to tune 6 valves. Instead, a ramp function was developed using arithmetic instructions inside TIA Portal to prevent overshooting.

Control parameters are implemented for the ramp function, these include minimum and maximum open percentage of the bulk dosing valve, and the start and end weight for the ramp function in order to determine a ramp multiplier seen below:

$$Ramp\ Multiplier = \frac{(Bulk\ Valve\ Open\ Max\ Open\ \% - Bulk\ Valve\ Min\ Open\ \%)}{(Start\ Ramp\ Weight - End\ Ramp\ Weight)}$$

The Ramp Multiplier is used as a multiplication factor for weight left to dose. The product of these is added to the valves minimum open position, creating control function for a linear falling gradient between the ramp weights start and end point, as demonstrated in the graph in Figure 5. The function was mathematically calculated with a start ramp weight of 5.1Kg & end ramp weight of 0.1Kg in Excel to ensure the mathematical theory produced the desired response before implementing the function in the PLC.

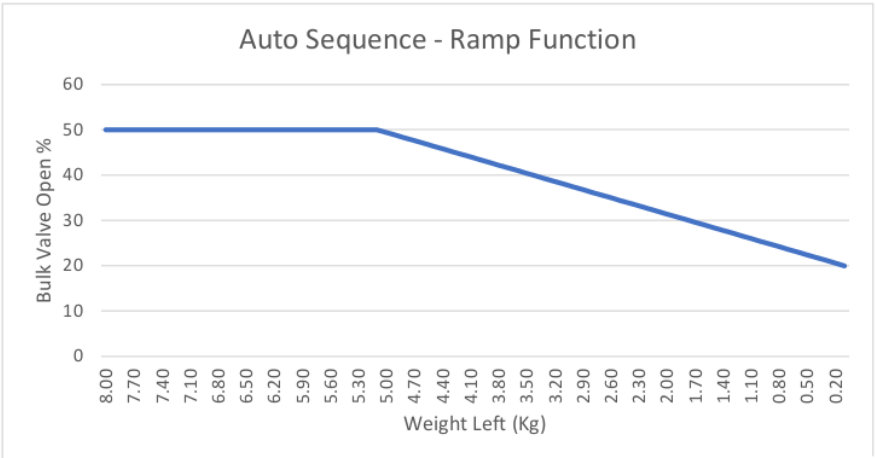


Figure 5 – Auto Sequence Ramp Function Mathematical Response

The graph demonstrates the valves response to the weigh scales rate of change, as the weight left reaches 5.1Kg the valve starts to close at a steady falling gradient in response to the weights rate of change, fully closing at 0.1Kg. At which point the fine dosing stage will take over to ensure the set-point is achieved with no overshoot.

Figure 6 shows the implementation of the ramp multiplier calculation in TIA Portal, which is implemented using in-built arithmetic functions.

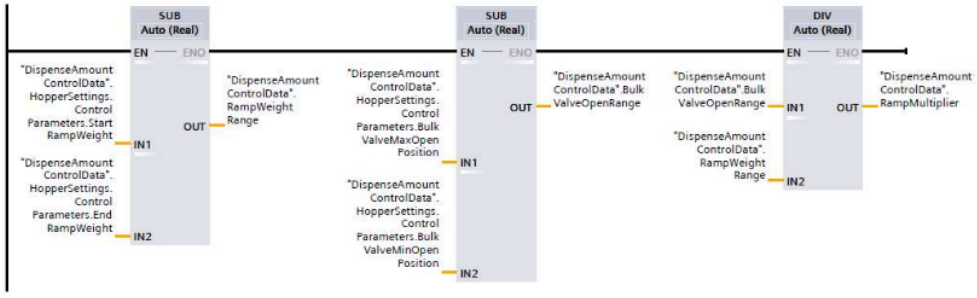


Figure 6 – Ramp Calculation in TIA Portal

The operator selects an ingredient type and weight, and confirms the mixing bowl presence. If the weight selected is greater than the start ramp weight the valve is opened to its maximum open position set in the Hopper settings HMI. As the weight left approaches the start ramp weight value, the ramp function is implemented controlling the dispense rate until the end ramp weight value is achieved, whereby the second-stage fine dosing valve takes over. Due to the largely varying consistencies of the 6 ingredients, the control parameters are variables that can be easily modified on the HMI to allow for the best possible response to be tuned. Appendix 9.5.7 displays the PLC program for the sequence.

3.3.3 Recipe Mode Sequence

The recipe mode sequence enables the system to dispense a user-defined recipe consisting of up to 16 layers each with a selected weight entered in the HMI, the layer can either be a hopper or external ingredient. The recipe mode utilises the dispense sequence closed-loop ramp function and sequence. The recipe mode is the solution to the business case that required the project, due to the labour-intensive time-consuming process of manually loading the ingredients multiple times per day.

Details for 100 recipes can be entered via the HMI and saved into the PLCs 'Recipes' datablock, allowing any recipe to be loaded into the PLCs "CurrentRecipe" datablock for dispensing from the HMI. The purpose of the layering dispense method is to aid with the mixing process before baking, producing a more consistent mix.

User-Defined Types (UDTs) are implemented to manage the data for the recipe. The UDT is a data structure allowing users to create their own data types with customised field structures, the UDT can be easily manipulated and nested into other UDTs speeding up the programming process. A UDT is created for the Layer Settings and for Product Settings. 'UDT_LayerSettings' is constructed of the Layer Type, Weight and the manual ingredients name if the layer type is a manual ingredient. 'UDT_ProductSettings' is a data structure for the recipe, consisting of the Recipe Name, Number of Layers and a 16-element array of 'UDT_LayerSettings' which stores the required information for each layer in the Recipes Datablock.

Once the start conditions are confirmed and the mixing bowl is in place, the operator will receive instructions through the HMI if the layer is a manual ingredient. If the layer is from the hopper, it will be accurately dosed utilising the closed-loop ramp function, storing the run data of the recipe including the date, time and batch codes utilised in the recipe to ensure the food safety constraint 'One Step Forward, One Step Back' traceability requirement of 178/2002

General Food Law Article 18 is achieved (gov.uk, 2002). Appendix 9.5.8 displays the Recipe Mode Sequence program in TIA Portal.

3.3.4 HMI Design

The HMI is designed following guidance from BS EN 63303 Human-Machine Interfaces for Process Automation Systems enabling the HMI to be designed utilising the following principles (bsi, 2021):

- **Consistency**: Consistent layout and visual style, so operators can easily recognize and navigate different screens.
- **Clarity**: Information presented on HMIs is clear and concise, with relevant data and alarms highlighted appropriately.
- **Usability**: The HMI is designed with the end-user in mind, with features like clear labels, intuitive navigation, and easy-to-understand feedback.

The screens are segregated by menus to ensure navigation is intuitive by splitting functions into categories. These include auto, manual, settings, alarms and diagnostics following the HMI architecture flowchart in appendix 9.4.4, ensuring that the information on the page is relevant to the function. The HMI background is greyscale with bright colours only used for indicators and messages, ensuring that key messages are visible to the operator and not missed due to flooding of bright unnecessary colours. Appendix 9.5.10 shows a HMI screen example.

4. Implementation and Management

The implementation phase commenced upon completion of the design. The PLC & HMI were ordered in November 2022 due to concerns of shortages that would've resulted in the project being halted at the implementation phase, other components were ordered upon design completion. All components apart from the DF2101 Fuse Module, Pilz Pnoz S5 relay and IDEM ES-SS Emergency Stop Station were booked out of into the stores before 06/02/2023, allowing for 90% of the control panel to be completed.

The initial Gantt chart planned that the author would complete the panel build and machine wiring. Due to the time-frame requirements of the Ffatri 4.0 project, with the tray bake line having priority to be commissioned, this was not achievable. A meeting was held with the production supervisor. The project tasks in the work breakdown structure, and the time-frame requirements in the Gantt chart were discussed and a decision was made that an electrician would complete the machine wiring and panel build to prevent the timing plan slipping. The control panel build was completed in-line with the Gantt chart timing plan.

Delay of the delivery of the machine frame from powder coating resulted in the manufacturing phase being delayed by 8 working days, causing the timing plan to be shifted. As the control panel had already been built, a contingency was made to recover the timing plan. 8 hours of electrical commissioning was brought forward to test and power up the panel, a test schedule was compiled and completed seen in appendix 9.7. Once complete, the PLC & HMI programs were downloaded, and the PAC3220 Meter, IO-Link Master and Weigh Scale Transmitter were configured by setting the IP addresses and Profinet device name, and all IO was mapped and configured in the datablock, recovering the timing plan by 2 days.

The system build was then completed, including electrical and mechanical commissioning. Utilising the diagnostic IO screens, the systems IO was tested to ensure that the internal datablock data were mapped to the correct physical address, the diagnostic screen allows for quick indication of the status of system IO.

The positioner valves were tested via the manual HMI to ensure the analogue word was scaled correctly. A 10% error was seen between the set-percentage on the HMI screen and the actual dial position of the valve. The valve was disconnected and a 250Ω resistor was connected as the load to prove if the error is due to wrong scaling or is a mechanical issue. The scaling was proved by measuring the voltage drop across the resistor as:

$$V_{drop}\ at\ 4mA = 0.004A\ \times 250\Omega = 1V$$
$$V_{drop}\ at\ 20mA = 0.020A\ \times 250\Omega = 5V$$

At the 0% (4mA) position the voltage across the resistor was measured at 1VDC, likewise 5VDC at the 100% (20mA) position, proving that the scaling is correct. Further inspection of the valves main leaf showed that at the 0% position the valve was not fully closed causing the 10% error. Referencing the Mucon manual seen in appendix 9.10, it was found that the stroke could be adjusted as the valves can be used in applications where large material is dosed, requiring the valve to be opened further than 90˚ (100%). The end-stroke was adjusted by the mechanical technician using feeler gauges to ensure that the gap between the valves was smaller than the diameter of a sugar grain, this was re-tested and the valve operated as intended with no offset error.

The hoppers were filled with ingredients and the valves were manually actuated from the HMI screen. It was found that both oats and caster sugar dosed as required, the consistency of both flours, scone mix and light brown sugar resulted in difficulty as the ingredients would build up and impede the orifice due to cohesive bridging. Cohesive bridging is the material block formed by particles that compress until they bind together, usually in particles that attract moisture such as flour, where a bridge forms strong enough to support the material weight above it resulting in blockages (USA, 2022). A meeting was held with the Mechanical Project Engineer, the author and valve supplier, it was decided that a method of agitation is required. The valve supplier recommended 'High Frequency Impact Vibrators' (HFIVs) to agitate the bridge seen in appendix 9.11.

Due to the time frame of the project and the availability of the HFIVs, the system will not be complete in-line with the original timing plan. Therefore, the system will be commissioned only using the Oats and Caster Sugar hoppers.

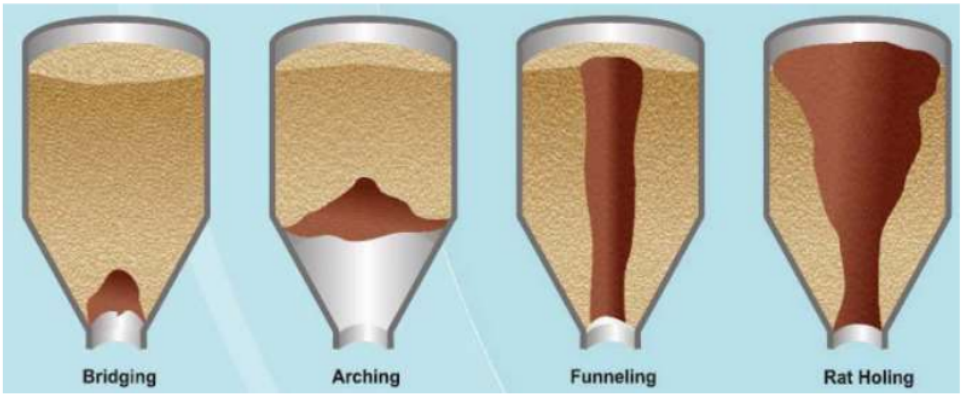


Figure 7 – Bulk Hopper Material Issues (Sugison, 2016)

A spreadsheet has been monitored weekly to track the project expenditure in terms of bought-out items and labour costs, seen in appendix 9.7. The project is currently within budget, with a total of £24,390.81 left. There are currently 102 hours left within budget to complete the system, which now includes the design, installation and commissioning of the vibration agitators.

Even though the project drifted from the Gantt chart after the panel build, it was highly useful in monitoring the progress and time spent on the project, allowing the contingencies to be added to monitor and control the projects position and to re-plan tasks as they differentiated from the plan. Likewise, the work-breakdown structure was essential in controlling the project tasks in a systematic order (Appendix 9.8 & 9.9).

5. Testing and Results

The system could only be partially tested with the Caster Sugar and Oats hoppers due to the bridging issues. The testing can be successfully undertaken as the recipe sequence requires only two ingredients. As the system has limited mechanical traversing components, and the valves had been previously tested the system was able to be functionally tested without soft testing. Testing was performed in two stages to ensure all aspects of the FDS have been met, this was ensured by following the test plan developed in the research report.

5.1 Conformity Testing

Table 3 in appendix 9.12.1 outlines the conformity test results; these tests ensure the FDS requirements that cannot be functionally tested are achieved. The conformity testing was largely successful with 19 of 24 of the requirements achieved.

P.11 was not met due to IFMs supply chain issues. Schneider Electric Miniature Circuit Breakers and Auxiliary Contacts are temporarily installed to provide DC overcurrent protection, the DF2101 modules will be retrofitted once delivered to ensure this requirement is met.

As the project is incomplete, requirements T.0 and F.0 cannot be considered passes. As the project requires modifications to implement HFIVs to alleviate the bridging issues, the technical file cannot be completed (T.0) until the design and commissioning are completed to ensure the necessary documentation is provided to adhere to all relevant standards. The project is currently within budget, however, until the project is delivered and signed-off it cannot be considered within budget (F.0).

One of the main constraints outlined in the research stage is machine safety. A paramount requirement for the system is to implement all necessary measures to protect people from harm when using or interacting with the system, by identifying and minimizing the risks outlined in the risk assessment. All safety aspects of the conformity testing have been achieved, apart from the emergency stop implementation due to supply-chain issues:

- The Performance Level (PL D) has exceeded the required Performance Level (PLr B) determined in the risk assessment. The SISTEMA report verified the reliability of safety architecture and components used, providing a reliable evaluation ensuring the safety function complies with EN ISO 13849-1, EN ISO 13849-2 & EN ISO 13850.

- All equipment within the ATEX zone has been verified, ensuring suitable rating for the zones, designed in accordance with manufacturer recommendations.
- Checklists have been completed ensuring compliance with The Electromagnetic Compatibility Directive 2014/30/EU and BS EN 60204-1:2018 Safety of machinery. Electrical equipment of machines General requirements, ensuring requirements of the machinery directive are met in order for UKCA compliance, seen in appendix 9.12.2.

5.2 Functional Testing

Functional testing verifies whether the system performs as intended and meets the FDS requirements, focusing on the functional aspects of the system, such as its features, functions, user interface, and performance. Table 4 in appendix 9.12.3 displays the functional testing table and evidence.

Functional testing has been successful, with 13 of 14 requirements being achieved. The only requirement not achieved is air saving mode, this aspect would remove power from the systems dump valve to conserve air when the system is not in sequence for a set-period of time. Due to the requirements for HFIVs which require large volumes of air, it has been decided to not implement air-saver mode until the final solution has been implemented and the air volume required for the HFIVs has been verified, as it could result in large volumes of air being regularly exhausted, potentially costing the customer more in the long term.

Punctuation Error

Overall testing of the three automatic modes has been successful. The simplicity of the “Empty Mode” sequence allowed for it to successfully run on the first cycle attempt for both caster sugar and oats, indicating that the hopper had emptied after a small time period where no change in weight is measured. The simple and intuitive HMI design ensures the sequence can be run with ease meeting requirement P.5.

“Dispense Mode” was also successfully commissioned, implementation of the closed-loop ramp function allowed for quick tuning of the valve’s response to the change in weight. Initially, the caster sugars valve open range was set too high, resulting in an overshoot of 200g from the set-point. The intuitive design of the control parameters on the HMI Hopper Settings screen enabled the range to be reduced quickly, resulting in accurate dosing within the limits. The control function was tuned by adjusting the start and end weights for the ramp function. It was found, both caster sugar and oats dosed well with a start ramp weight of 5.1Kg, the end ramp weight was initially set to 0.1Kg, therefore once the weight left to dispense is 100g the leaf valve closes and the second stage rotor-dose valve takes over finely dose the remaining

ingredient. This worked well for the oats; however, the fine nature of caster sugar required an end ramp weight of 0.3Kg to ensure it did not overshoot.

Recipe mode was the final sequence to test, due to the bridging issues the recipes dispensed could only contain oats and caster sugar. A recipe was created in the product settings menu, and saved as an array element in the Recipes datablock under 'UDT_Recipes'. Pressing 'Load' copied it into the current recipe datablock, satisfying the requirements of FDS P.3. When running the sequence, issues were found where the valves would not actuate in the step required. The structure that the PLC is written in allows the sequence to be stepped through by writing the next step number into "SeqNoNext", this enabled the step that contained the error to be quickly found. The 'cross-references information' tool in TIA Portal was used to find that the output controlling the valves was being written to in two places, resulting in the coil permanently off.

Upon resolution, the sequence was cycled through successfully, by both dispensing only hopper ingredients and by adding external ingredients successfully meeting the requirements of P.4 & P.7, displaying the run data for the systems recipe to enable the 'One Step Forward, One Step Back' traceability requirement of Food Law Article 18 of Regulation (EC) No 178/2002 to be fulfilled, satisfying the food traceability constraint outlined in the research stage (Parliament, 2013).

All IO and Profinet statuses were tested via HMI diagnostic screens. The MCBs and pressure switch were tripped to ensure that their signals are wired correctly and mapped to the correct input. The outputs were manually actuated in the PLC, ensuring that the statuses of both the 5/3 Valve and Positioner valves were correctly displayed, and the diagnostic information for both electricity and compressed air consumption were verified by comparing the information on the HMI to the PAC3220 meter and SD6500 meter respectively, achieving requirements E.1 & E.2.

The final functional test was to ensure that the alarm screen is correctly implemented, each alarm condition was tested to ensure that the correct device is triggering its corresponding alarm. All alarms were correctly implemented, enabling fault finding time to be drastically reduced by providing the maintenance engineer with relevant diagnostic information, satisfying the requirements of P.12.

6. Evaluation of Project Outcomes

This shows the importance of better planning and purchasing earlier

Despite the issues occurring with 4 of 6 hoppers and supply-chain issues, the project has remained largely relevant to the original requirements set-out in the FDS, with the majority of these requirements successfully achieved.

6.1 Constraints

6.1.1 Machine Safety

The main project constraint is safety, all aspects of the FDS' safety points have been achieved, apart from the emergency stop installation. The control system is designed in accordance with EN ISO 13849-1, EN ISO 13849-2 & EN ISO 13850 achieving a performance level (PL D) with the safety related parts of control system (SRP/CS) reliability verified through SISTEMA.

All components within the ATEX zone are suitably installed & rated in-line with the requirements of The Equipment and Protective Systems Intended for use in Potentially Explosive Atmospheres Regulations 2016. All intrinsic circuits are designed following the manufacturers recommendations.

The system has been earth-bonded, tested and labelled in accordance with BS EN 60204-1:2018 8.2.4, and all energy sources can be locked in the off position to allow for maintenance activities to be safely completed. The system has undergone BS EN 60204-1 & EMC checklists, ensuring that the system has satisfied requirements of the Machinery Directive for CE/UKCA marking.

Delivery issues have prevented the implementation of the emergency stop circuit, however, the configuration utilising the Pnoz S5's delayed contact has been implemented on previous projects, posing no risk to further delay the project.

6.1.2 Professional Conduct, Ethics & Legality

A key constraint outlined in the research stage was the requirement to ensure 178/2002's 'General Food Law' Article 18 is followed, maintaining the "one step back, one step forward" supply-chain rule. The implementation of the 'Run Data' datablock was successful in storing data on each recipe dispensed, including start & end dates, times, system operator, weight dosed and batch-codes of the ingredients used, ultimately producing a recipe batch-code to be used in the next stage of production, ensuring the product is traceable.

During the design and implementation, the key regulations in the design of hygienic machinery outlined in the Supply of Machinery (Safety) Regulations 2008 was referenced and followed ensuring all hygienic requirements were followed for design, cleaning and maintenance.

The system has been designed to minimise adverse environmental impacts, it is designed to allow for the 6 ingredients to be easily changed via the HMI if the customer no longer uses any of the ingredients, providing flexibility and preventing the machine from being redundant if ingredients change.

All components were ethically sourced through well-known distributors and suppliers.

6.1.3 Environmental and Sustainable

Environmental considerations were outlined in the FDS, the implementation to incorporate "Air-Saver" functionality to remove air from the system if no action is made on the machine in a time period, in order to prevent air being wasted due to small leaks. The requirement for HFIVs for the hopper bridging issue has paused this requirement, due to the high-volume of air needed to actuate the HFIVs, it is likely that this implementation of this functionality would have adverse effects, costing the customer money by regularly exhausting large amounts of air.

During commissioning, it was observed that the maximum current draw by the system was 2.33A (560W) at 240V, at worst case it is estimated that the system will cost 4.48kWh per day, therefore:

$$Daily\ Running\ Cost = 4.48kWh \times £0.34 = £1.52\ per\ day$$
$$Yearly\ Running\ Cost = £1.52 \times £300 = £456\ per\ year$$

The current method of loading mixing bowls requires a full-time employee, costing £22,536 per annum, the implementation of the system will require operator intervention 1 hour per day, saving £19,719 per year by removing a non-value added labour-intensive task, enabling labour to be used on value-added tasks such as improving recipes & processes.

6.1.4 Intellectual Property

The system is not patented, it is not protected by the Patents Act 1997 therefore competitors cannot be stopped from replicating the machine (gov.uk, 2019). Intellectual property (IP) includes Drawings, PLC Programs & technical documentation, and are the property of the Original Equipment Manufacturer (OEM). Upon sign-off, the customer will receive a machine manual consisting of electrical, mechanical general assembly & pneumatic drawings, maintenance requirements, operating instructions for the machine and fault finding. The PLC can be connected to and the HMI/PLC programs can be extracted.

It is possible that the customer could replicate the system from the drawings provided, however, they do not receive detailed designs for machined parts or the technical file containing the machinery directive EHSRs, Risk Assessments, ATEX documentation and test documents. Therefore, the customer could replicate the machine but must be able to compile a technical file for the system with the required documentation to put the system on the UK/EU market.

Why doesn't the customer receive the technical file?

6.2 Supply Chain

A risk outlined in the research stage was the current supply-chain issues potential to pause the project at the implementation. The effects of Brexit, Ukrainian War & IC Chip shortage has been evident, impacting the availability of parts preventing aspects of the FDS being completed.

The delay of the DF2101 module, ATEX rated Emergency Stop & Pilz Pnoz S5 relay prevented requirements P.11 & S.8 of the FDS being achieved. The delayed components are commonly used posing no further risk to the project and will be implemented once delivered.

All aspects of the FDS that failed are a direct result of supply-chain issues.

6.3 Mechanical Issues

Due to the delays in receiving the frame from powder coating, progress was slow completing the mechanical build. Valves from Mucon had been factory assembled wrongly, resulting in the valve being mounted in the wrong direction of flow resulting in the valve opening in the opposite direction, time was lost stripping-down and re-assembling the units.

The issues discovered in the testing phase indefinitely delayed the project's completion until a mechanical solution is successfully implemented, resulting in one of the main aspects of the FDS not being achieved, preventing the test plan to be successfully completed. However, the principle of operation has been tested and the control parameters in the HMI Hopper Settings screen will allow for quick commissioning of the remaining hoppers when the HFIV solution is implemented.

6.4 Financial

The project is currently within budget as seen in figure 8, however further modifications are required to overcome the bridging issues requiring design, implementation and documentation time to be spent, along with the cost of bought out items. The modifications are due to unforeseen issues not accounted for in the design, it is the responsibility of the authors company to rectify the issues.

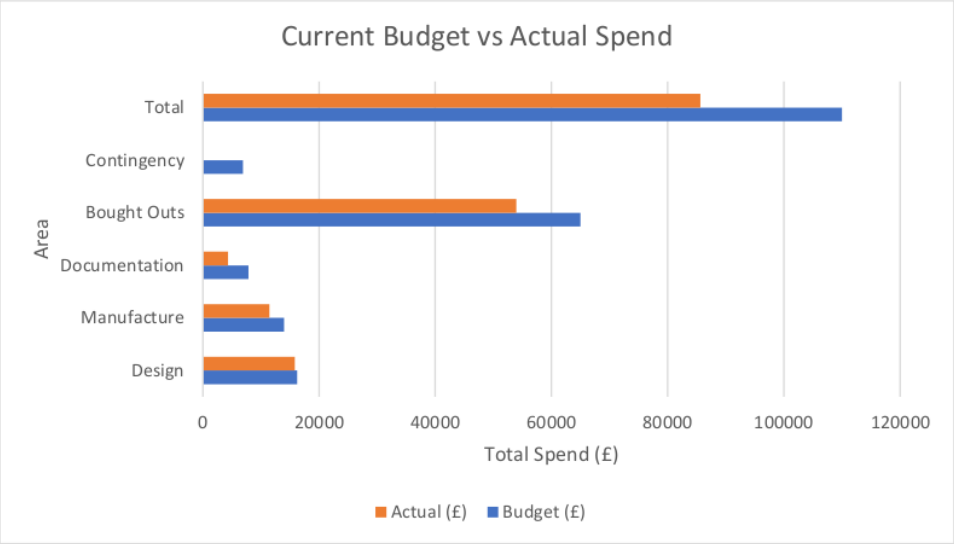


Figure 8 – Current Budget vs Actual Spend

7. Conclusions and Recommendations

7.1 Conclusions

The project design, implementation & evaluation has been partially successful, meeting 32 of the 38 required FDS requirements. As not all FDS aspects have been satisfied within the timeframe resulting in an incomplete system, the project cannot be considered a success.

The electrical design was efficiently completed utilising EPLAN, allowing for quick automated generation of parts lists exported into requisition forms and ordered as soon as the design finished. SISTEMA was essential in verifying and validating the SRP/CS, ensuring that the main constraint from the research stage was addressed providing the customer with a safe machine compliant with EN ISO 13849-1, 13849-2 & 13850.

Utilising a Siemens PLC with Profinet devices significantly reduced software development time, the automation network was quickly developed due to the minimal complexity using GSDML files. Utilising UDTs helped create structured datablocks that were easily manipulated to be used across the three automatic sequences, allowing code sections to be re-used reducing development time.

The design and implementation phase highlighted the importance of developing a structured Functional Design Specification (FDS). The FDS was essential in outlining the project requirements including customer needs, legal and commercial standards and constraints that had to be addressed to conform to relevant standards. Referral to the FDS ensured that the design stage was efficient with clear targets, resulting in the project remaining on scope without drifting.

The implementation phase's success is due to the project management techniques implemented; the Gantt chart was essential in tracking the project progress especially as the project drifted from the initial plan due to contingencies. The Gantt chart illustrated the project dependencies between tasks, this was highly useful allowing for quick alterations to progress the project when aspects were delayed, reducing the time lost. Likewise, the WBS was essential for hierarchical breakdown of tasks, enabling the project to be divided into centralised tasks in the required order helped control the project progress. The cost tracking spreadsheet provided a key control measure to track expenditure and hours, ensuring that time and financial issues can be monitored, to introduce contingencies before it is too late.

The testing plan developed was successful, ensuring all aspects of the FDS were critically tested. The outstanding requirements will be implemented once parts are delivered. Both the

IFM fuses and Pilz Pnoz S5 have been integrated on similar machines, therefore implementation of these poses no further risks to the project.

The system is compliant with BS EN 60204-1 & The Electromagnetic Compatibility Regulations 2016 as confirmed by the test plan checklists, ensuring that the system will conform to the machinery directive requirements for CE/UKCA marking.

Even though the project is incomplete, it is highly likely that the project will be delivered under budget. The component cost for the 4-off HFIVs is £1980 resulting in a total of £55,949.19 spent on bought-out equipment, 28 hours has been estimated to commission the HFIVs and remaining four hoppers, resulting in a projected labour cost of £37,100 including technical documentation. It is anticipated that the total project spend is £91,069.19 as seen in figure 9, £18,930.81 under budget, ensuring that an essential aspect of the FDS is achieved.

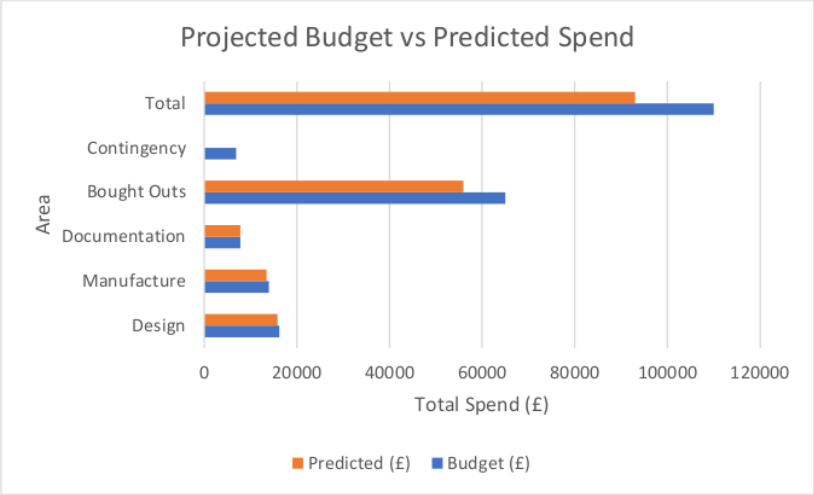


Figure 9 – Projected Budget vs Actual Spend

What is the difference between this figure and figure 8?

The delays have impacted the customers production scheduling, their order books have increased resulting in increased manual workload that would be alleviated by the system. However, the customer is aware and has been regularly updated on the supply chain issues which cannot be avoided. Project delays due to supply-chain issues were made clear in the quotation, posing no financial repercussions due to late delivery. The system will be installed and signed off by June 2023 providing the customer with a fully-automated solution saving £19,719 per year.

7.2 Recommendations

Derivative

Proportional-Differential (PD) control could be implemented to provide greater control over the first-stage valve. Proportional control utilises the error between the setpoint and current process variable (PV) to calculate an output signal proportional to the error, where the error is used to adjust the CV PV, Derivative control uses the rate of change of the process variable to prevent overshoot. PD control combines both techniques to create a control system that responds to changes in the process variable quickly and accurately maintaining stability. Implementing PD control removes the requirement for the second-stage valve process, making the PLCs digital output card and 5/3 Valve manifold redundant saving the company £2436.16 in hardware and labour costs and increasing the cycle time by removing sequence steps. With less components and a less-complex software program, the system will be easier to maintain.

The SIMATIC IOT2050 industrial IoT gateway could have been better utilised, in conjunction with the Unified Comfort Panels ability to run MindSphere apps. An app could be developed to better display information on process and run data in the form of analytical graphs to display information in a user-friendly way.

A recommendation for the future is to create a stock control app in MindSphere to monitor the current stock compared to the required stock. With the aim for the production manager to be able to prioritise the required Mixes which could then be written to the Recipe datablock for dispensing from the app through to MindSphere, increasing efficiency, reducing operator error.

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9. Appendix

Appendix 9.1.1 - Explanation of Solution 1

The first stage is a proportional valve, linearly controlled by a 4-20mA signal from an AQ-8xU/I HS analog output card, offering 16-bit resolution to precisely control the position of the main ‘leaf’ valve to dose the bulk of the 6 ingredients. The analog signal is repeated through Pepperl+Fuchs intrinsic barriers to ensure that voltage is limited within the ATEX zone to prevent any sparks potentially igniting dust clouds when dosing.

Once the target weight is almost achieved, the second stage fine-dosing stage takes over. A rotor-dosing valve sits in the leaf valve, controlled by centre position open 5/3 valves in an ATEX EX N manifold. As the valve rotates from 0-180° fine amounts of ingredients are dosed, typically 20-30g to ensure the ingredient weight is accurate (Mastrolonardo, 2022).

A Micro Weighing Solutions ATEX rated load cell scale will accurately measure ingredients dosed, allowing for weights up to 300Kg to be measured within the ATEX zone via an Intrinsic Barrier connected to a Profinet DGT1SX high-speed digital weight transmitter sending 4800 readings per second to the PLC, ensuring quick and accurate performance (Booth, 2022).

A Profinet IFM IO-Link master monitors air quality and consumption data from an SD6500 compressed air meter and provides operator feedback through a DV2130 Andon and buzzer. It was initially planned to implement a DF2101 24VDC Current protection module, however, supply chain issues have prevented this. Electricity consumption and characteristics will be monitored over Profinet by a Siemens PAC3220 meter.

A Siemens MTP1200 12” Unified Comfort Panel HMI provides operator interface to control the system process, create and save recipes and will provide diagnostic and manual screens to assist maintenance during fault finding activities. A Siemens IOT2050 will be implemented to enable data collection of the system to be implemented into the end-users Siemens MindSphere system.

Due to the compressed air shut-off valve being situated on a mezzanine floor out of the operator’s range, re-analysis of the risk assessment required an emergency stop to be implemented as a safety measure to quickly stop the machine in the case of an emergency or dangerous situation. The safety circuit will be designed in accordance with EN ISO 13849-1 and EN ISO 13850, with the safety functions Performance Level (PL) validated through a SISTEMA report, this requirement is added to the FDS.

Appendix 9.1.2 - Supplier Emails

These belong in the log-book

Oyster Composite Valves

Hi Thomas

Thank you for your email. See answers below

- Could you explain the operation of the valve?

  The valve consists of a main leaf with a smaller rotary valve inset into one side of the leaf, with a separate control shaft. The valve requires two actuators to operate, and these may be fitted with either one or two positioners for improved control.

  The movement of the main leaf gives the main discharge of product. As the target weight is approached the main closure element should be closed. In the dosing phase the OYSTER COMPOSITE VALVE uses the rotary dosing element to enable volumetric dosing. With each cycle of rotation through 0-180° and back it discharges the contents of four lobes. In this way a high accuracy of dosing can be achieved.

- Do the valves come with controllers? Or does air need to be pulsed onto the main disc valve to control its position?

  You will see from the quotation that the Composite valves are supplied with an actuator and positioner on the main flap and a 180° actuator to operate the fine dosing head which will require a solenoid valve to control it, which we can also supply.

- How is the rotor dosing ball controlled?

The Fine feed takes place with the main flap fully closed and the dosing head rotating backwards and forwards discharging very small quantities of product each time. This is quite slow, typically 20-30g per cycle and so it is desirable to minimise the amount of material discharged during this phase, hence the importance of setting the inter-mediate feed as accurately as possible for each type of powder so as to get as close as possible to the target before activating the fine feed. At all stages of the process, due account must be taken of the in-flight weight which will vary during each phase.

- Is the 4-20milliamp signal used for just the position of the rotor dosing ball?

The bulk discharge phase uses a 4-20mA positioner on the main flap to open the valve 100% for the initial stages of the operation. If the control system allows it, as the weight approaches the cut-off for the next phase, the valve progressively closes.
Alternatively for each type of powder it is possible to establish one or two opened positions to give a fast and a slower discharge rate. This is the fastest material flow rate and so by discharging the maximum amount of material possible in this mode will help
to minimise the overall time to complete the fill. Speed and timing of closing during this phase are key parameters.

- Could we have any available Electrical / Pneumatic schematics please>

See attached installation manual for the positioner. Regarding the solenoid valve this would presumably be 2GD intrinsic security and so will need to be wired in via a suitable barrier.

Kind Regards

Rocco Mastrolonardo
Mucon and Aftermarket Manager

Figure 10 – Two-Stage Valve Operation Explanation Email (Mastrolonardo, 2022)

To: Marc Lewis <lewism@parmley-graham.co.uk>
Subject: 5174 - Barriers

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Hi Marc,

We have a project at the moment which is going to be in ATEX zones 21/22 with 6 electro-pneumatic valves for proportional control through analogue outputs from a 1500 PLC in the zone.

What do you recommend for intrinsically safe barriers for these? I see you supply P&F barriers.

Below is the requirements for the barrier for electro-pneumatic valves.

Explosion regulations	IEC 60079-0:2017, IEC 60079-1:2014 IEC 60079-18:2015, IEC 60079-11:2011		
Explosion proof	Ex ia IIC T5/T6 Gb		
Barrier specifications	Ui	Ii	

Kind Regards,

Tom Grennan

Figure 11 – Email to Parmley Graham for Positioner Barriers

Cc: Shenton Ian <ishenton@gb.pepperl-fuchs.com>
Subject: RE: Parmley Graham - RE: 5174 - Barriers

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Hi Marc,

Thank you for the information.

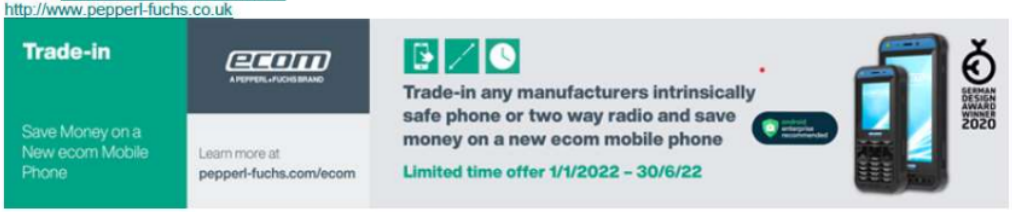
Please find attached the datasheet for the KCD2-SCD-Ex1 which I hope will be of interest.

Best regards

Ben Drury
Technical Support Engineer
Pepperl+Fuchs GB Ltd.
Process Automation Division
77 Ripponden Road
Oldham, Lancashire OL1 4EL
England

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Sales Enquiries: +44 161 622 6309
Technical Support: +44 161 622 6313

Direct: +44 161 622 6223
Switchboard: +44 161 633 6431
Fax: +44 161 624 6537
E-Mail: bdrury@gb.pepperl-fuchs.com
http://www.pepperl-fuchs.co.uk



Intrinsically Safe Mobile Devices from **ecom Instruments, a division of Pepperl+Fuchs.**

8

Figure 12 – Response Email to from Pepperl+Fuchs Intrinsic Barrier

You were asked not to include datsheets in the report

SMART Current Driver KCD2-SCD-Ex1

Technical Data

Power dissipation	≤ 600 mW at 20 mA and 500 Ω load
Power consumption	≤ 700 mW
Input	
Connection side	control side
Connection	terminals 5-, 6+
Input signal	4 ... 20 mA , limited to approx. 26 mA
Input voltage	open loop voltage of the control system < 30 V
Voltage drop	approx. 6 V at 20 mA
Input resistance	> 100 kΩ, with field wiring open
Output	
Connection side	field side
Connection	terminals 1+, 2-
Voltage	≥ 13 V at 20 mA
Current	4 ... 20 mA
Load	0 ... 650 Ω
Ripple	20 mV_{rms}

Figure 13 – Pepperl+Fuchs IS Barrier Datasheet (pepperl+fuchs, 2022)

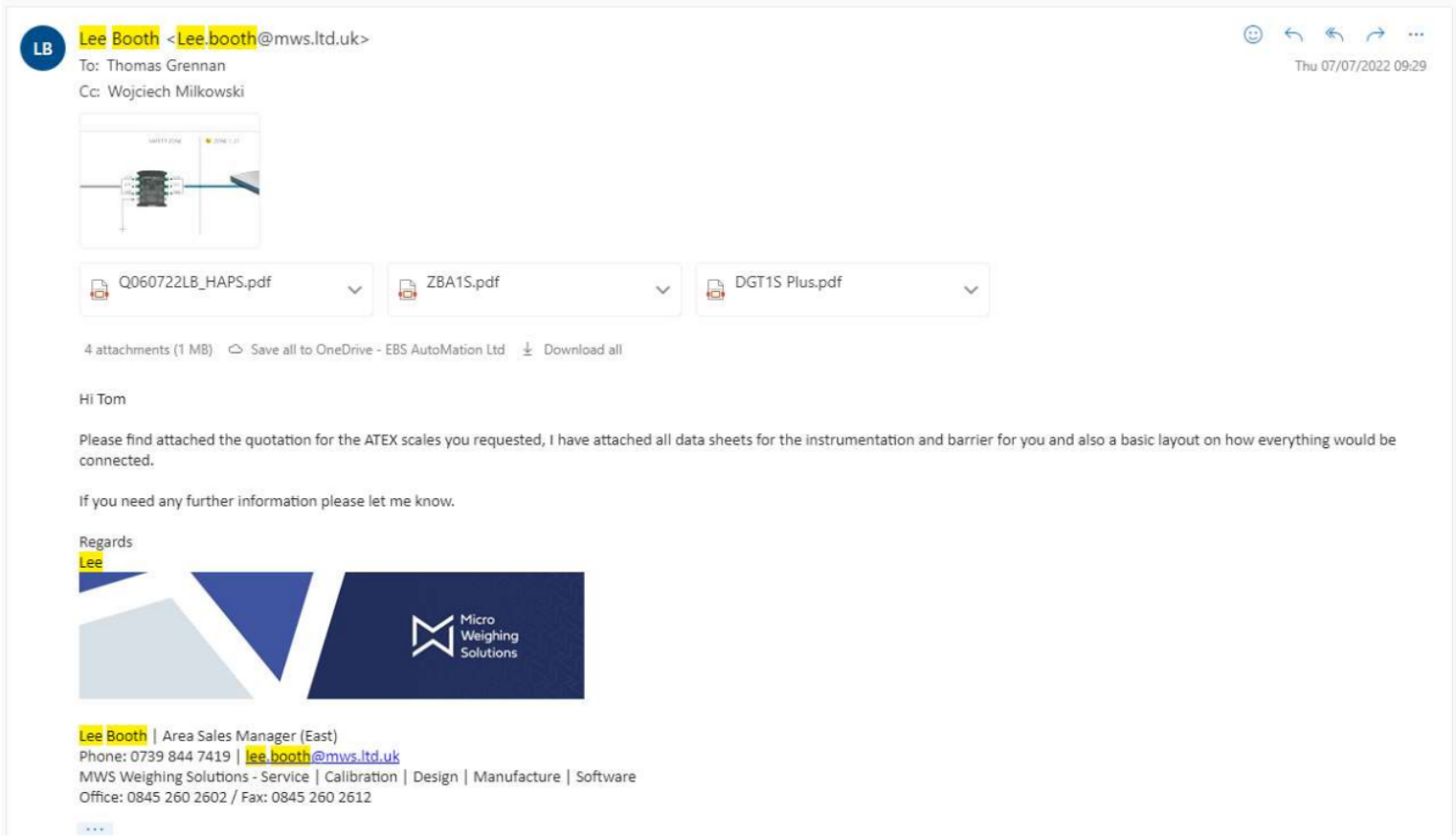
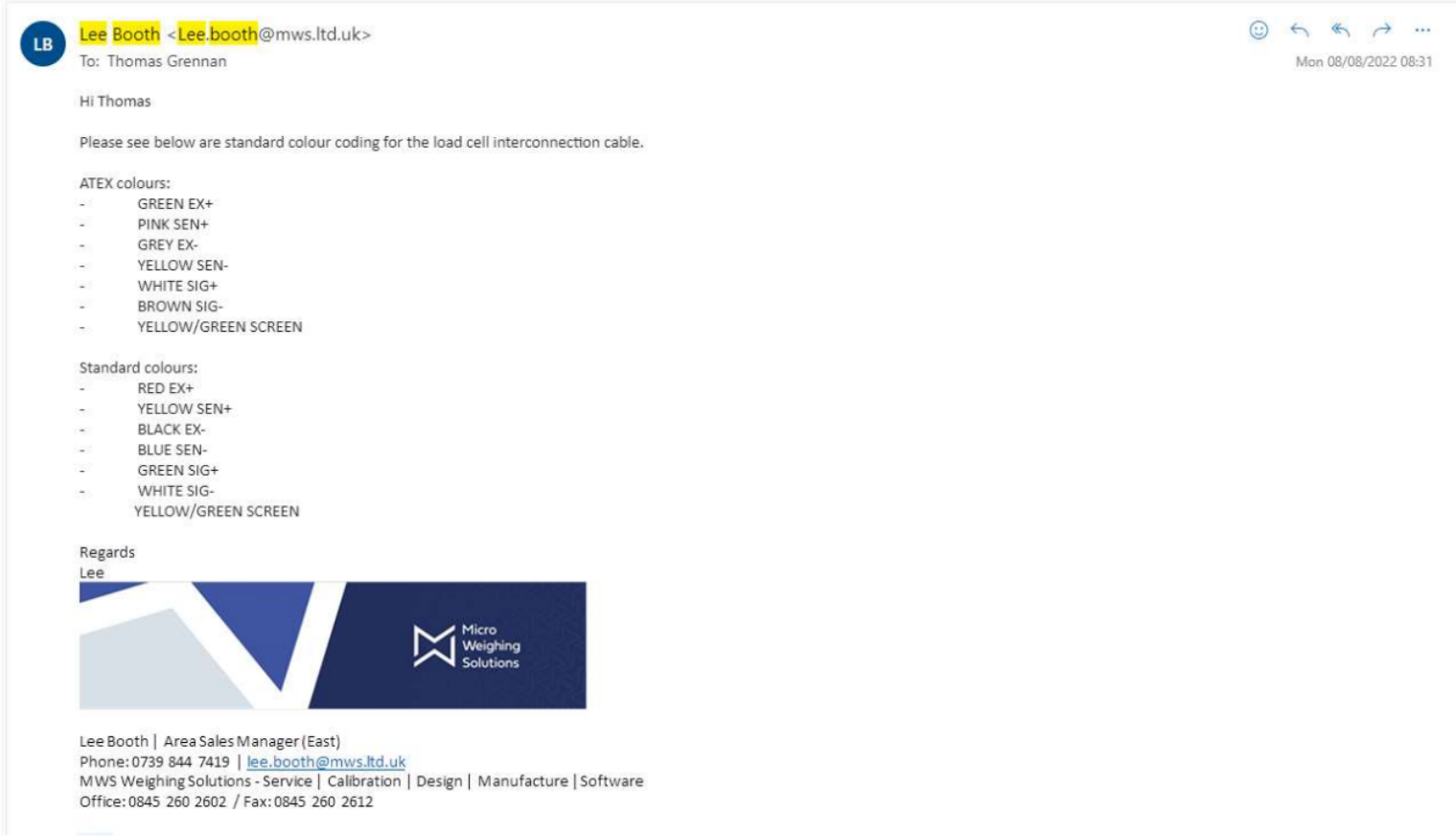


Figure 14 – Email from MWS on ATEX Zone 21 Weigh Scale (Booth, 2022)



LB

Lee Booth <Lee.booth@mws.ltd.uk>

To: Thomas Grennan

Mon 08/08/2022 08:31

Hi Thomas

Please see below are standard colour coding for the load cell interconnection cable.

ATEX colours:
- GREEN EX+
- PINK SEN+
- GREY EX-
- YELLOW SEN-
- WHITE SIG+
- BROWN SIG-
- YELLOW/GREEN SCREEN

Standard colours:
- RED EX+
- YELLOW SEN+
- BLACK EX-
- BLUE SEN-
- GREEN SIG+
- WHITE SIG-

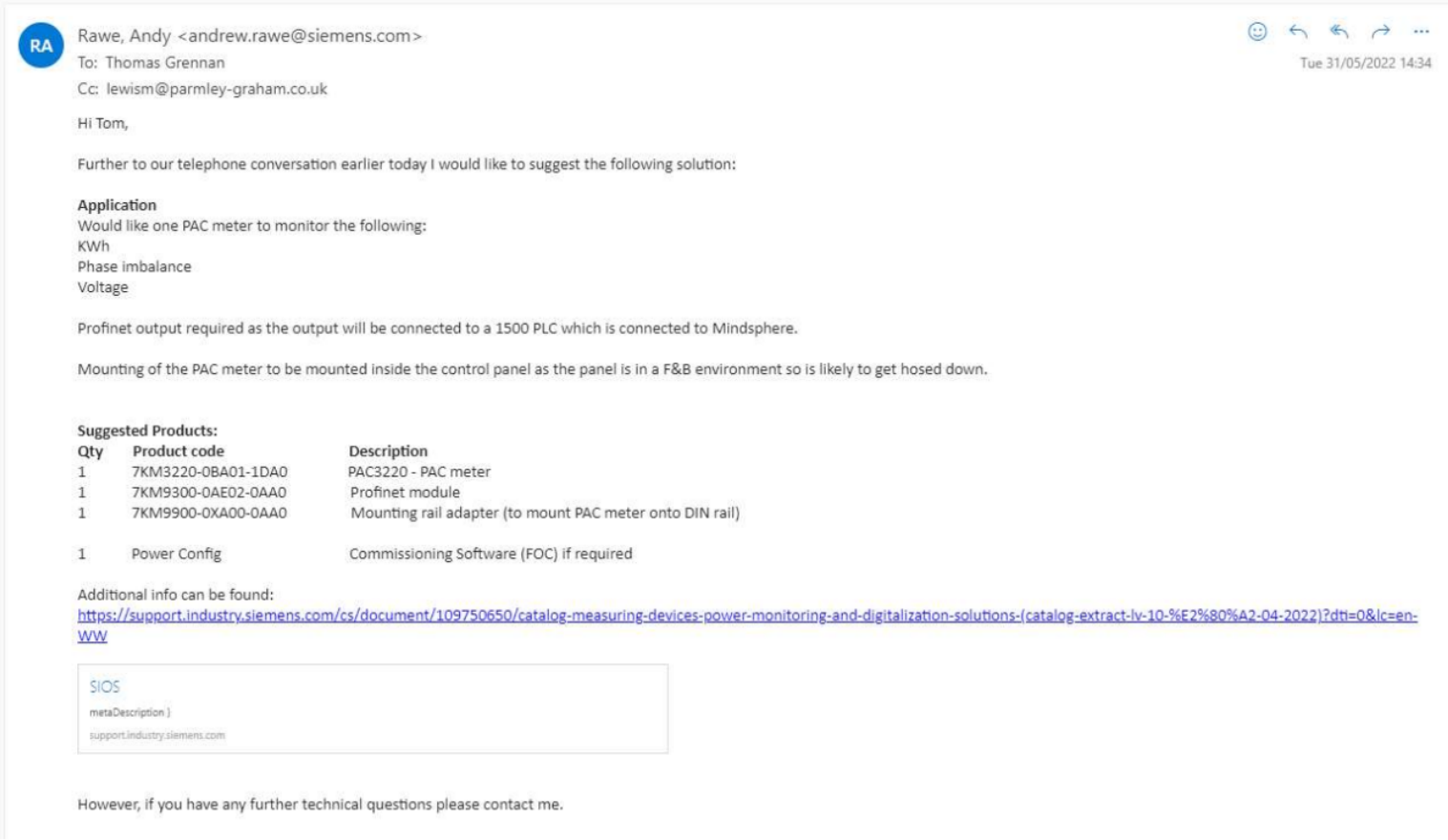
YELLOW/GREEN SCREEN

Regards
Lee

Micro Weighing Solutions

Lee Booth | Area Sales Manager (East)
Phone: 0739 844 7419 | lee.booth@mws.ltd.uk
MWS Weighing Solutions - Service | Calibration | Design | Manufacture | Software
Office: 0845 260 2602 / Fax: 0845 260 2612

Figure 15 – Email from MWS ATEX Weigh Scale Core Colours (Booth, 2022)



RA

Rawe, Andy <andrew.rawe@siemens.com>

To: Thomas Grennan

Cc: lewism@parmley-graham.co.uk

Tue 31/05/2022 14:34

Hi Tom,

Further to our telephone conversation earlier today I would like to suggest the following solution:

Application
Would like one PAC meter to monitor the following:
KWh
Phase imbalance
Voltage

Profinet output required as the output will be connected to a 1500 PLC which is connected to Mindsphere.

Mounting of the PAC meter to be mounted inside the control panel as the panel is in a F&B environment so is likely to get hosed down.

Suggested Products:

Qty	Product code	Description
1	7KM3220-0BA01-1DA0	PAC3220 - PAC meter
1	7KM9300-0AE02-0AA0	Profinet module
1	7KM9900-0XA00-0AA0	Mounting rail adapter (to mount PAC meter onto DIN rail)
1	Power Config	Commissioning Software (FOC) if required

Additional info can be found:
https://support.industry.siemens.com/cs/document/109750650/catalog-measuring-devices-power-monitoring-and-digitalization-solutions-(catalog-extract-lv-10-%E2%80%A2-04-2022)?dti=0&lc=en-WW

SIOS
metaDescription }
support.industry.siemens.com

However, if you have any further technical questions please contact me.

Figure 16 – Siemens Email for PAC Meter Application (Rawe, 2023)

From: Thomas Grennan <Thomas.Grennan@ebs.uk.com>
Sent: 20 September 2022 16:12
To: Darren Byford <darren.byford@sifamtinsley.com>
Subject: 5174 - CTs

Hi Darren,

Can you recommend a din rail mountable current transformer for the following,

10A Input
1A OR 5A Output
Accuracy Class 1.0

Kind Regards,

Tom Grennan

EBS
AUTOMATION

EBS Automation Ltd
7 Heol Cropin, Parc Dafen, Dafen, Llanelli, Carmarthenshire, SA14 8QW

Tel. 00 44 (0) 1554 779090
Fax. 00 44 (0) 1554 779099
www.ebs.uk.com

Registration No. 3310971
VAT No. 558 2301 47

IMPORTANT - The information in this e-mail message is confidential and may be legally privileged and protected by law. The intended recipient only is authorised to access it. if you are not the intended recipient, please notify the sender as soon as possible and delete any copies. Unauthorised use, dissemination, distribution, publication or copying of this communication is prohibited.

Figure 17 – Sifam Tinsley CT Reccomendation Request Email

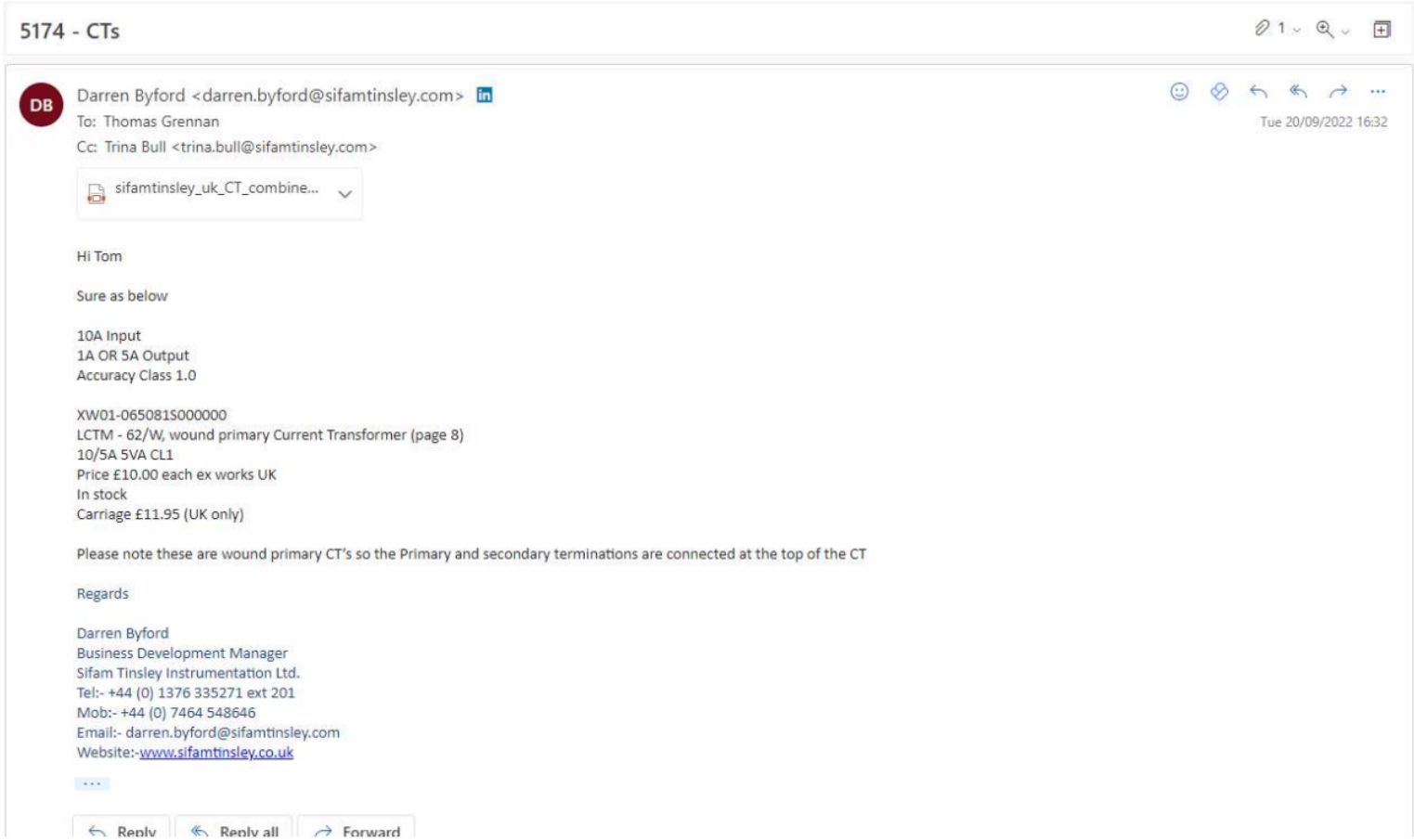


Figure 18 - Sifam Tinsley CT Reccomendation Email Response (Byford, 2022)

Appendix 9.2 - Electrical Design

Appendix 9.2.1 – Electrical Design Explanation

The electrical schematics are broken down into various functions, these are:

- **AC Power**: This consists of a 13A Socket for a BS 1363 plug, strictly to charge the programmers laptop, supply to a 240VAC-24VDC Power Supply and a Siemens PAC3220 power monitoring meter and associated current transformer (CT). The application was discussed with Andy Rawe from Siemens who recommended the PAC3220 meter with a Profinet module (Rawe, 2023). Rawe stated that "Siemens' offering of CTs start at 50A, it is better to source your own as due to the low current the full range of the CT will not be used" (2023) . After a discussion with Darren Byford from Sifam Tinsley, a suitable CT was recommended for the application (Byford, 2022). The e-mail trails of the discussions are seen in appendix 9.1.

- **DC Power:** The DC Power is supplied from the secondary of the 240VAC-24VDC power supply. This supplies the Panel 24V, Field 24V, HMI 24V, IO-Link 24V, Weigh Scale 24V and Positioner Barrier 24V. Originally, in the FDS 24V current protection was provided in the form of a DF2101 IO-Link fuse header, which offered the ability to monitor current consumption and other acyclic parameters. However, a lead time of July 2023 has resulted in Schneider Electric MCBs & Auxiliary contacts to be used, allowing for current protection up to 60VDC (Electric, 2023).

- **Weigh Scale:** The weigh scale accurately measures the ingredients dosed into the mixing bowl; and will be situated in ATEX zone 21. Micro Weighing Solutions provided a solution consisting of a scale that meets ATEX EU Declaration of Conformity. The solution was supplied with a Dini Argeo DGT1SX Plus Profinet Transmitter and barrier to ensure the application is intrinsically safe and can interface with the PLC through Profinet. The circuit is designed following recommendations from MWS & Dini Argeo.

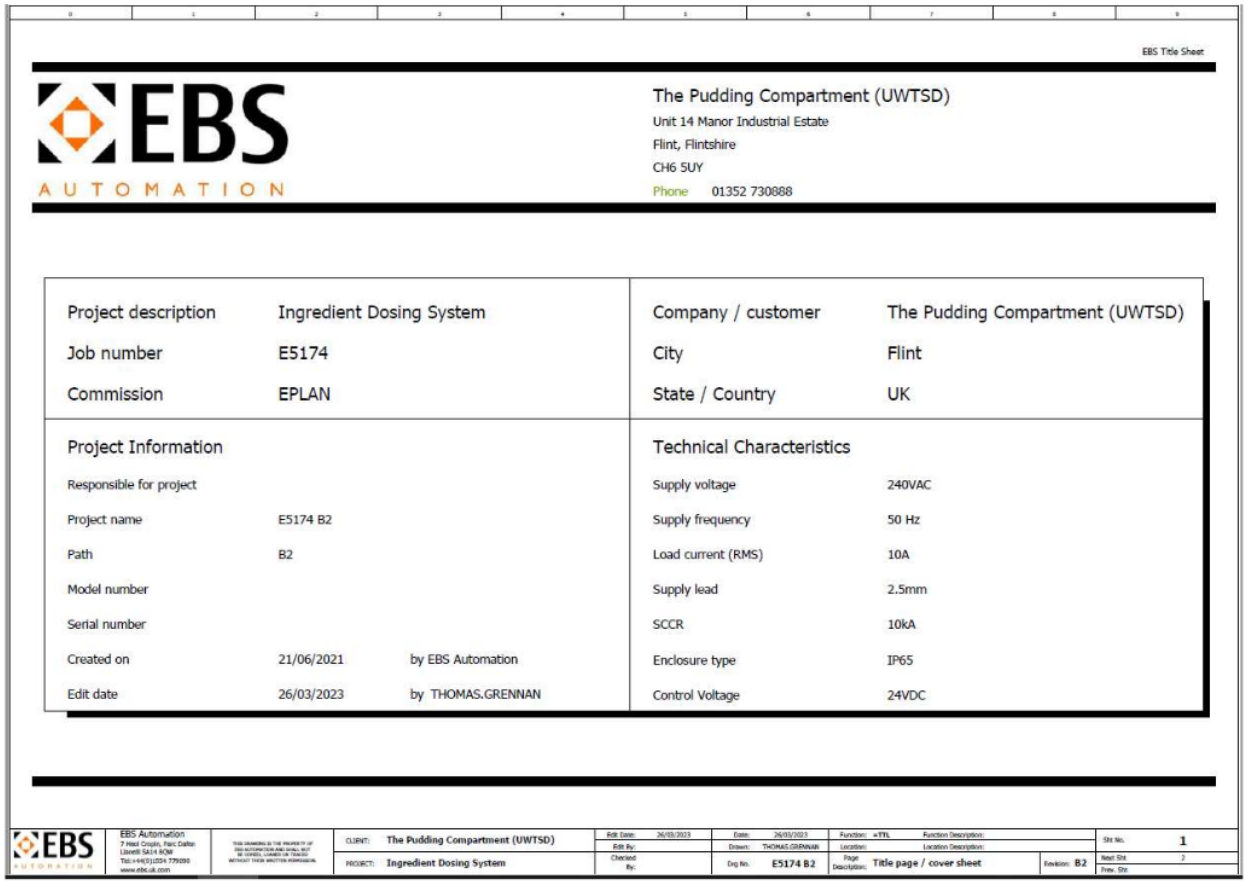
- **Positioner:** The positioners are the first stage valve to control the bulk dosing phase, supplied by Mucon. The positioner consists electro-pneumatic leaf valve which opens from 0-100% (0-90˚) linearly in response to a 4-20milliamp input. Datasheets from Mucon were sent to UK Pepperl+Fuchs suppliers Parmley Graham, who recommended their KCD2-SCD-Ex1 Smart Current Driver to achieve intrinsic safety. The driver isolates and repeats the 4-20mA signal from the safe zone in the non-safe

zone at <13VDC, ensuring that the signal cannot generate a spark within the ATEX zone, each positioner requires its own barrier (pepperl+fuchs, 2022).

- **Programmable Logic Controller (PLC)**: The PLC controls the process, the ingredient dosing system requires digital inputs, digital outputs and analog outputs. The digital inputs consist of a main air pressure signal, the status of MCBs through auxiliary contacts and the status of the emergency stop relay. The digital outputs will control 5/3 Valves required for the second-stage fine dosing process through 24V interface relays. The valves have been designed within a 'non-sparking' EX N manifold for use within the ATEX zone. Analog outputs are implemented to control the positioners, the analog output is fed into the input side of the positioner barrier supplied by a Siemens AQ 8 x U/I HS analog output module (Siemens, 2021).

- **Safety**: A Pilz PNOZ S5 safety relay monitors the emergency stop safety function. Safety relays are designed to provide high reliability and performance to ensure that safety functions are activated when needed (Pilz, 2022). The safety relay monitors the status of the channels through the emergency stop contacts, if either channel is broken it disables the relay contacts, in turn turning off the system dump valve and removing power from the relay commons, ensuring that the valves cannot operate. The PNOZ S5 is essential due to its delayed contact option, a situation could occur where the emergency stop is pressed mid-valve stroke which will cause the hopper to empty its ingredients. The PNOZ S5 is configured that when the safety function is activated it will instantaneously remove 24V from the actuators, but will delay removing power from the dump valve to ensure that the valve meets its end-of-stroke and closes. In compliance with BS EN 60204-1 clause 9.2.3.4.2 the emergency stop function will be active in all modes, overriding all other functions, a "Control On" pushbutton will reset the safety circuit, but will not initiate a restart (BSI, 2021). The emergency stop pushbutton will be of the mushroom type allowing for quick actuation by a palm or fist required by BS EN 60204-1 clause 10.7.2, the button will be red in colour with a yellow background legend in accordance with BS EN 60204-1 10.2.1

Appendix 9.2.2 – Electrical Design Schematics



EBS Title Sheet

EBS AUTOMATION

The Pudding Compartment (UWTSD)
Unit 14 Manor Industrial Estate
Flint, Flintshire
CH6 5UY
Phone 01352 730888

Project description	Ingredient Dosing System	Company / customer	The Pudding Compartment (UWTSD)
Job number	E5174	City	Flint
Commission	EPLAN	State / Country	UK

Project Information			Technical Characteristics	
Responsible for project			Supply voltage	240VAC
Project name	E5174 B2		Supply frequency	50 Hz
Path	B2		Load current (RMS)	10A
Model number			Supply lead	2.5mm
Serial number			SCCR	10kA
Created on	21/06/2021	by EBS Automation	Enclosure type	IP65
Edit date	26/03/2023	by THOMAS.GRENNAN	Control Voltage	24VDC

EBS AUTOMATION | EBS Automation 7 Heol Croglin, Parc Dafen Llanelli SA14 8QW Tel:+44(0)1554 779090 www.ebs.uk.com

CLIENT: The Pudding Compartment (UWTSD)
PROJECT: Ingredient Dosing System
Edit Date: 26/03/2023 | Edit By:
Checked By:
Date: 26/03/2023 | Drawn: THOMAS.GRENNAN
Dwg No. E5174 B2
Function: =TTL | Function Description:
Location: | Location Description:
Page Description: Title page / cover sheet | Revision: B2
Sht No. 1 | Next Sht 2 | Prev. Sht

Figure 19 – Electrical Schematics Front Sheet (Grennan, 2023)

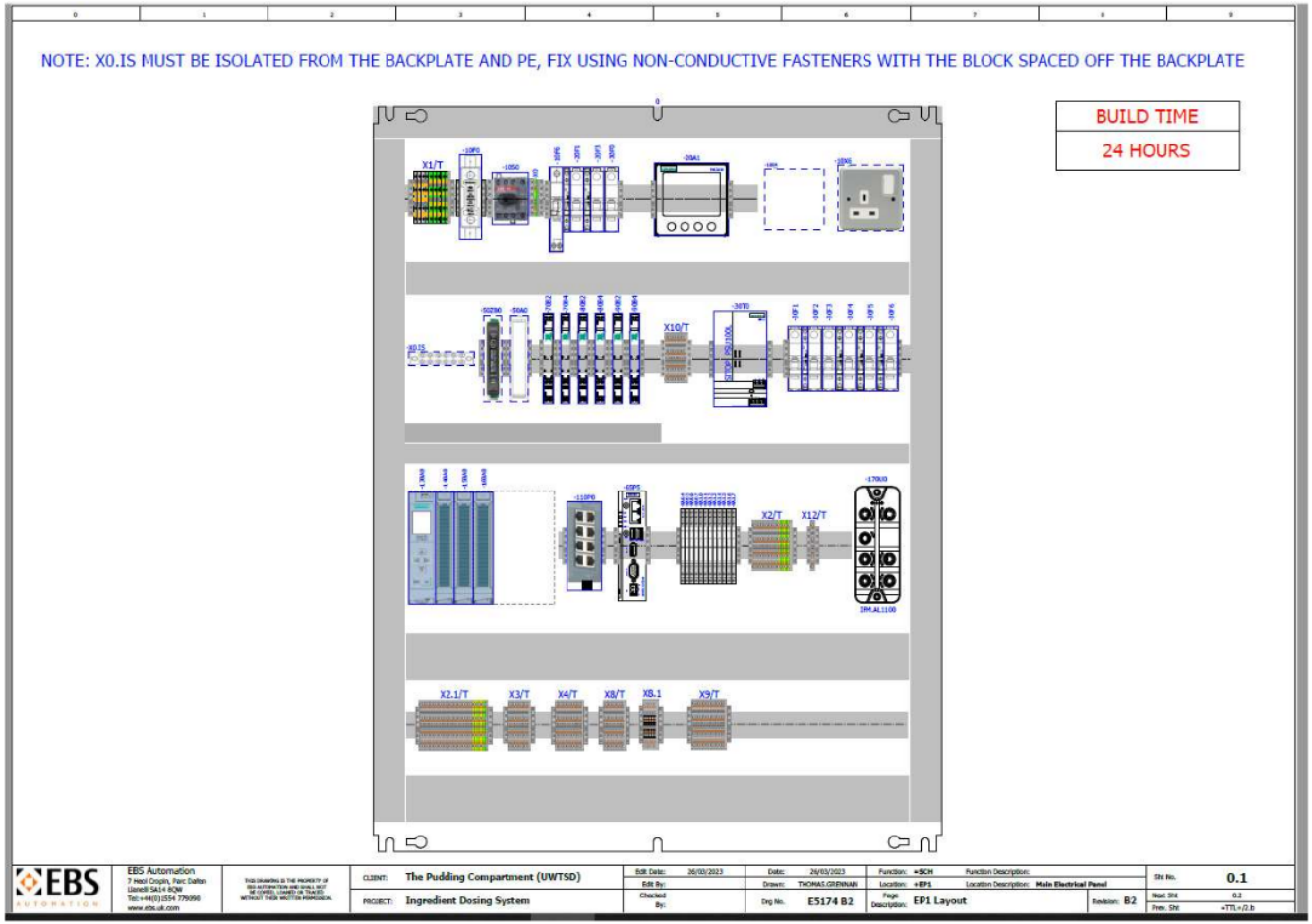


Figure 20 - Electrical Schematics Panel Layout (Grennan, 2023)

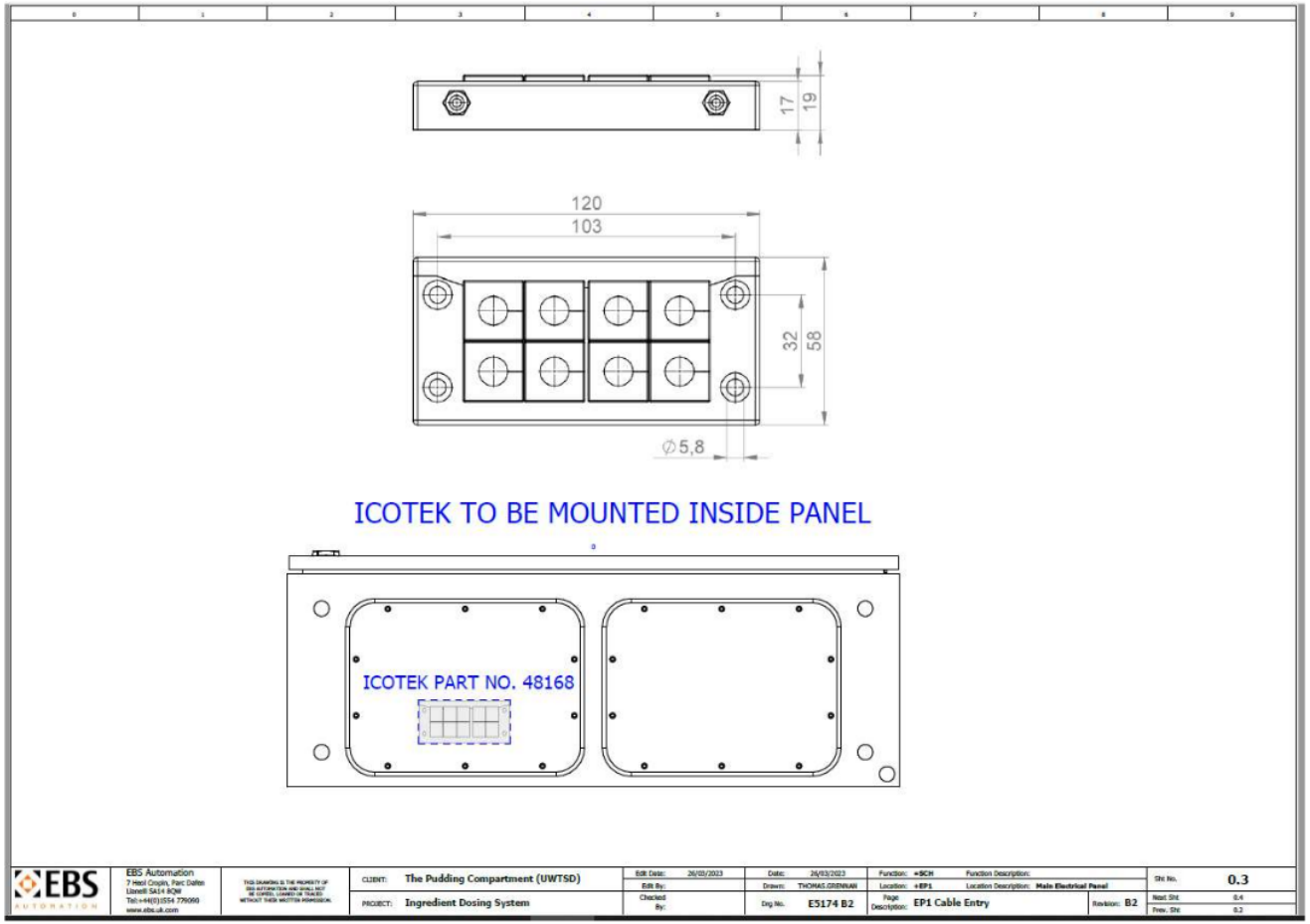


Figure 21 - Electrical Schematics Cable Entry (Grennan, 2023)

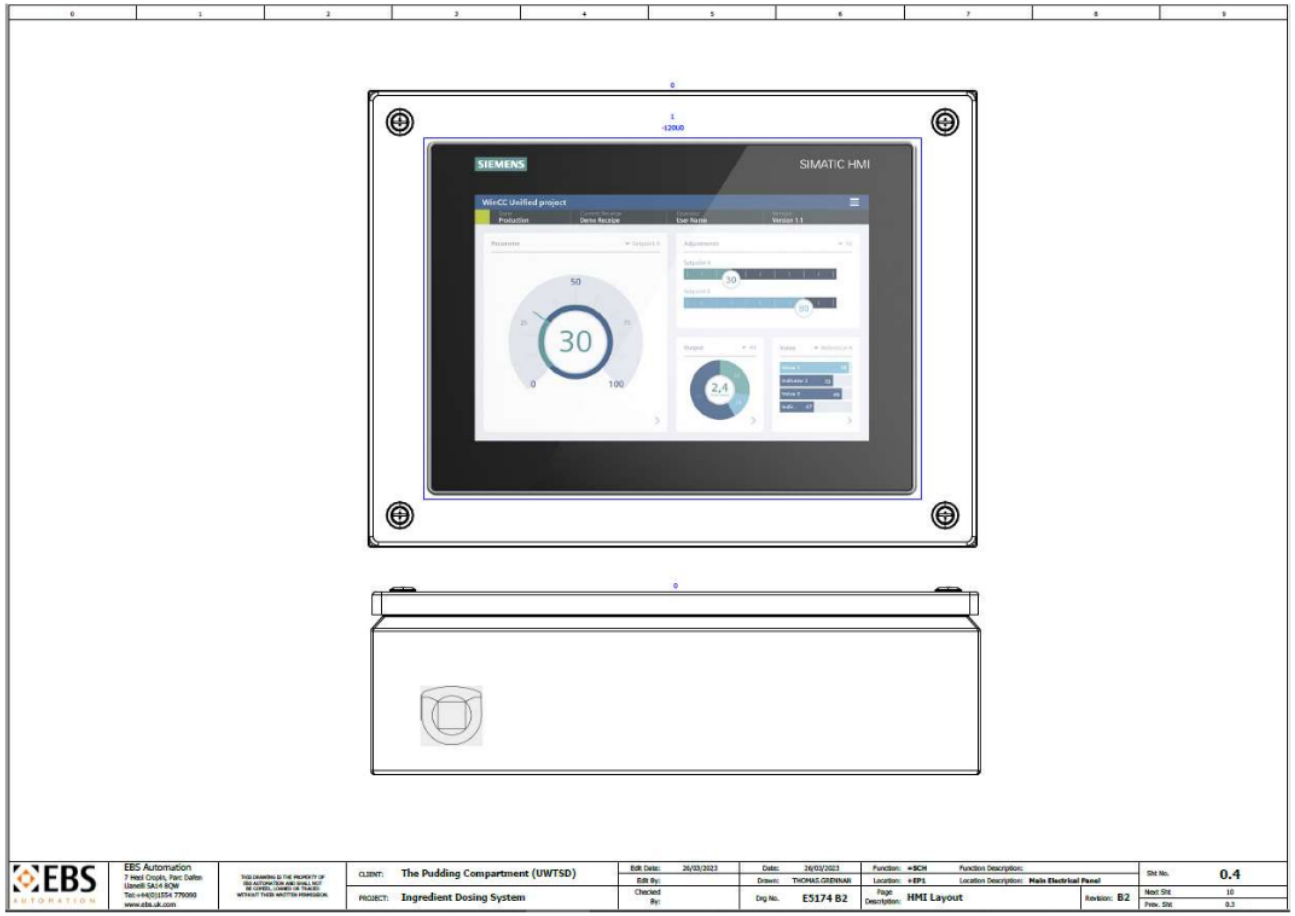


Figure 22 – Electrical Schematics HMI Panel

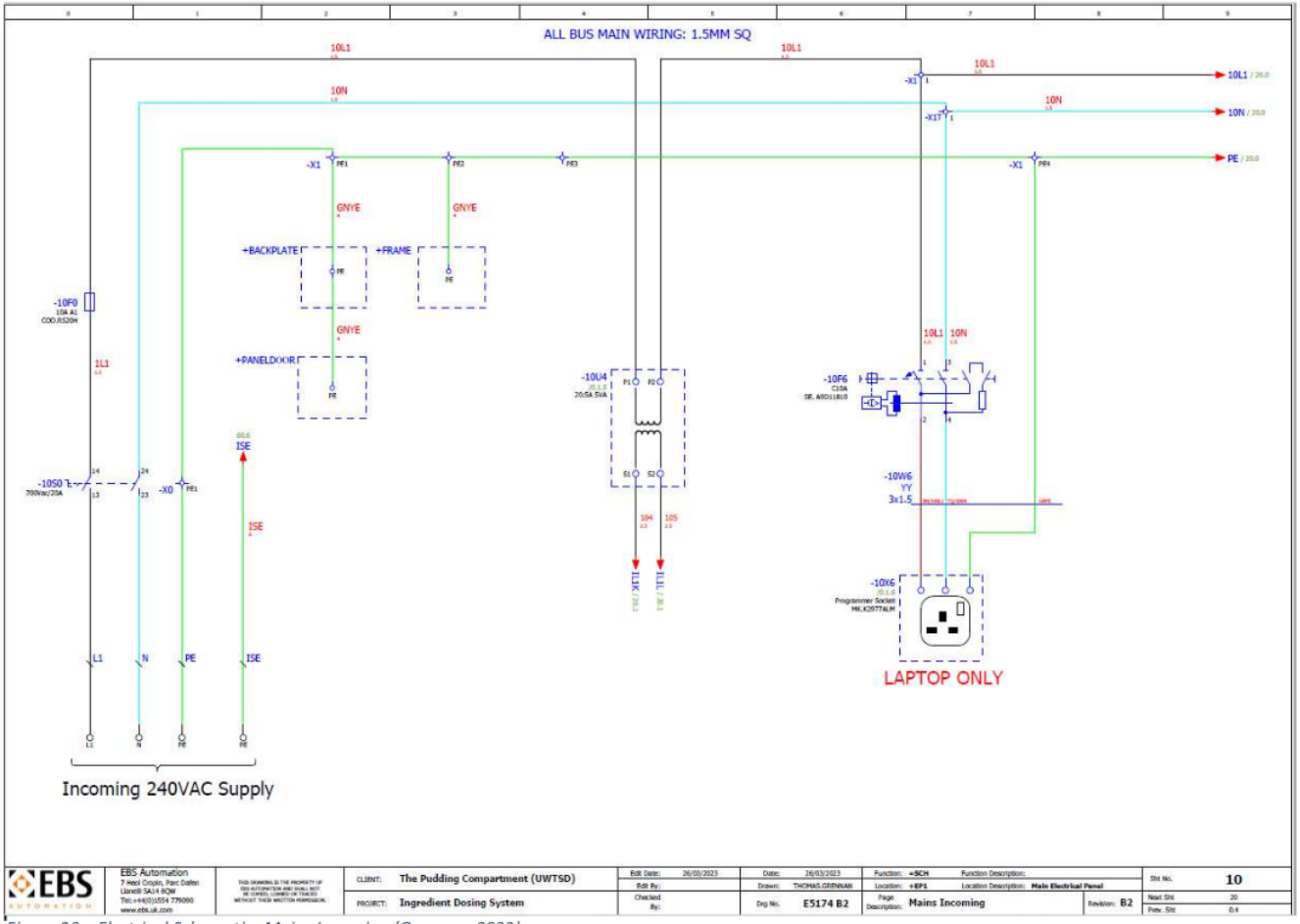


Figure 23 – Electrical Schematics Mains Incoming (Grennan, 2023)

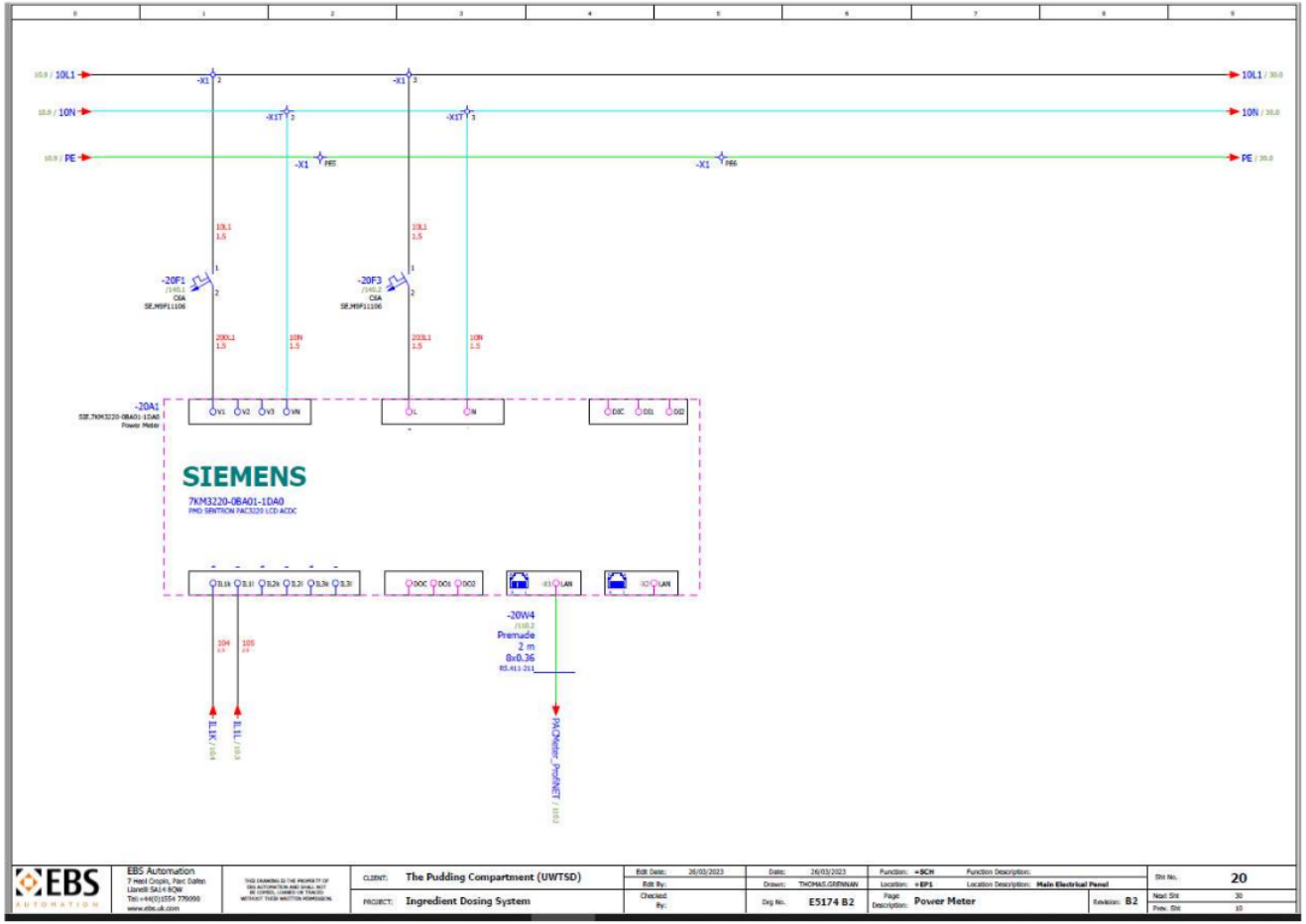


Figure 24 - Electrical Schematics PAC Meter (Grennan, 2023)

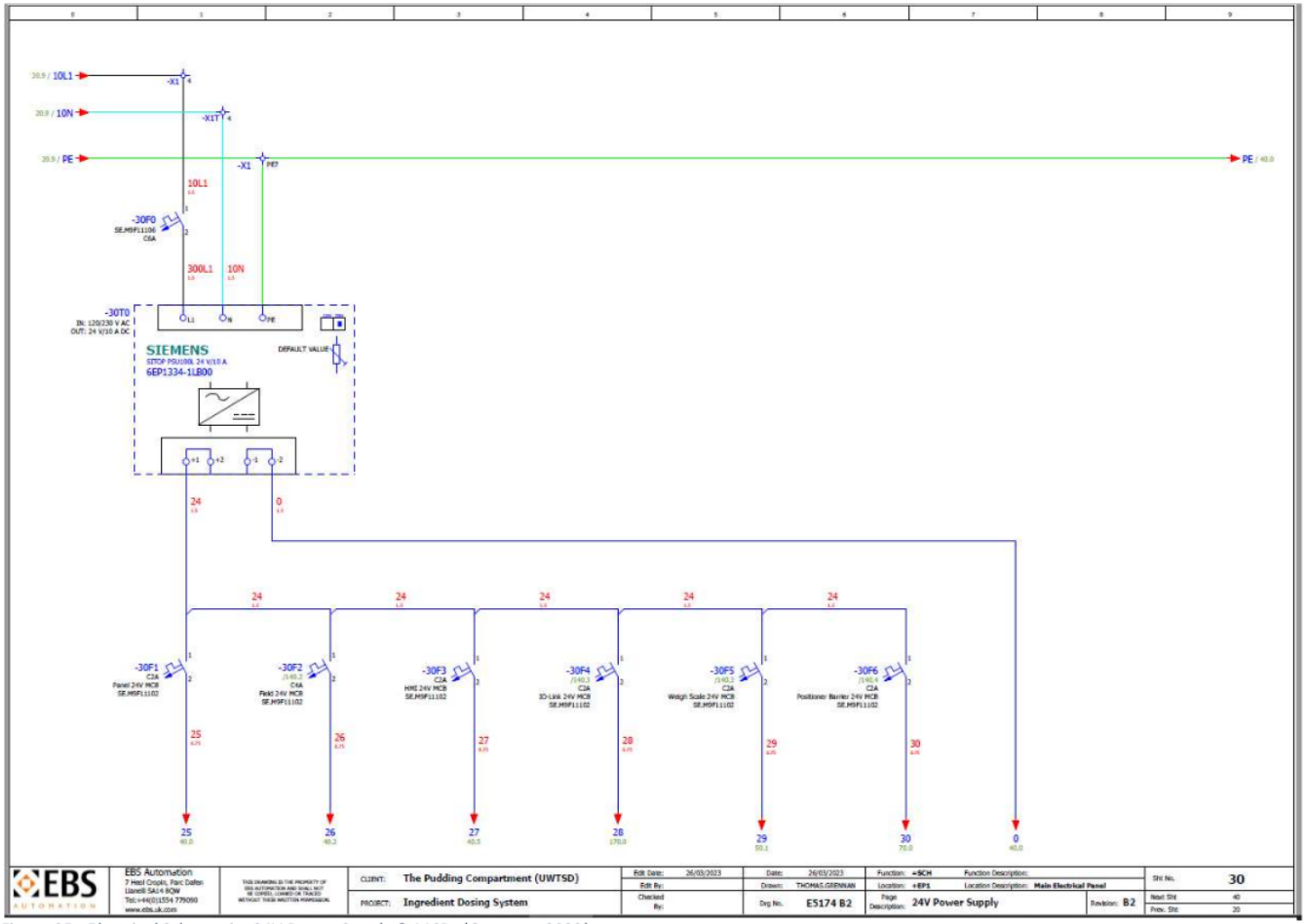


Figure 25 - Electrical Schematics 24V Power Supply & MCBs (Grennan, 2023)

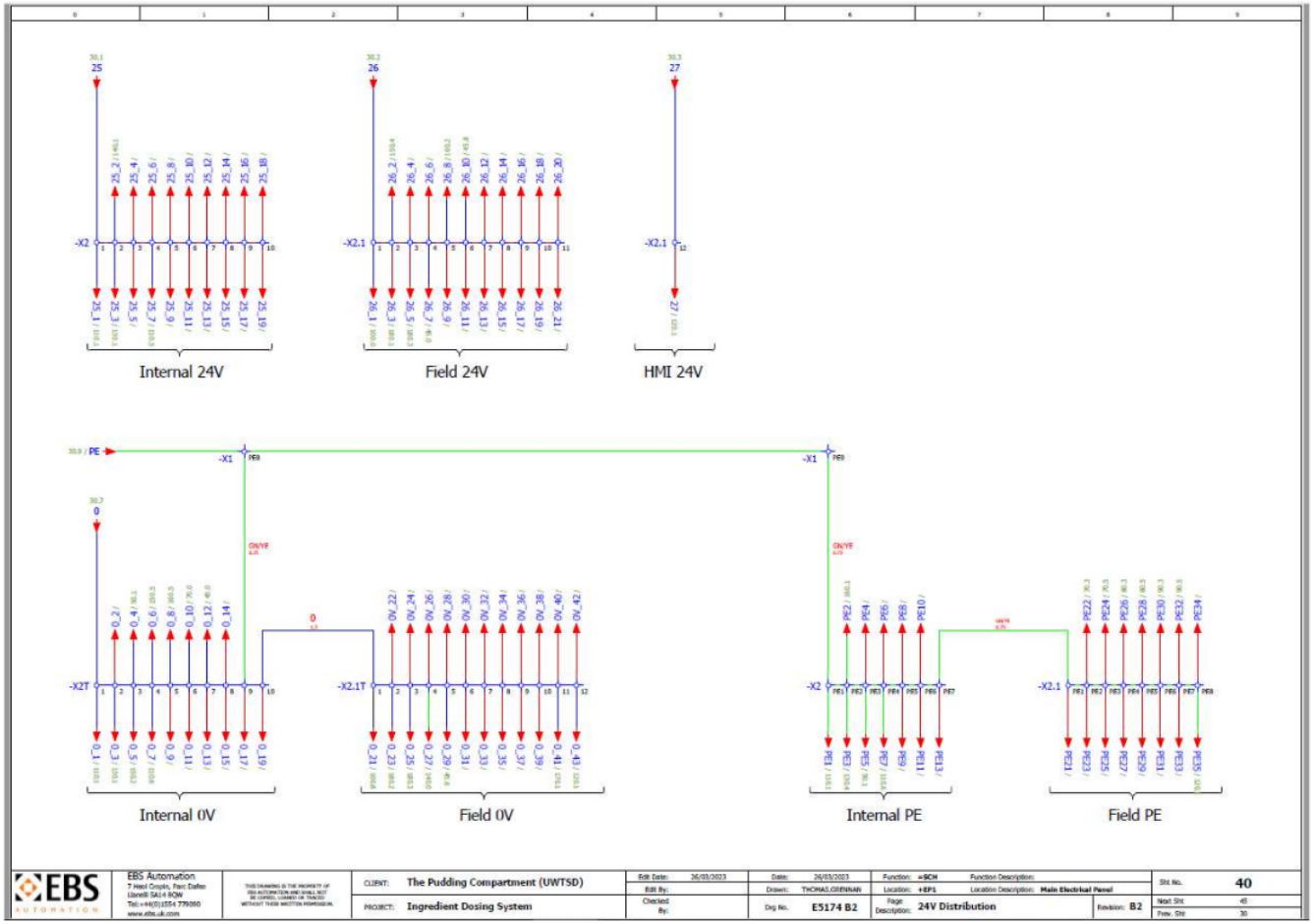


Figure 26 - Electrical Schematics 24V Distribution (Grennan, 2023)

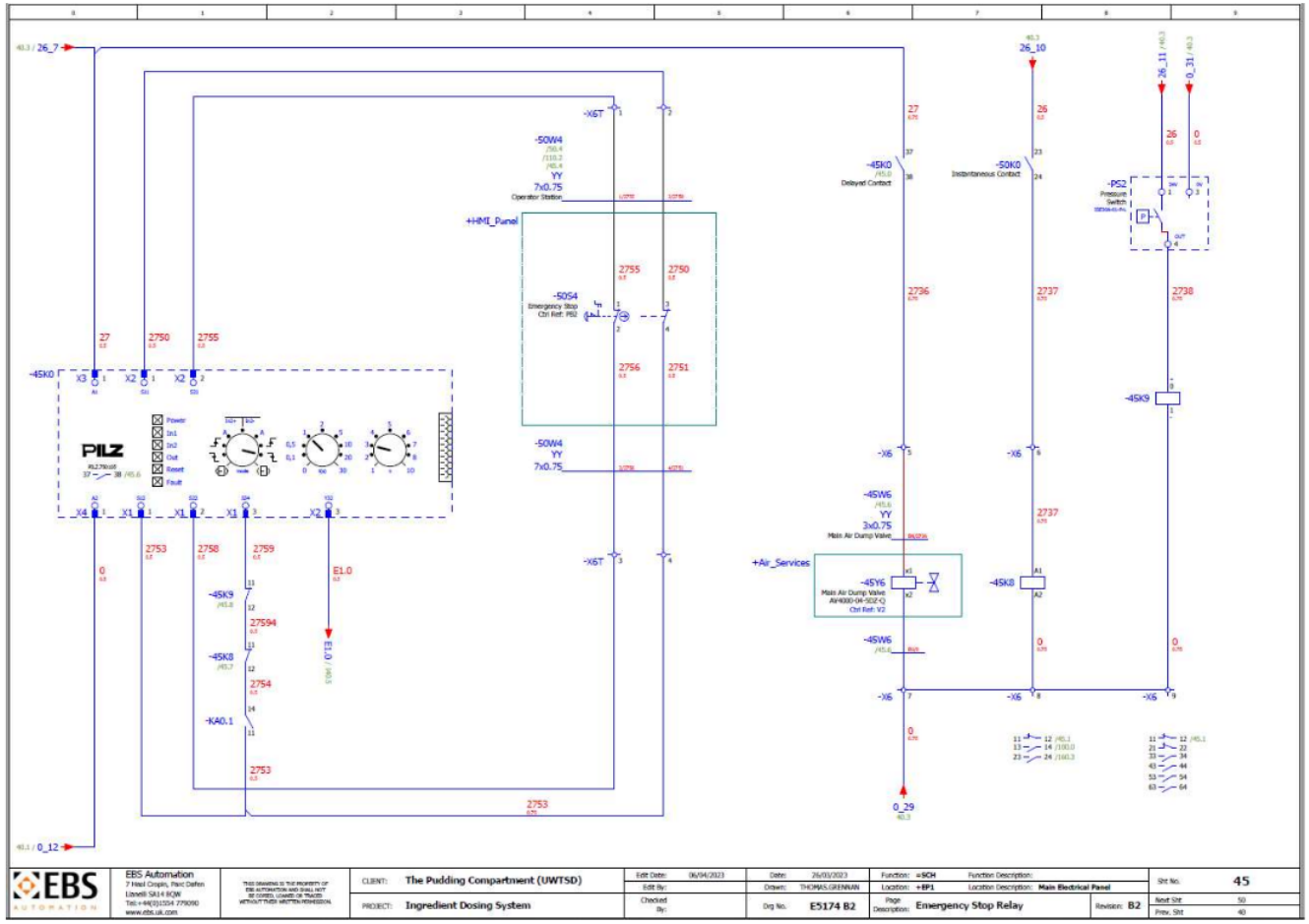


Figure 27 - Electrical Schematics Emergency Stop Circuit (Grennan, 2023)

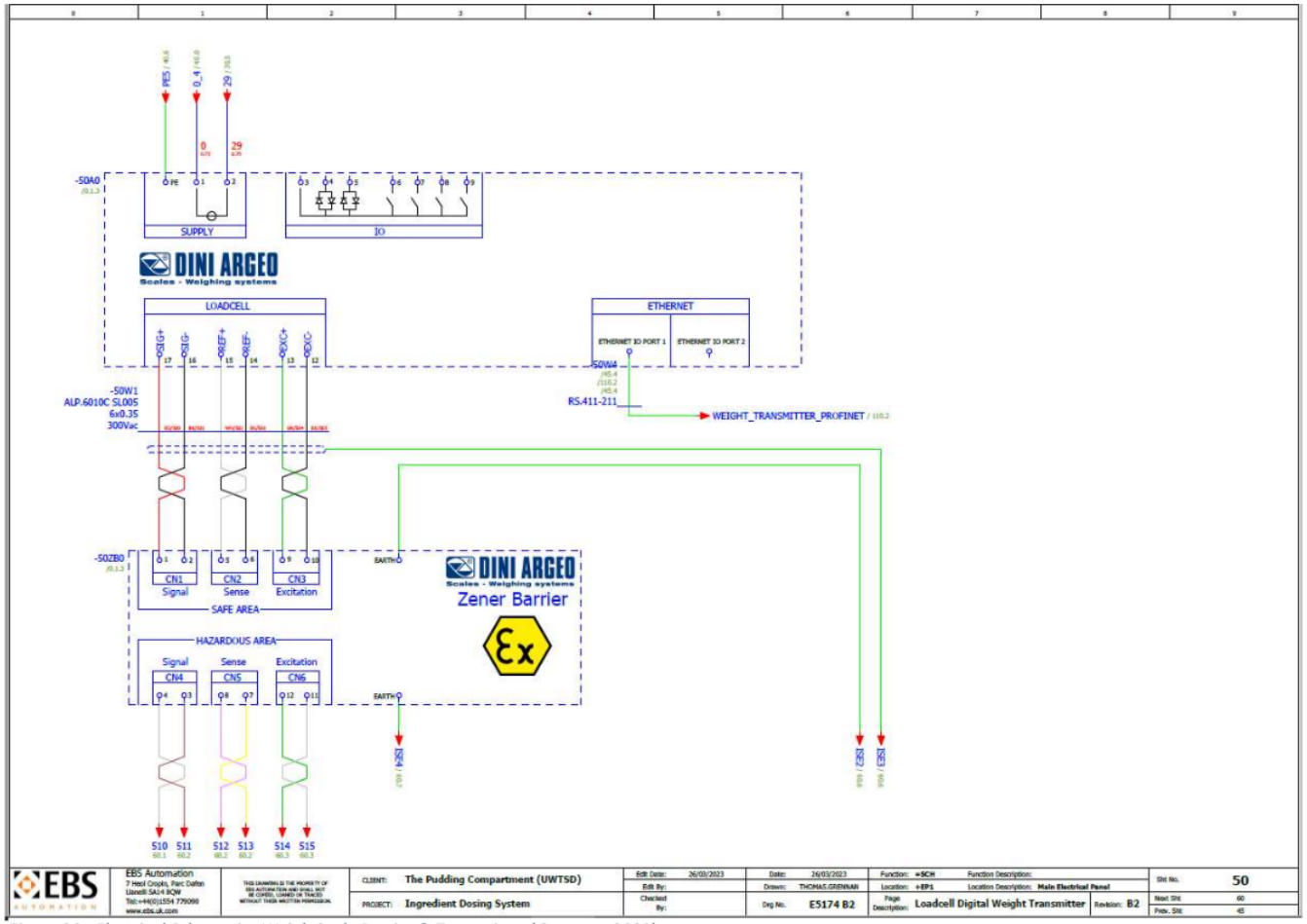


Figure 28 - Electrical Schematics Weigh Scale Barrier & Transmitter (Grennan, 2023)

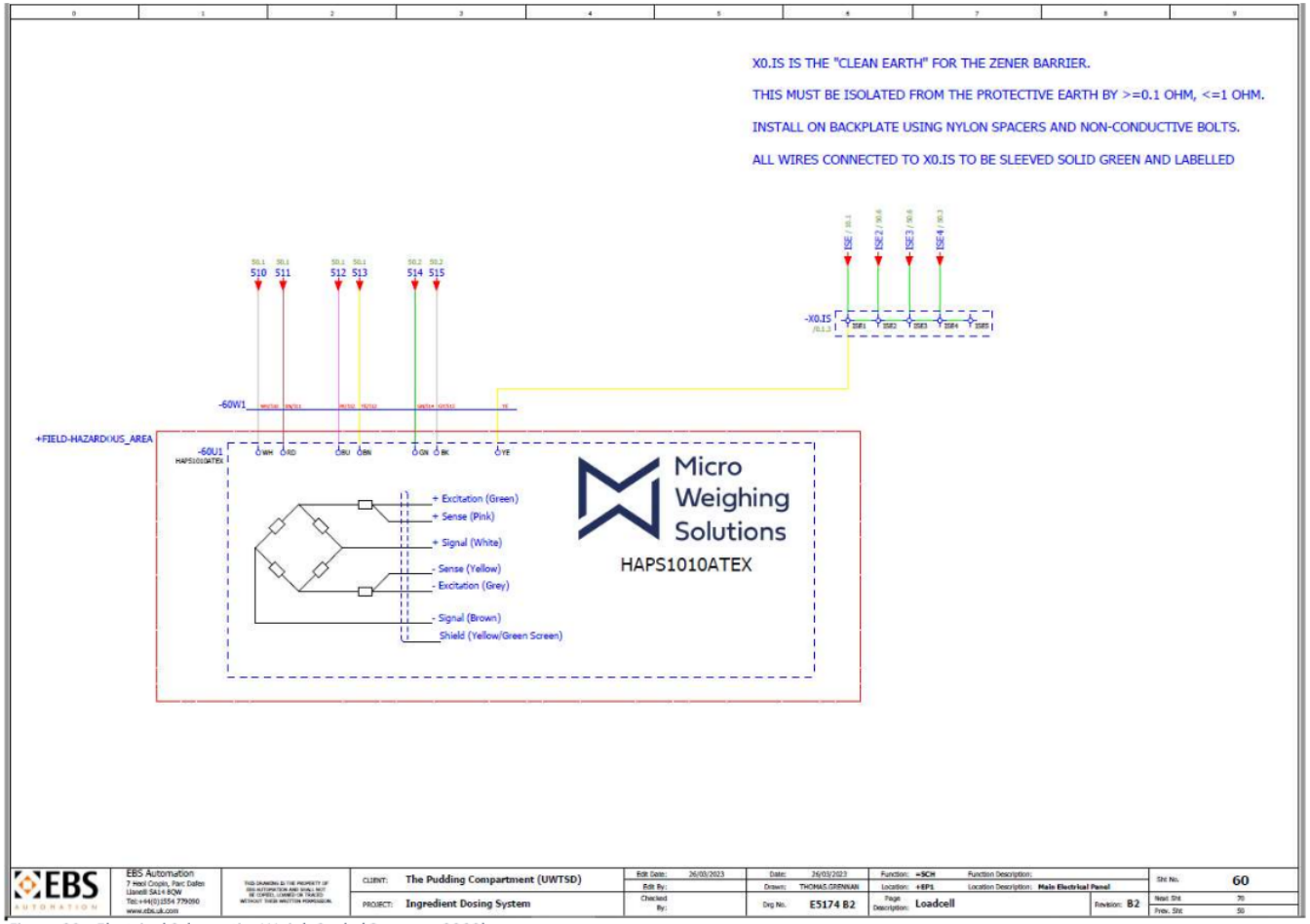


Figure 29 - Electrical Schematics Weigh Scale (Grennan, 2023)

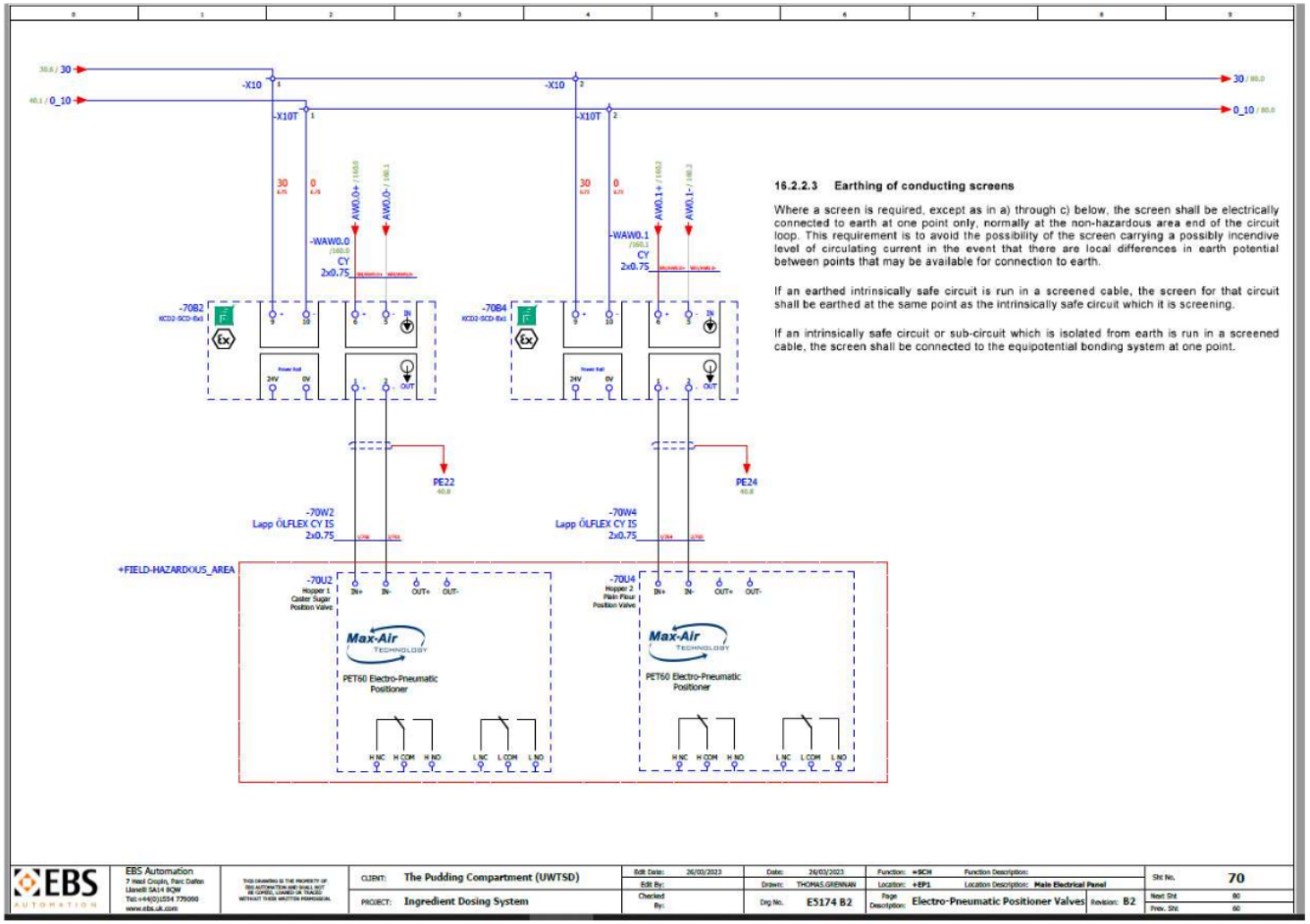


Figure 30- Electrical Schematics Hopper 1 & 2 Barrier Positioner (Grennan, 2023)

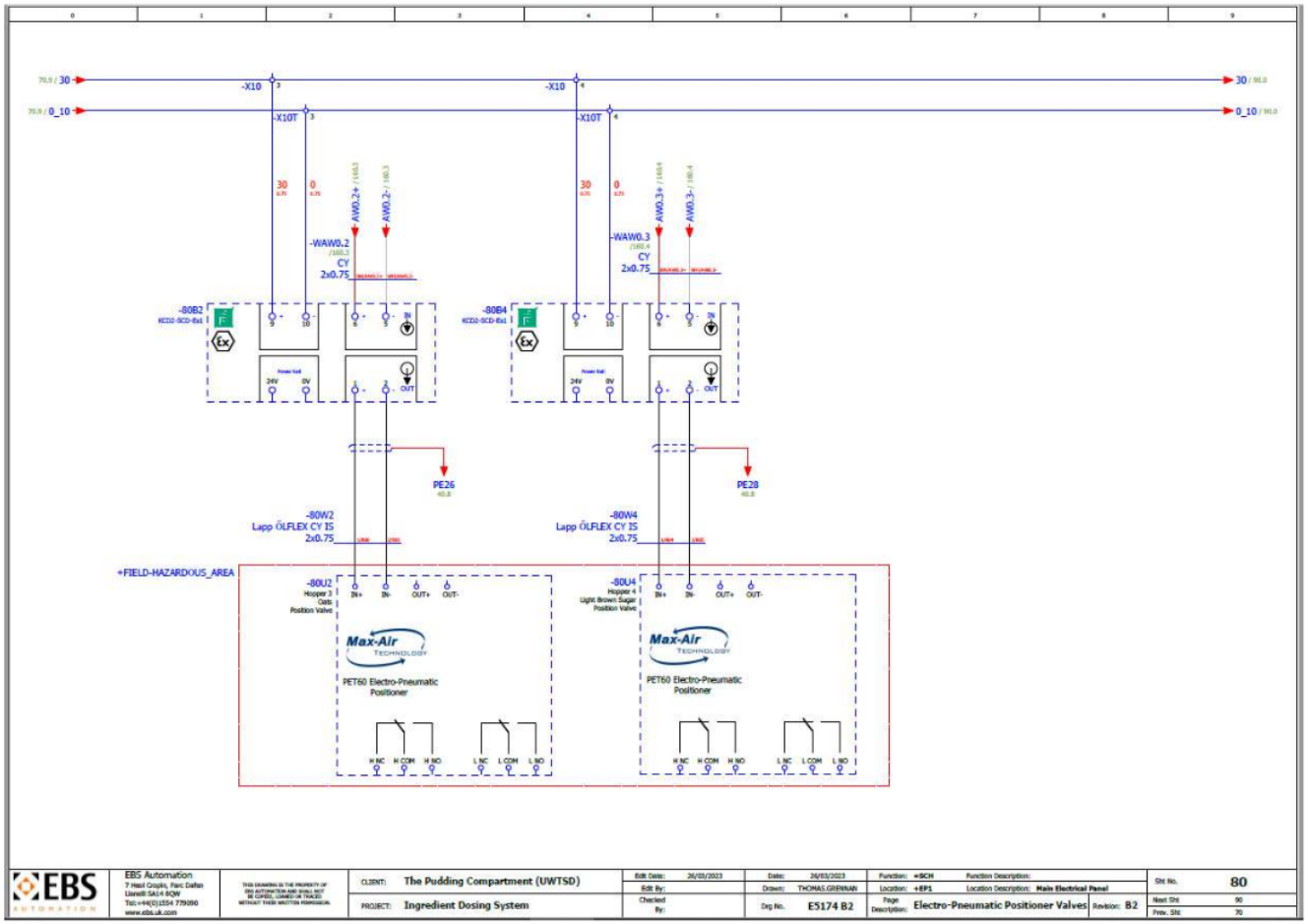


Figure 31 - Electrical Schematics Hopper 3 & 4 Barrier Positioner (Grennan, 2023)

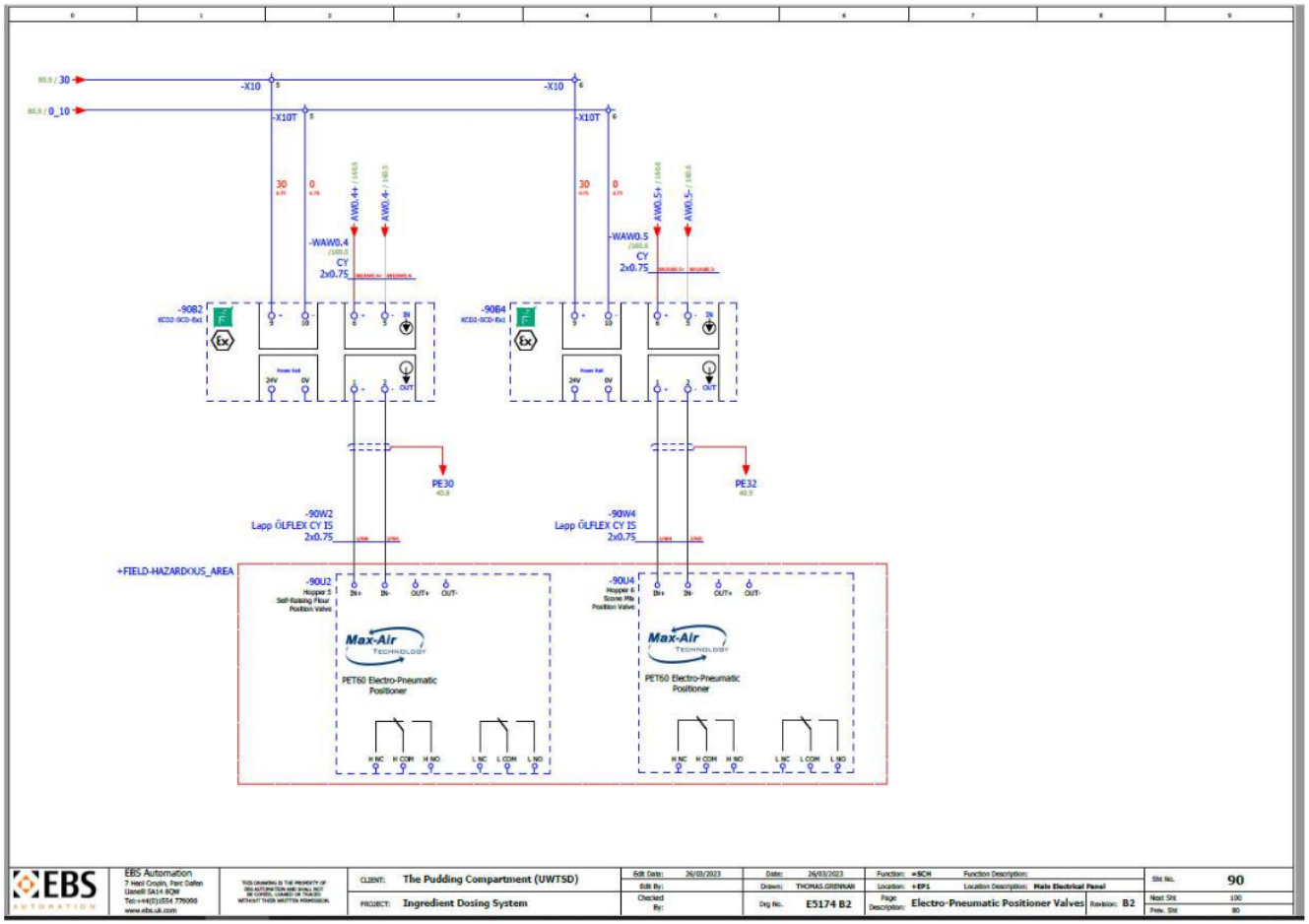


Figure 32 - Electrical Schematics Hopper 5 & 6 Barrier Positioner (Grennan, 2023)

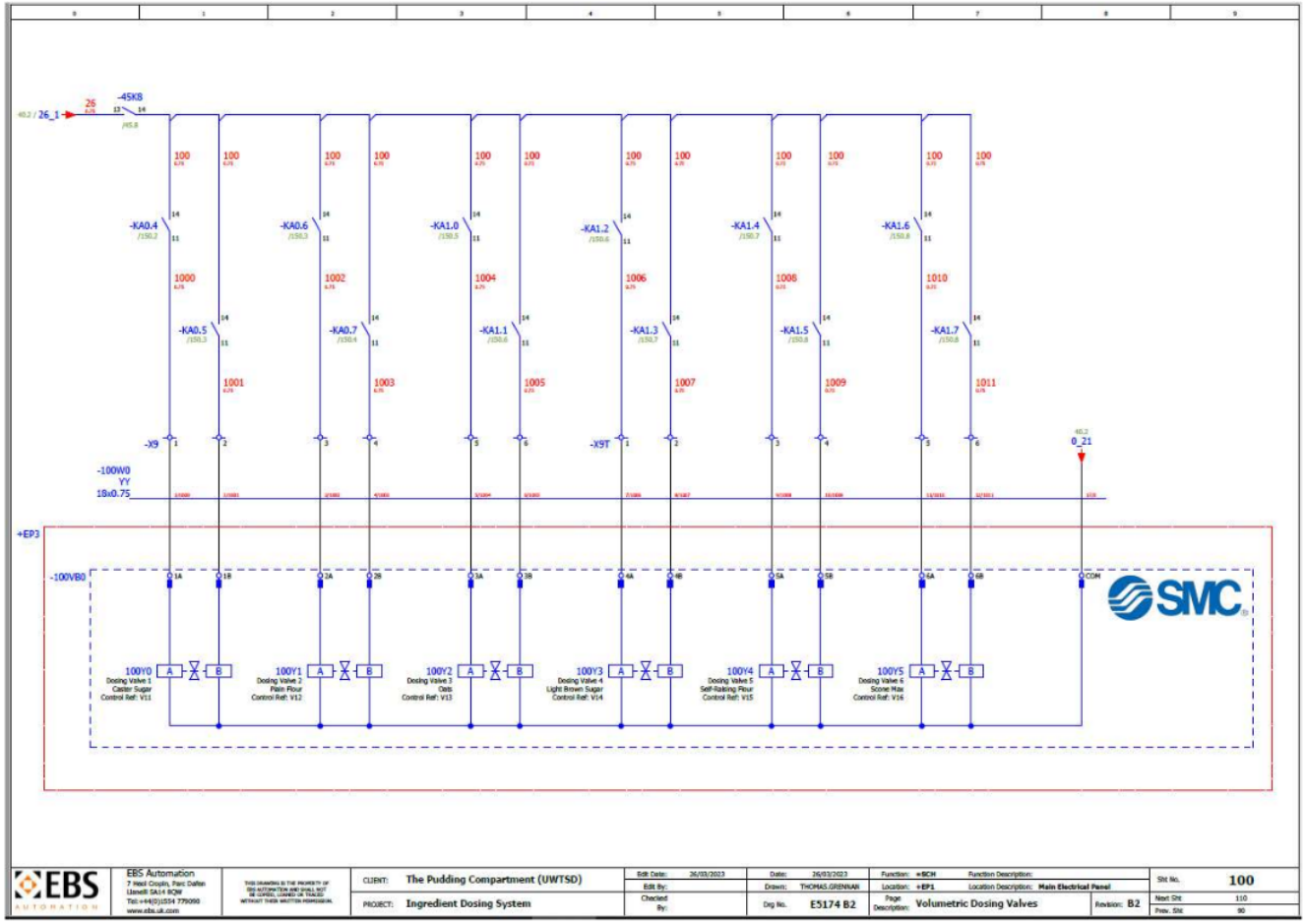


Figure 33 - Electrical Schematics 2nd Stage Valve Manifold (Grennan, 2023)

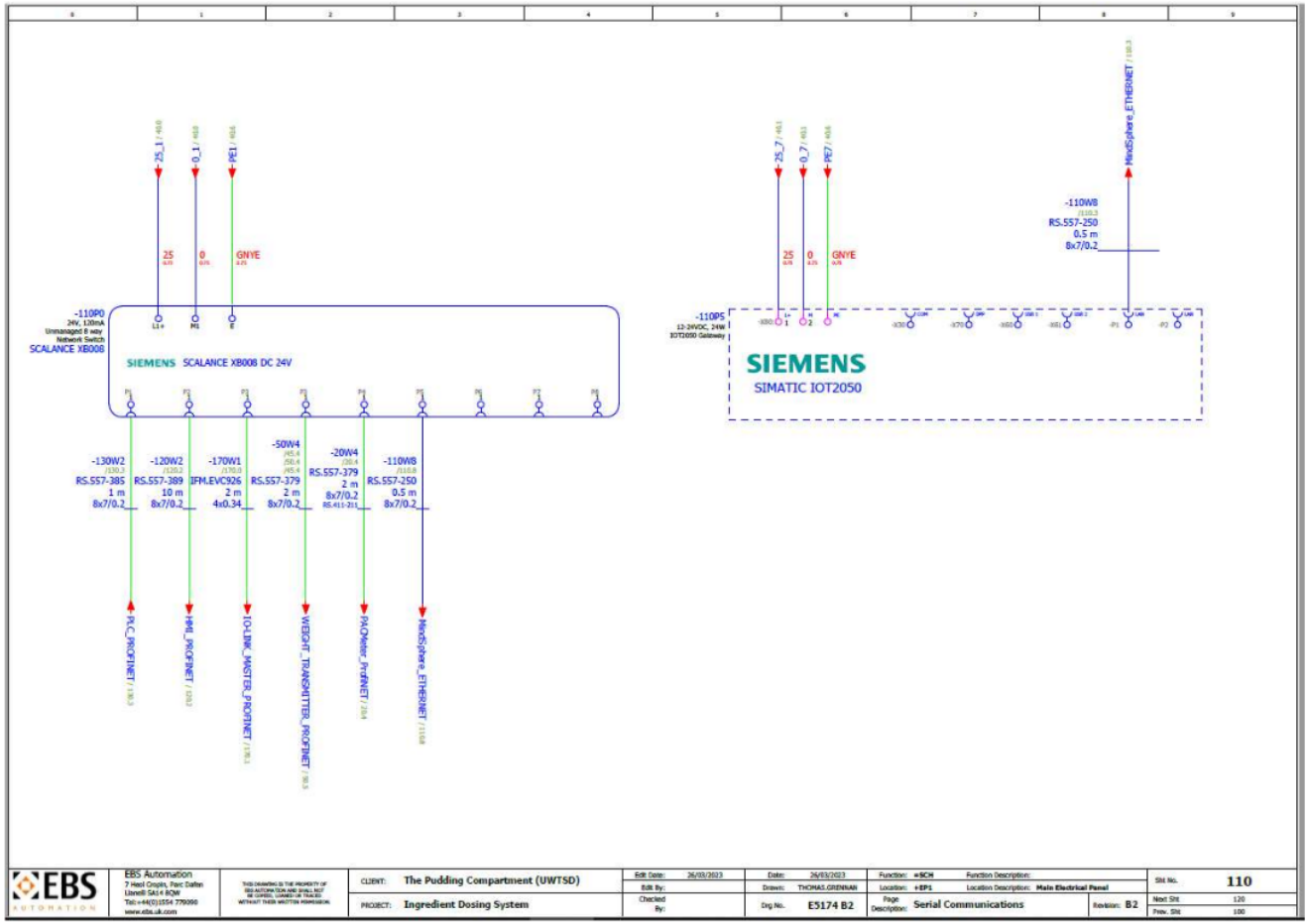


Figure 34 - Electrical Schematics Serial Communications (Grennan, 2023)

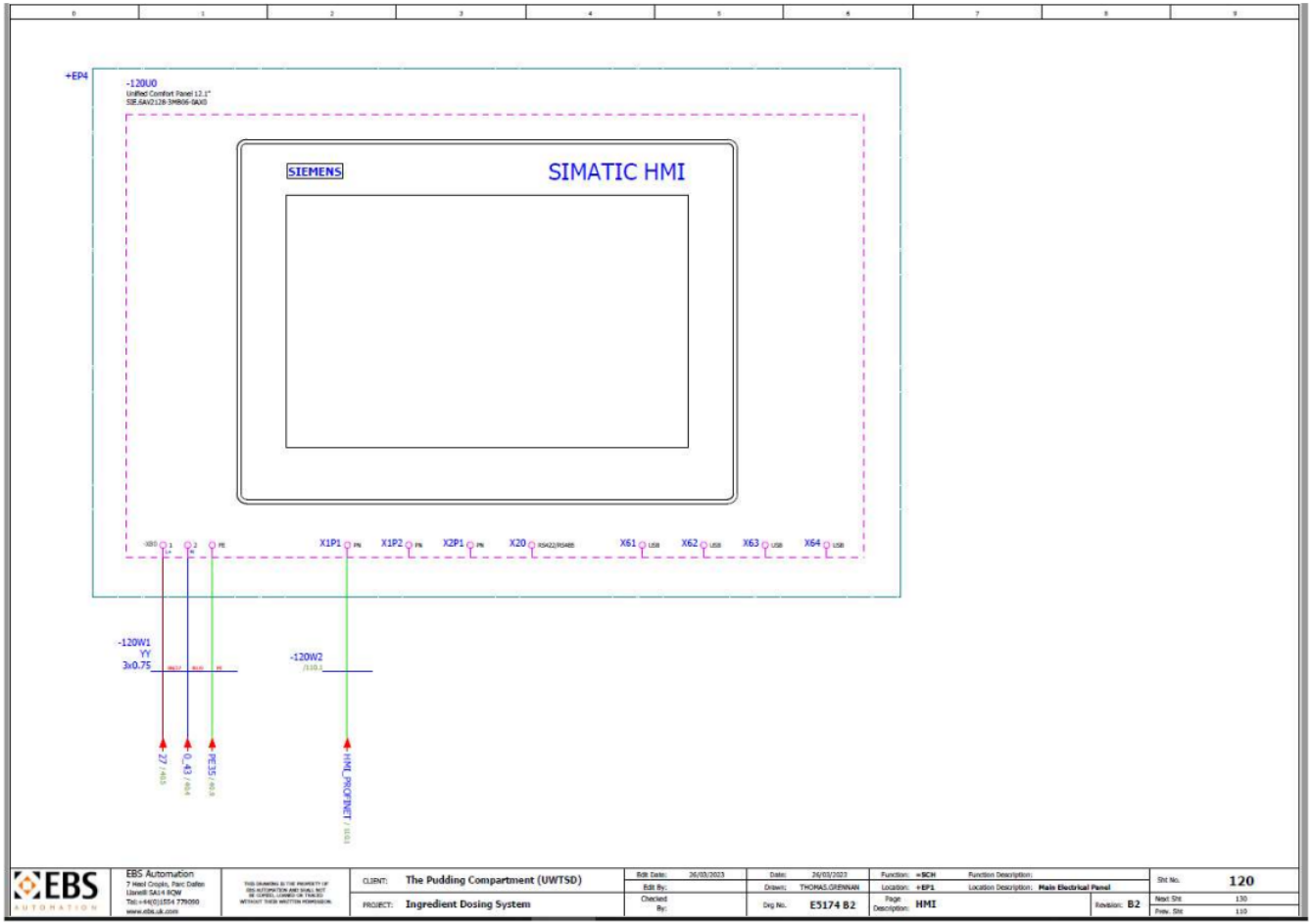


Figure 35 - Electrical Schematics HMI (Grennan, 2023)

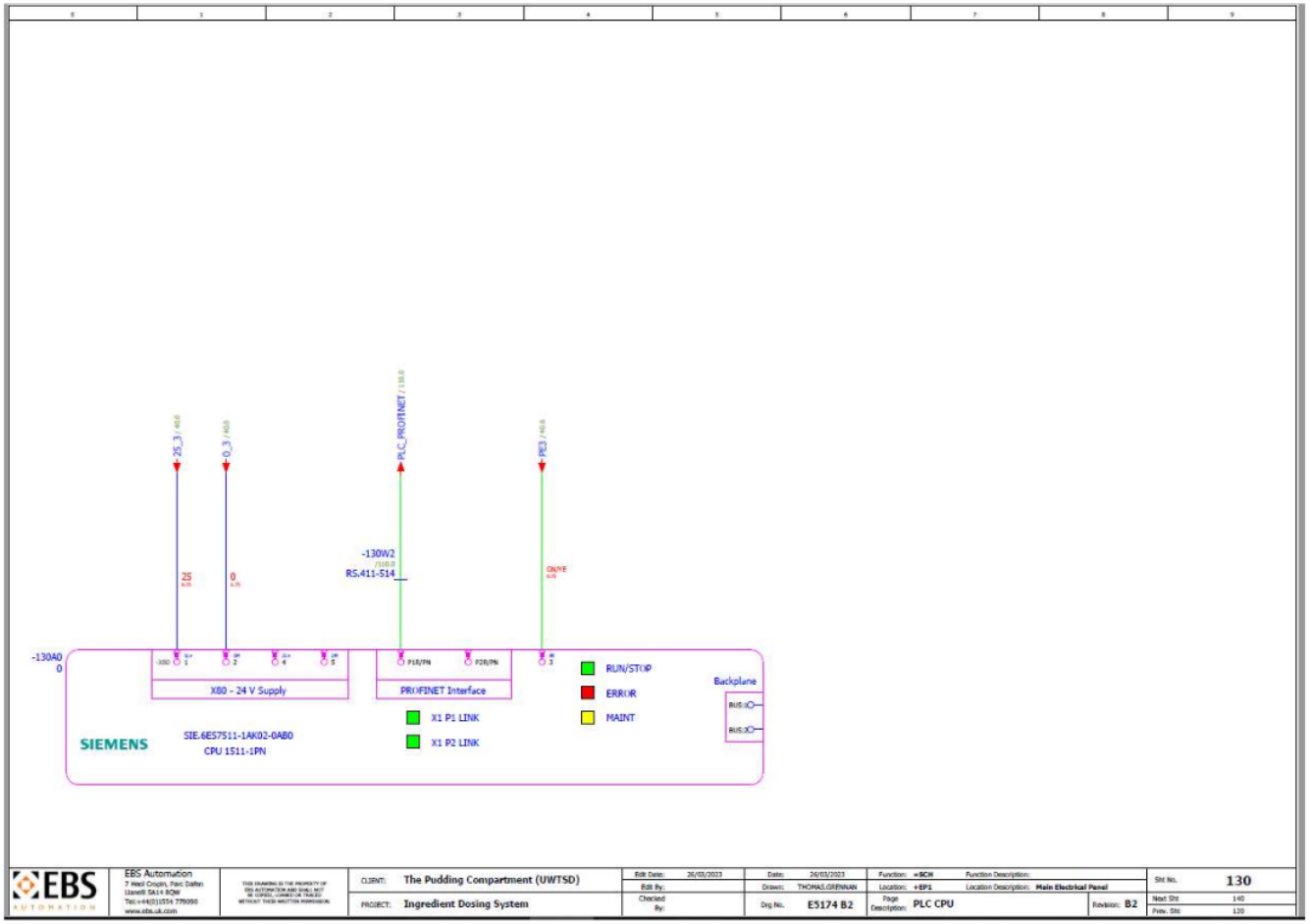


Figure 36 - Electrical Schematics PLC CPU (Grennan, 2023)

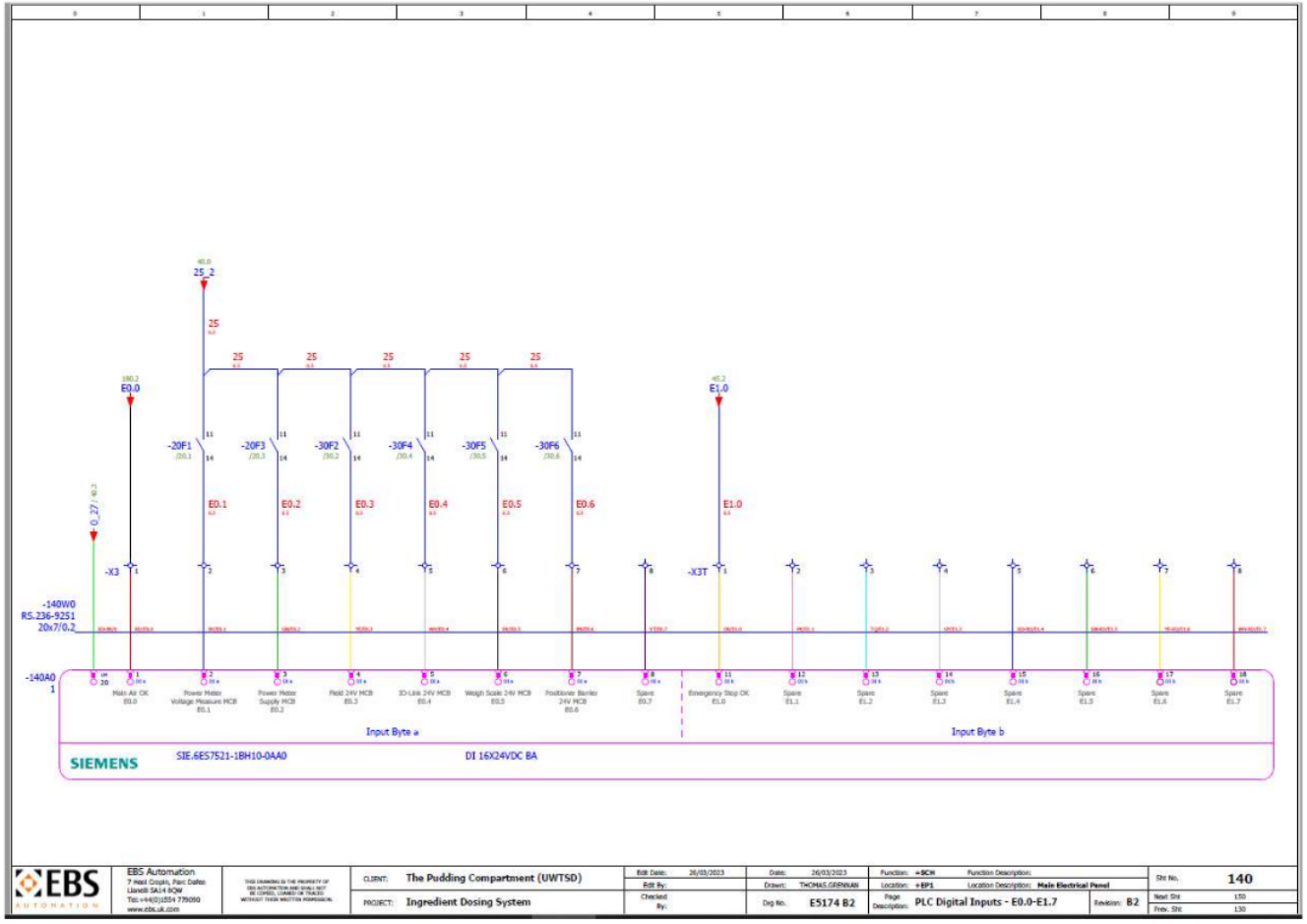


Figure 37 - Electrical Schematics PLC Digital Inputs (Grennan, 2023)

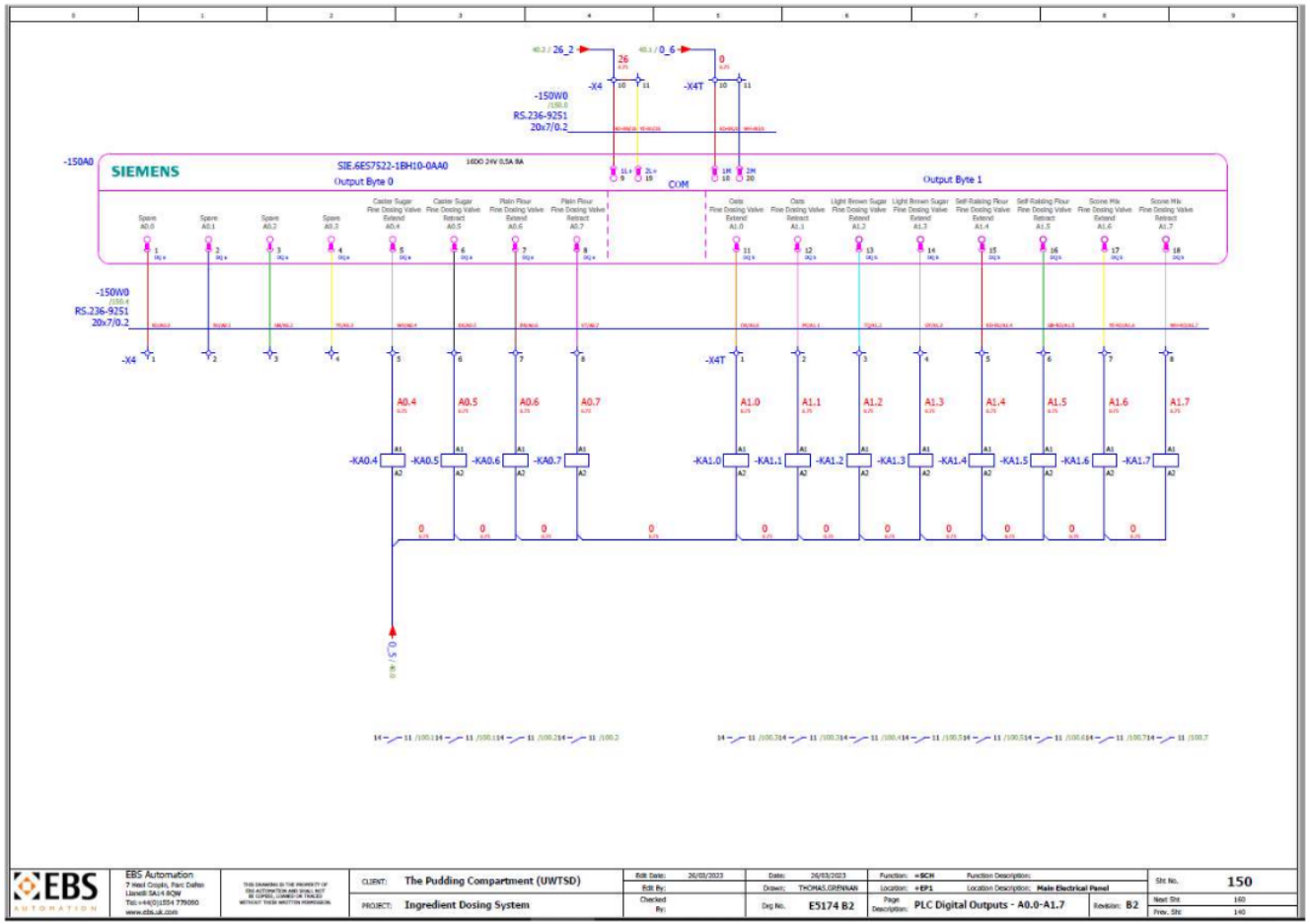


Figure 38 - Electrical Schematics Digital Outputs (Grennan, 2023)

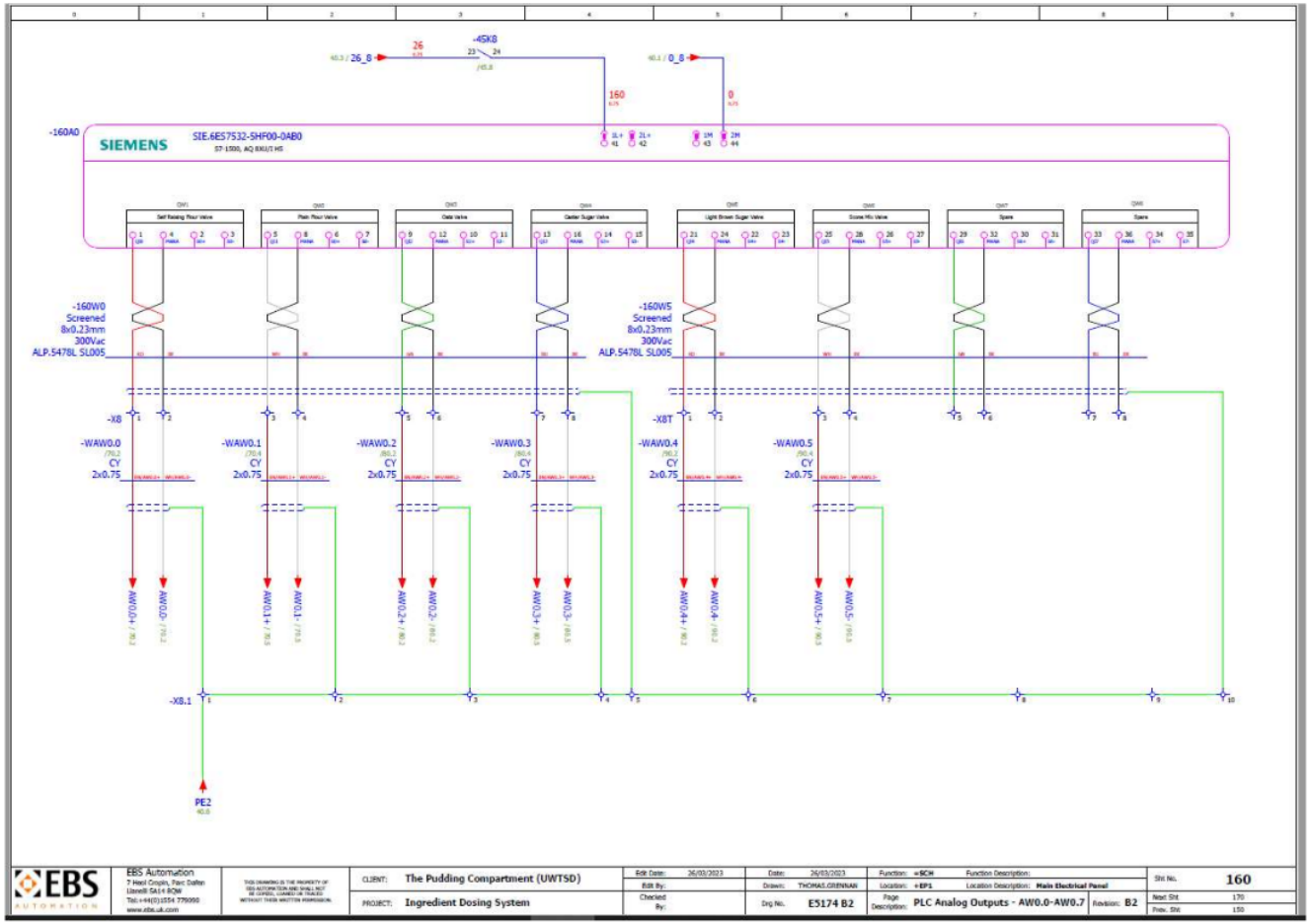


Figure 39 - Electrical Schematics PLC Analog Outputs (Grennan, 2023)

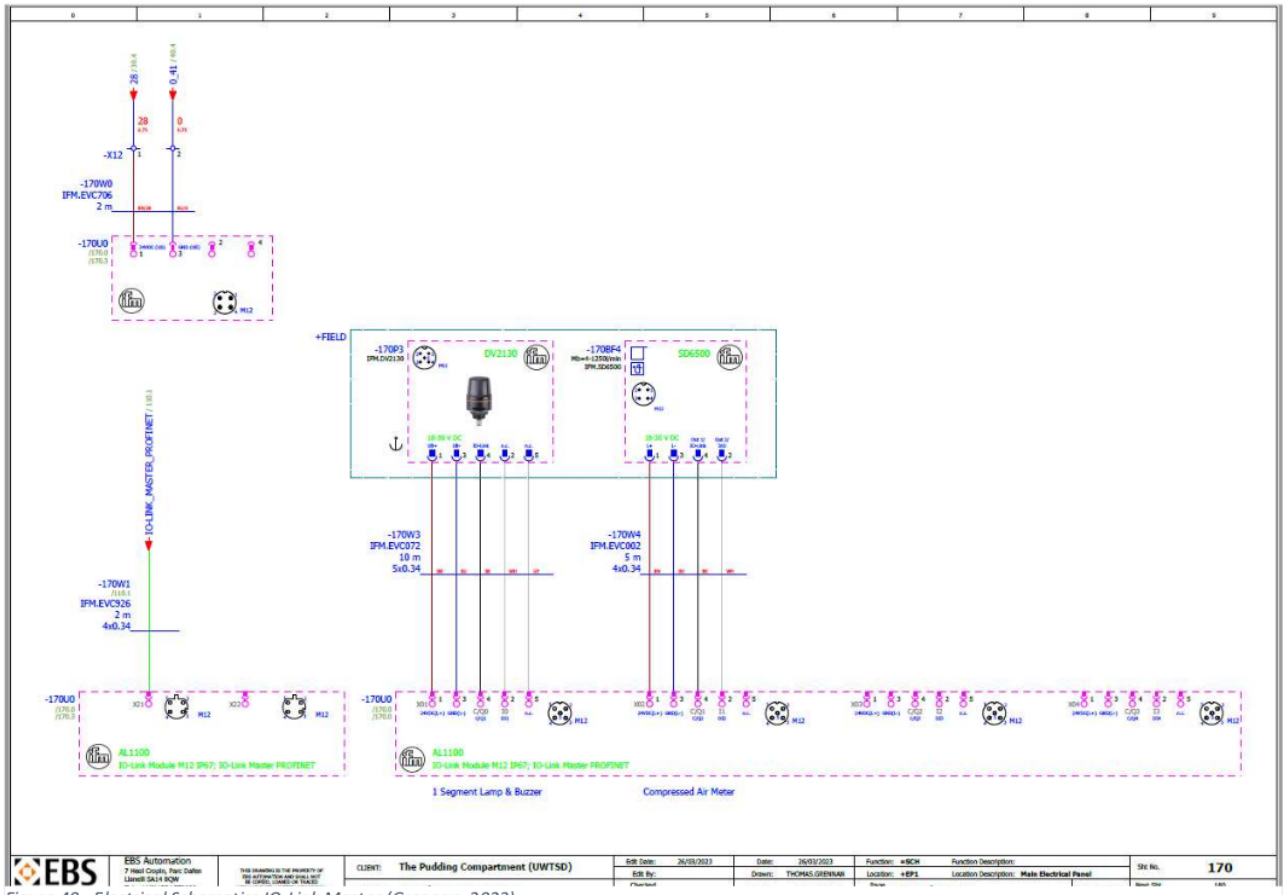


Figure 40 - Electrical Schematics IO-Link Master (Grennan, 2023)

Appendix 9.2.3 – Electrical Safety

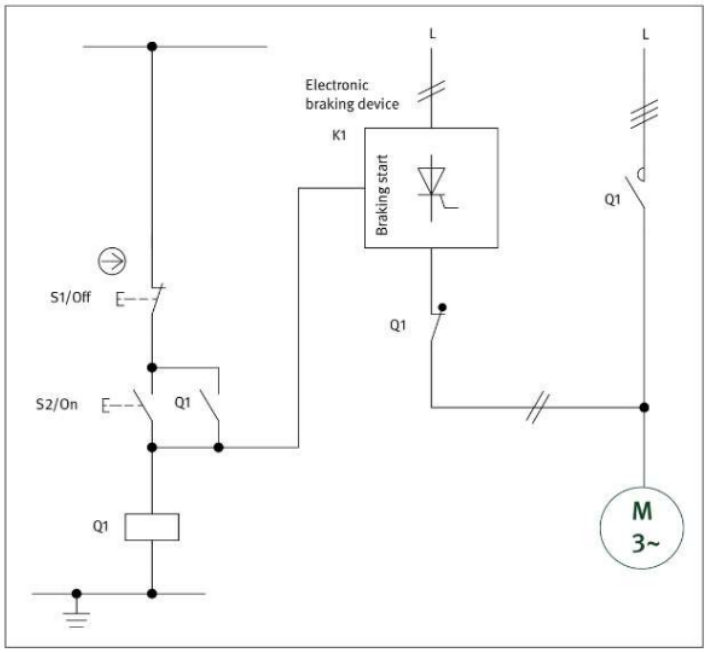


Figure 41 – Category B Architecture Example

The requirements for category B architecture are:

- *"Components used in the safety-related parts of the control system must be designed, manufactured, and tested according to relevant standards.*
- *The control system must be designed so that safety functions are independent of the normal control functions and cannot be easily bypassed.*
- *The control system must have diagnostic features to detect faults in the safety-related parts and provide a warning when a fault is detected.*
- *The control system must have redundancy and diversity to ensure that a single fault in a component or system does not result in loss of the safety function.*
- *The control system must be validated to ensure that it meets the required PL and is suitable for the intended application"* (DGUV, 2017).

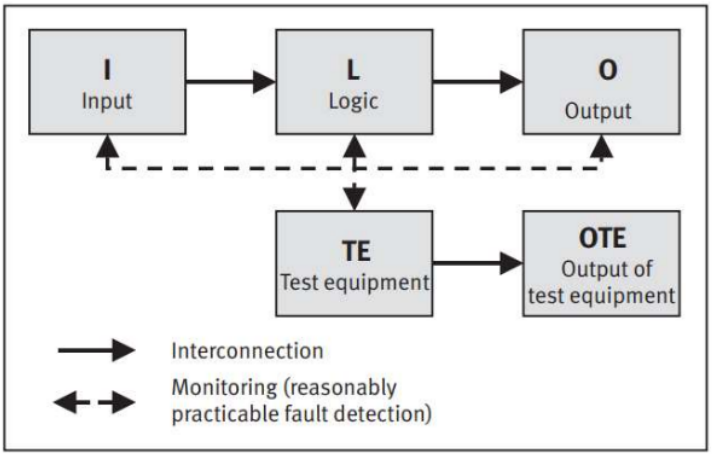


Figure 42 - Category 2 Architecture (DGUV, 2017)

Appendix 9.3 - SISTEMA Report

SISTEMA - Safety Integrity Software Tool for the Evaluation of Machine

Project name: UWTSD 5174

File date: 11/04/2023 08:17:49 Report date: 11/04/2023 Checksum: d3oedc96b5a2c38715490 6f223796a34

PR Project name: UWTSD 5174

Project file name:	C:\Users\Thomas.Grennan\Desktop\Sistema\UWTSD 5174.ssm
Creation date:	19/07/2021 08:27:18
Project status:	
Project number:	
Project version:	
Authors:	Thomas.Grennan
Project managers:	
Inspectors:	
Dangerous point/machine:	
Documentation:	
Document:	
Version of software:	2.0.8 build 4
Version of standard:	ISO 13849-1:2015, ISO 13849-2:2012
Checksum:	d3cedc96b5a2c38715490 6f223796a34
Options:	☑ Use DC intermediate levels for calculation of PFHD (more precise) ☐ MTTFD capping for category 4 lower from 2500 to 100 years.
Status:	green
Note:	There are no warnings listed for this project (or it's subordinate basic elements).

Print options

☑ Show Safety functions ☑ also show Subsystems
☑ also show Blocks ☑ also show Elements

Contained safety functions

SF Name: Emergency Stop
Required: PLr b Reached: PL d PFHD [1/h]: 2.8E-7 Status: green

Contained subsystems

SB Name: SMC AV3000 Series Soft Start
Resulting PL: d PFHD [1/h]: 2.5E-7 Category: 2
MTTFD [a]: 100 (High) DCavg [%]: 93.1 (Medium) CCF Points: 95 (fulfilled)

Contained channels / blocks / Elements

CH Name: Channel 1 (MTTFD [a]: 100)

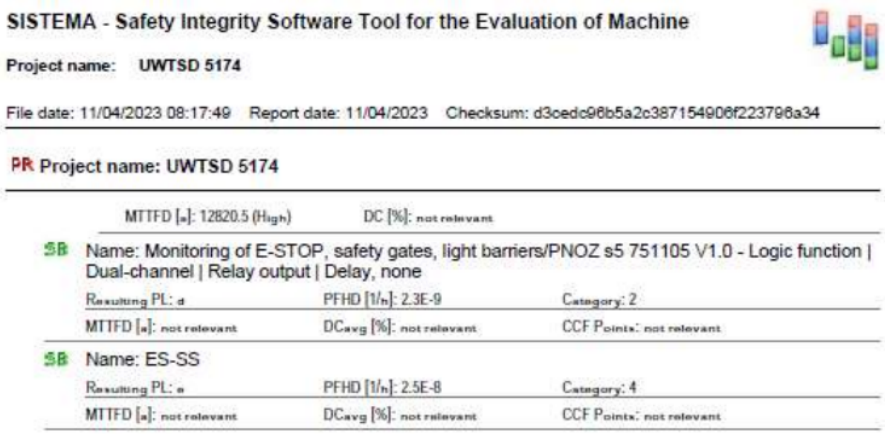
BL Name: SMC AV3000
MTTFD [a]: 859 (High) DC [%]: 90 (Medium)

BL Name: G7SA Omron (IEC 61810-3 Forcibly Guided Relay)
MTTFD [a]: 1666.7 (High) DC [%]: 99 (High)

TE Name: Test channel (MTTFD [a]: 100)

BL Name: Pressure Switch

Figure 43 – SISTEMA Report Part 1


SISTEMA - Safety Integrity Software Tool for the Evaluation of Machine

Project name: UWTSD 5174

File date: 11/04/2023 08:17:49 Report date: 11/04/2023 Checksum: d3cedc96b5a2c38715490f223796a34

PR Project name: UWTSD 5174

MTTFD [a]: 12820.5 (High) DC [%]: not relevant

SB Name: Monitoring of E-STOP, safety gates, light barriers/PNOZ s5 751105 V1.0 - Logic function | Dual-channel | Relay output | Delay, none

Resulting PL: d PFHD [1/h]: 2.3E-9 Category: 2

MTTFD [a]: not relevant DCavg [%]: not relevant CCF Points: not relevant

SB Name: ES-SS

Resulting PL: e PFHD [1/h]: 2.5E-8 Category: 4

MTTFD [a]: not relevant DCavg [%]: not relevant CCF Points: not relevant

Figure 44 – SISTEMA Report Part 2

The number of operations of the safety function is calculated as:

$$n_{op} = \frac{d_{op} \times h_{op} \times 3600/h}{t_{cycle}} = \frac{300 \times 8 \times 3600/h}{3600} = 2400\ Op\ per\ year$$

Appendix 9.4 - Software Development

Appendix 9.4.1 - Empty Sequence Flow Chart

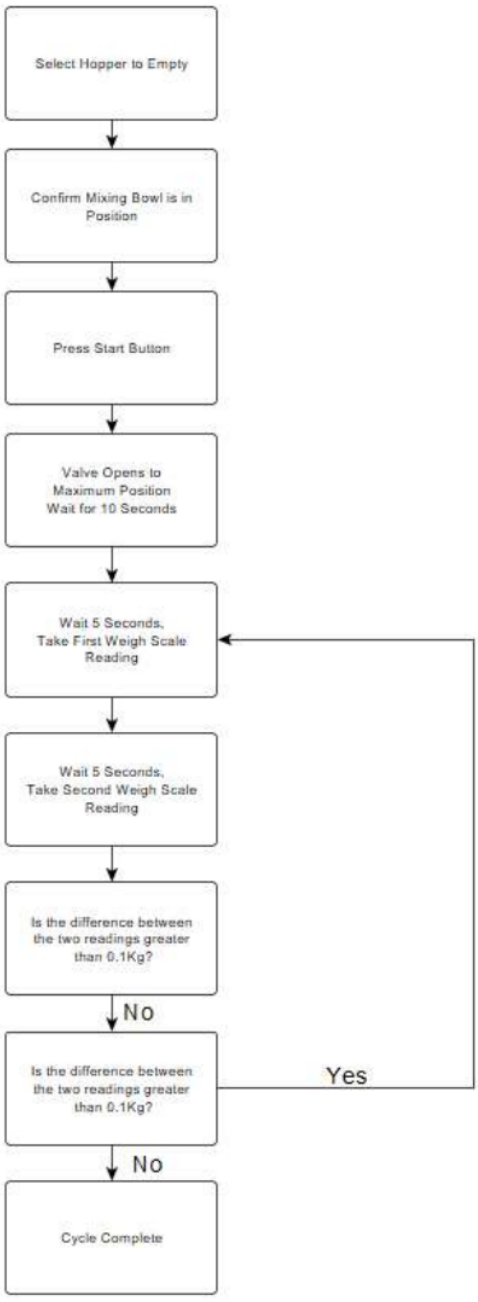


Figure 45 – Empty Sequence Flow Chart

Appendix 9.4.2 - Dispense Amount Sequence Flow Chart

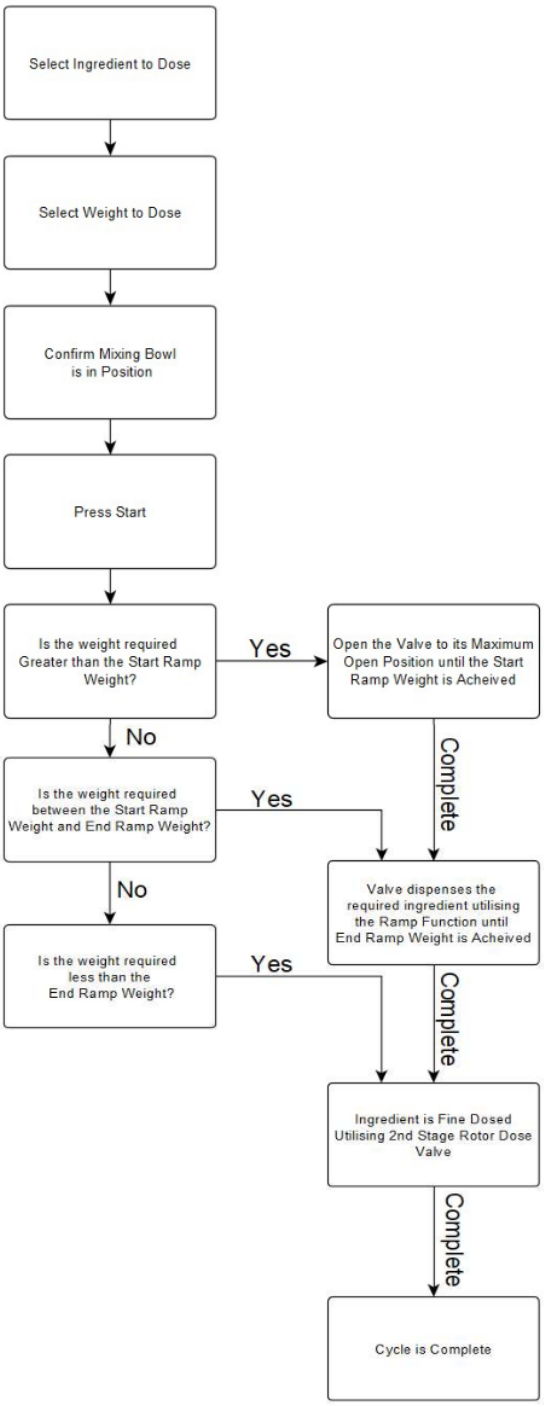


Figure 46 – Dispense Amount Sequence Flowchart

Appendix 9.4.3 - Recipe Sequence Flow Chart

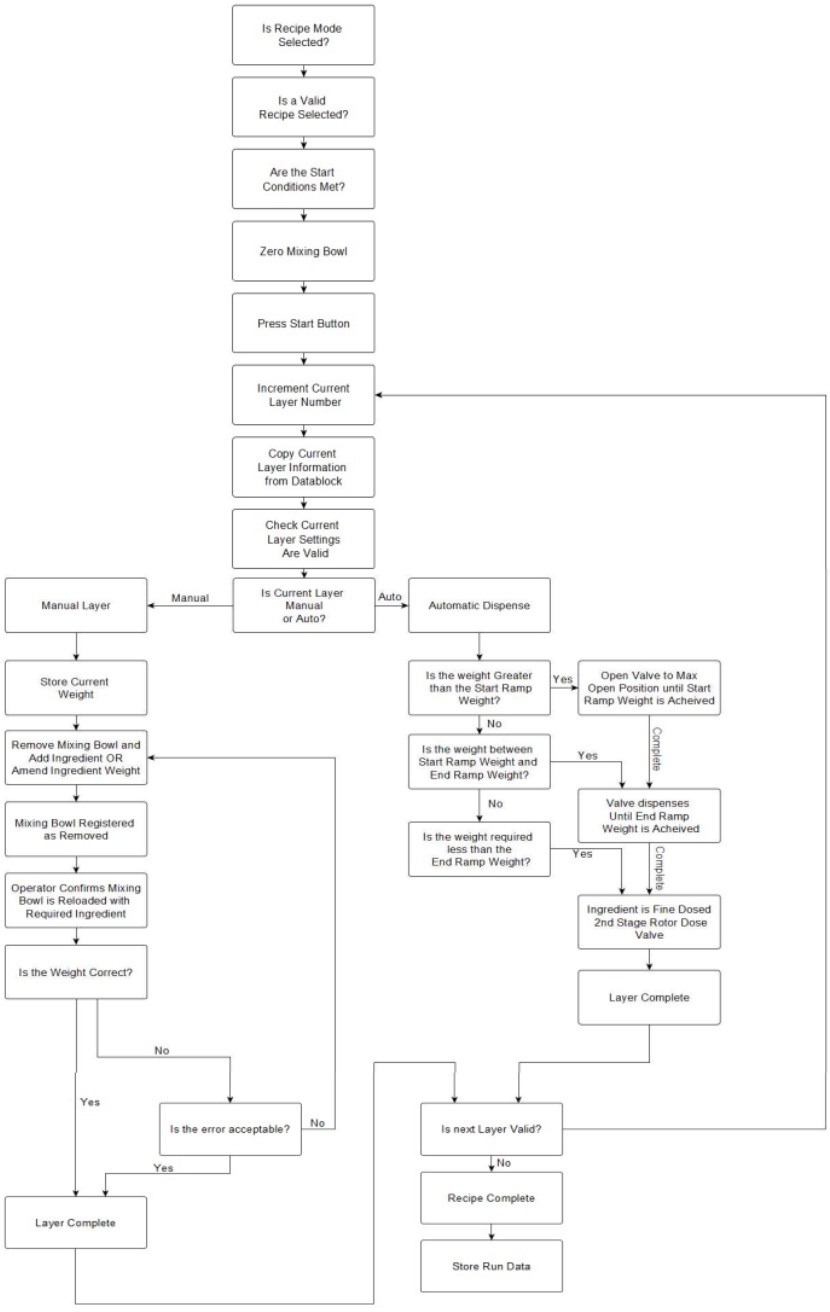


Figure 47 – Recipe Mode Sequence Flow Chart

Appendix 9.4.4 - HMI Architecture

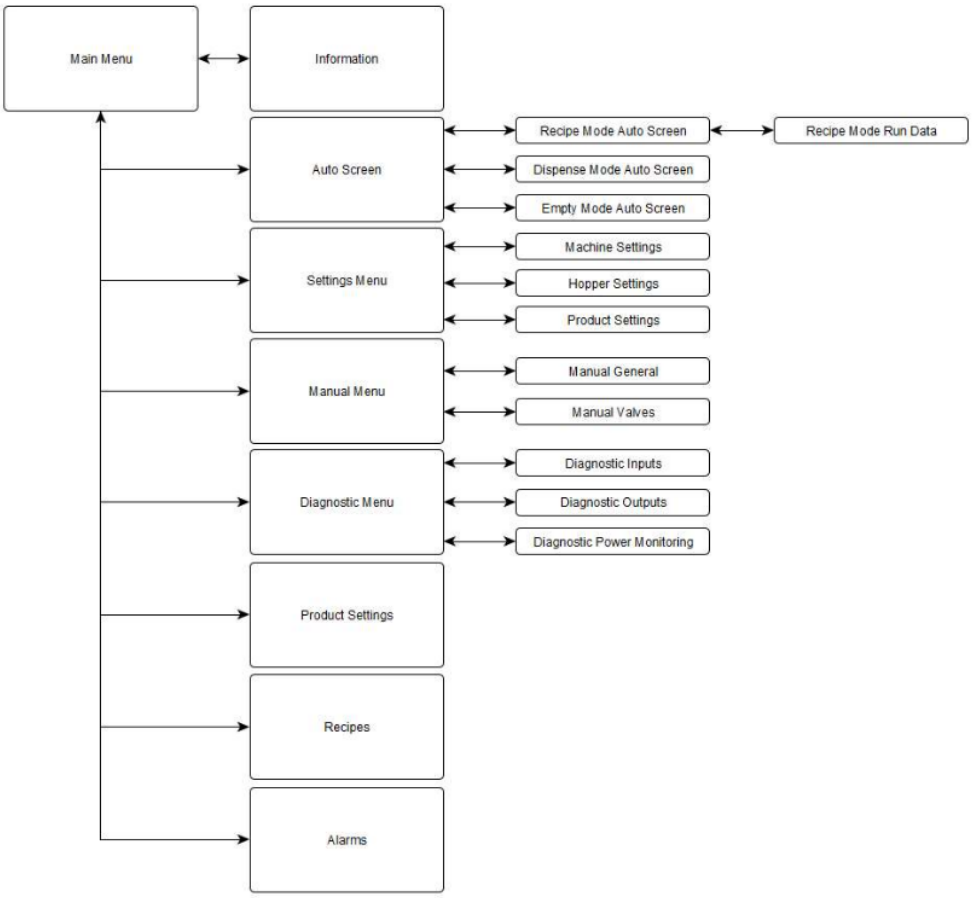


Figure 48 – HMI Screen Layout Architecture

Appendix 9.5 - PLC Software

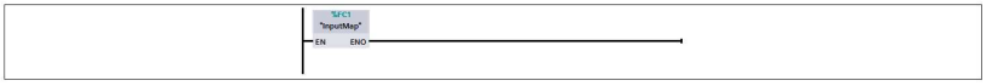
Appendix 9.5.1 – Organization Block

Main [OB1]

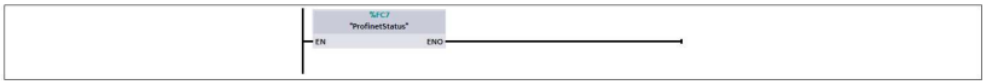
Main Properties							
General							
Name	Main	**Number**	1	**Type**	OB	**Language**	LAD
Numbering	Automatic						
Information							
Title	"Main Program Sweep (Cycle)"	**Author**		**Comment**		**Family**	
Version	0.1	**User-defined ID**					

Name	Data type	Default value	Comment
Input			
Initial_Call	Bool		Initial call of this OB
Remanence	Bool		=True, if remanent data are available
Temp			
Constant			

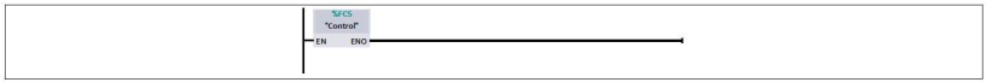
Network 1: Input Map



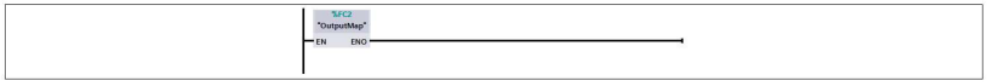
Network 2: Profinet Status



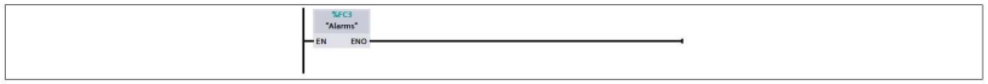
Network 3: Control



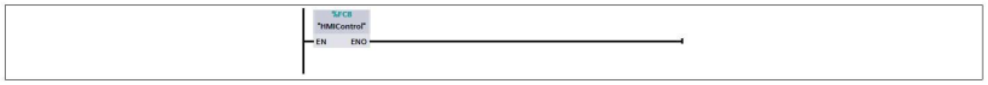
Network 4: Output Map



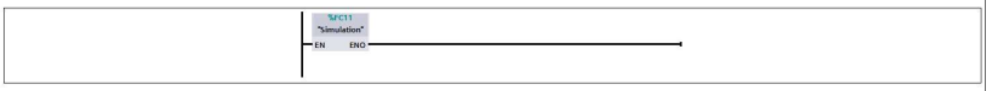
Network 5: Alarms



Network 6: HMI Control



Network 7: Simulation

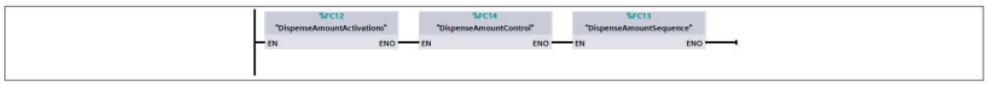


Network 8: Empty Mode

Figure 49 – PLC Software Organization Block



Network 9: Dispense Amount Mode



Network 10: Recipe Mode



Figure 50 - PLC Software Organization Block

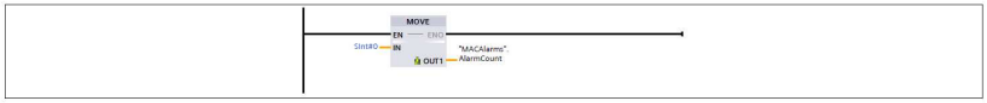
Appendix 9.5.2 – Alarms

Alarms [FC3]

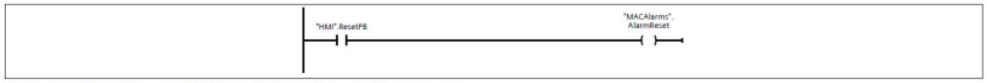
Alarms Properties							
General							
Name	Alarms	Number	3	Type	FC	Language	LAD
Numbering	Automatic						
Information							
Title		Author		Comment		Family	
Version	0.1	User-defined ID					

Name	Data type	Default value	Comment
Input			
Output			
InOut			
Temp			
Constant			
▼ Return			
Alarms	Void		

Network 1: Alarms Count Clear



Network 2: Alarms Reset



Network 3: MAC Alarm 1 - PAC Meter Voltage Measure MCB Tripped

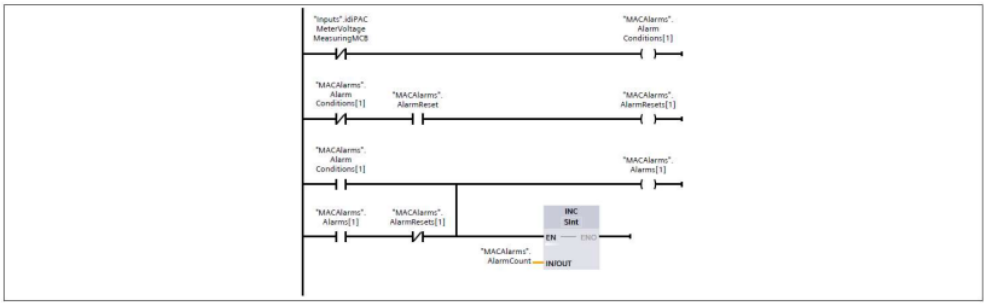
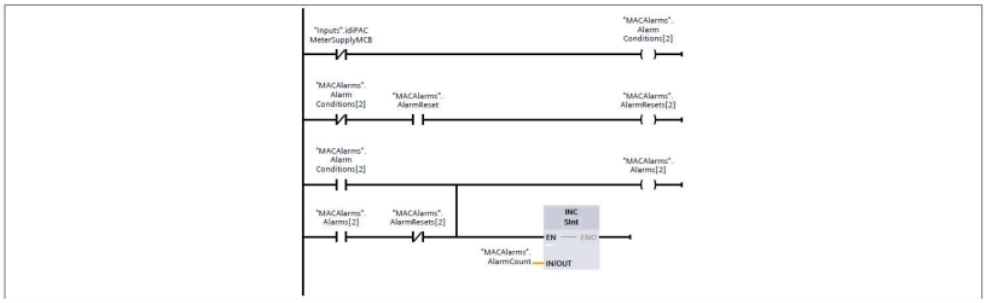
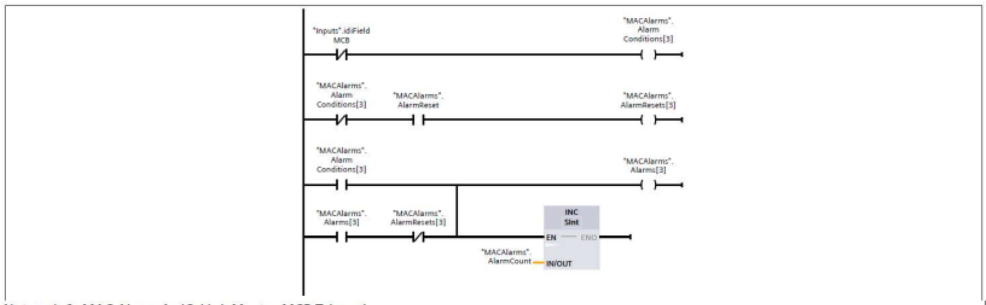


Figure 51 - PLC Software Alarm Function Call

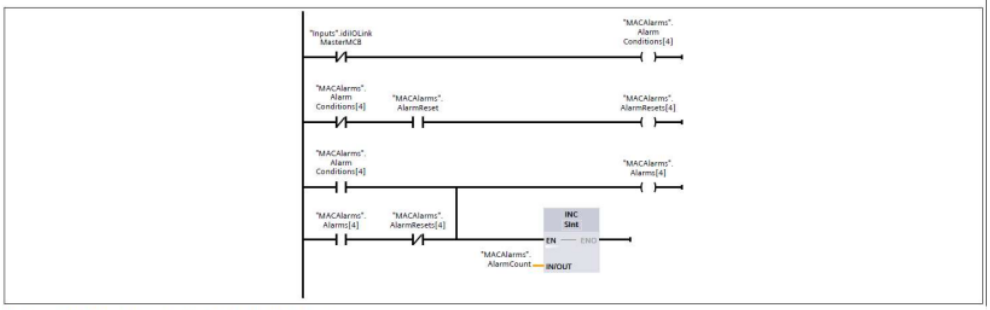
Network 4: MAC Alarm 2 - PAC Meter Voltage Supply MCB Tripped



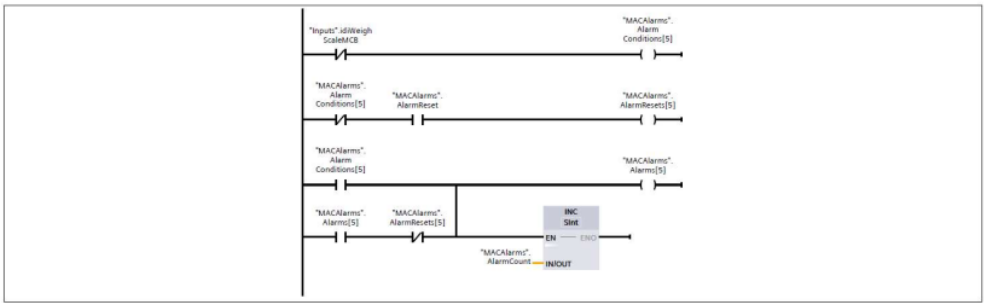
Network 5: MAC Alarm 3 - Field Supply MCB Tripped



Network 6: MAC Alarm 4 - IO-Link Master MCB Tripped

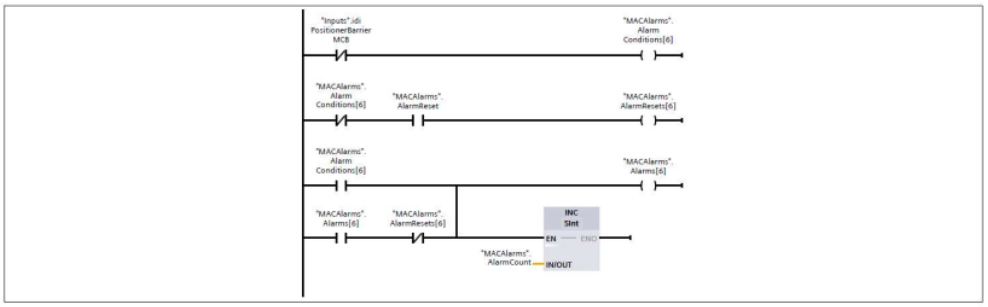


Network 7: MAC Alarm 5 - Weigh Scale MCB Tripped

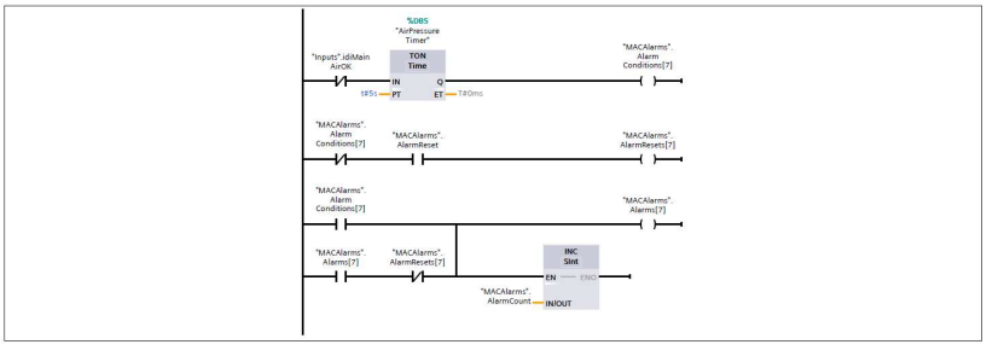


Network 8: MAC Alarm 6 - Positioner Valve Intrinsic Barrier MCB Tripped

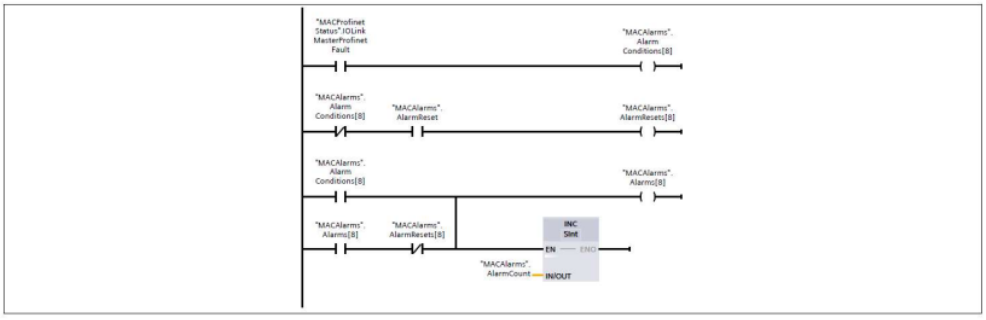
Figure 50 - PLC Software Alarm Function Call



Network 9: MAC Alarm 7 - Main Air Pressure too Low



Network 10: MAC Alarm 8 - IO-Link Master Communication Fault



Network 11: MAC Alarm 9 - Light Tower Communication Fault

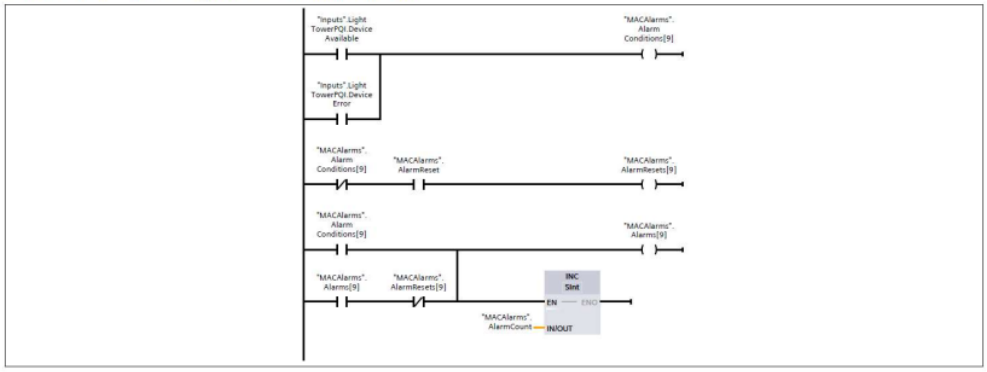
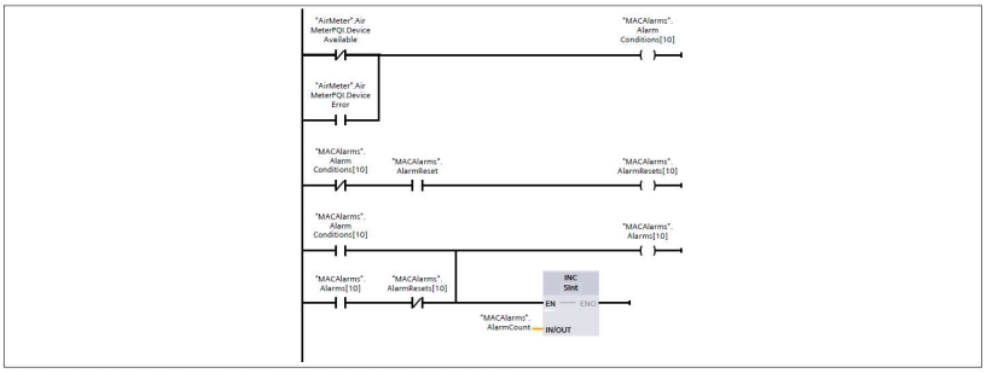
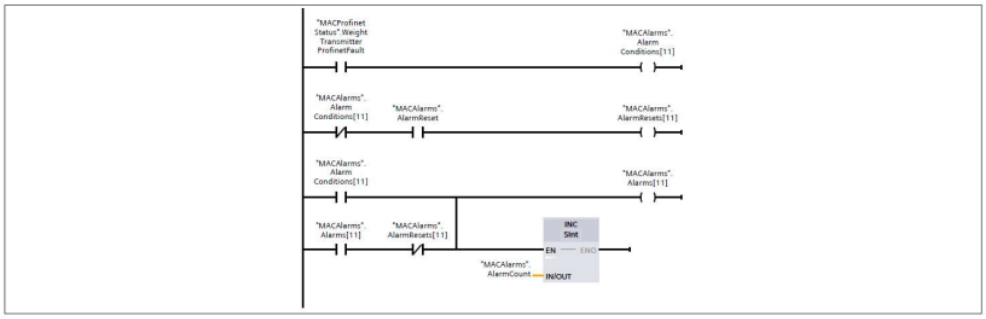


Figure 51 - PLC Software Alarm Function Call

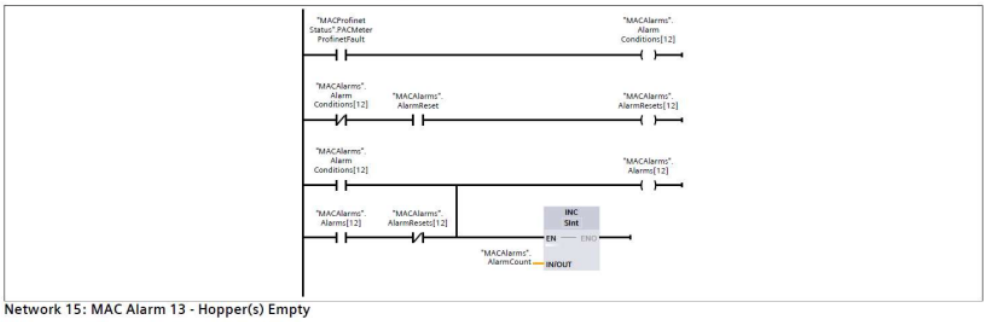
Network 12: MAC Alarm 10 - Compressed Air Meter Communication Fault



Network 13: MAC Alarm 11 - Weigh Scale Transmitter Communication Fault



Network 14: MAC Alarm 12 - PAC Meter Communication Fault



Network 15: MAC Alarm 13 - Hopper(s) Empty

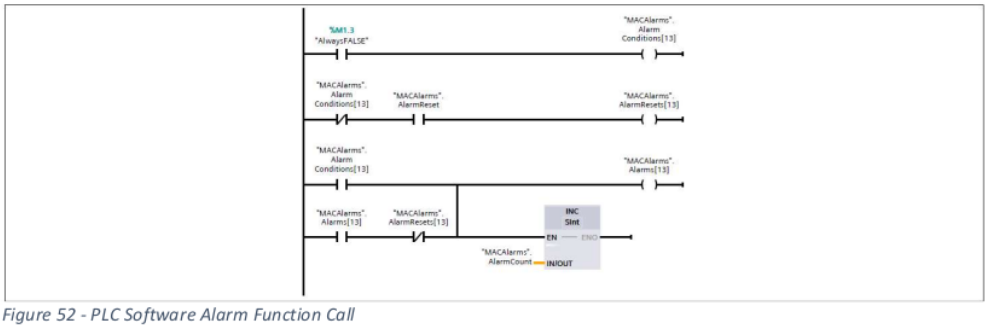
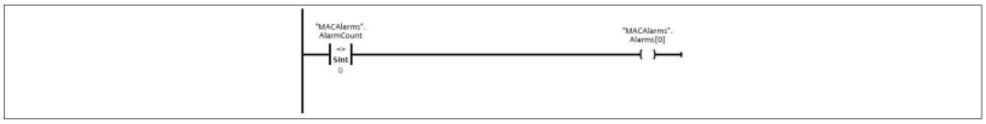


Figure 52 - PLC Software Alarm Function Call

Network 16: Is there an Alarm?

If the Alarm count is not equal to 0, there is an active alarm



Network 17: Alarm Present

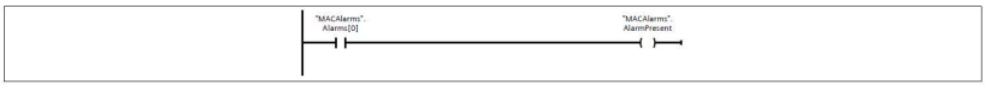
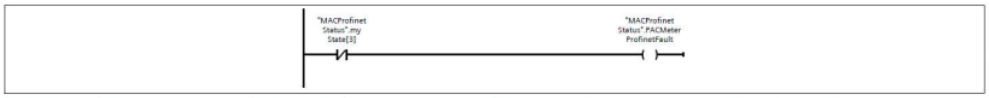


Figure 53 - PLC Software Alarm Function Call

Appendix 9.5.3 – Profinet Device Status

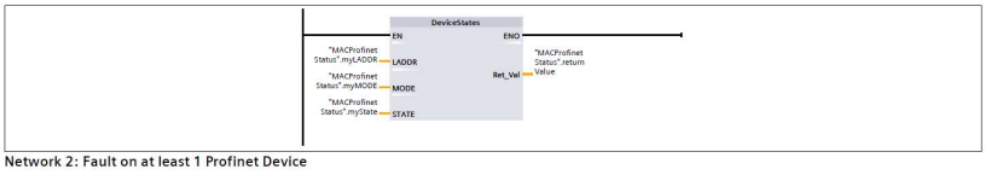
Network 5: Profinet Fault on PAC Meter



Version	0.1	User-defined ID	

Name	Data type	Default value	Comment
Input			
Output			
InOut			
Temp			
Constant			
▼ Return			
ProfinetStatus	Void		

Network 1: Profinet Status



Network 2: Fault on at least 1 Profinet Device



Network 3: Profinet Fault on Weight Transmitter



Network 4: Profinet Fault on IO-Link Master

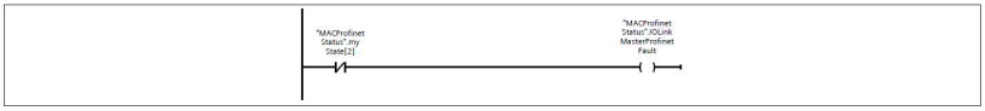


Figure 54 - PLC Software Profinet Device States Function Call

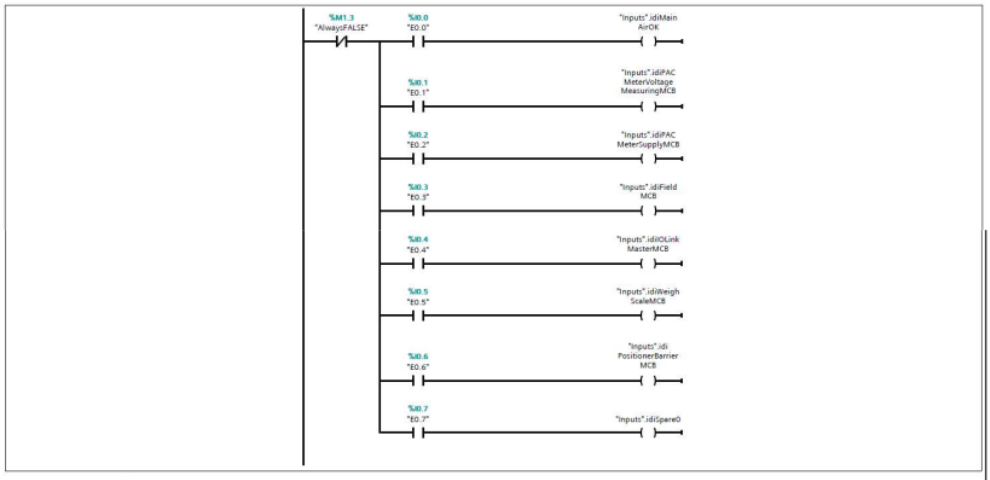
Appendix 9.5.4 – Input Map

InputMap [FC1]

InputMap Properties							
General							
Name	InputMap	**Number**	1	**Type**	FC	**Language**	LAD
Numbering	Automatic						
Information							
Title		**Author**		**Comment**		**Family**	
Version	0.1	**User-defined ID**					

Name	Data type	Default value	Comment
Input			
Output			
InOut			
Temp			
Constant			
▼ Return			
InputMap	Void		

Network 1: Input Byte 0



Network 2: Input Byte 1

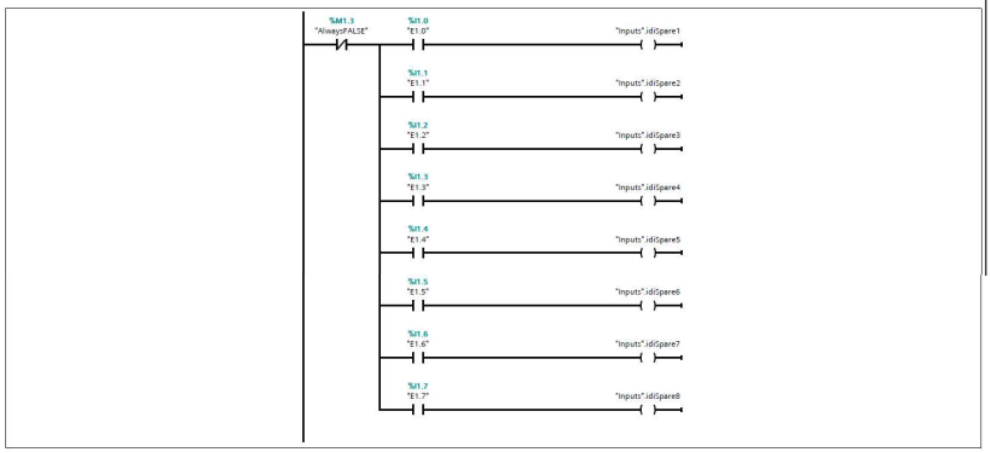
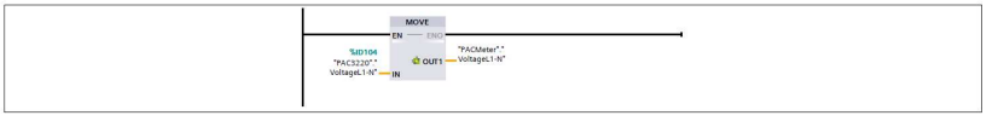
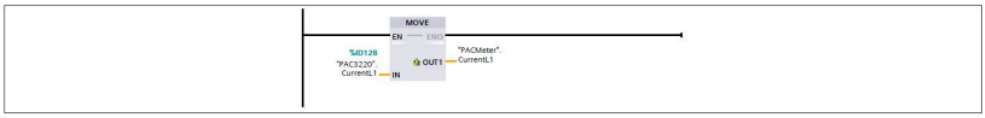


Figure 55 - PLC Input Map Function Call

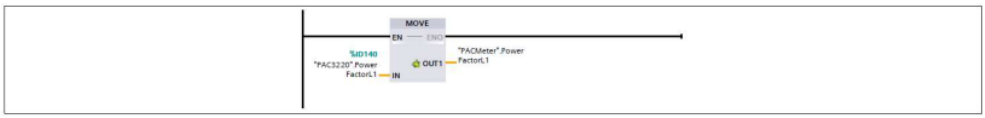
Network 3: PAC Meter Voltage L1-N



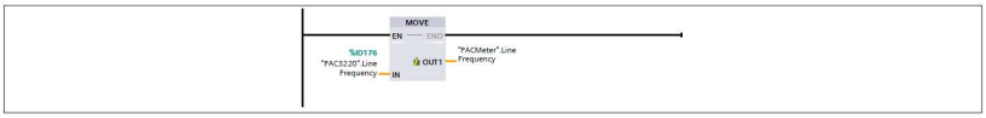
Network 4: PAC Meter Current L1-N



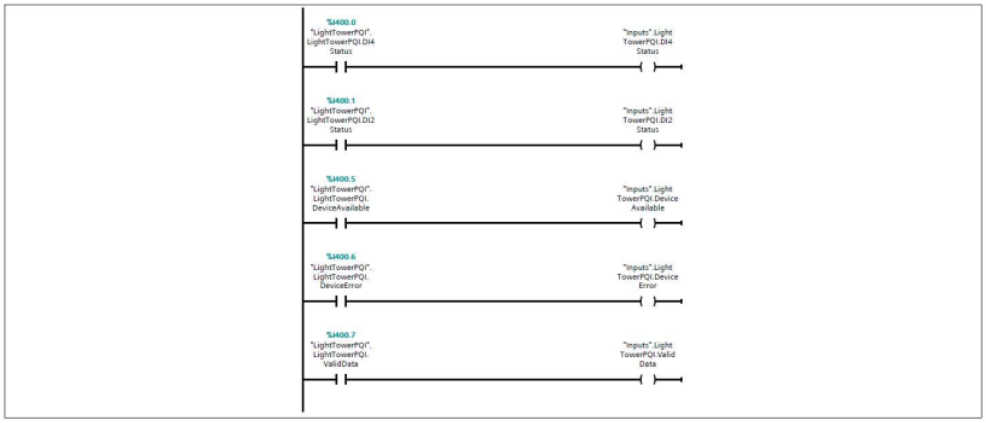
Network 5: PAC Meter Power Factor L1



Network 6: PAC Meter Line Frequency



Network 7: Light Tower Port Qualifier Information (PQI)



Network 8: Air Meter Totaliser

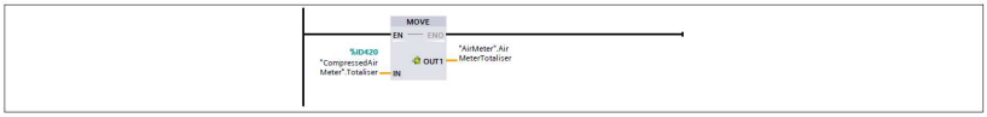
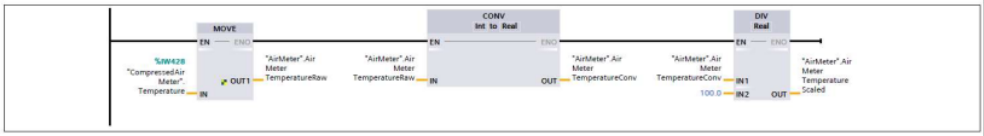


Figure 56 – PLC Input Map Function Call

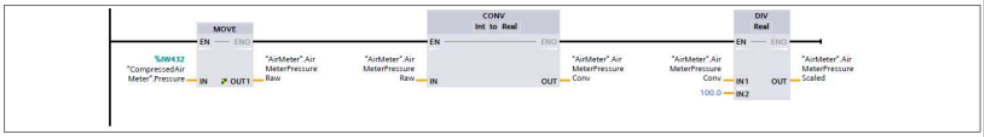
Network 9: Air Meter Flow



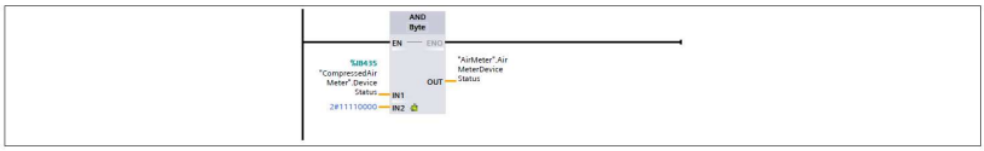
Network 10: Air Meter Temperature



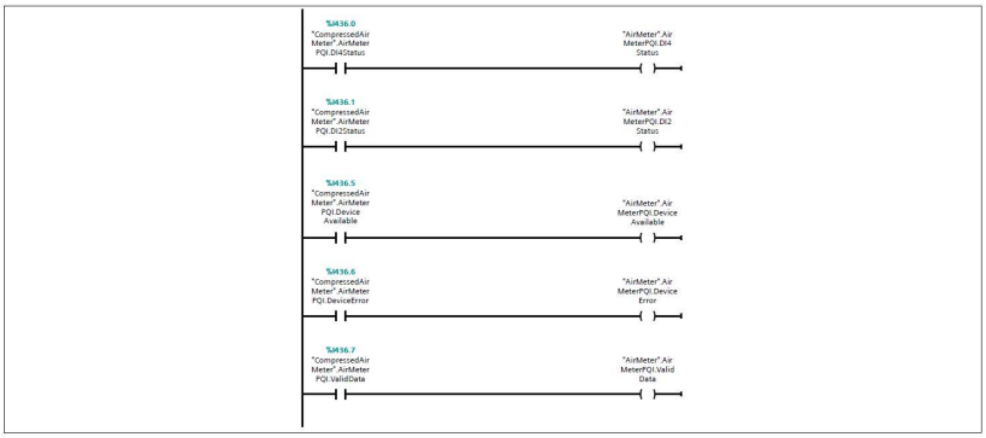
Network 11: Air Meter Pressure



Network 12: Air Meter Device Status



Network 13: Air Meter Port Qualifier Information (PQI)



Network 14: Weigh Scale Converted to Real

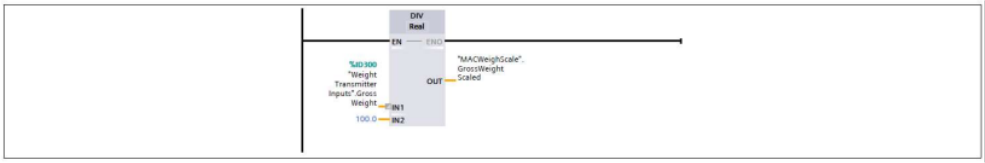
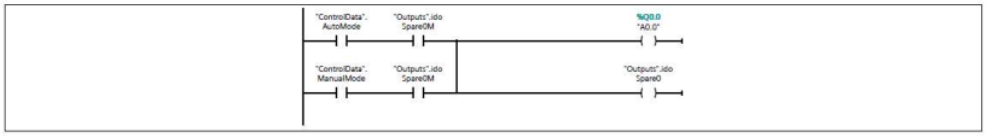


Figure 57 – PLC Input Map Function Call

Appendix 9.5.5 – Output Map

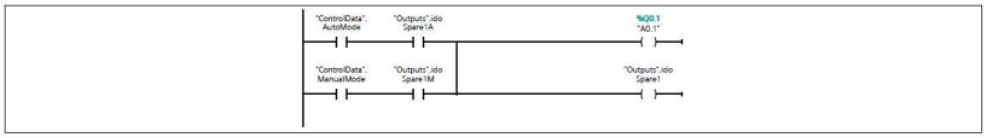
Network 1: Output A0.0

Spare



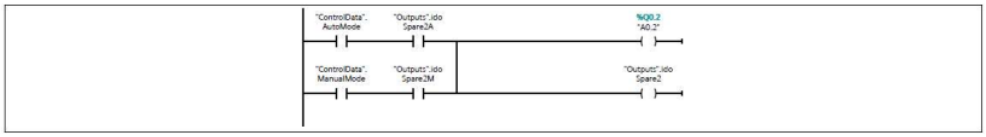
Network 2: Output A0.1

Spare



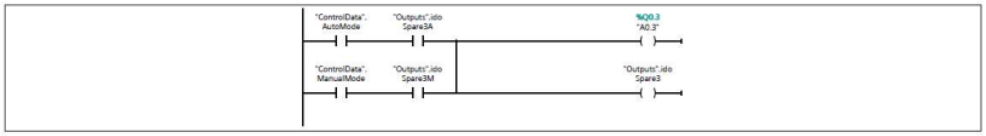
Network 3: Output A0.2

Spare



Network 4: Output A0.3

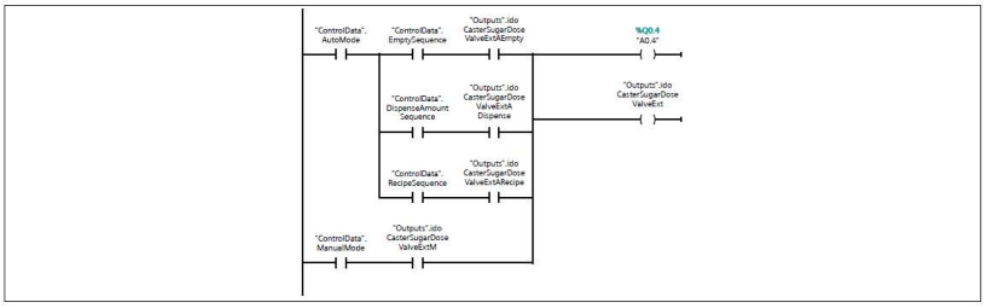
Spare



Network 5: Output A0.4

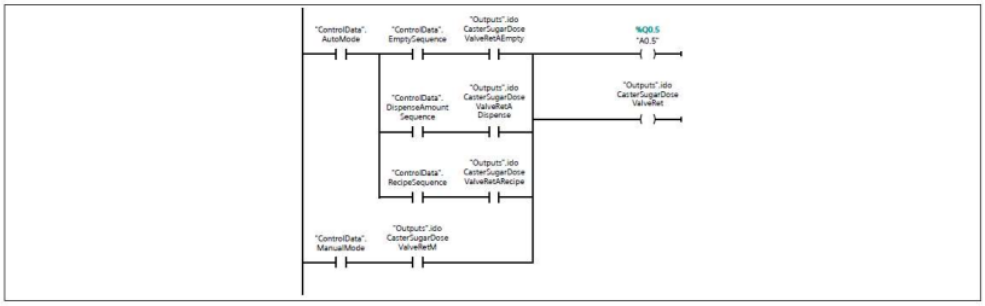
Caster Sugar Dosing Valve Extend

Figure 58 – PLC Output Map Function Call



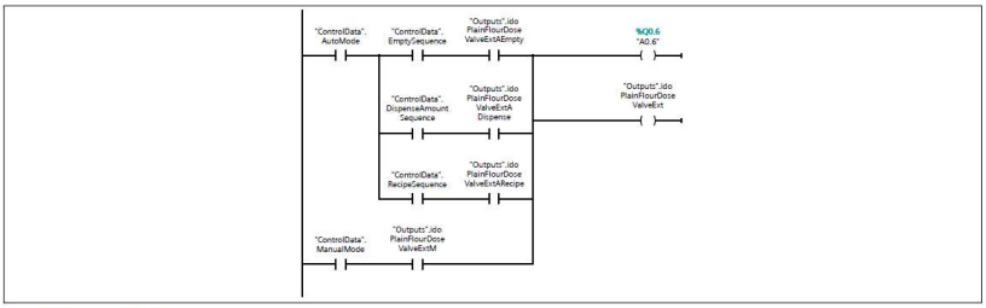
Network 6: Output A0.5

Caster Sugar Dosing Valve Retract



Network 7: Output A0.6

Plain Flour Dosing Valve Extend



Network 8: Output A0.7

Plain Flour Dosing Valve Retract

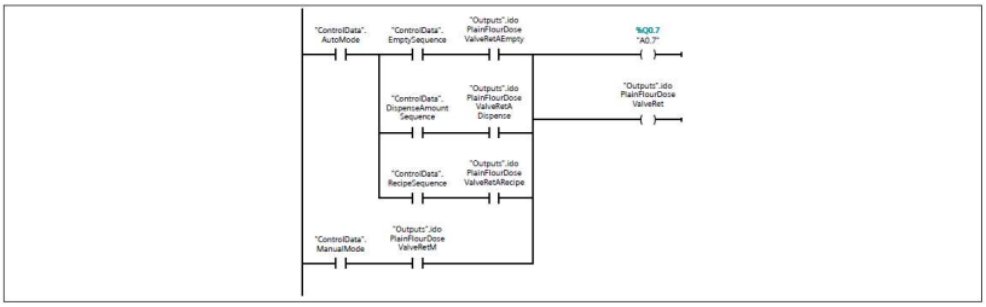
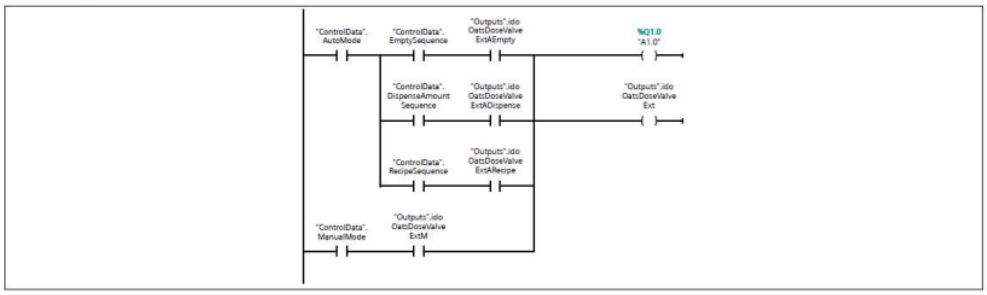


Figure 59 – PLC Output Map Function Call

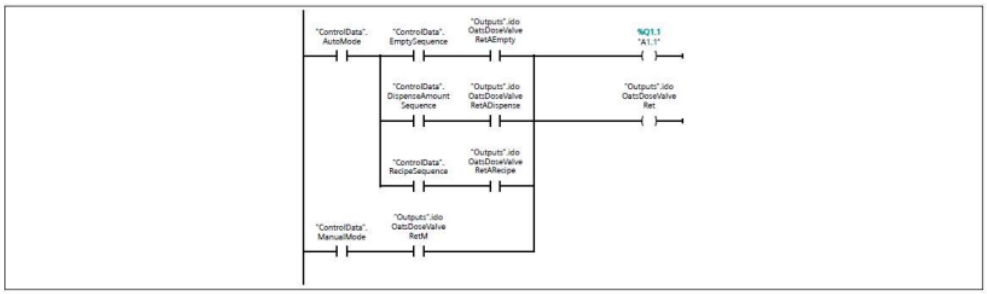
Network 9: Output A1.0

Oats Dosing Valve Extend



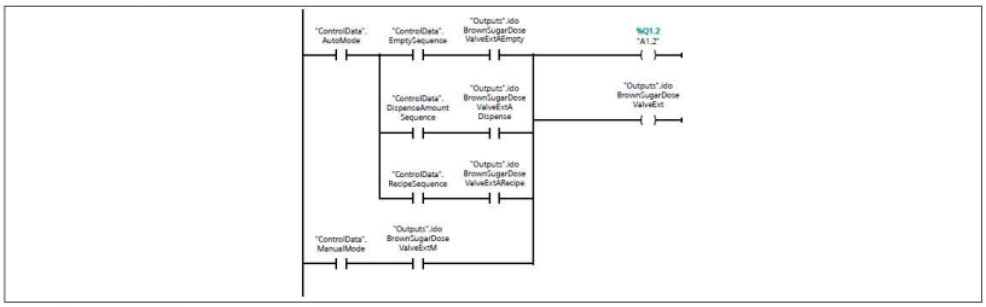
Network 10: Output A1.1

Oats Dosing Valve Retract



Network 11: Output A1.2

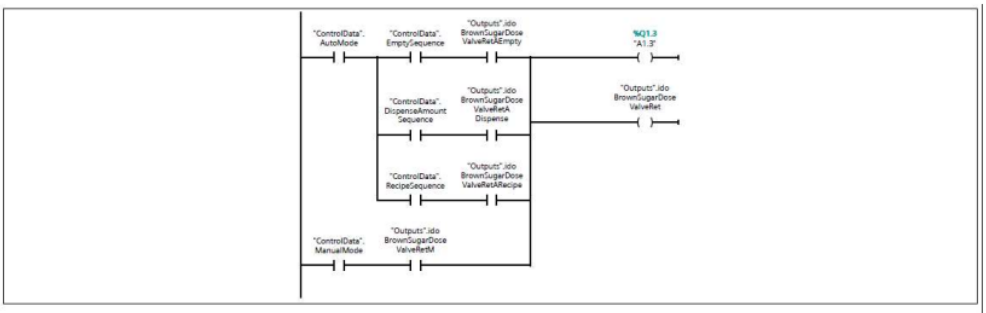
Light Brown Sugar Dosing Valve Extend



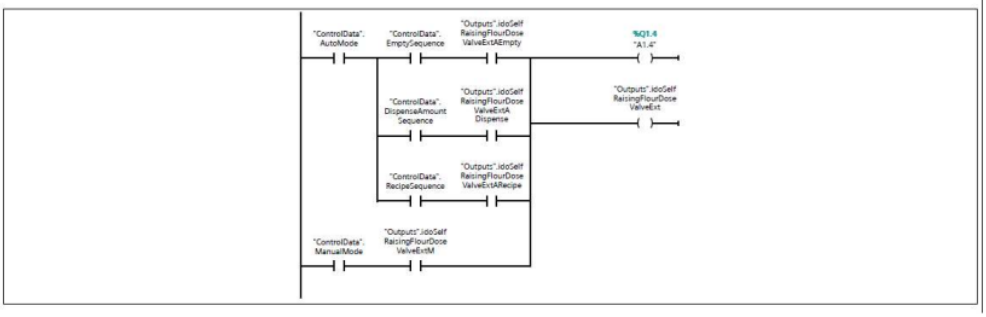
Network 12: Output A1.3

Light Brown Sugar Dosing Valve Extend

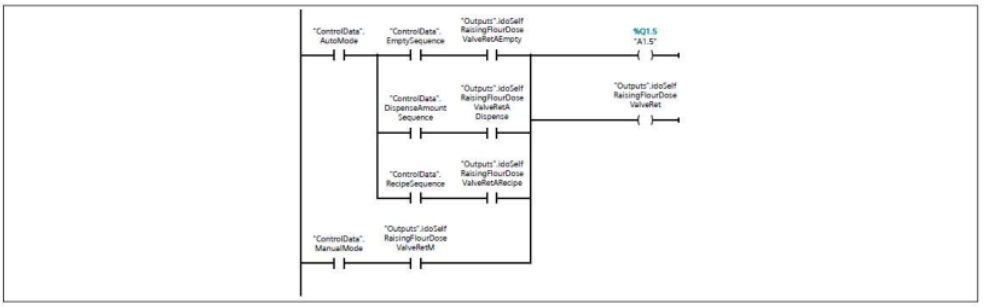
Figure 60 – PLC Output Map Function Call



Network 13: Output A1.4



Network 14: Output A1.5



Network 15: Output A1.6

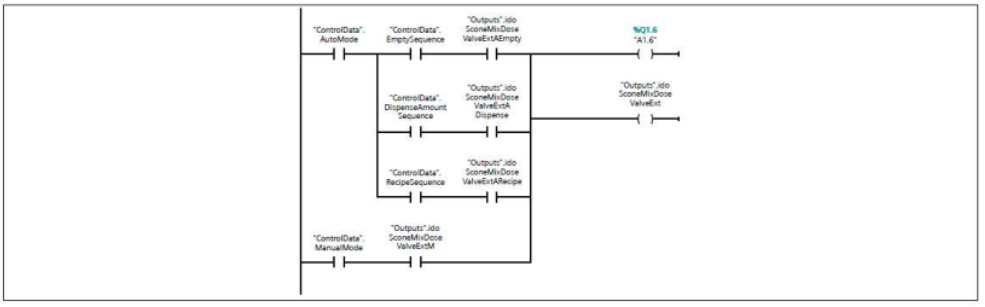
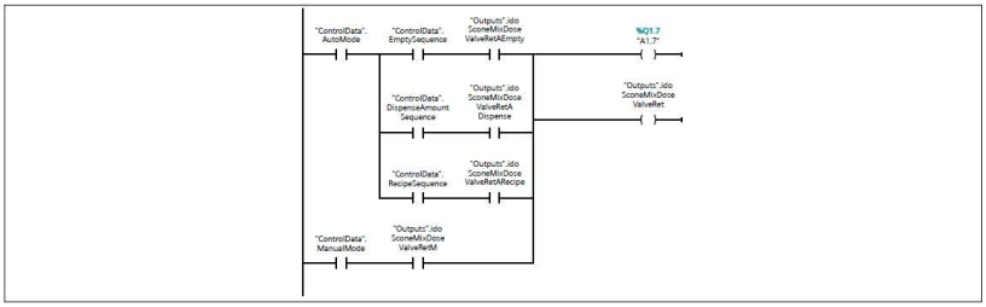


Figure 61 – PLC Output Map Function Call

Network 16: Output A1.7



Network 17: Caster Sugar Bulk Dosing Valve

Caster Sugar Valve Analog Output

Figure 62 - PLC Output Map Function Call

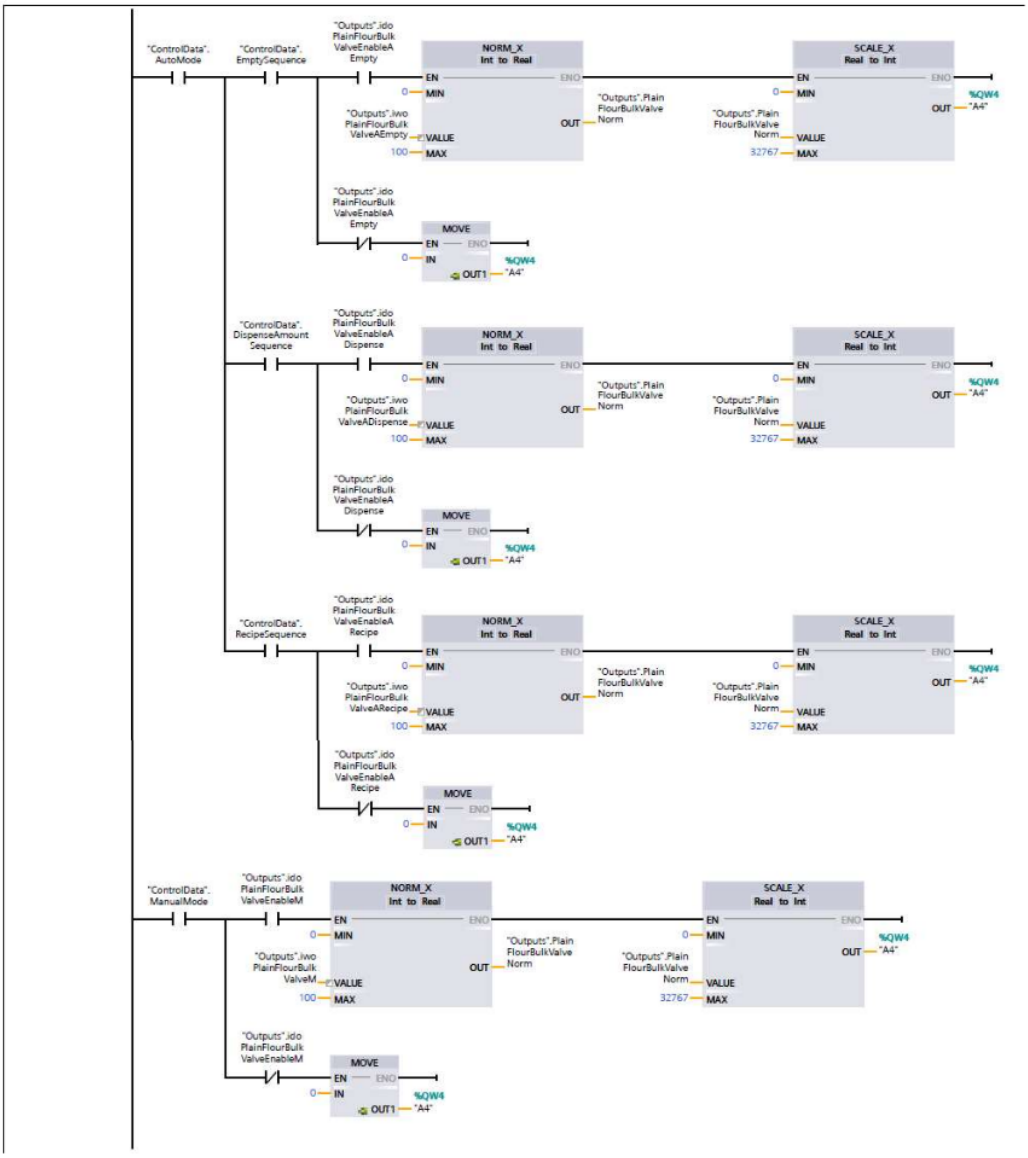


Figure 63 - PLC Output Map Function Call

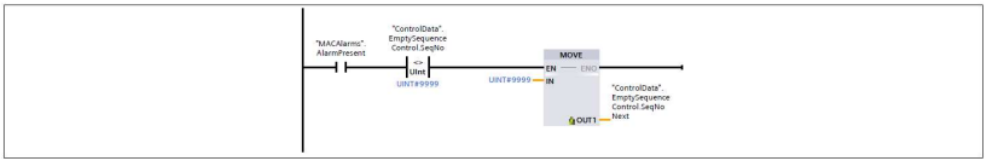
Appendix 9.5.6 – Empty Sequence

EmptySequence [FC9]

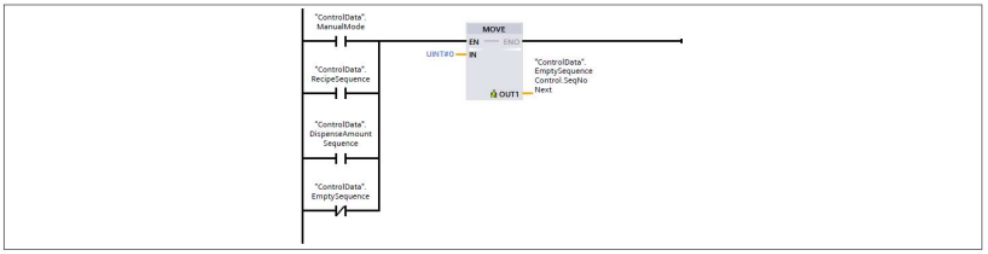
EmptySequence Properties							
General							
Name	EmptySequence	**Number**	9	**Type**	FC	**Language**	LAD
Numbering	Automatic						
Information							
Title		**Author**		**Comment**		**Family**	
Version	0.1	**User-defined ID**					

Name	Data type	Default value	Comment
Input			
Output			
InOut			
Temp			
Constant			
▼ Return			
EmptySequence	Void		

Network 1: Alarm, Jump to Step 9999



Network 2: If Another Mode is Active, Go to Step 0



Network 3: Update Sequence Numbers

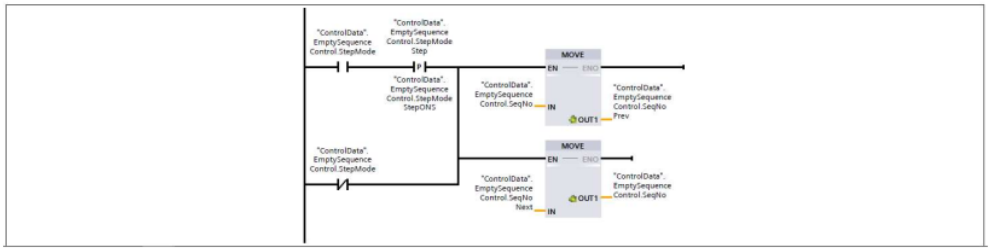
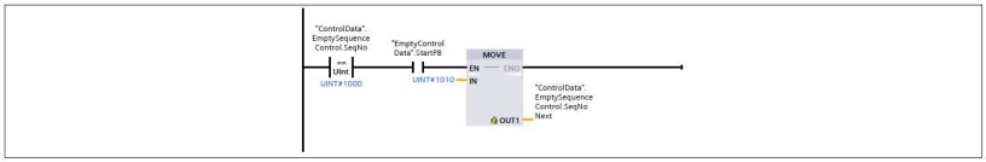
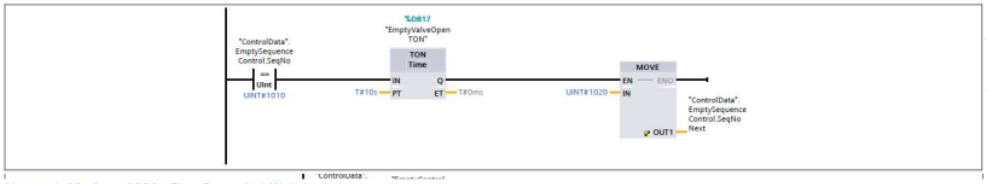


Figure 64 – Empty Sequence Function Call

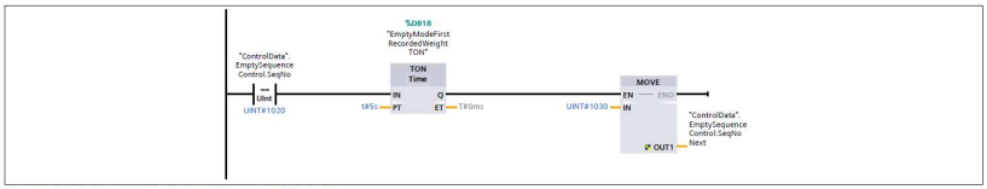
Network 8: Step 1000 - Wait for Start Pushbutton



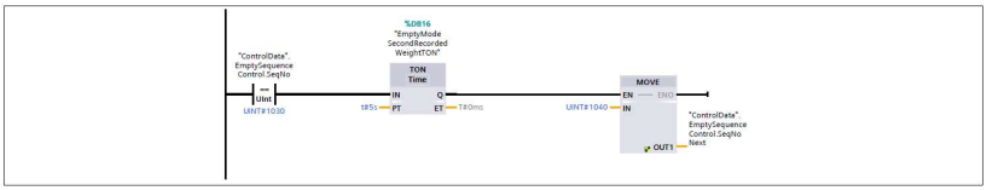
Network 9: Step 1010 - Open Valve



Network 10: Step 1020 - First Recorded Weight



Network 11: Step 1030 - Second Recorded Weight



Network 12: Step 1040 - Compare First and Second Recorded Weight

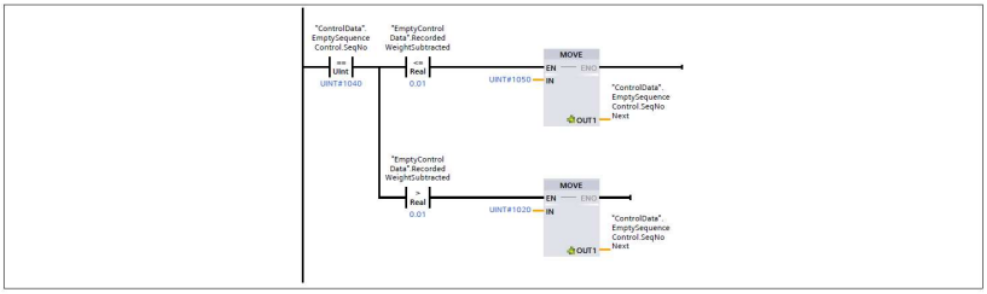
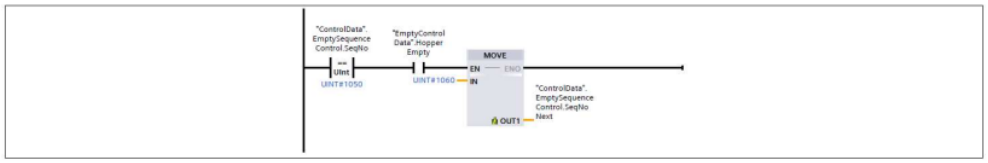
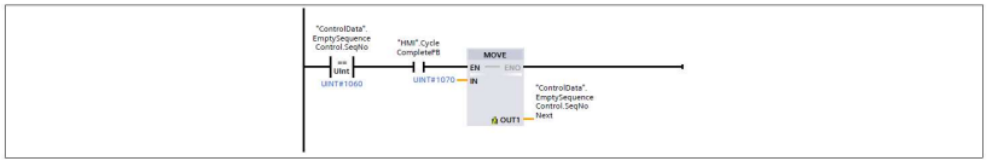


Figure 65 - Empty Sequence Function Call

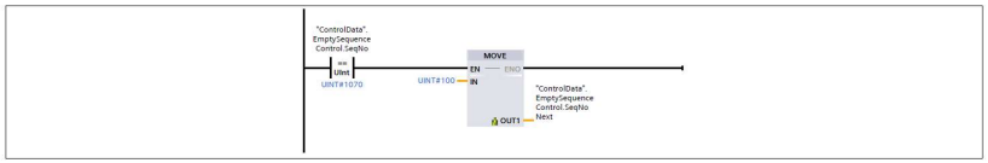
Network 13: Step 1050 - Hopper Empty



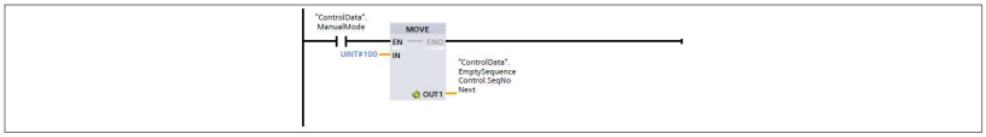
Network 14: Step 1060 - Confirm End of Cycle



Network 15: Step 1070 - Clear Hopper Parameters



Network 16: Manual Mode



Network 17: Step 9999 - Alarm

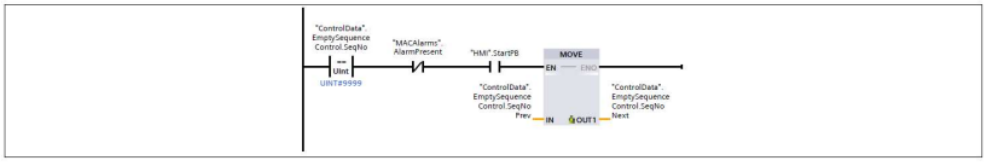


Figure 66 - Empty Sequence Function Call

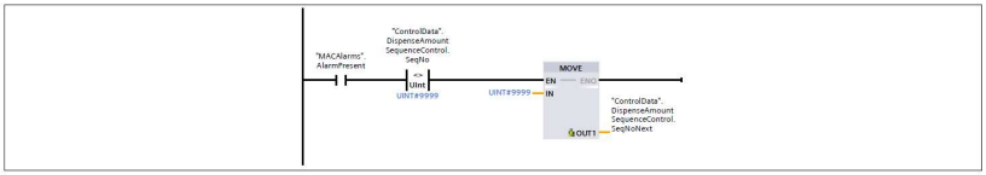
Appendix 9.5.7 – Dispense Amount Sequence

DispenseAmountSequence [FC13]

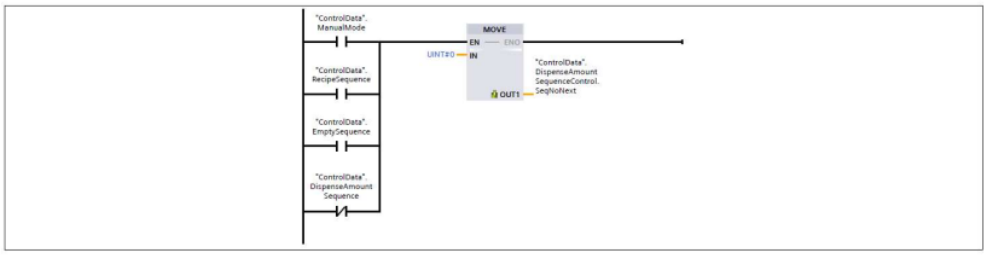
DispenseAmountSequence Properties							
General							
Name	DispenseAmountSequence	**Number**	13	**Type**	FC	**Language**	LAD
Numbering	Automatic						
Information							
Title		**Author**		**Comment**		**Family**	
Version	0.1	**User-defined ID**					

Name	Data type	Default value	Comment
Input			
Output			
InOut			
Temp			
Constant			
▼ Return			
DispenseAmountSequence	Void		

Network 1: Alarm, Jump to Step 9999



Network 2: If Another Mode is Active, Go to Step 0



Network 3: Update Sequence Numbers

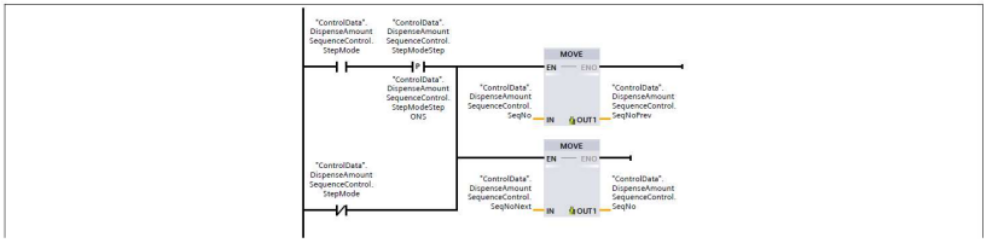
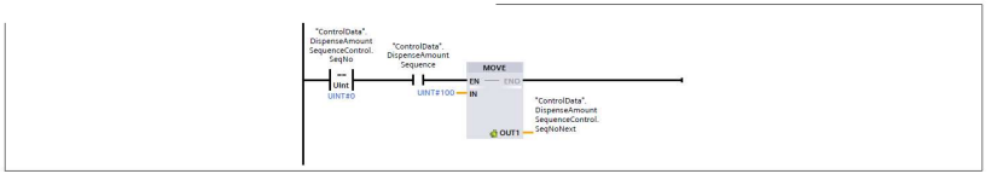
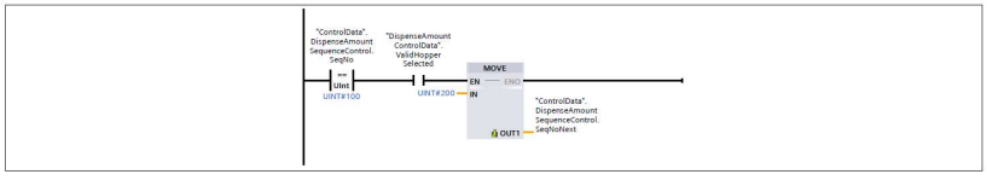


Figure 67 – Dispense Amount Sequence Function Call

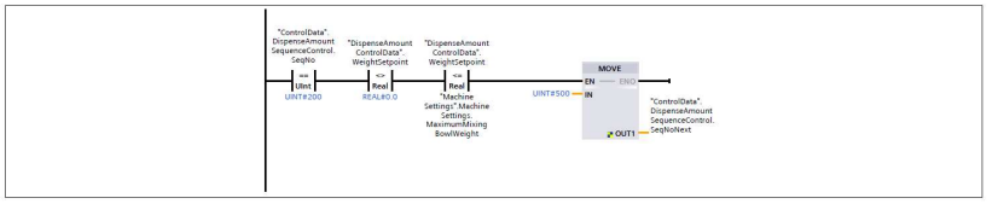
Network 4: Step 0 - Dispense Amount Sequence Mode Selected



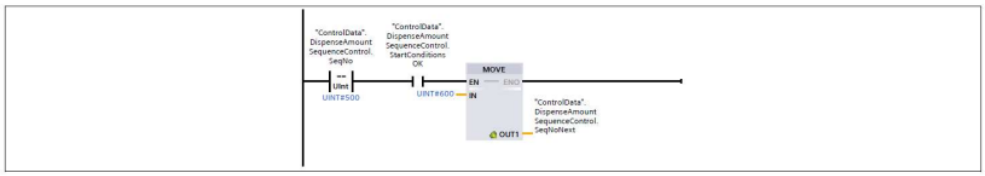
Network 5: Step 100 - Select Ingredient to Dispense



Network 6: Step 200 - Select Weight to Dispense



Network 7: Step 500 - Start Conditions Ok & Zero Mixing Bowl



Network 8: Step 600 - Zero Mixing Bowl

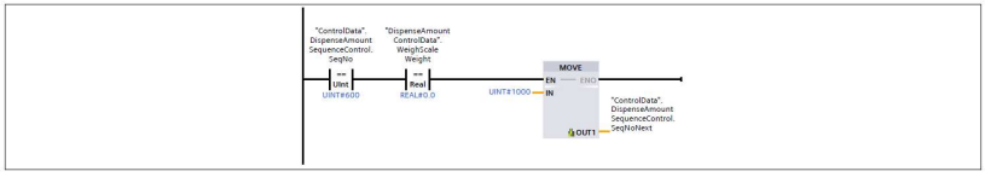
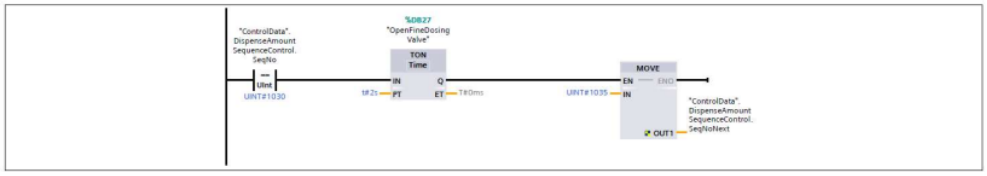
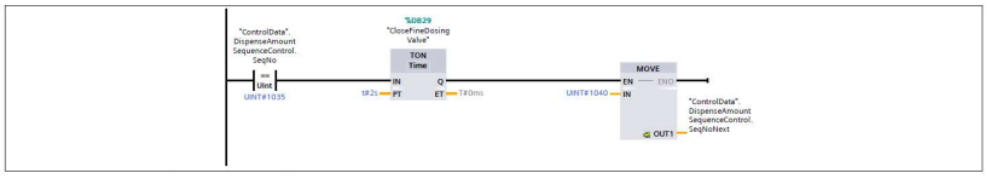


Figure 68 - Dispense Amount Sequence Function Call

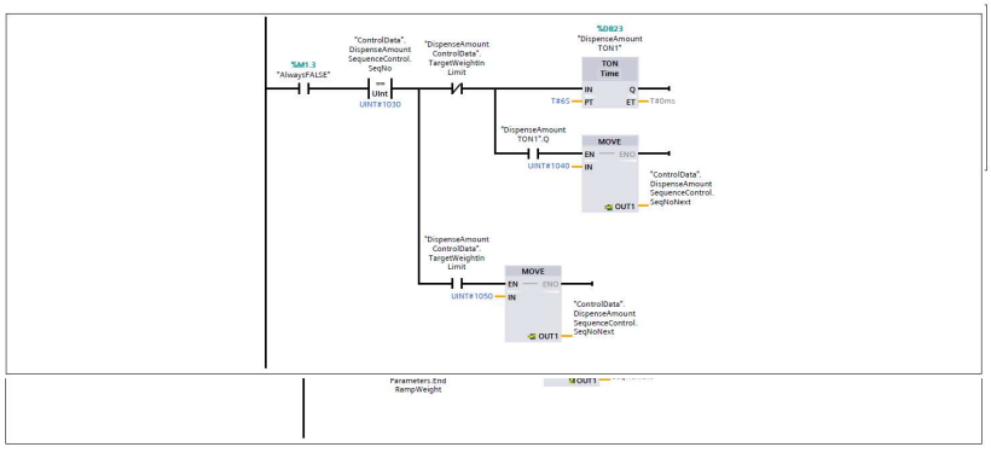
Network 12: Open Fine Dosing Valve



Network 13: Close Fine Dosing Valve



Network 14: Step 1030 - Fine Dosing Stage



Network 11: Step 1025 - Allow Bulk Dosing Valve to Close

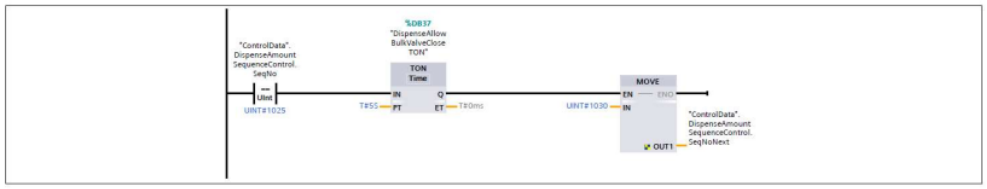
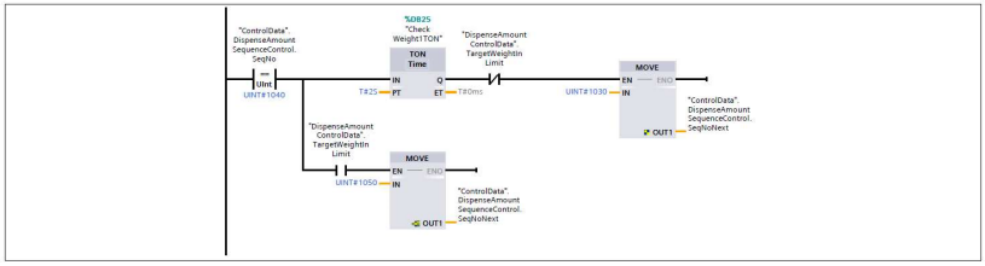
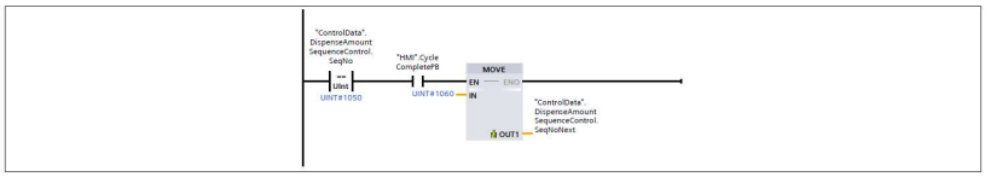


Figure 69 - Dispense Amount Sequence Function Call

Network 15: Step 1040 - Check Weight



Network 16: Step 1050 - Target Weight Acheived, Confirm Cycle Complete



Network 19: Manual Mode

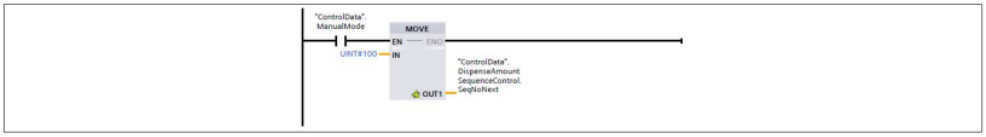


Figure 70 - Dispense Amount Sequence Function Call

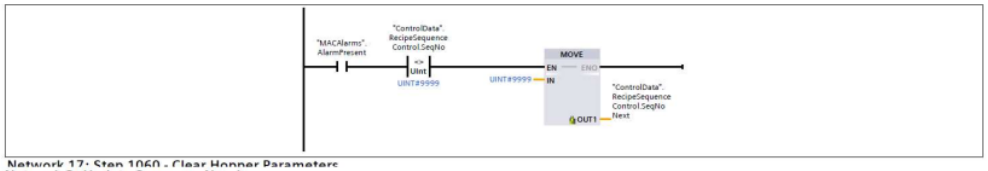
Appendix 9.5.8– Recipe Mode Sequence

RecipeSequence [FC18]

RecipeSequence Properties							
General							
Name	RecipeSequence	**Number**	18	**Type**	FC	**Language**	LAD
Numbering	Manual						
Information							
Title		**Author**		**Comment**		**Family**	
Version	0.1	**User-defined ID**					

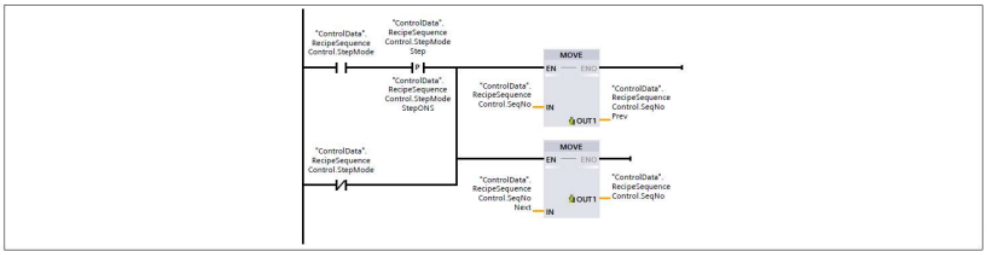
Name	Data type	Default value	Comment
Input			
Output			
InOut			
Temp			
Constant			
▼ Return			
RecipeSequence	Void		

Network 1: Alarm, Jump to Step 9999

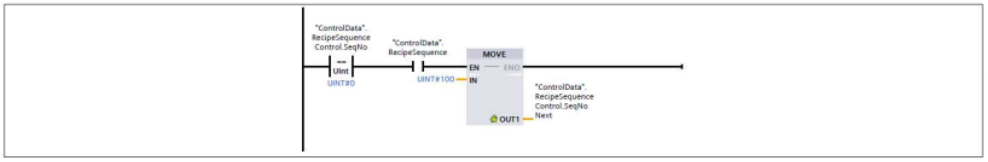


Network 17: Step 1060 - Clear Hopper Parameters

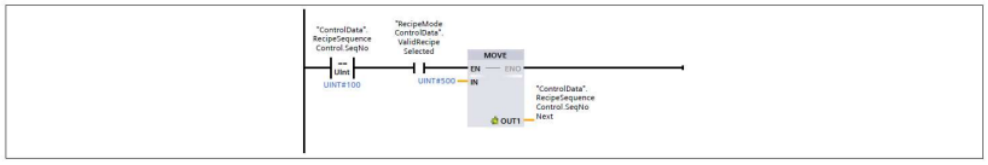
Network 2: Update Sequence Numbers



Network 3: Step 0 - Recipe Sequence Mode Selected

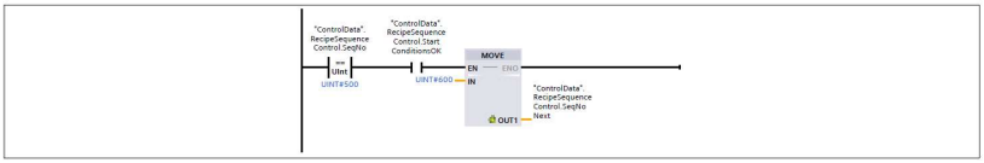


Network 4: Step 100 - Select Valid Recipe

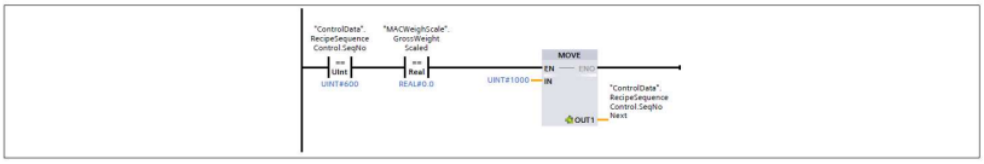


Network 5: Step 500 - Start Conditions Ok

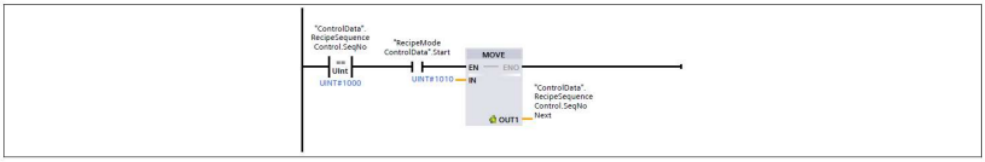
Figure 71 – Recipe Mode Sequence Function Call



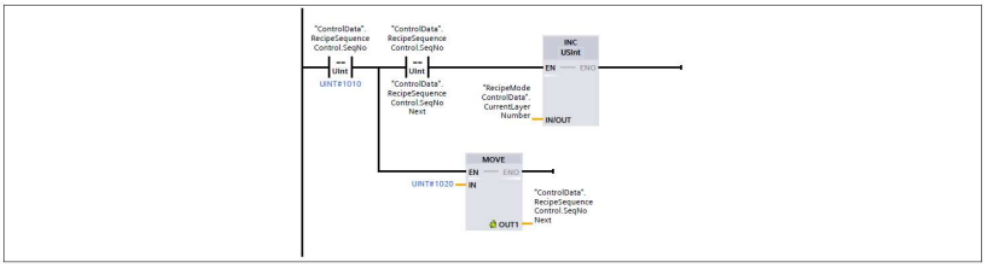
Network 6: Step 600 - Zero Mixing Bowl



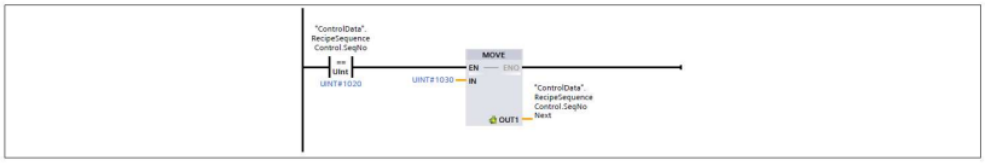
Network 7: Step 1000 - Wait for Start Button



Network 8: Step 1010 - Increment Current Layer Number



Network 9: Step 1020 - Copy Current Layer Info from Recipe DB



Network 10: Step 1030 - Check Current Layer Settings Valid

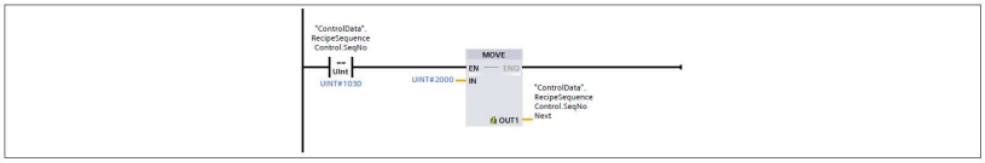
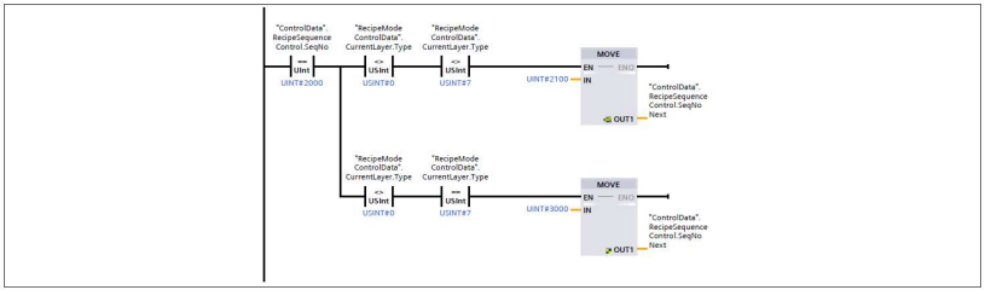
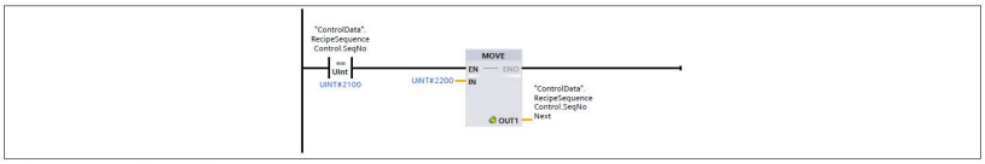


Figure 72 - Recipe Mode Sequence Function Call

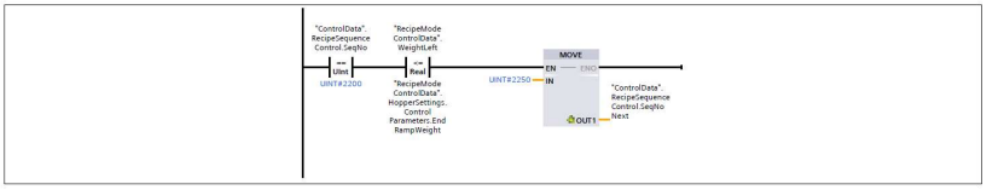
Network 11: Step 2000 - Is Layer Manual or Auto?



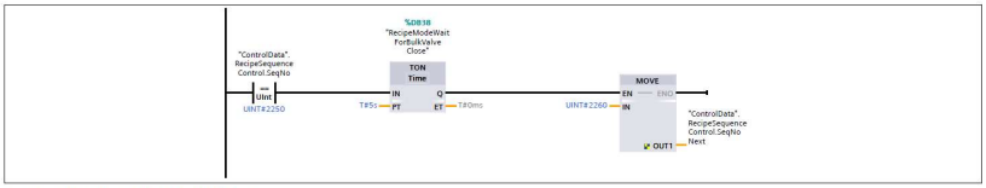
Network 12: Step 2100 - Auto Dispense



Network 13: Step 2200 - Bulk Dosing Stage



Network 14: Step 2250 - Wait for Bulk Dosing Valve to Close



Network 15: Step 2260 - Check Weight

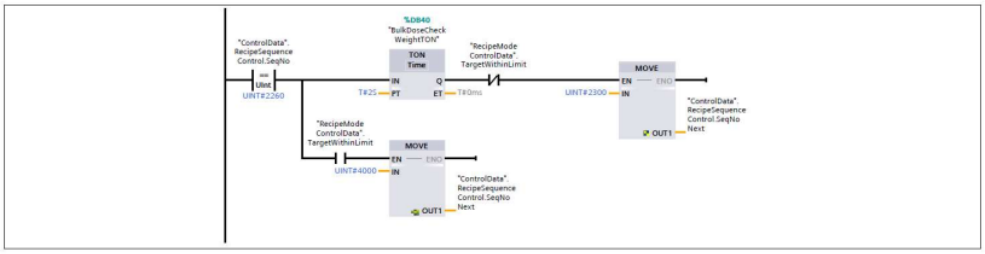
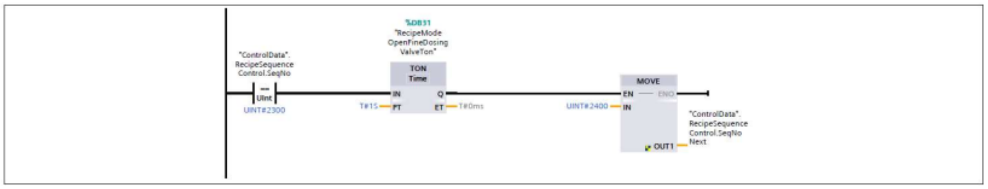
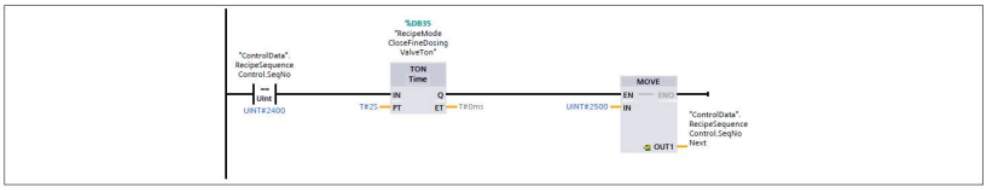


Figure 73 - Recipe Mode Sequence Function Call

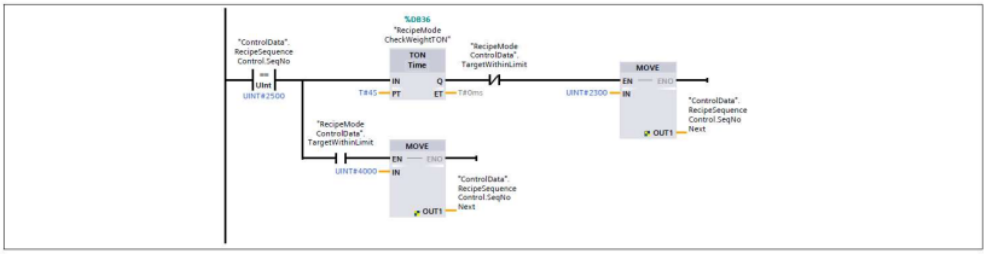
Network 16: Step 2300 - Open Fine Dosing Valve



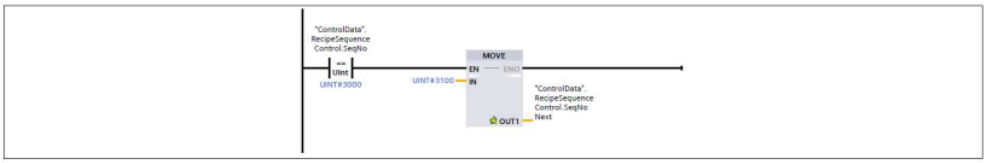
Network 17: Step 2400 - Close Fine Dosing Valve



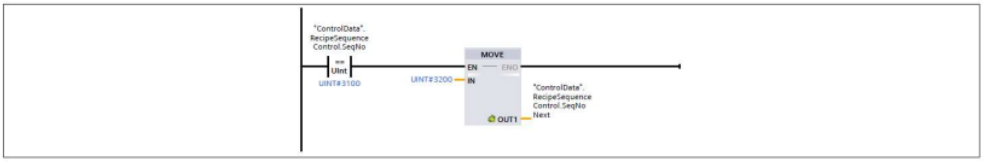
Network 18: Step 2500 - Check Weight



Network 19: Step 3000 - Manual Ingredient

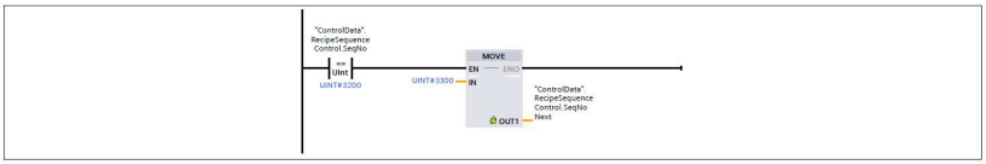


Network 20: Step 3100 - Store Current Weight

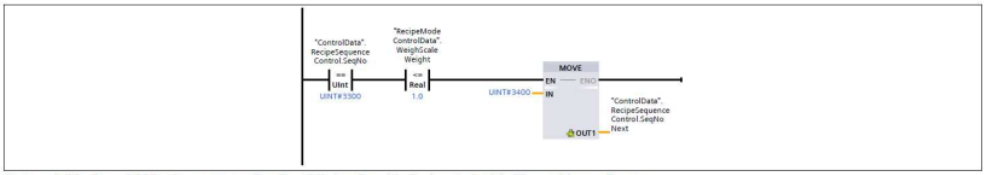


Network 21: Step 3200 - Remove Mixing Bowl & Add Manual Ingredient

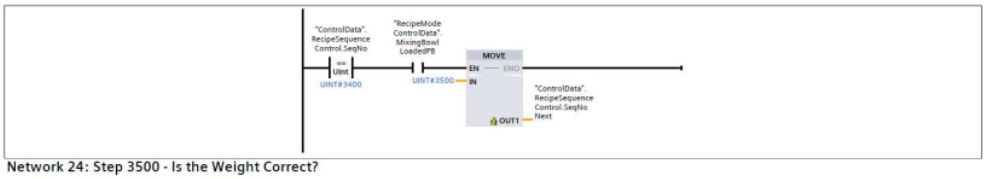
Figure 74- Recipe Mode Sequence Function Call



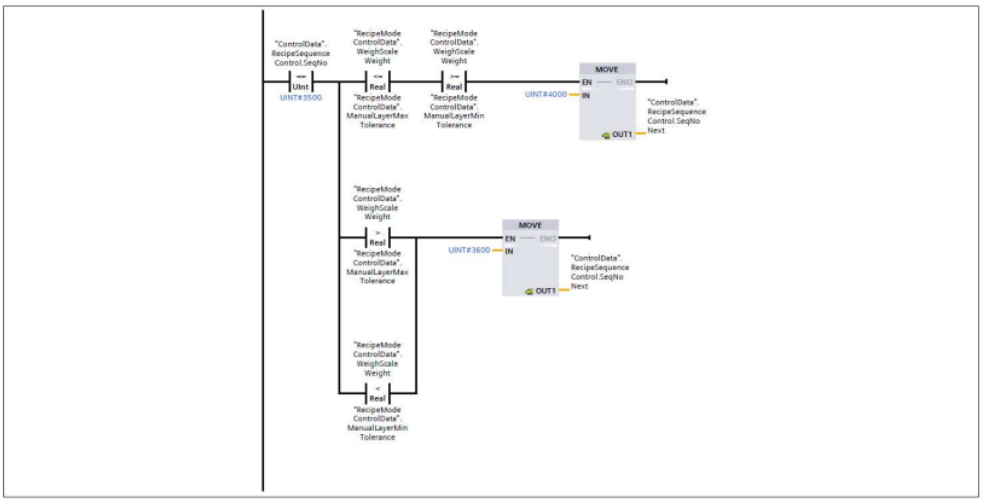
Network 22: Step 3300 - Mixing Bowl has been Removed



Network 23: Step 3400 - Operator to Confirm Mixing Bowl is Re-loaded with Manual Ingredient



Network 24: Step 3500 - Is the Weight Correct?



Network 25: Step 3600 - Manual Ingredient Weight is not correct

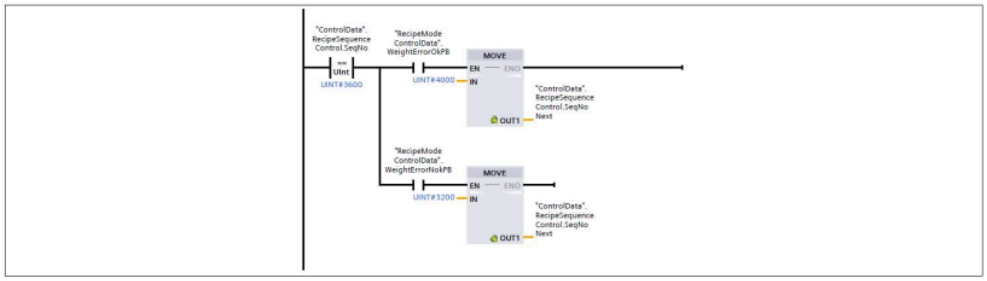
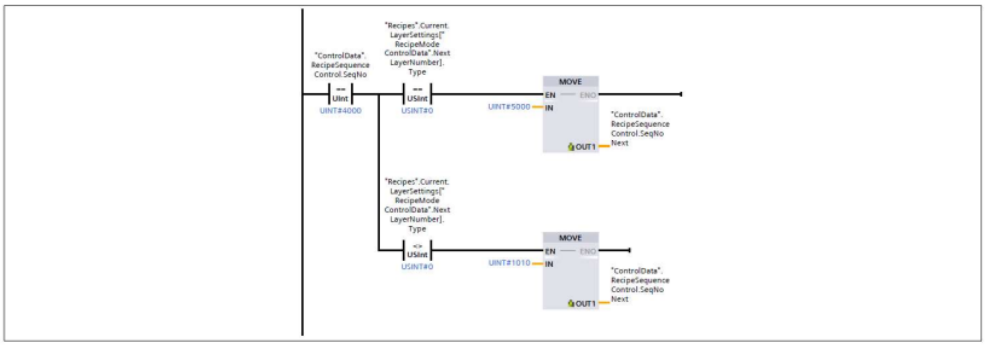
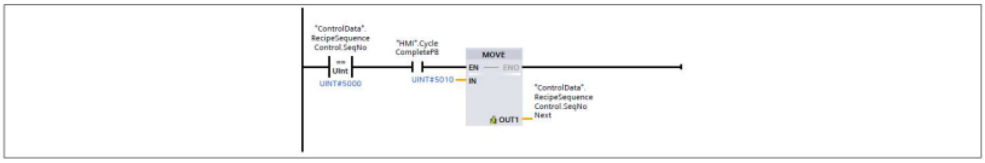


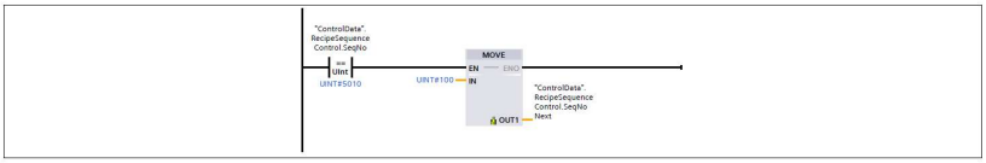
Figure 75 - Recipe Mode Sequence Function Call



Network 27: Step 5000 - Recipe Complete



Network 28: Step 5010 - Store Run Data



Network 29: Step 9999 - Alarm

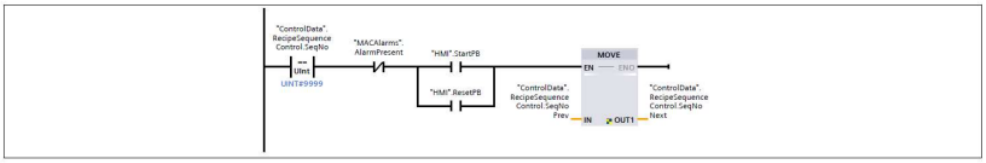


Figure 76 - Recipe Mode Sequence Function Call

Appendix 9.5.9 – Hardware Configuration



Figure 77 - Ingredient Hopper System PLC Configuration

Output parameters

Overview of output parameters

Channel number	Parameter settings	Output type	Output range	Reaction to CPU STOP
0	Manual	Current	4..20mA	Shutdown
1	Manual	Current	4..20mA	Shutdown
2	Manual	Current	4..20mA	Shutdown
3	Manual	Current	4..20mA	Shutdown
4	Manual	Current	4..20mA	Shutdown
5	Manual	Current	4..20mA	Shutdown
6	From template	Voltage	+/- 10V	Shutdown
7	From template	Voltage	+/- 10V	Shutdown

Figure 79 - Analog Output Channel Configuration

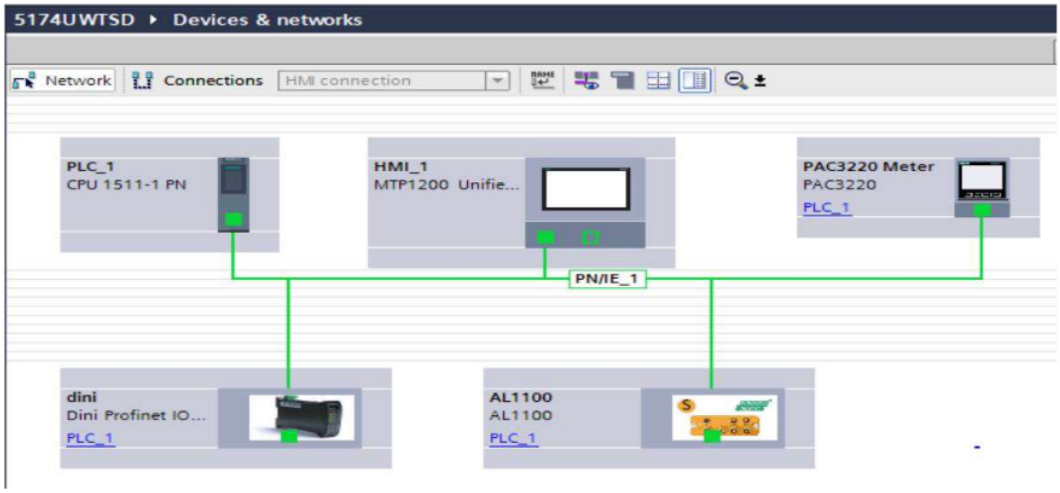


Figure 78 - Ingredient Hopper System Profinet Network

Appendix 9.5.10 – HMI Screen Example

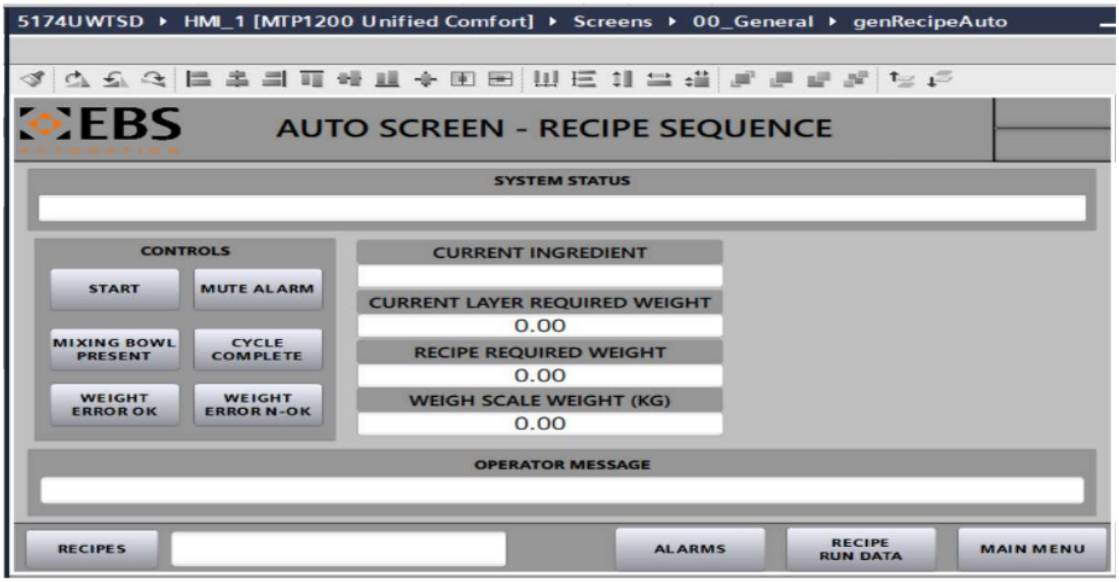


Figure 80 – Recipe Mode Auto Screen

Appendix 9.6 - Panel Build & Test

Appendix 9.6.1 – Panel Build



Figure 81 – Panel Backplate



Figure 82 – Panel Layout

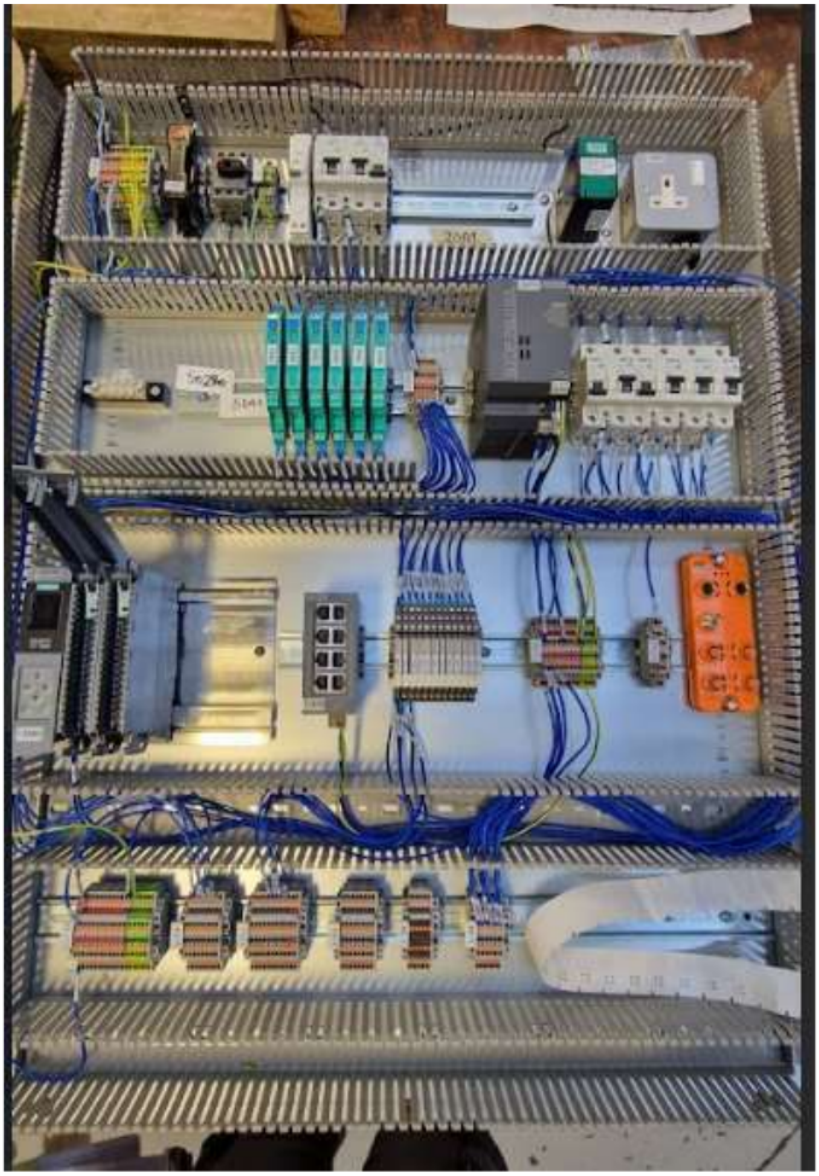


Figure 83 – Panel Wiring



Figure 84 – Completed Panel in Enclosure

Appendix 9.6.2 – Electrical Pre-Commissioning Checks

EBS 5174 Ingredient Dosing System – Electrical Pre-Commissioning Checks

1. Pre-Power-Up Checks

Test – Pre Power-Up Checks
Ensure that the main isolator is OFF and all MCBs are ON:

- Open Circuit between Live & Neutral
- Open Circuit between Live & Earth
- Open Circuit between Neutral & Earth
- Open Circuit between Live & 24V
- Open Circuit between Live & 0V
- Open Circuit between Neutral & 24V
- Open Circuit between Neutral & 0V
- Open Circuit between Earth & 24V
- Continuity between Earth & 0V
- Main Fuse is rated at 10A
- Resistance between incoming earth (X0/PE1) & Backplate <0.5Ω
- Resistance between incoming earth (X0/PE1) & Panel Door <0.5Ω

Tick to Confirm ✓

Test – Main Isolator

- Turn main Isolator OFF
- Turn all MCBs OFF
- Connect 240V supply to Isolator incoming terminals
- Voltage between Live & Neutral = 240V +10% / -6%
- Voltage between Live & Earth = 240V +10% / -6%
- Voltage between Live & Neutral = 0V

Tick to Confirm ✓

Test – Mains Supply

- Turn main isolator ON
- Voltage between 10F6 Incoming & X1T/1 = 240V +10% / -6%
- Voltage between 20F1 Incoming & X1T/1 = 240V +10% / -6%
- Voltage between 20F3 Incoming & X1T/1 = 240V +10% / -6%
- Voltage between 30F0 Incoming & X1T/1 = 240V +10% / -6%

Tick to Confirm ✓

Figure 85 – Electrical Pre-Commissioning Checks Sheet 1

Test – 24V Internal (25)

- Turn on MCB 30F1
- Voltage between X2/1 & X2T/1 = 24VDC
- Scalance Ethernet Switch 110P0 is ON
- PLC 130A0 is ON
- IOT2050 Gateway 110P5 is ON

Tick to Confirm ☑

Test – 24V Field (26)

- Turn on MCB 30F2
- Voltage between X2.1/1 & X2.1T/1 = 24VDC
- Main Air Pressure Switch PS1 is ON
- Soft Start Valve V20 is ON
- Output Card 150A0 has 24VDC between 1L+ & 1L-

Tick to Confirm ☑

Test – HMI Power (27)

- Turn on MCB 30F3
- Voltage between X2.1/12 & X2.1T/1 = 24VDC
- HMI 120U0 is ON

Tick to Confirm ☑

Test – IO-Link Master (28)

- Turn on MCB 30F4
- Voltage between X12/1 & X12/2 = 24VDC
- IO-Link Master 170U0 is ON

Tick to Confirm ☑

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08/02/2023

Figure 86 - Electrical Pre-Commissioning Checks Sheet 2

3. IO Checks

3.1 Digital Inputs

I/O Ref	I/O Description	Wiring
E0.0	Main Air OK	✓
E0.1	Power Meter Voltage Measure MCB	✓
E0.2	Power Meter Supply MCB	✓
E0.3	Field 24V MCB	✓
E0.4	IO-Link 24V MCB	✓
E0.5	Weigh Scale 24V MCB	✓
E0.6	Positioner Barrier 24V MCB	✓
E0.7	Spare	✓
E1.0	Emergency Stop OK	✓
E1.1	Spare	✓
E1.2	Spare	✓
E1.3	Spare	✓
E1.4	Spare	✓
E1.5	Spare	✓
E1.6	Spare	✓
E1.7	Spare	✓

3.2 Digital Outputs

I/O Ref	I/O Description	Wiring
A0.0	Spare	✓
A0.1	Spare	✓
A0.2	Spare	✓
A0.3	Spare	✓
A0.4	Caster Sugar Fine Dosing Valve Extend	✓
A0.5	Caster Sugar Fine Dosing Valve Retract	✓
A0.6	Plain Flour Fine Dosing Valve Extend	✓
A0.7	Plain Flour Fine Dosing Valve Retract	✓
A1.0	Oats Fine Dosing Valve Extend	✓
A 1.1	Oats Fine Dosing Valve Retract	✓
A 1.2	Light Brown Sugar Fine Dosing Valve Extend	✓
A 1.3	Light Brown Sugar Fine Dosing Valve Extend	✓
A 1.4	Self-Raising Flour Fine Dosing Valve Extend	✓
A1.5	Self-Raising Flour Fine Dosing Valve Retract	✓
A1.6	Scone Mix Fine Dosing Valve Extend	✓
A1.7	Scone Mix Fine Dosing Valve Retract	✓

Thomas Grennan
08/02/2023

Figure 87 - Electrical Pre-Commissioning Checks Sheet 3

EBS 5174 Ingredient Dosing System – Electrical Pre-Commissioning Checks

Developed by - Electrical Engineer

Name: T. Grennan
Signature: TGrennan
Date: 08/02/2023

Checked by – Senior Automation Engineer

Name: S. Waters
Signature: SPWaters
Date: 22nd March 2023

Verified by – Electrical Engineer

Name: T. Grennan
Signature: TGrennan
Date: 22/03/2023

Thomas Grennan
08/02/2023

Figure 88 - Electrical Pre-Commissioning Checks Sheet 4

Appendix 9.7 Budget vs. Actual Cost

Electrical Material				
Supplier	**Cost**	**Order Date**	**Date Required by**	**Delivery Date**
Applied Automation	£87.64	16/01/23	06/02/23	23/01/2022
BPX	£126.77	16/01/23	06/02/23	11/01/2023
ICOTEK	£29.40	16/01/23	06/02/23	23/01/2023
ifm	£351.69	16/01/23	06/02/23	19/01/2023
Parmley Graham	£5,648.69	03/11/22	06/02/23	23/01/2023
R&M	£157.70	16/01/23	06/02/23	03/02/2023
Routeco	£662.68	16/01/23	06/02/23	25/01/2023
RS	£172.48	16/01/23	06/02/23	02/02/2023
Underwoods	£190.92	16/01/23	06/02/23	03/02/2023
Western Automation	£103.22	16/01/23	06/02/23	03/02/2023
Mucon	£42,130.00	25/07/22	06/02/23	16/12/2022
MWS	£4,308.00	16/01/23	06/02/23	19/01/2023
Actual Cost	**£53,969.19**			
Budget	£65,000.00			

Labour				
Department	**Budget Hours**	**Actual Hours**	**Remaining Hours**	**Last Updated On:**
Design	232	226	0	30/03/2023
Manufacture	200	164	0	
Documentation	112	62	0	
Hours	544	452	0	
Cost	£ 45,000.00	£ 31,640.00	£ -	

Cost Tracker - Budget vs Actual	
Budget	£110,000.00
Actual Cost	£85,609.19

Table 2 – Budget Vs Actual Cost

Appendix 9.8 - Gantt Chart

Ingredient Dosing System - Project Gantt Chart

A useful planning chart but a key would be helpful

Project Start: Tue, 03/01/2023

Display Week: 1

TASK	RESOURCE	PROGRESS	START	END
Phase 1 - Design				
Panel Layout	TG	100%	3/1/23	4/1/23
Electrical Schematic & SISTEMA Report	TG	100%	5/1/23	12/1/23
Electrical Parts List / Requisition Forms	TG	100%	13/1/23	16/1/23
Mechanical General Assembly Design	WM	100%	3/1/23	24/1/23
Mechanical Detailed Design & Pneumatics	WM	100%	25/1/23	4/2/23
Mechanical Parts List / Requisition Forms	WM	100%	8/1/23	7/2/23
Sequence Design	TG	100%	17/1/23	18/1/23
Software Design	TG	100%	19/1/23	29/1/23
HMI Design	TG	100%	30/1/23	5/2/23
Machinery Directive & Technical File	TG/WM	65%	3/1/23	30/3/23
Phase 2 - Manufacture				
Panel Build	TG	100%	6/2/23	12/2/23
Machine Wiring	TG	100%	13/2/23	21/2/23
Milling / Turning / Welding	AUTOMATION	100%	9/1/23	7/2/23
Mechanical Assembly	AUTOMATION	90%	8/2/23	17/2/23
Pneumatic Assembly	AUTOMATION	100%	18/2/23	21/2/23
Mechanical Comissioning	WM	90%	22/2/23	27/2/23
Electrical Comissioning	TG	100%	22/2/23	27/2/23
Software Comissioning	TG	75%	28/2/23	14/3/23
Phase 3 - Documentation				
Manufacturer Acceptance Test / Trials	TG/WM	30%	15/3/23	20/3/23
Despatch & Installation	AUTOMATION	0%	21/3/23	27/3/23
Machine Manual	TG/WM	50%	21/3/23	27/3/23
BS EN 60204-1 Checklist	TG	100%	28/3/23	28/3/23
EMC Directive (2014/30/EU) Checklist	TG	100%	28/3/23	28/3/23
Customer Training	TG	0%	29/3/23	30/3/23
Sign-off	TG	0%	31/3/23	31/3/23

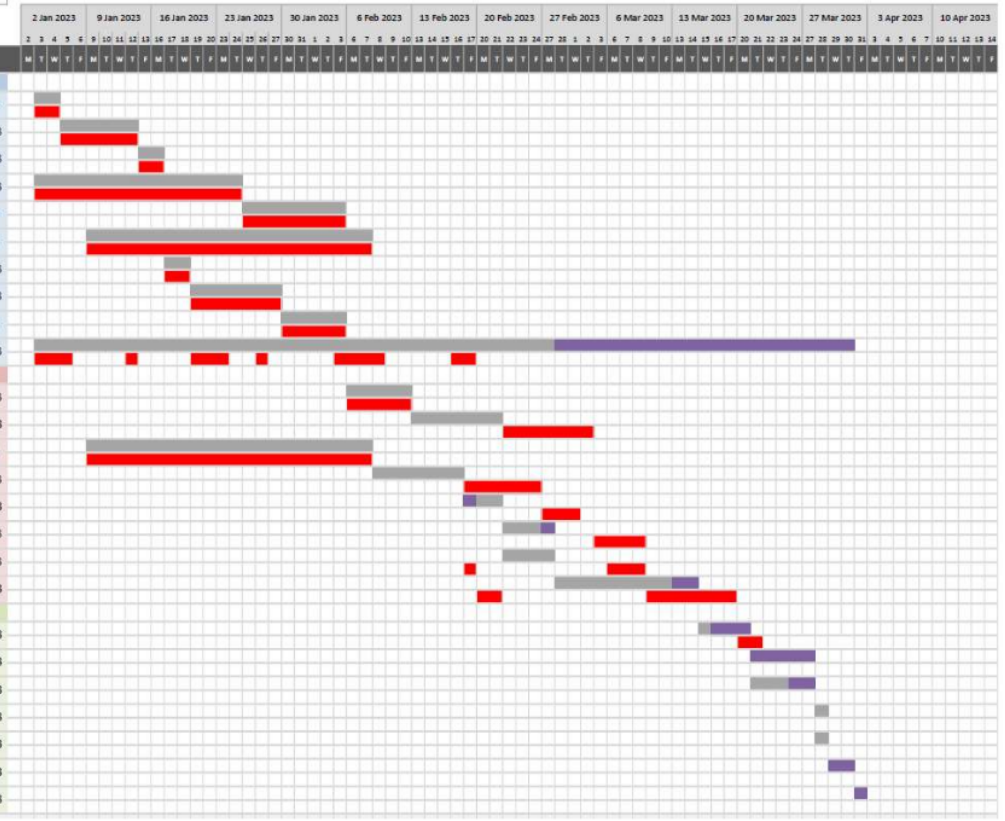


Figure 89 – Gantt Chart – Planned Vs Actual

Appendix 9.9 - Work Breakdown Structure (WBS)

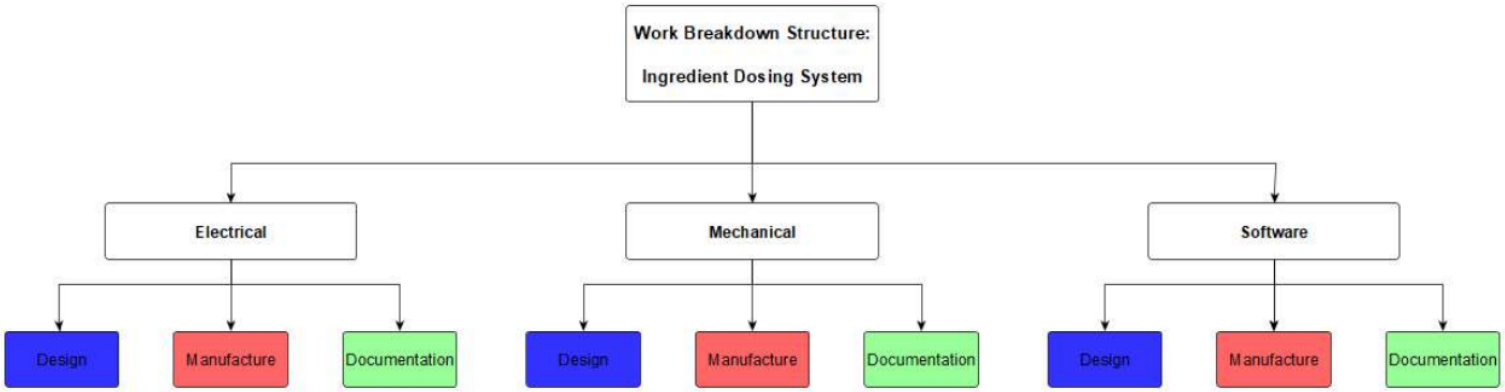


Figure 90 – Work Breakdown Structure Overview

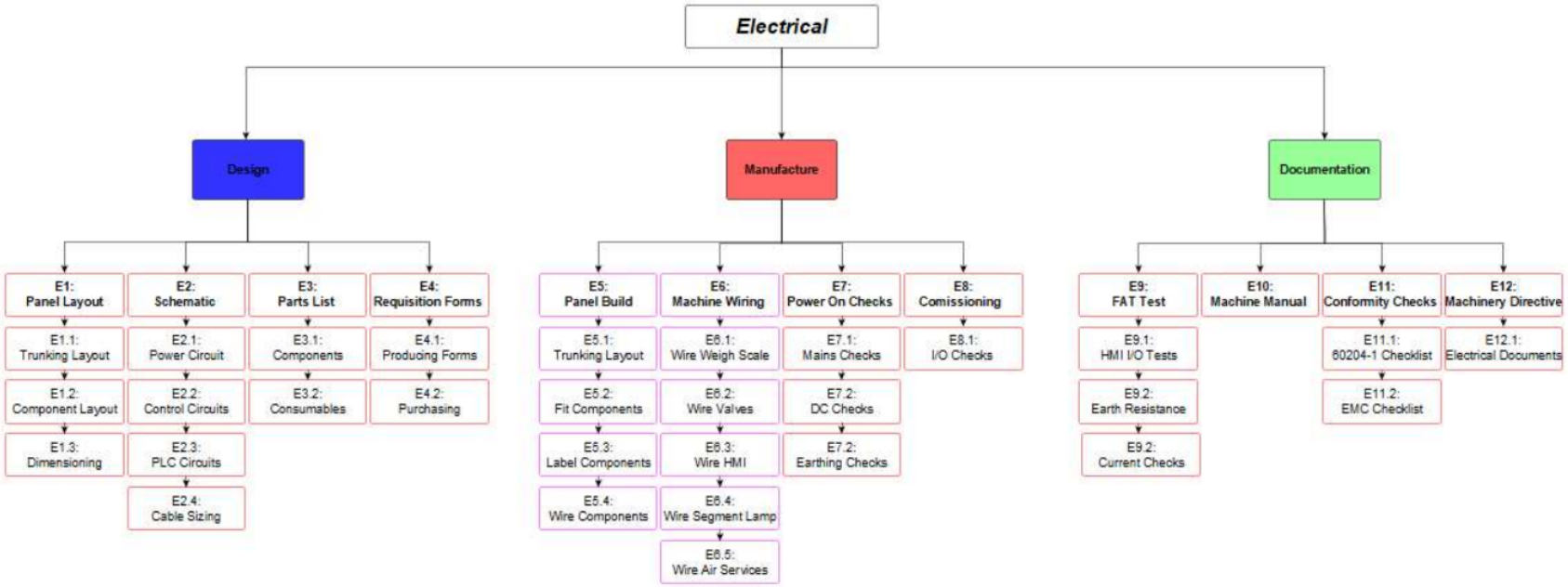


Figure 91 – Work Breakdown Structure Electrical

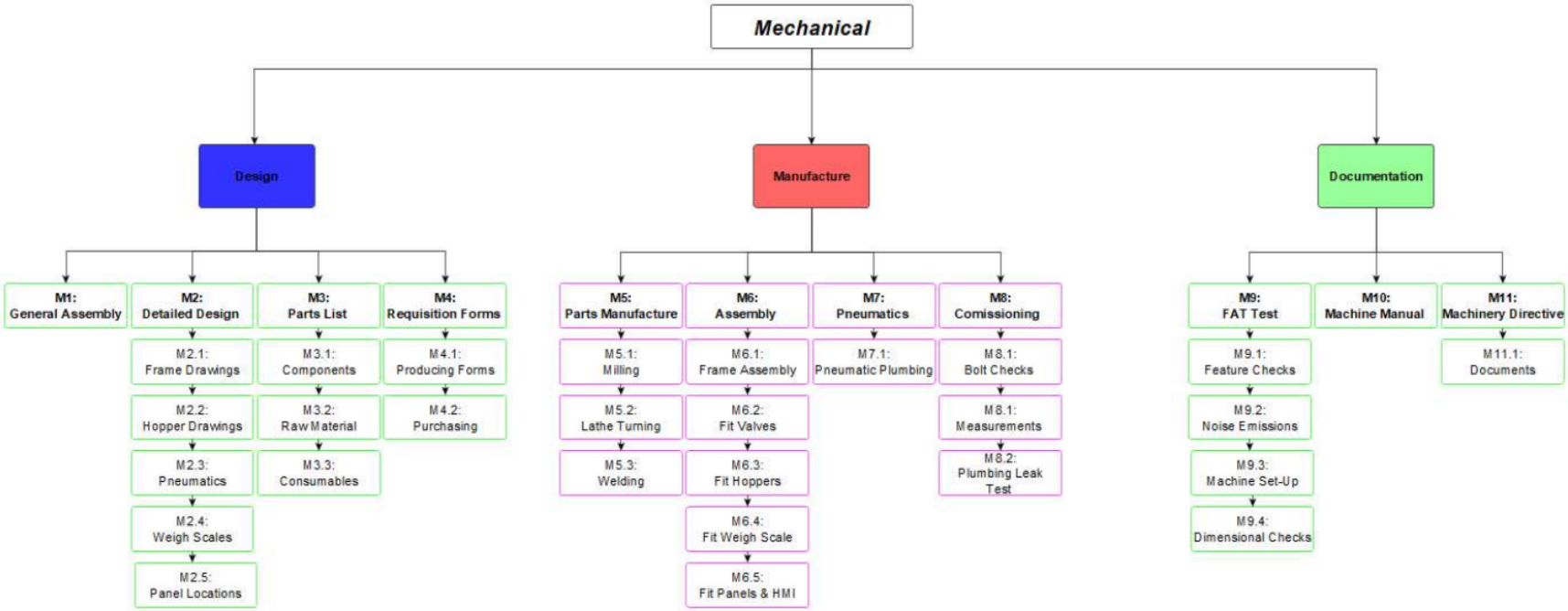


Figure 92 – Work Breakdown Structure Mechanical

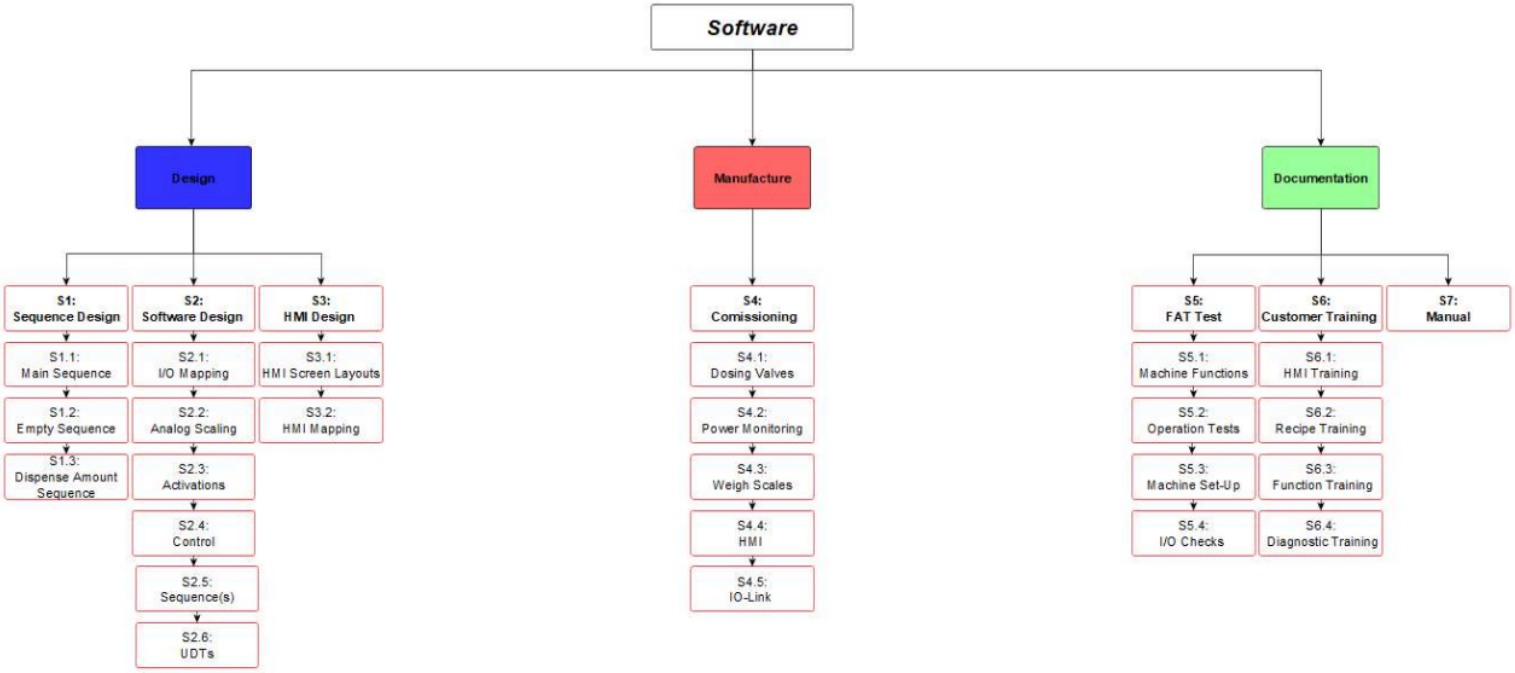


Figure 93 – Work Breakdown Structure Software

This information did not need to be included

Appendix 9.10 - Positioner Adjustment Documentation

CHAPTER 2: TECHNICAL FEATURES & DATA

2 – 1 METHOD OF OPERATION

AIR TO CLOSE
CLOCKWISE ROTATION

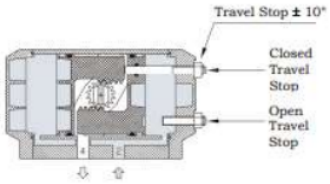


Figure 2.a

AIR TO OPEN
COUNTER CLOCKWISE ROTATION

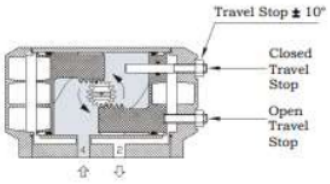


Figure 2.b

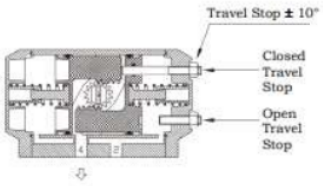


Figure 2.c

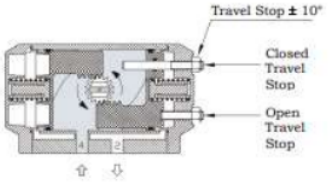


Figure 2.d

Figure 94 – Positioner Adjustment

Appendix 9.11 – HFIV Quote

From: Harry Mills <harry@vibtec.com>
Sent: 05 April 2023 18:48
To: Wojciech Milkowski <Wojciech.Milkowski@ebs.uk.com>
Subject: RE: Flour hopper enquiry

Hi Wojciech,

I have had more of a think about this enquiry and I think a soft impact knocker may be better to combat bridging in this flour.
So I think this could be worth a try too.
The GT I think will be more suitable for the sugar.

See below:

1 off FPK40 High Frequency Impact Vibrator £495.00
Leadtime approx. 4-5 weeks

We could agree on a trial and return basis. We can give you 2 weeks to try the units and if the results are not satisfactory, we will credit all in full, but the goods will have to be returned to us in as new condition with the original packaging.

Kind regards,

Harry Mills

VIBTEC
VIBRATECHNIQUES LTD
Vibration Solutions

Harry Mills
20 Cecil Pashley Way, SHOREHAM-BY-SEA, BN43 5FF
Tel: +44 (0)1273 430977 **Fax**: +44 (0)1273 430978
Email: sales@vibtec.com **Web**: www.vibtec.com
Registered No: 717356

Figure 95 – HFIV Quote (Mills, 2023)

Appendix 9.12 – Testing

Appendix 9.12.1 – Conformity Testing Test Plan

Firstly, the conformity testing was performed. Conformity testing ensures that the FDS requirements that cannot be functionally tested are implemented and correct.

Conformity Tests					
Ref.	Test Description	Expected Outcome	Actual Outcome	Pass or Fail?	Evidence
P.0	Check the Hopper Capacity for Caster Sugar, Light Brown Sugar, Buttery Scone Mix and Rolled Jumbo Oats Hoppers	4-off 375 Litre capacity stainless steel hoppers are fitted for Caster Sugar, Light Brown Sugar, Buttery Scone Mix and Rolled Jumbo Oats	4-off 375 Litre capacity stainless steel hoppers are fitted for Caster Sugar, Light Brown Sugar, Buttery Scone Mix and Rolled Jumbo Oats	Pass	Figure 96
P.1	Check the Hopper Capacity for Plain & Self-Raising Flour	2-off 500 Litre capacity stainless steel hoppers fitted for Plain & Self-Raising Flour	2-off 500 Litre capacity stainless steel hoppers fitted for Plain & Self-Raising Flour	Pass	Figure 97
P.8	Check the screen size of the GUI	GUI has a 12” Screen	Siemens MTP1200 12” Unified Comfort Panel Installed	Pass	Figures 98-99
P.10	Check PLC network	System is connected to a Siemens IOT2050 Gateway	Siemens IOT2050 Gateway wired in control panel	Pass	Figure 100
P.11	Check 24V Circuit Protection	IFM DF2101 IO-Link Module Wired	Supply chain issues, the DF2101 is on an extended lead time. Temporarily replaced by MCBs & Auxiliaries.	Fail	Figure 101
S.0	Compare the PL rating to the PLr rating	SISTEMA report confirms that the PL is greater than or equal to the PLr (PLr B)	Sistema Report confirms that the system has achieved Performance Level D.	Pass	Figure 102
S.1	Inspect all protective conductor bonding points	All protective conductor bonding points are labelled in accordance with IEC 60417-5019:2006-08	All protective conductor bonding points are labelled in accordance with IEC 60417-5019:2006-08	Pass	Figure 103

S.2	Check the ATEX rating of electrical components in the ATEX zone	All equipment within the ATEX zone is rated suitably to the risk assessment.	All electrical components in the ATEX zone are suitably rated.	Pass	Figures 104-107
S.3	Turn the main shut-off valve off and lock with padlock	Air Service unit is locked and cannot be reinstated, pressure switch indicates <0.5 Bar	Air Service Unit shut-off valve can be padlocked in the off position.	Pass	Figure 121
S.4	Turn the panel isolator off and lock with padlock	Electrical Isolator is locked and cannot be reinstated	Control Panel isolator can be padlocked in the off position.	Pass	Figure 122
S.5	Confirm that all electrical signals between the safe zone and ATEX zone are connected through barriers, or are suitably rated to allow for no barrier	Signals between the safe zone and ATEX zones are connected through intrinsic barriers, or are suitably rated to require no barrier	Signals between the safe zone and ATEX zones are connected through intrinsic barriers. The HMI & 5/3 Valve manifold are rated to allow for no barriers.	Pass	Figure 108
S.6	Confirm EMC checklist has been completed	EMC Checklist is completed and passed	EMC Checklist is completed and passed ,Signed off.	Pass	Figures 109-114
S.7	Ensure that all mains live parts are protected against contact	All mains live parts are located in enclosures that provide protection against contact, which can only be opened by a proprietary key.	All mains live parts are located in enclosures that provide finger protection against contact to IP2X. The panel can only be opened by a proprietary key.	Pass	Figures 115-120
S.8	System has Emergency Stop	System has an emergency stop pushbutton in the operator area	Emergency Stop has not been delivered due to IDEM supply chain issues	Fail	Fail
S.9	The system must conform to the Safety of machinery. Electrical equipment of machines General requirements BS EN 60204-1:2018	The BS EN 60204-1:2018 Checklist has been completed and passed	The BS EN 60204-1 Checklist is complete & signed off, whilst observed by a Senior Engineer	Pass	Figure 123
A.0	Check machine frame RAL colour	Machine Frame is powder coated to RAL9003	Machine Frame is powder coated to RAL9003	Pass	Figure 124

A.1	Check the specification of control panels in the safe zone	Control Panels outside of ATEX zone are Mild Steel IP54, finished in RAL7035	Control Panels outside of ATEX zone are Mild Steel IP54, finished in RAL7035	Pass	Figures 125-129
A.2	Check the specification of control panels in the ATEX zone	Control Panels in ATEX zone are Stainless Steel IP66, unfinished	Control Panels in ATEX zone are Stainless Steel IP66, unfinished	Pass	Figures 130-131
A.3	Check actuator colours	Actuator Colours conform with BS EN 60204-1:2018	Actuator Colour of the Emergency Stop will conform with BS EN 60204-1:2018	Pass	Figure 132
T.0	Check that the technical file is compiled	Technical File is compiled and saved in the project folder	Technical File has not been completed as the system is not complete	Fail	Fail
F.0	Check that the project budget has not been exceeded	Project budget has not been exceeded	Project is incomplete, it is currently within budget and is predicted to be delivered in budget	Fail	Fail
G.0	Measure the distance between the floor and centre of the GUI	GUI is measured at 1.5m from the centre to the floor	HMI is mounted 1.5m from the floor to its centre	Pass	Figures 134-135
G.1	Measure the distance between the floor and centre of the main panel isolator	Main electrical isolator is measured between 0.6m and 1.7m from the floor	Main electrical isolator is mounted between 0.6m and 1.7m from the floor	Pass	Figure 136
G.2	Ensure all maintenance activities can be undertaken	All maintenance activities can be suitably undertaken	As the HFIVs have not been installed, it cannot be determined if they can be suitably maintained	Fail	Fail

Table 3 – Conformity Test Table

Appendix 9.12.2 – Conformity Testing Evidence

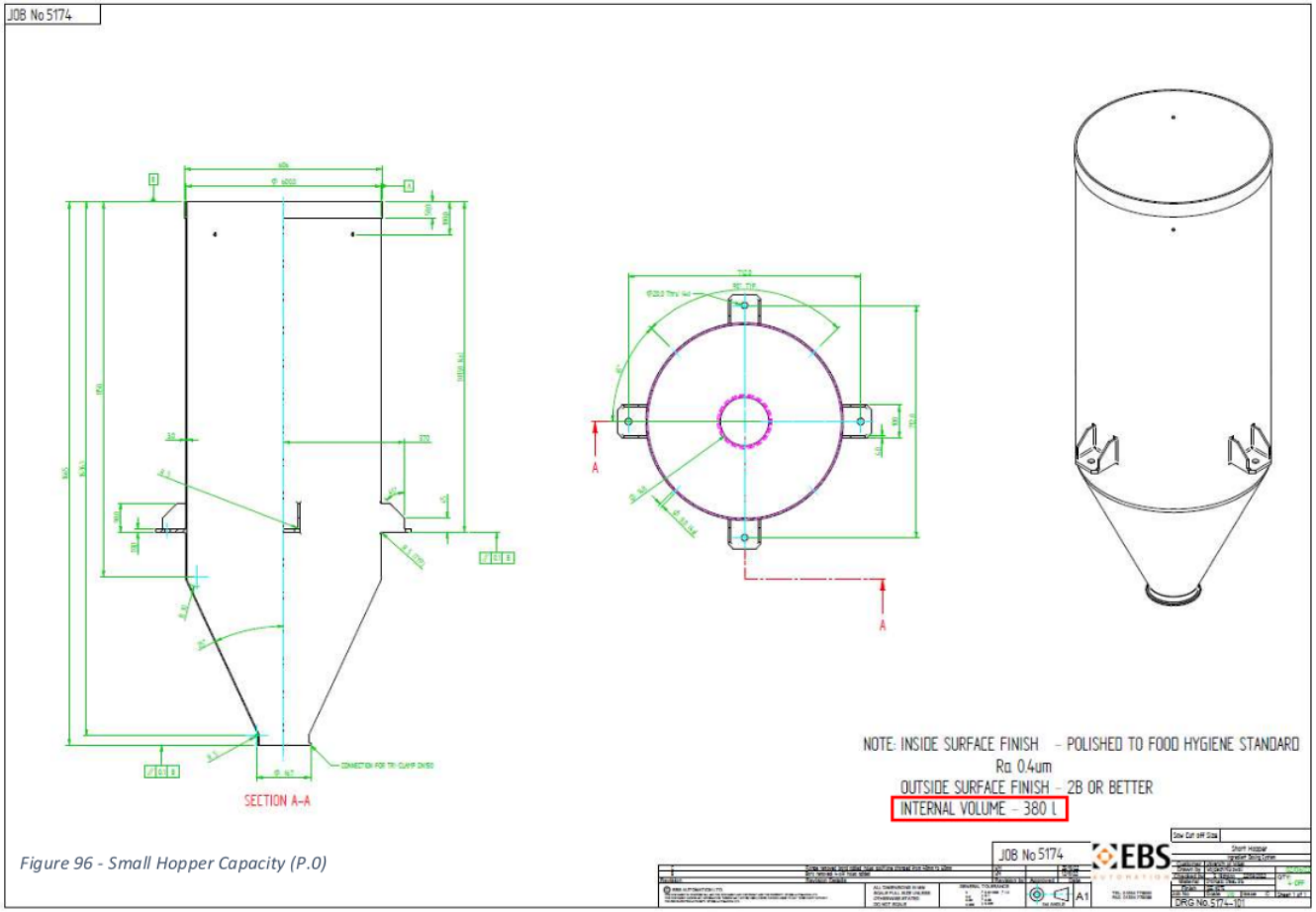


Figure 96 - Small Hopper Capacity (P.0)

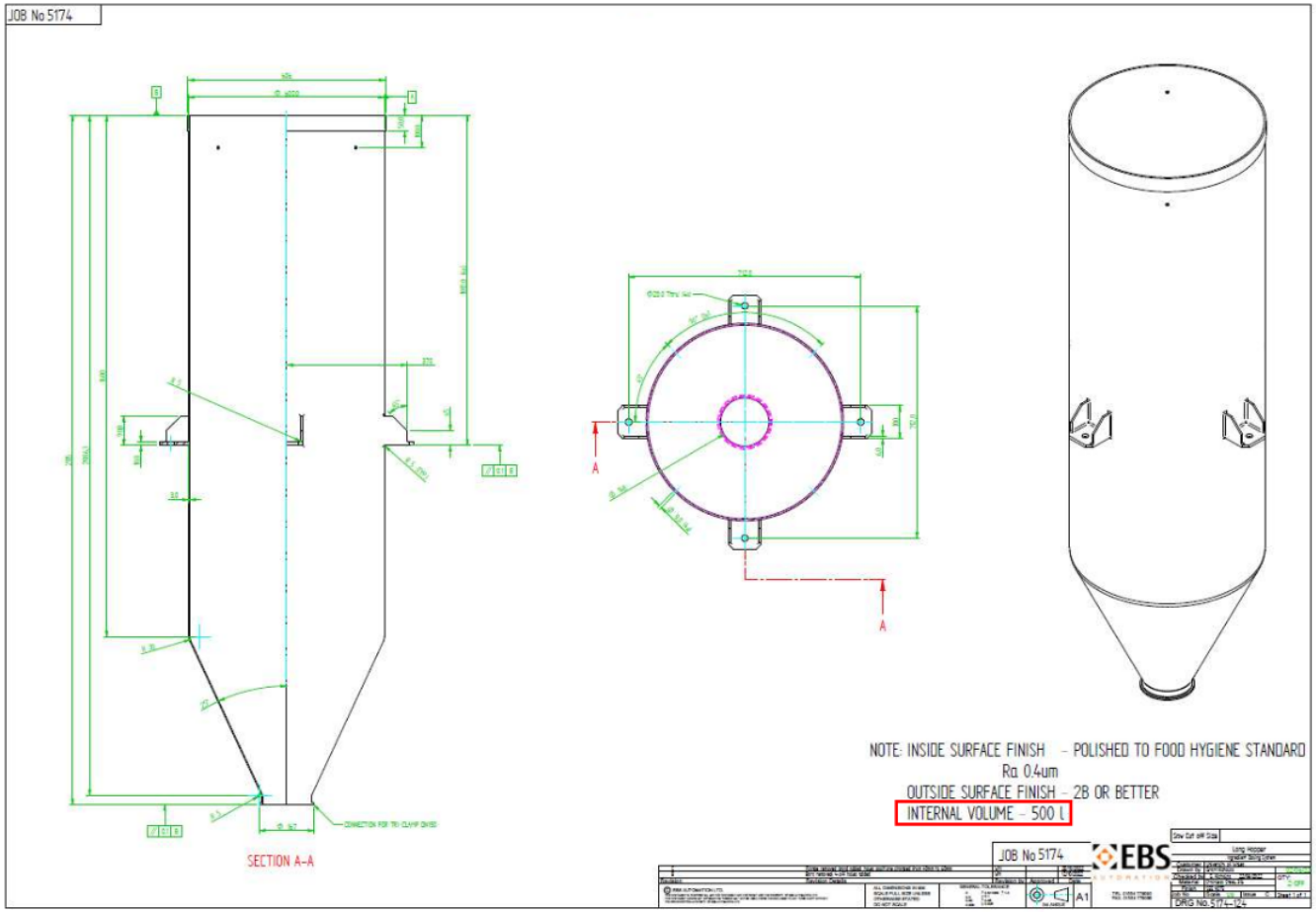


Figure 97 – Big Hopper Capacity (P.1)

Data sheet **6AV2128-3MB06-0AX0**



Figure similar

SIMATIC HMI MTP1200, Unified Comfort Panel, touch operation, 12.1" widescreen TFT display, 16 million colors, PROFINET interface, configurable from WinCC Unified Comfort V16, contains open-source software, which is provided free of charge See enclosed Blu-Ray

General information	
Product type designation	MTP1200 Unified Comfort
Display	
Design of display	TFT
Screen diagonal	12.1 in
Display width	261.1 mm
Display height	163.2 mm
Number of colors	16 777 216

Figure 98 – MTP1200 HMI Datasheet (P.8)



Figure 99 - MTP1200 HMI Label (P.8)



Figure 100 – Siemens MindConnect 2050 (P.10)



Figure 101 – MCBs Replacing DF2101 (P.11)

Contained safety functions

SF Name: Emergency Stop

Required: PLr b | Reached: PL d | PFHD [1/h]: 2.8E-7 | Status: green

Contained subsystems

SB Name: SMC AV3000 Series Soft Start

Resulting PL: d | PFHD [1/h]: 2.5E-7 | Category: 2

MTTFD [a]: 100 (High) | DCavg [%]: 93.1 (Medium) | CCF Points: 95 (fulfilled)

Contained channels / blocks / Elements

CH Name: Channel 1 (MTTFD [a]: 100)

BL Name: SMC AV3000

MTTFD [a]: 859 (High) | DC [%]: 90 (Medium)

BL Name: G7SA Omron (IEC 61810-3 Forcibly Guided Relay)

MTTFD [a]: 1666.7 (High) | DC [%]: 99 (High)

TE Name: Test channel (MTTFD [a]: 100)

BL Name: Pressure Switch

SISTEMA a free of charge tool from IFA | Page 1 / 3

Figure 102 – SISTEMA Report PLd (S.0)

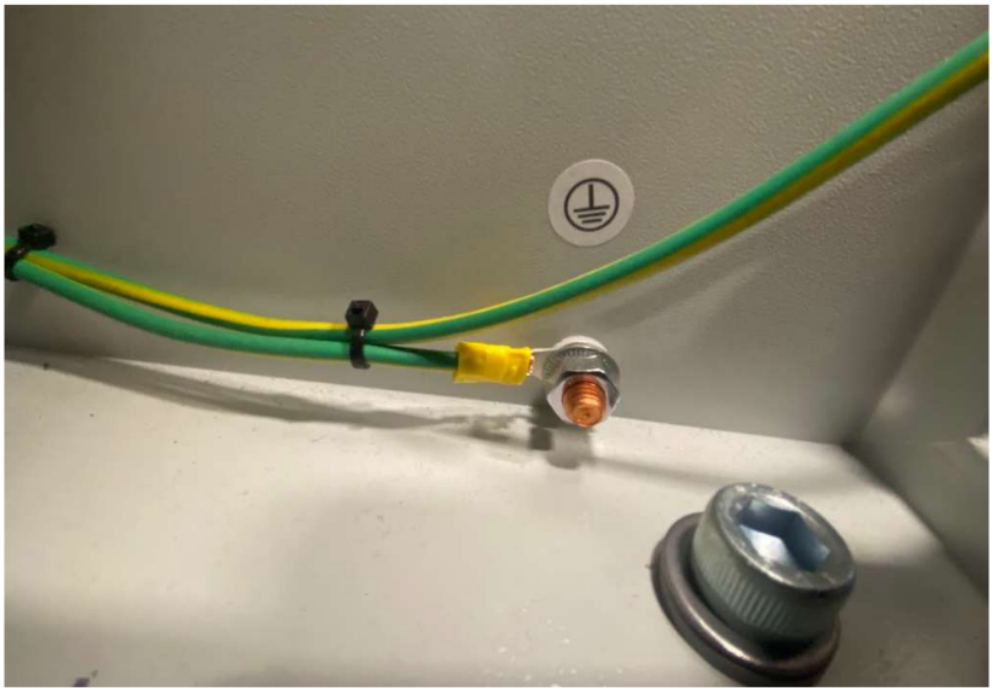


Figure 103 – Earth Bonding Compliance (S.1)



Figure 104 – HMI ATEX Compliance (S.2)

Code	Details
HAPS1010ATEX	Low profile floor scale, utilising Flintec SB8 Beam Load Cells giving non-approved hiresolution capability of up to 15,000 divisions, 3 Mtrs of output cable as standard. Optional side rails are castellated steel and welded onto the top plate for a clean hygenic finish. Including 1 Ramp and 3 metres of interconnection cable Material: 304 Stainless Steel with Glass Bead Blast finish Load Cells: 4 x Flintec SB8 IP68 Shear Beam Weighing Area l x w (mm) 1000mm x 1000mm Capacities (kg) 300kg x 0.02kg 
DFWATEX2GD-1	**DFW "ATEX2GD": WEIGHT INDICATOR FOR ATEX 1 & 21 ZONES** IP68 stainless steel, ATEX 2GD indicator. 17-key keypad and LCD display. Protection mode: ATEX II 2(2)G Ex ib [ib Gb] IIC T4 Gb for gases and ATEX II 2(2)D Ex tb [ib Db] IIIC T197°C IP65 Db for dust. Complete with manual and DECLARATION OF CONFORMITY. To be combined always with the PW200XRDxxx series' power adapter or DFWBP76ATEX battery. Provided with safety instructions and the ATEX EU declaration of conformity (EN, DE, FR, ES and IT).

Figure 105 – Weigh Scale ATEX Compliance (S.2)

(1) **EU - Type Examination Certificate**

(2) Equipment and protective systems intended for use in potentially explosive atmospheres – **Directive 2014/34/EU**

(3) EU - Type Examination Certificate Number

EPS 18 ATEX 1 156 X **Revision 1**

(4) Equipment: Electropneumatic positioner type TS600

(5) Manufacturer: TISSIN Co., Ltd.

(6) Address: 201-1105, No 397, Seokcheon-ro, Ojeong-gu, Bucheon-Si, Korea

(7) This equipment and any acceptable variation thereto are specified in the annex to this certificate and the documentation therein referred to.

(8) Bureau Veritas Consumer Products Services Germany GmbH, notified body No. 2004 in accordance with Article 21 given in the Directive 2014/34/EU of the European Parliament and of the Council of 26 February 2014, certifies that this equipment has been found to comply with the essential health and safety requirements relating to the design and construction of equipment and protective systems intended for use in potentially explosive atmospheres, given in Annex II of the Directive. The examination and test results are recorded in the confidential documentation under the reference number 18TH0255.

(9) Compliance with the essential health and safety requirements has been assured by compliance with:

EN 60079-0:2012+A11:2013 **EN 60079-0:2018 (IEC 60079-0:2017)**

EN 60079-1:2014 **EN 60079-11:2012**

EN 60079-18:2015/A1:2017

(10) If the sign "X" is placed after the certificate number, it indicates that the equipment is subject to special conditions for safe use specified in the annex to this certificate.

(11) This EU - Type Examination Certificate relates only to the design and examination of the specified equipment in accordance with Directive 2014/34/EU. Further requirements of this Directive apply to the manufacture of this equipment and its placing on the market. Those requirements are not covered by this certificate.

(12) The marking of the equipment shall include the following:

II 2G Ex db mb IIB/IIC T6/T5 Gb
II 2G Ex ia IIC T6/T5 Gb
II 2D Ex tb IIIC T85°C/T100°C Db IP66



Certification department of explosion protection Nuremberg, 2019-05-09

H. Schaffer

Page 1 of 2

Certificates without signature and seal are void. This certificate is allowed to be distributed only if not modified. Extracts or modifications must be authorized by Bureau Veritas Consumer Products Services Germany GmbH. EPS 18 ATEX 1 156 X, Revision 1.

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Figure 106 – Positioner ATEX Compliance 1 (S.2)

(13) **Annex**

(14) **EU - Type Examination Certificate EPS 18 ATEX 1 156 X** **Revision 1**

(15) Description of equipment:

Electro-Pneumatic valve positioner TS600 series controls the valve stroke in response to an input signal of 4~20mA DC from the control panel, DCS or calibrator.

Enclosure fulfils IP66 rating according to EN 60529.

Electrical data:

4~20mA DC

Intrinsically safe version:

Ui max 28V

Ii max 101mA

Pi max 707mW

Figure 107 - ATEX Barriers (S.5)



Figure 108 - Positioner ATEX Compliance 2 (S.2)



Figure 109 – EMC Checklist (S.6)

Title ..... EMC - Checklist
Version 1.10
Document no. 100151
Original ..... en
Author ..... Festo

Last saved 08.08.2017

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Internet: http://www.festo.com
E-Mail: service_international@festo.com

Figure 110 - EMC Checklist (S.6)

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2.2 Control cabinet 7

2.3 Cable ducts 8

2.4 System environment 8

Figure 111 - EMC Checklist (S.6)

2 Checkpoints

2.1 Common

- Are all system segments consistently earthed – check carefully because, for example, metal cable ducting is often interrupted! Wherever interruptions are discovered, both ends must be connected with at least one braided copper strap! A **single** gap destroys the shield effect of the entire duct! ✓
- Pay special attention to the laying of cables between the system and the control cabinet – this differs from the cabling used at the manufacturer's location during commissioning. Ask the customer to open covered cable ducts in this area for this reason! ✓
- Is there an equipotential bonding busbar? How and where is it connected? (At Festo: The central point conductor is connected to a foundation earth electrode in the transformer station and is then star-connected to the equipotential bonding busbars in production.) ✓
- Is meshed earthing used, i.e. are numerous system components connected to functional earth via earthing straps? (Numerous earthing straps connected in parallel result in a low-impedance connection to earth potential, even for high frequencies!) N/A
- Cross-section of earthing cables at least 4 sq. mm? ✓
- Does the system consist of anodised extruded profiles? Are the individual elements screwed together with T-head nuts which reliably puncture the anodised coating? N/A
- Machine base segments connected consistently with low-impedance – above all check for paint on painted frame sections which prevents large-area surface contact. ✓
- Plastic or metal cable ducts? Plastic ducts should only be used in earthed system segments, because they are otherwise susceptible to field-related interference. ✓
- Cables are consistently laid along an earthed machine base. A metal cable duct is used where this isn't possible. ✓
- Cables or cable harnesses do not protrude "into the air" as a loop. ✓
- Where foils are processed, conveyor belts are used or in the case of insulated workpiece carriers during a welding process: have brushes or ionising bars been installed in order to disperse charges? N/A
- Welding units with HF ignition – is the welding electrode holder earthed? N/A
- The shielding effect is poor where large lattice support structures are used. For example, massive field interference can occur in proximity to welding units. N/A
- All cables are laid along earthed metal structures, i.e. no surfaces are spanned due to laying. ✓

Figure 112 - EMC Checklist (S.6)

2.2 Control cabinet

- Bare mounting plate (e.g. galvanized steel sheet metal), massively earthed. ✓
- The following applies in general: all of the control cabinet's metal parts must make large-area surface contact with each other – no paint to paint! ✓
- Control cabinet door connected to the cabinet itself via short, braided copper straps? In the case of large control cabinets, 3 braided copper straps should be connected which are evenly distributed over the length of the door. ✓
- Is earthing to components mounted in the control cabinet door connected? ✓
- Bare converter housings make large-area surface contact with bare, earthed mounting plate. N/A
- Devices which generate interference (e.g. converters) and sensitive control components spatially separated from each other? ✓
- There are no cables which form loops in the air, i.e. all cables are laid close to earthed sheet metal parts/housings. ✓
- Motor cables laid separately from signal lines? N/A
- Signal cables are only fed into the control cabinet from one side. ✓
- Reserve lines are connected to functional earth at both ends. ✓
- Shielded cables: the shield is connected with good surface contact immediately after entry into the control cabinet. ✓
- Shielded cables: the shield is connected with large-area surface contact upstream and downstream from a clamp. ✓
- Shield connection not on painted surfaces? ✓
- Connection established between 0 V and functional earth? (due to PELV: in accordance with DIN EN 60204-1, one side of the circuit or a point within the energy source for this circuit must be connected to the protective circuit). ✓
- Mains filters installed correctly? The bare mains filter housing makes good surface contact with the bare mounting plate and is not mounted on the painted control cabinet! If this is not the case, unscrew and remove the mains filter, and strip the paint down to bare metal. N/A
- Mains filter: cables laid correctly? – i.e. the filtered cable is not led back to the unfiltered end and laid parallel to the incoming mains cable! N/A
- Filter for converter installed very close to the converter? N/A

Figure 113 - EMC Checklist (S.6)

Checkpoints

2.3 Cable ducts

- Are power cables (e.g. motor cables) and sensitive signal cables laid separately? ✓
- Uninterrupted metal partitions in metal cable ducts? N/A
- Are cables separated according to cable category, or is everything mixed up? Seperate ✓

2.4 System environment

- Are there potential sources of interference in the system's environment (e.g. welding units, converters, electric drives)? No
- Are metal cable ducts consistently earthed with low-impedance? Yes
- Are cable reserves wound up as coils? If so uncoil, fold in the middle and wind back up doubled over (bifilar winding). Unwound
- Is sporadic interference detected (e.g. due to a gantry crane, a lift, air conditioning or a welding unit)? No.

JJ Greiner

22/02/2023.

Figure 114 - EMC Checklist (S.6)



Miniature circuit breaker (MCB), Multi9 C60N, 1P, 2A, C curve, 10kA (IEC/EN 60947-2)

M9F11102

Environment

Heat dissipation	2.6 W at 240 V - 2 A
IP degree of protection	IP20 conforming to IEC 60529 IP40 (modular enclosure) conforming to IEC 60529

Figure 115 – MCB IP Protection (S.7) (SE, 2023)

OT25F3

Mounting Type	Base mounting
Number of Poles	3
Cable Cross-Section	Cu 0.75 ... 10 mm²
Wire Stripping Length	Main Circuit 10 mm Main Circuit 0.38 in
Degree of Protection	Front IP20
Terminal Type	Screw Terminals
Tightening Torque	acc. IEC 60947-1 0.8 N·m
Mechanical Durability	20000
Lock Type	No

Figure 116 –Isolator IP Protection (S.7) (Eaton, 2023)

DATASHEET - RS20H



Fuse-holder, low voltage, 20 A, AC 690 V, BS88/A1, 1P, BS, front connected

Powering Business Worldwide

Katalog Nr. **RS20H**

Delivery program

Product range			Fuse accessory
Basic function			Fuse-holder
Field of application			low voltage
Rated current	I	A	20
Rated voltage			AC 690 V
Construction size			BS88/A1
Description			front connected Paint finish
Protection			IP20
Number of poles			1P
usable for size/applications			NITD and NIT fuse-links
Standard/Approval			BS
Standards/Regulations			BS88-2 IEC 60269-2

Figure 117 – Main Fuse IP Protection (S.7) (Eaton, 2023)

Product datasheet

Specifications



iC60H - earth leakage circuit breaker - 1P + N - C curve - 6 A - 30m A - 240 V

Local distributor code: 396790053 A9D11806

Environment

Standards	IEC 61009-1 AS/NZS 61009.1 IEC 61009-2-2 BS EN 61009-1
IP degree of protection	IP20

Figure 118 - RCBO IP Protection (S.7) (SE, 2023)

sifam tinsley

XMER Moulded Case Range - Class 0.2S



XMER - Class 0.2S

XMER CT's are square type and encapsulated with UL94V-0 approved polycarbonate. These metering CT's feature sealable terminal covers and a wide range of primary current ratings with a high accuracy class suitable for tariff metering applications. Available in various, Bus bar sizes, case widths, and mounting options.

OMEGA XMER

Features

- Comprehensive class accuracy
- Cost effective moulded case current transformer
- Various mounting options including wall mounting, cable mounting, bus bar mounting and DIN rail mounting
- 0.2s accuracy class
- Wire sealable terminal covers
- Suitable for tariff metering

Specifications

- Primary current 80A to 7500A
- Secondary current 1A or 5A
- Accuracy class 0.2s
- Over current limiting factor FS5, FS10, FS15
- Rated frequency 50Hz or 60Hz
- Rated continuous thermal current (standard) 1,2 x in
- Rated short time thermal current with 60 x in, 1 s (Max 40kA)
- Rated isolation level 0.72/3 kV or 0.72/4 kV
- Place of insulation Indoor
- Altitude up to 2000 m
- Degree of protection IP20
- Degree of pollution 2
- Ambient temperature -5°C to + 55°C (0-95% relative humidity, non condensing!)
- Storage temperature -25°C to + 70°C
- Applied standards IEC 60044-1 / IEC 61869-1 : Performance, IEC - 61010 - 2 : Safety.

Figure 119 – CT IP Protection (S.7) (Tinsley, 2021)

Degree of protection and protection class

Degree of protection and protection class		
Protection class		Protection class II when installed
Degree of protection according to IEC 60529	Device front panel	IP65
	Device rear panel	IP20

If a higher degree of protection is required for a specific application, the customer must take suitable measures.

Figure 120 – PAC3220 IP Protection (Siemens, 2019)

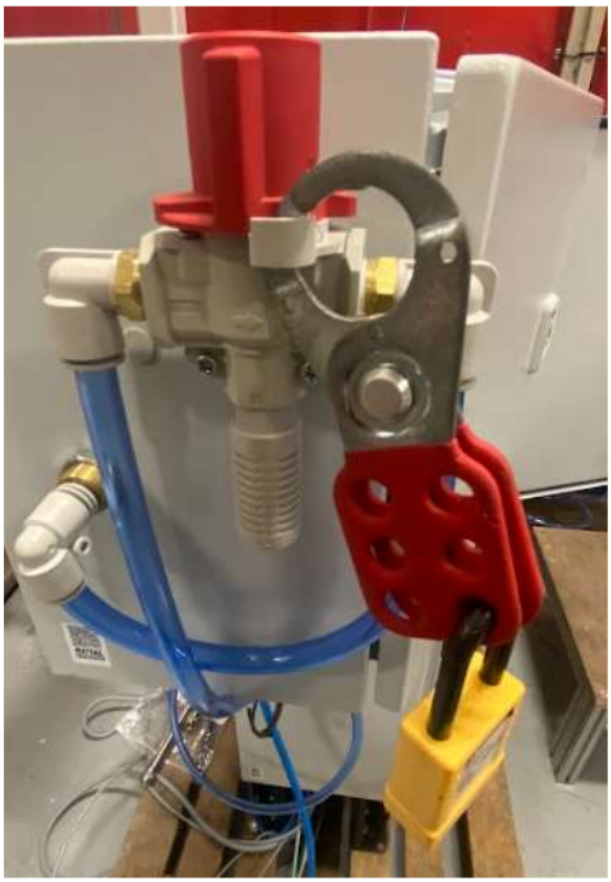


Figure 121 – Main Air Valve Locked (S.3)



Figure 122 – Main Panel Isolator Locked (S.4)

List for the safety
testing of machines
– Electrical equipment –

IFA
Institut für Arbeitsschutz der
Deutschen Gesetzlichen Unfallversicherung

01.07

3 Information on the test specimen and the test

Record/procedure No.:	
Type of test:	Partial test — Equipment ☑ Control ☑ Electrical ☑
Applicant:	EBS Automation LTD
Manufacturer:	EBS Automation LTD
Test specimen: Type: Year of manufacture: Serial No./Product No.:	Ingredient Dosing System Full 2023 EBS 5174 - 123
Testing performed on (date):	22/02/2023
At (company):	EBS Automation LTD
Testing performed by:	Thomas Grennan - [illegible]
Observed by:	Stephen Waters [signature]

PAGE 1

(R)=Recommendation
Edition August 2010

Figure 123 – BS EN 60204-1: 2018 Checklist Certificate (S.9)

JOB No 5174			EBS AUTOMATION	Saw Cut off Size	
				Bottom Frame	
				Ingredient Dosing System	
				Customer	University of Wales
Revision by	Approved	Date		Drawn by	Wojciechmilkowski 17/06/22
ERANCE 1000 ±1.0	3rd ANGLE	A0	TEL. 01554 779090 FAX. 01554 779099	Checked by	QTY: 1-OFF
				Material	
				Finish	Hygienic paint RAL9003
				Job No	Scale 1:10 Issue A Sheet 1 of 1
				DRG No. 5174-GA04	

Figure 124 - Frame RAL Colour (A.0)



Figure 125 - Safe Zone Manifold Panel (A.1)



Figure 126 - Safe Zone Pneumatic Panel Part Number (A.1)

Model No.	AX 1045.000
Benefits	More interior installation options thanks to integral enclosure locators on a 25 mm system pitch pattern combined with the interior installation rail and our diverse range of system accessories Maintains the protection category (UL approval) by mounting the interior installation rail with no drilling required. Base configuration rail provides additional mounting level and increased load capacity Simple planning and configuration with the Rittal RiPanel configurator
Material	Enclosure: Sheet steel Door: Sheet steel, all-round foamed-in PU seal
Surface finish	Enclosure and door: Dipcoat primed, powder-coated on the outside, textured paint Mounting plate: Zinc-plated
Colour	RAL 7035
Supply includes	Enclosure with door(s) Gland plate(s) in enclosure base Mounting plate Perforated door strip Lock: 3 mm double-bit
Protection category NEMA	NEMA 1, 3R, 4, 12
Protection category to IEC 60 529	IP 66

Figure 127 – Safe Zone Manifold Panel Data (A.1)



Figure 128 – Safe Zone Main Panel Part Number (A.1)

Model No.	AX 1180.000
Benefits	More interior installation options thanks to integral enclosure locators on a 25 mm system pitch pattern combined with the interior installation rail and our diverse range of system accessories Maintains the protection category (UL approval) by mounting the interior installation rail with no drilling required. Base configuration rail provides additional mounting level and increased load capacity Simple planning and configuration with the Rittal RiPanel configurator
Material	Enclosure: Sheet steel Door: Sheet steel, all-round foamed-in PU seal
Surface finish	Enclosure and door: Dipcoat primed, powder-coated on the outside, textured paint Mounting plate: Zinc-plated
Colour	RAL 7035
Supply includes	Enclosure with door(s) Gland plate(s) in enclosure base Mounting plate Perforated door strip Lock: 3 mm double-bit
Protection category NEMA	NEMA 1, 3R, 4, 12
Protection category to IEC 60 529	IP 66

Figure 129 - Safe Zone Main Panel Data (A.1) (Rittal, 2023)



Figure 130 – ATEX Zone HMI Panel (A.2)

Model No.	KL 1530.010
Material	Enclosure: Stainless steel 1.4301 (AISI 304) Cover: Stainless steel 1.4301 (AISI 304), all-round foamed-in PU seal
Surface finish	Enclosure and cover: Brushed, grain 180
Supply includes	Enclosure with cover Quick-release fastener including plastic bushes
Protection category NEMA	NEMA 4X
Protection category to IEC 60 529	IP 66
IK Code	IK08
Dimensions	Width: 400 mm Height: 300 mm Depth: 120 mm

Figure 131 – HMI Panel Non Safe Zone (A.2) (Rittal, 2023)



Figure 132 – Emergency Stop Actuator Colour (A.3) (IDEM, 2023)

10.2 Actuators

10.2.1 Colours

Actuators (see 3.1.1) shall be colour-coded as follows.

The colours for START/ON actuators should be WHITE, GREY, BLACK or GREEN with a preference for WHITE. RED shall not be used.

The colour RED shall be used for emergency stop and emergency switching off actuators (including supply disconnecting devices where it is foreseen that they are for use in an emergency). If a background exists immediately around the actuator, then this background shall be coloured YELLOW. The combination of a RED actuator with a YELLOW background shall only be used for emergency operation devices.

Figure 133 – BS EN 60204-1 Actuator Requirements (A.3) (BSI, 2021)

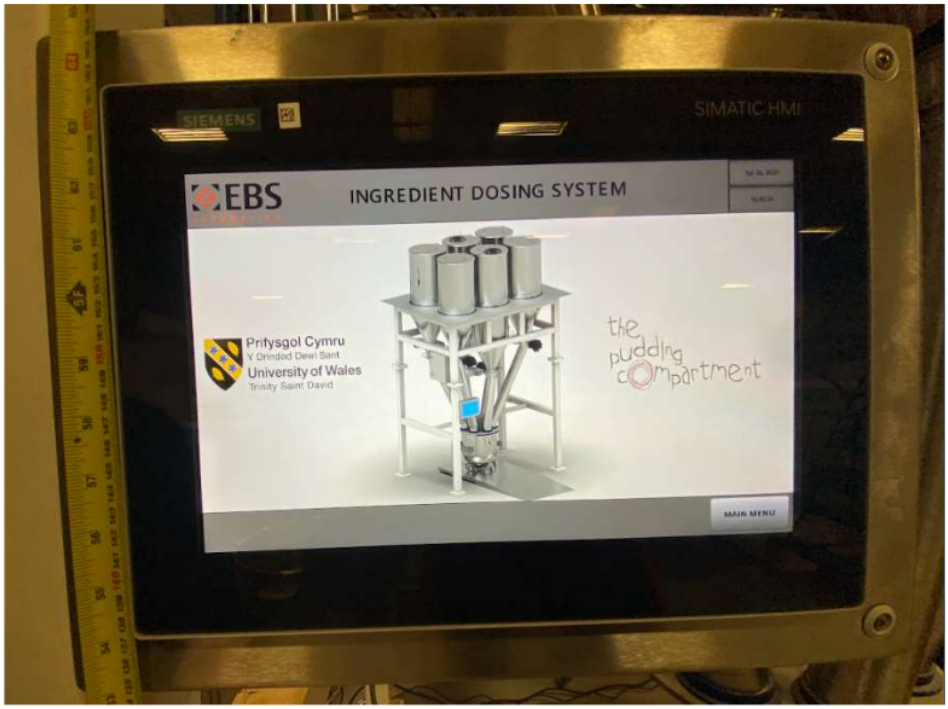


Figure 134 – Measurement between HMI & Floor 1.5m (G.0)

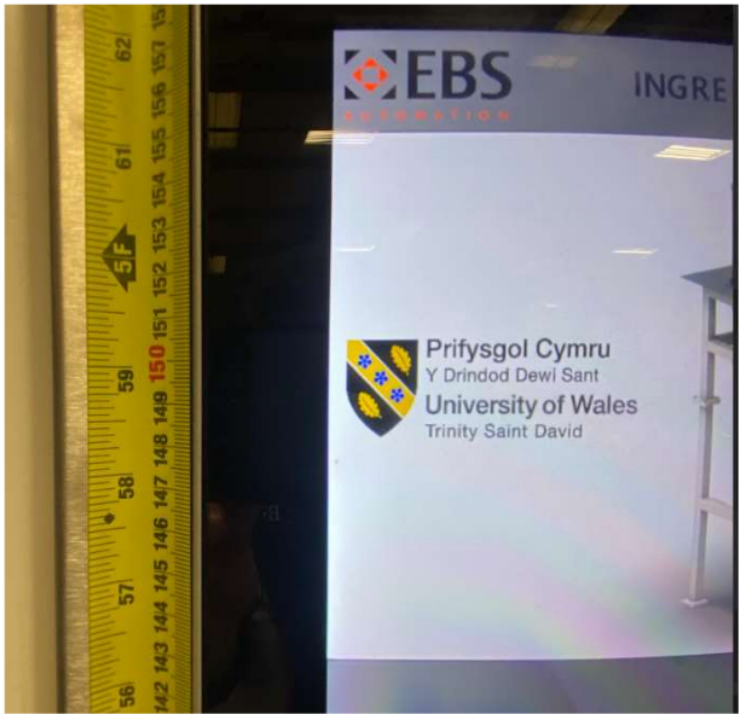


Figure 135 - Measurement between HMI & Floor 1.5m (G.0)



Figure 136 - Measurement between Isolator & Floor 1.08m (G.1)

Appendix 9.12.3 – Functional Testing Test Plan

Functional Tests					
Ref.	Test Description	Expected Outcome	Actual Outcome	Pass or Fail?	Evidence
P.2	When the hoppers are empty, start a dosing cycle	After 10 seconds, the system indicates that the hopper is empty	In automatic modes, if the hopper is empty it is detected within 10 seconds	Pass	Figure 146
P.3	On the GUI recipe screen, add a new recipe and press save.	In the controller software, the new recipe is saved	A Recipe can be added in the Product Settings screen. When the save button is pressed the user entered information is stored in the Recipes datablock and can then be loaded into the current recipe datablock	Pass	Figures 137 - 139
P.4	During a cycle that requires external product, add a product and enter the product weight	System acknowledges addition of external product, carries on with sequence	During a recipe which requires external product, the operator receives clear information to add a manual ingredient. Once the operator confirms that the ingredient is loaded, the weight is measured and the sequence continues.	Pass	Figures 140 - 142
P.5	Run a “Empty Sequence”	System runs an empty sequence, removes all product from the selected hopper.	System runs an empty sequence, removes all product from the selected hopper.	Pass	Figures 143 - 146
P.6	Load the scale with 300Kg	Scale indicates a weight of 300Kg, Weight displayed on GUI	Not practical to test, supplier quote confirmed 300Kg capacity	Pass	Figure 147

P.7	Dose 10 different recipes into the mixing bowl on the scale	Each recipe is manually weighed and is accurate to +/- 20g	10 different recipes have been dosed and are all accurate within 20g per ingredient.	Pass	Figure 148
P.9	Test the incoming supply voltage	Incoming voltage is tested at 230V +/- 10%, All panel equipment is powered on	Incoming voltage tested at 240VAC; all components are powered	Pass	Figures 149 - 150
P.12	Must include Alarms Screen	Alarm screen implemented displaying alarms on Inputs & Profinet Network	Alarm screen displays indications on the state of the system inputs	Pass	Figures 151 – 172
D.0	Check GUI 'Diagnostics' screen	Diagnostics screen displays the status of the system Inputs & Outputs	Diagnostic screens display the status of all inputs, outputs and status of the Profinet devices.	Pass	Figures 173 - 175
D.1	During a sequence, check the 'Auto' screen	Auto screen displays current sequence step number	Auto screen displays a message on the current sequence step	Pass	Figure 176
D.2	In any mode, shut off the main air isolation valve	System detects loss of air pressure and flags an alarm	When the air pressure drops below the set-point for 5s, an alarm is flagged in any mode.	Pass	Figure 163 - 164
E.0	In any mode, do not control any machine functions	After 15 minutes of no operator action, the system removes power to the dump valve, removing air from the system.	Not implemented due to addition of HFIVs to combat cohesive bridging	Fail	Fail
E.1	Check 'System Info' Screen	System Info screen displays Electricity-consumption-information	'Diagnostic Power Monitoring' Screen displays electricity consumption information	Pass	Figure 177

E.2	Check ‘System Info’ Screen	System Info screen displays Air consumption information	‘Diagnostic Power Monitoring’ Screen displays air consumption information	Pass	Figure 177

Table 4 - Functional Testing Test Table

Appendix 9.12.4 - Functional Design Specification Testing Evidence

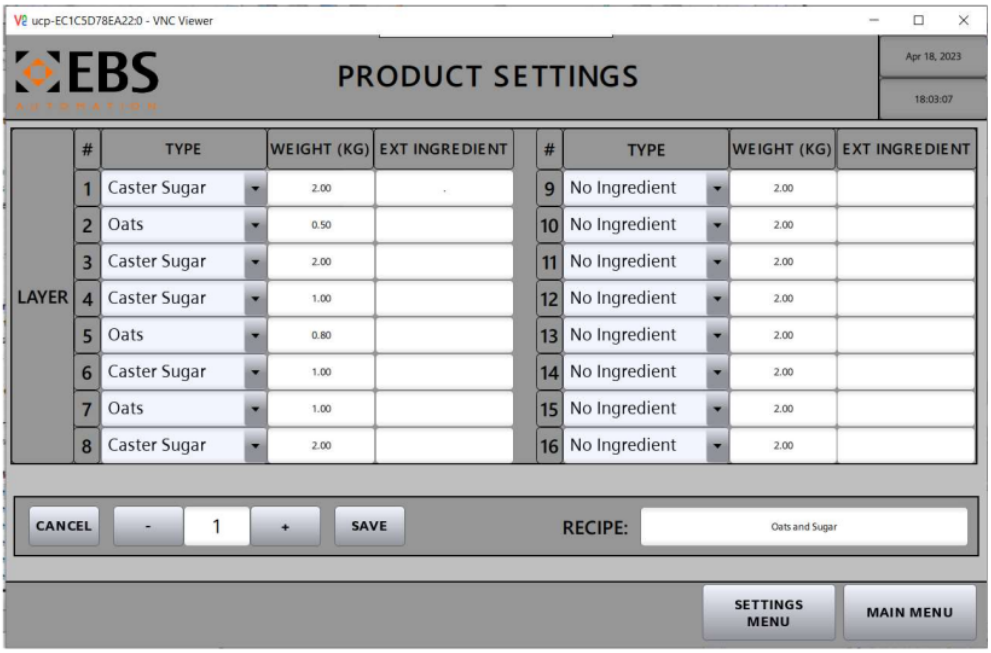


Figure 138 - Entering Recipe on HMI (P.3)

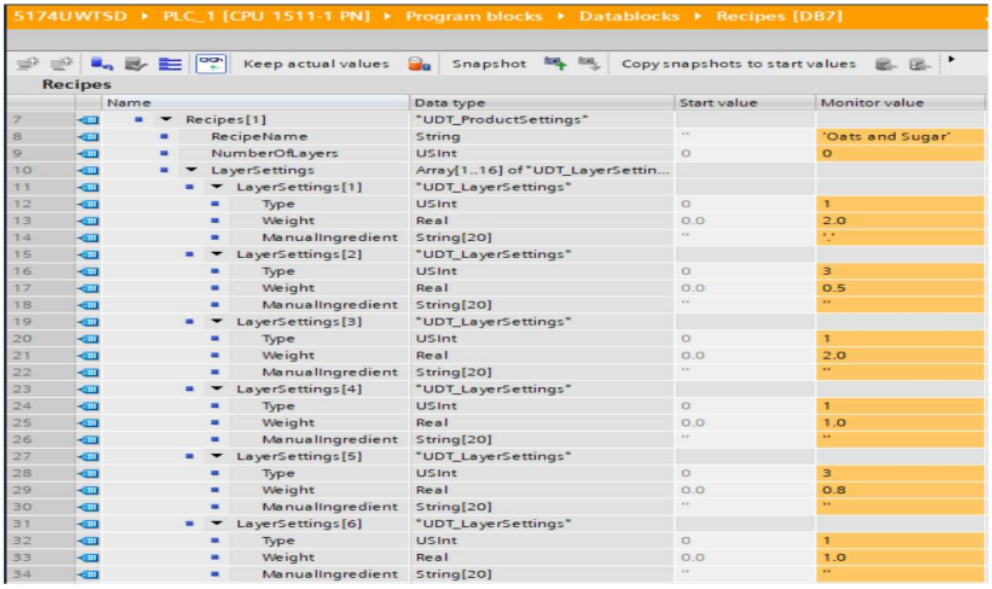
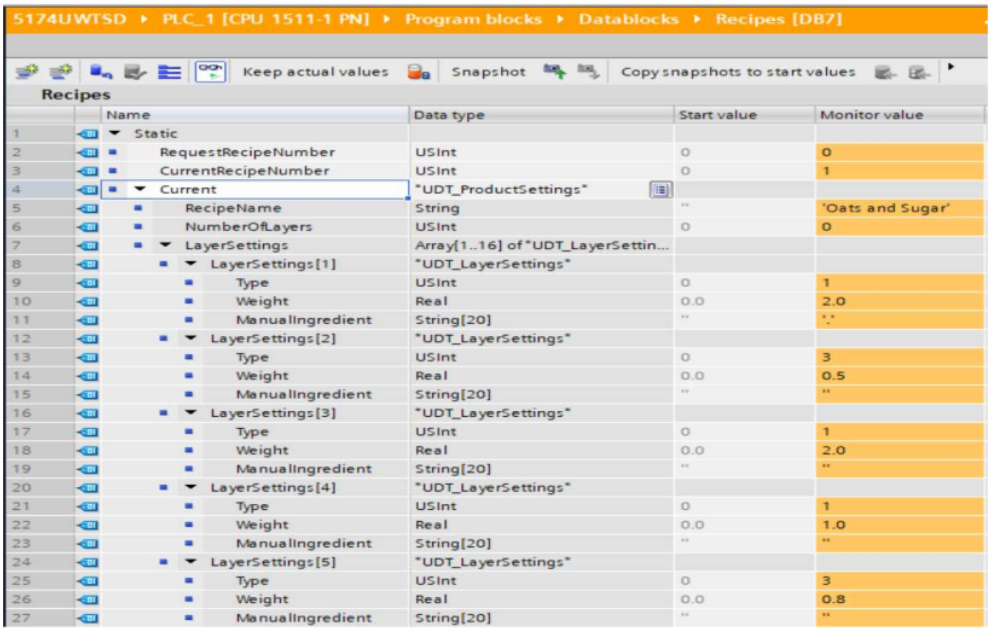


Figure 137 – Saving Recipe in Edit Datablock (P.3)



	Name	Data type	Start value	Monitor value
1	Static			
2	RequestRecipeNumber	USInt	0	0
3	CurrentRecipeNumber	USInt	0	1
4	Current	"UDT_ProductSettings"		
5	RecipeName	String	''	'Oats and Sugar'
6	NumberOfLayers	USInt	0	0
7	LayerSettings	Array[1..16] of "UDT_LayerSettin...		
8	LayerSettings[1]	"UDT_LayerSettings"		
9	Type	USInt	0	1
10	Weight	Real	0.0	2.0
11	ManualIngredient	String[20]	''	''
12	LayerSettings[2]	"UDT_LayerSettings"		
13	Type	USInt	0	3
14	Weight	Real	0.0	0.5
15	ManualIngredient	String[20]	''	''
16	LayerSettings[3]	"UDT_LayerSettings"		
17	Type	USInt	0	1
18	Weight	Real	0.0	2.0
19	ManualIngredient	String[20]	''	''
20	LayerSettings[4]	"UDT_LayerSettings"		
21	Type	USInt	0	1
22	Weight	Real	0.0	1.0
23	ManualIngredient	String[20]	''	''
24	LayerSettings[5]	"UDT_LayerSettings"		
25	Type	USInt	0	3
26	Weight	Real	0.0	0.8
27	ManualIngredient	String[20]	''	''

Figure 139 – Edit Recipe Copied to Current Recipe (P.3)

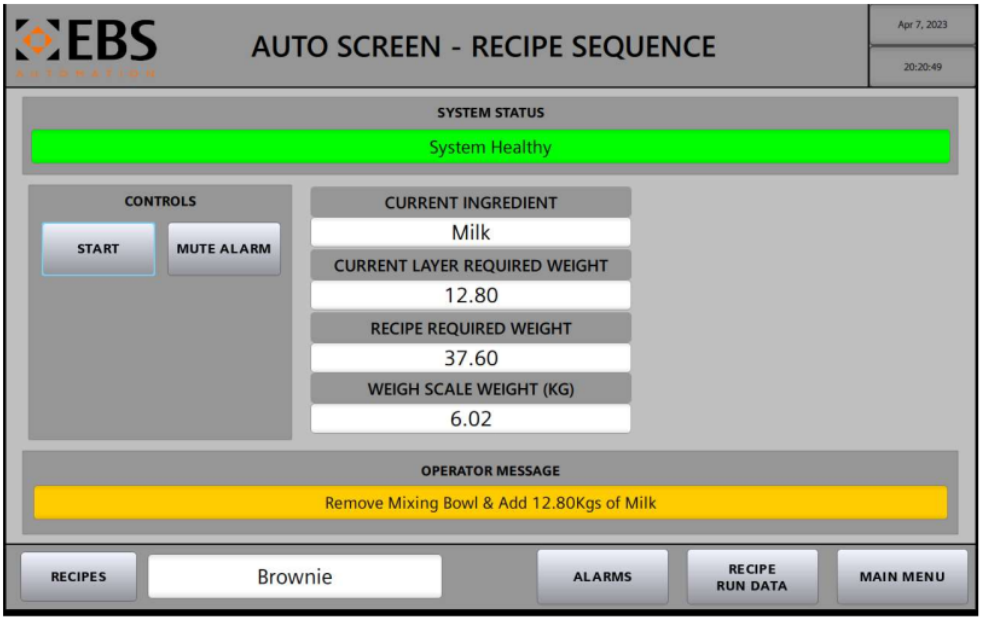


Figure 140 - Functional Test Evidence – Addition of External Ingredient Instruction (P.4)

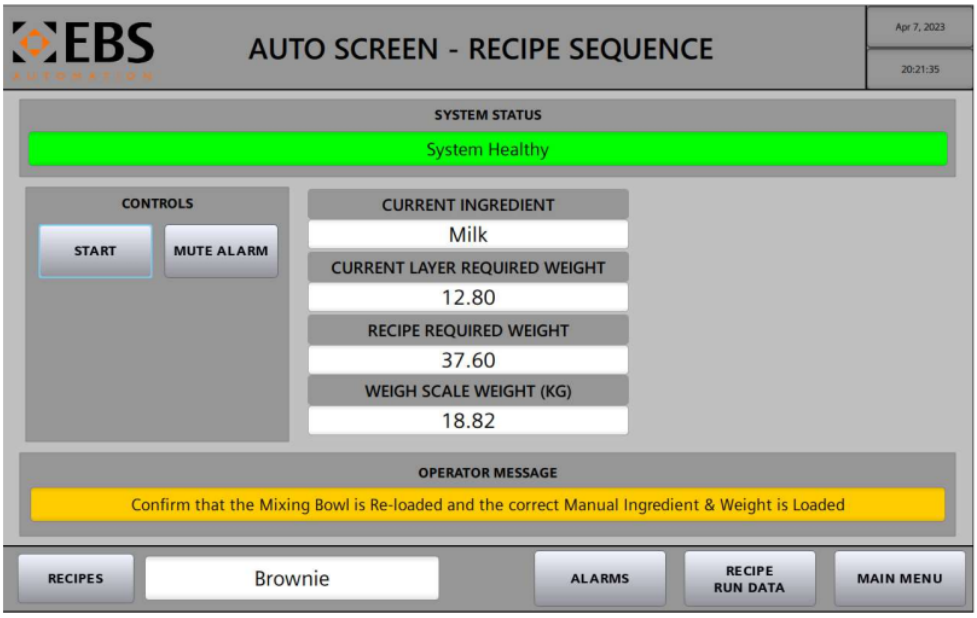


Figure 141 - Functional Test Evidence – Confirmation of Ext Ingredient Instruction (P.4)

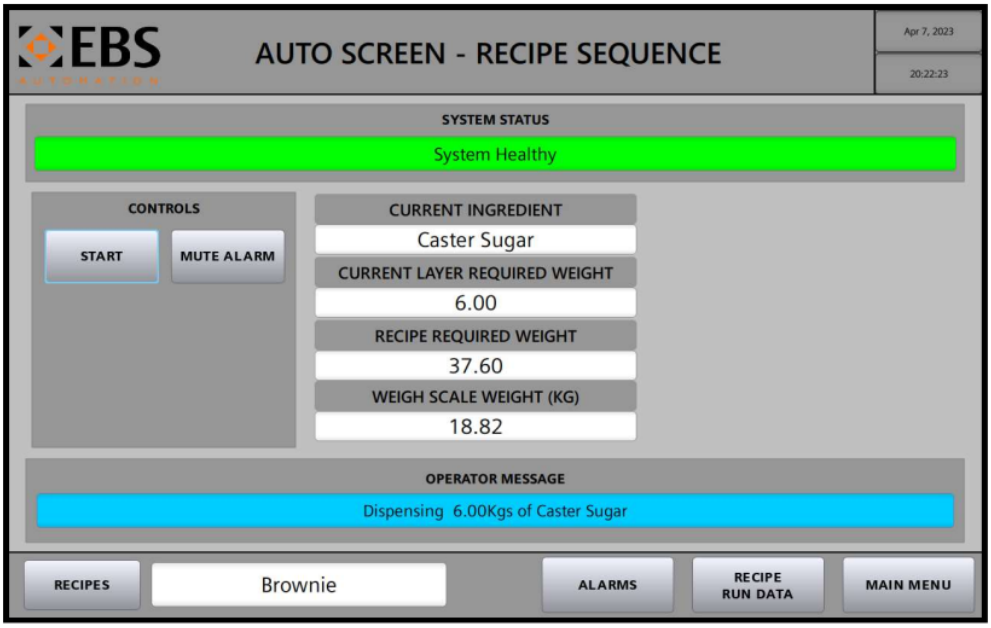


Figure 142 - Functional Test Evidence – Acceptance (Weight OK) of Ext Ingredient Instruction (P.4)

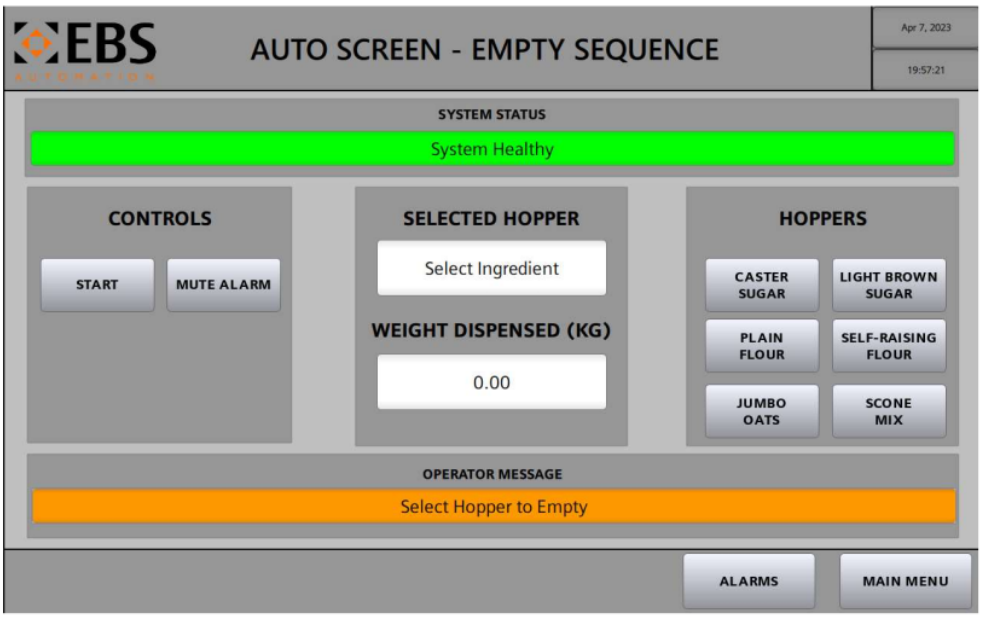


Figure 143 - Functional Test Evidence – Empty Sequence Process on HMI 1 (P.5)

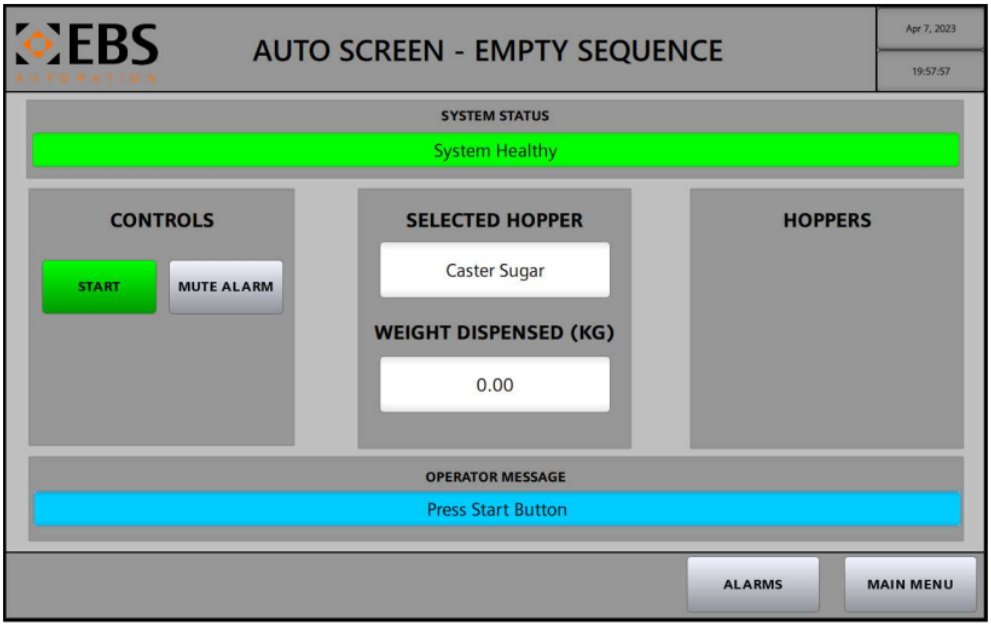


Figure 144 - Functional Test Evidence – Empty Sequence Process on HMI 2 (P.5)

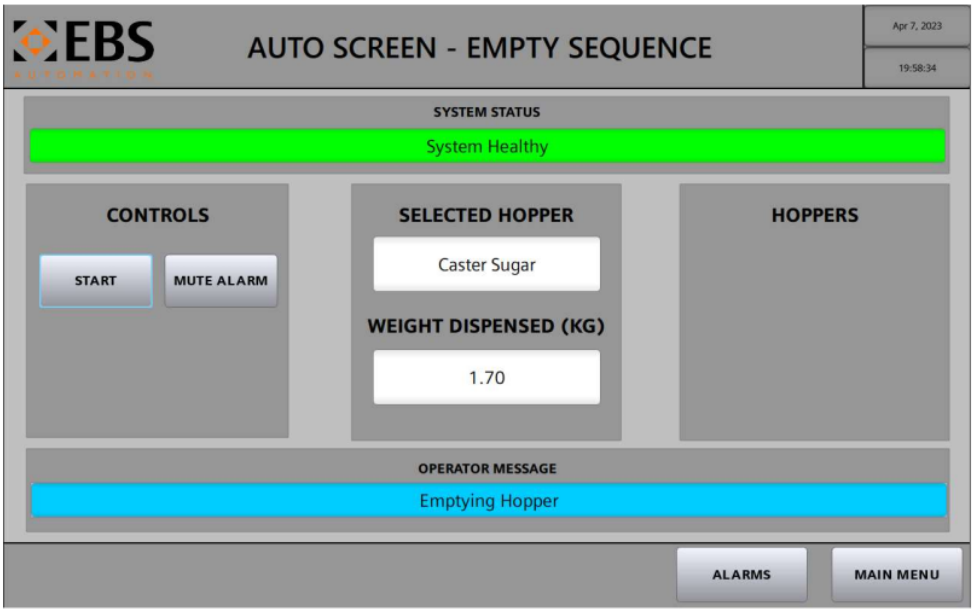


Figure 145 - Functional Test Evidence – Empty Sequence Process on HMI 3 (P.5)

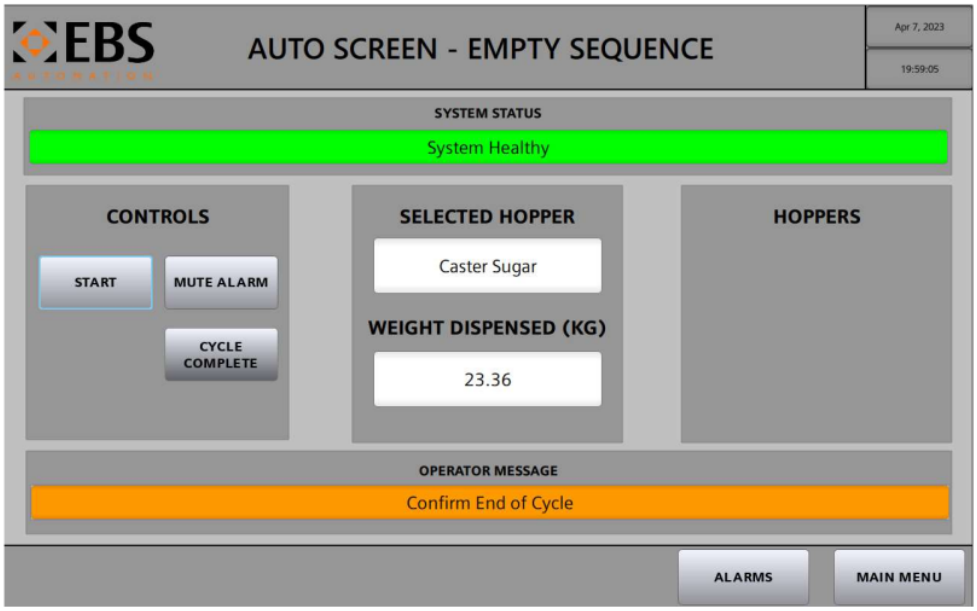


Figure 146 - Functional Test Evidence – Empty Sequence Process on HMI 4 (P.5)

Quote ID: Q060722LB_HAPS
Date: 06/07/2022

MWS
Precision & Reliability in Perfect Balance

Unit 6, Meer End, Birstall
Leicester LE4 3EH
Tel: 0845 260 2602
sales@mws.ltd.uk

FAO: Thomas Grennan
EBS Automation Ltd
7 Heol Cropin,
Parc Dafen,
Dafen,
Llanelli,
Carmarthenshire,
SA14 8QW

Re: Q060722LB_HAPS

Dear Tom,

Many thanks for your interest in our products and services, please find below our quotation for the stainless steel platform scales you requested.

Code	Details	List Price	Qty	Total
HAPS1010ATEX	Low profile floor scale, utilising Flintec SB8 Beam Load Cells giving non-approved hiresolution capability of up to 15,000 divisions, 3 Mtrs of output cable as standard. Optional side rails are castellated steel and welded onto the top plate for a clean hygenic finish. Including 1 Ramp and 3 metres of interconnection cable Material: 304 Stainless Steel with Glass Bead Blast finish Load Cells: 4 x Flintec SB8 IP68 Shear Beam Weighing Area l x w (mm) 1000mm x 1000mm Capacities (kg) 300kg x 0.02kg	4,445.00	1.00	3,556.00

Figure 147 - Functional Test Evidence – Weigh Scale Capacity (P.6)

EBS AUTOMATION

RECIPE SEQUENCE RUN DATA

Apr 7, 2023
20:13:21

LAYER	INGREDIENT	MANUAL TYPE	REQ WEIGHT (KG)	ACTUAL WEIGHT (KG)
1	Caster Sugar	.	2.00	2.00
2	Jumbo Oats		0.50	0.50
3	Caster Sugar		2.00	2.02
4	Caster Sugar		1.00	1.00
5	Jumbo Oats		0.80	0.80
6	Caster Sugar		1.00	1.00
7	Jumbo Oats		1.00	1.02
8	Caster Sugar		2.00	2.02
9	Jumbo Oats		2.00	2.00
10	Jumbo Oats		2.00	2.00
11			2.00	0.00
12			2.00	0.00
13			2.00	0.00
14			2.00	0.00
15			2.00	0.00
16			0.00	0.00

START TIME & DATE: 07. April 2023 | 7:11:07 PM
END TIME & DATE: 07. April 2023 | 7:12:55 PM
DURATION (S): 108
TOTAL WEIGHT (KG): 10.32

CURRENT RECIPE: Oats and Sugar
AUTO SCREEN
MAIN MENU

Figure 148 - Functional Test Evidence – Recipe Dosed with 10 Ingredients Run Data (P.7)

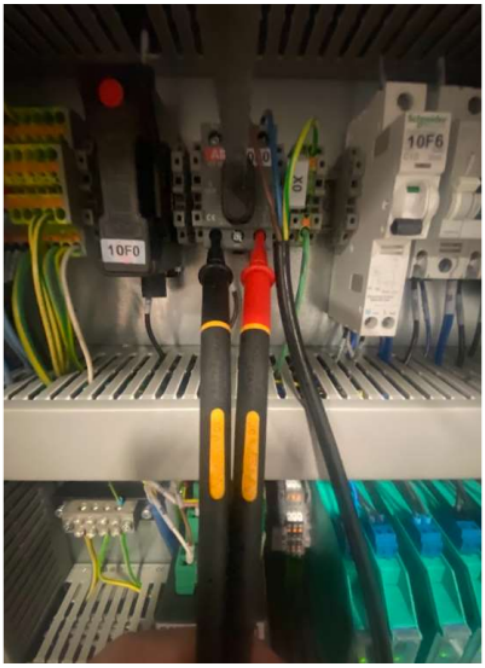


Figure 149 - Functional Test Evidence – Testing Incoming Supply (P.9)



Figure 150 - Functional Test Evidence – Recipe Dosed with 10 Ingredients (P.7)

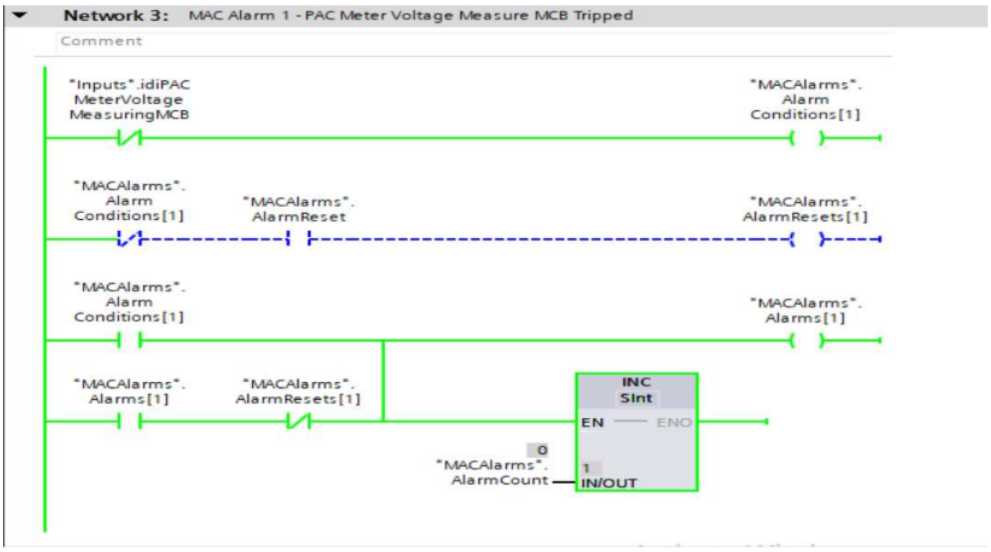


Figure 151 - Functional Test Evidence – Alarm 1 Network (P.12)



Figure 152 - Functional Test Evidence – Alarm 1 HMI (P.12)

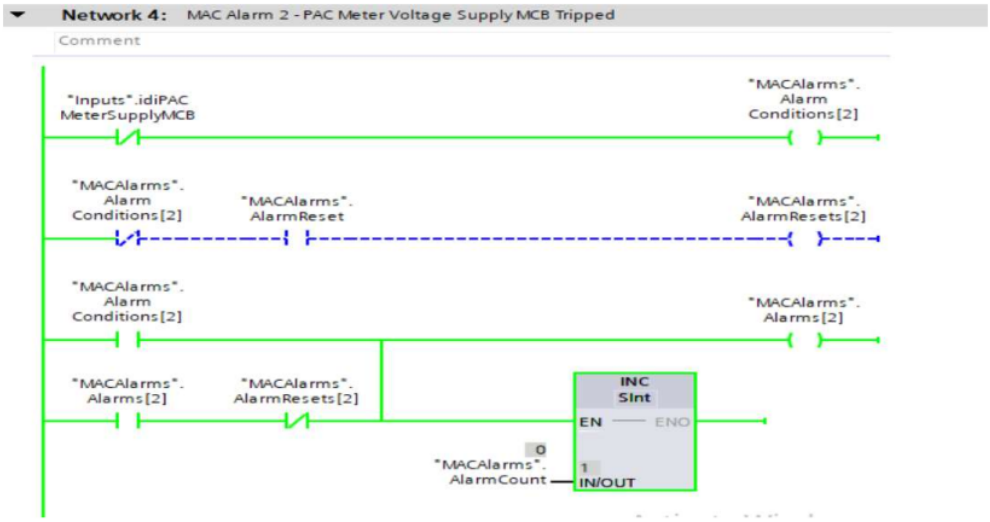


Figure 153 - Functional Test Evidence – Alarm 2 Network (P.12)

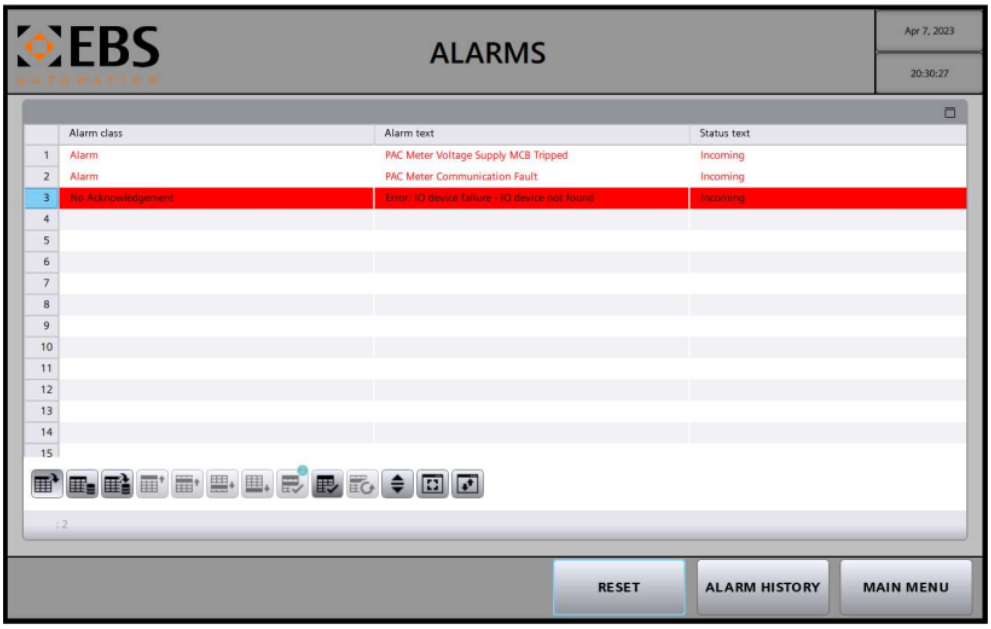


Figure 154- Functional Test Evidence – Alarm 2 HMI (P.12)

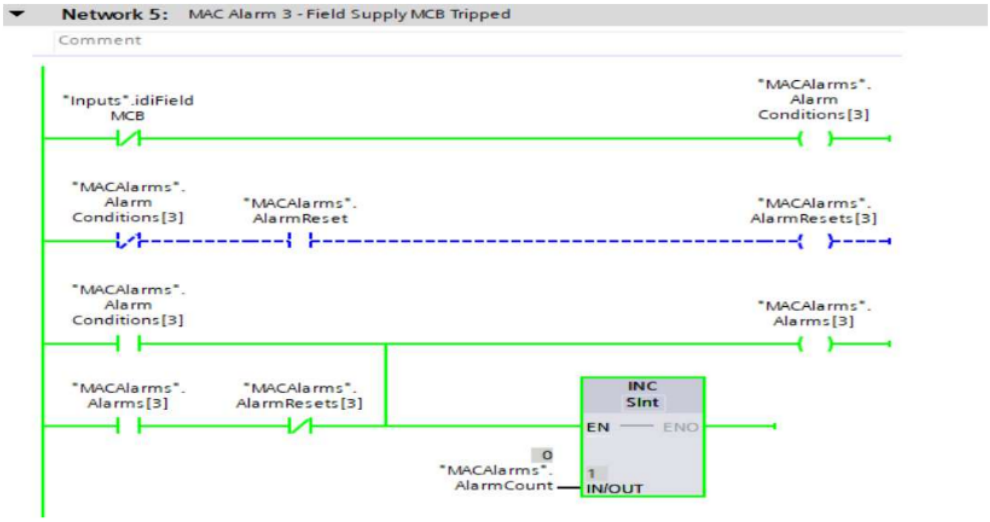


Figure 155- Functional Test Evidence – Alarm 3 Network (P.12)

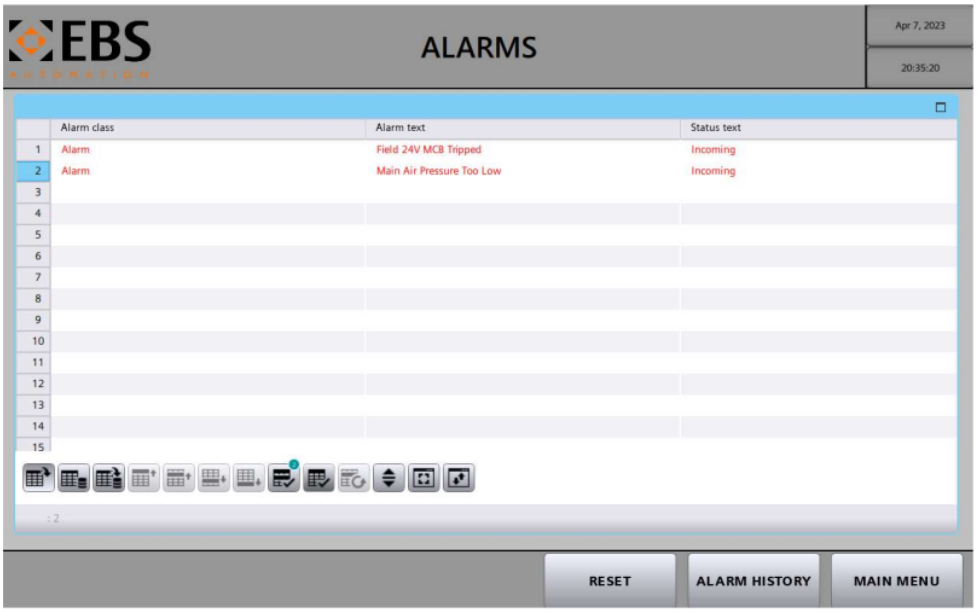


Figure 156 - Functional Test Evidence – Alarm 3 HMI (P.12)

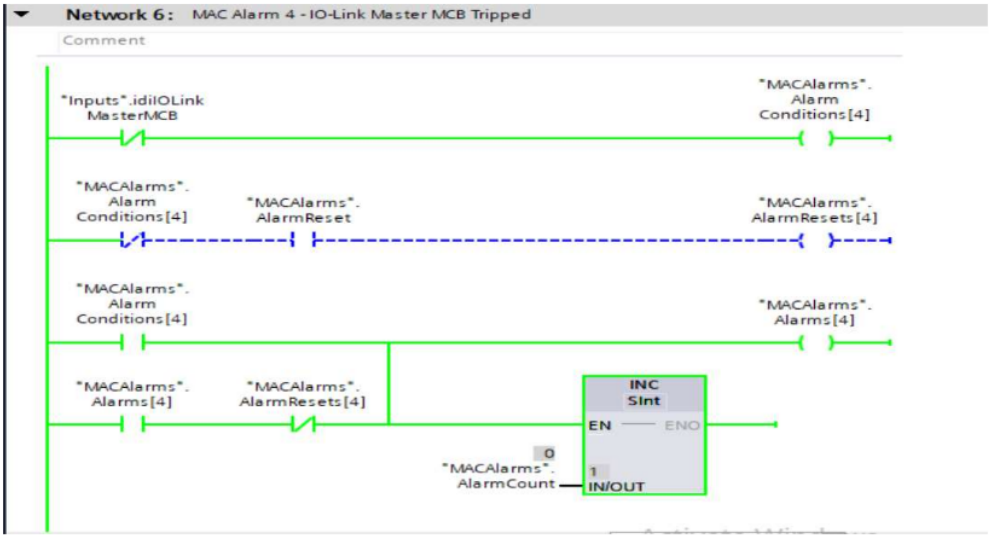


Figure 157- Functional Test Evidence – Alarm 4 Network (P.12)

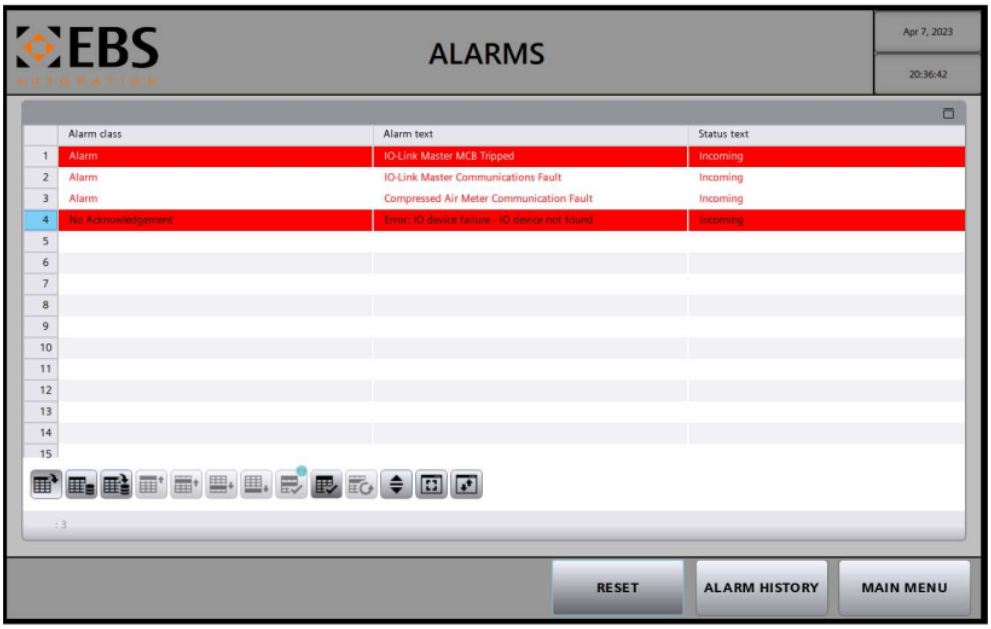


Figure 158- Functional Test Evidence – Alarm 4 HMI (P.12)

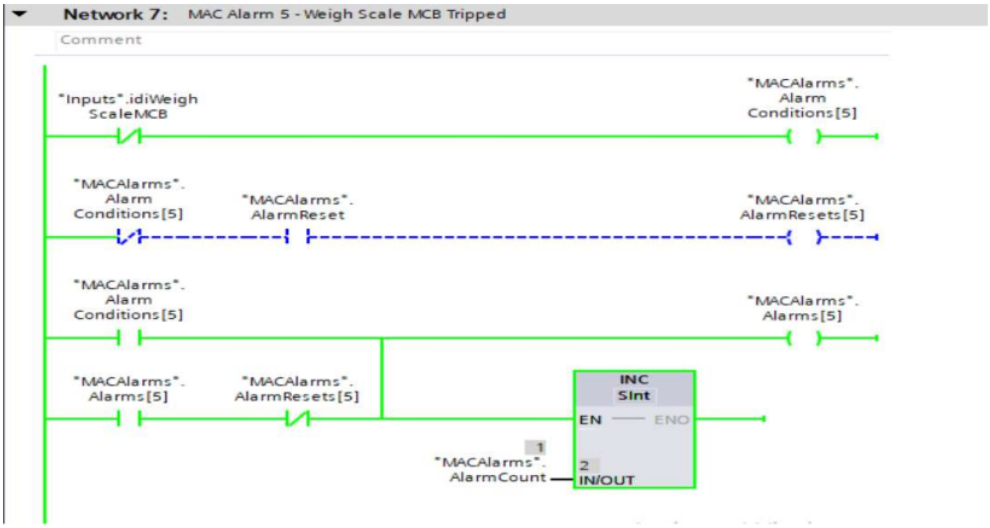


Figure 159- Functional Test Evidence – Alarm 5 Network (P.12)

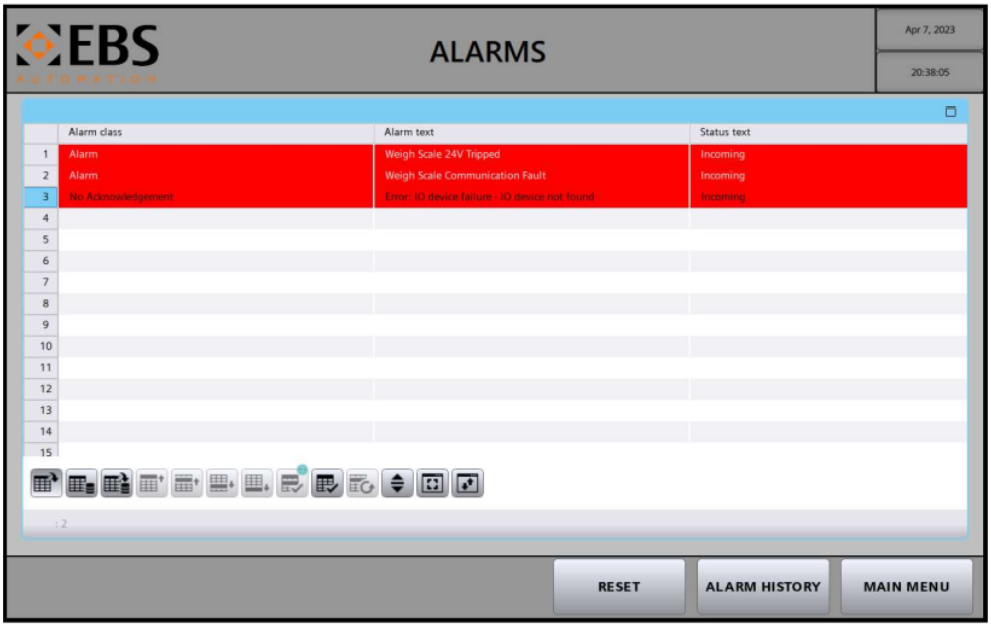


Figure 160 - Functional Test Evidence – Alarm 5 HMI (P.12)

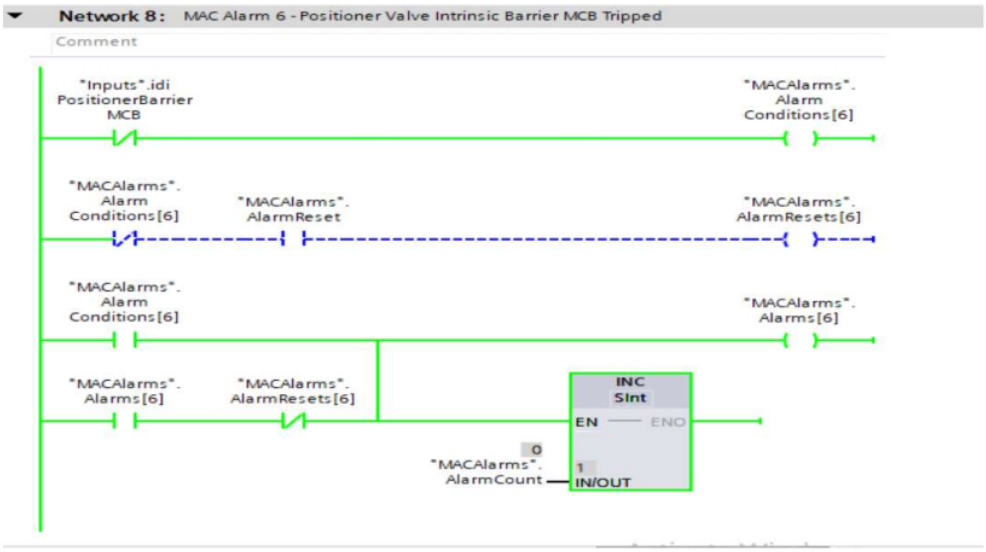


Figure 161 - Functional Test Evidence – Alarm 6 Network (P.12)

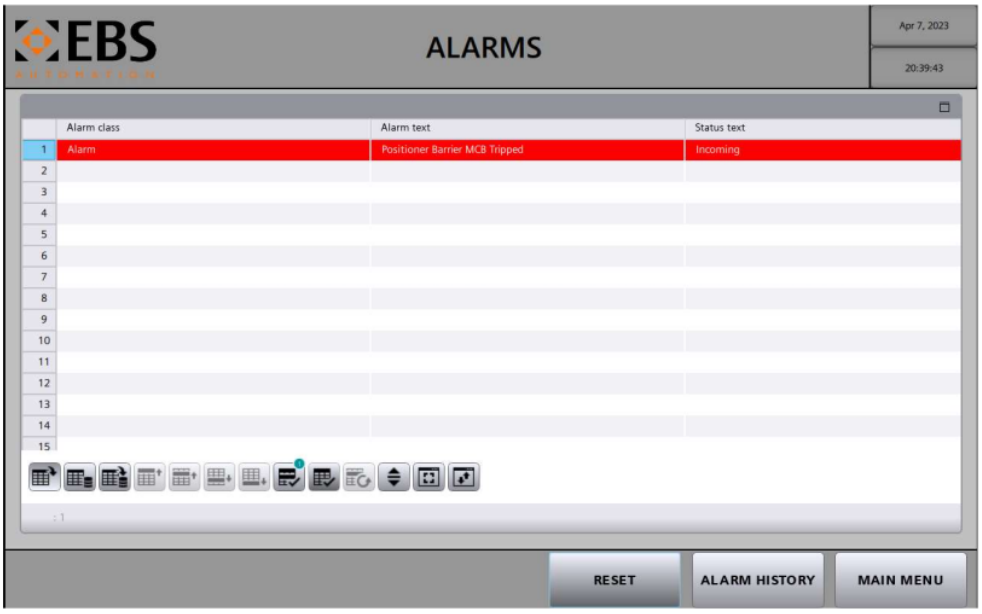


Figure 162- Functional Test Evidence – Alarm 6 HMI (P.12)

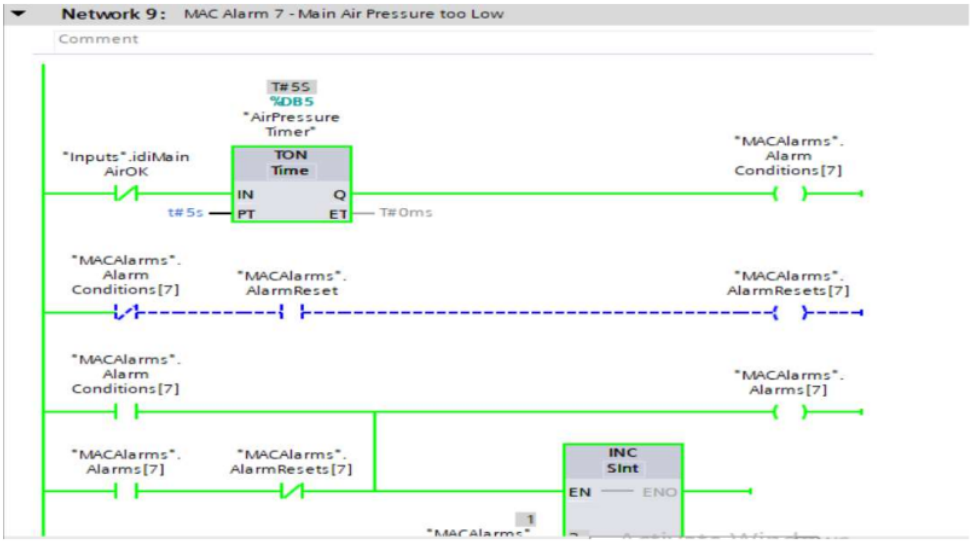


Figure 163 - Functional Test Evidence – Alarm 7 Network (D.2 / P.12)

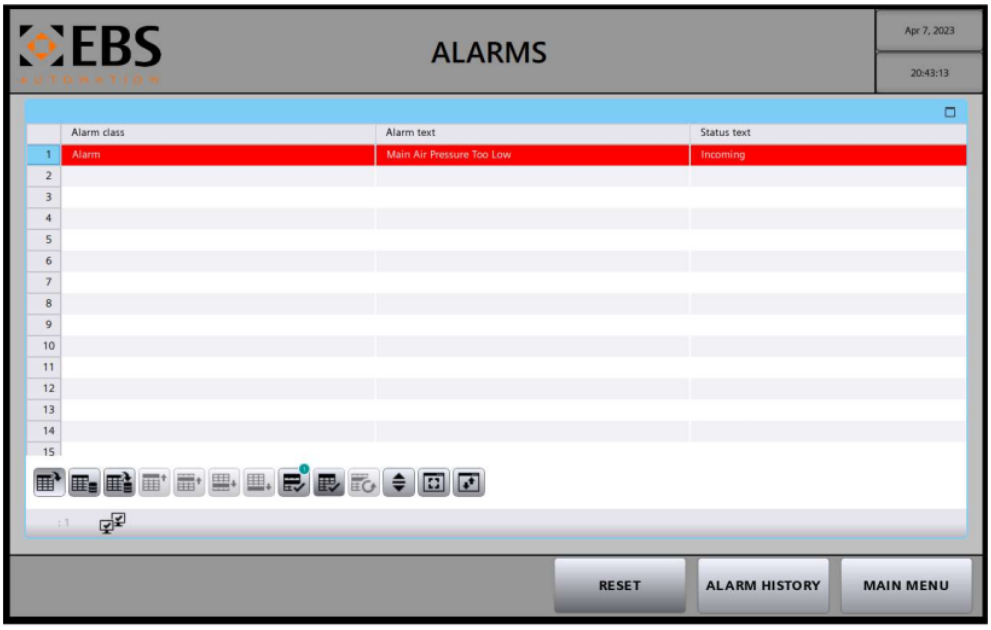


Figure 164 - Functional Test Evidence – Alarm 7 HMI (D.2 / P.12)

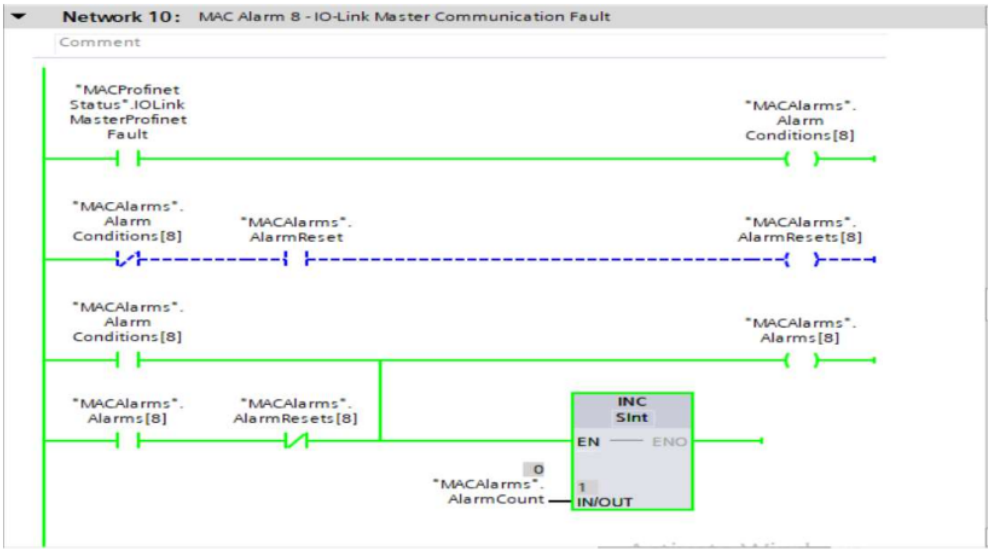


Figure 165 - Functional Test Evidence – Alarm 8 Network (P.12)

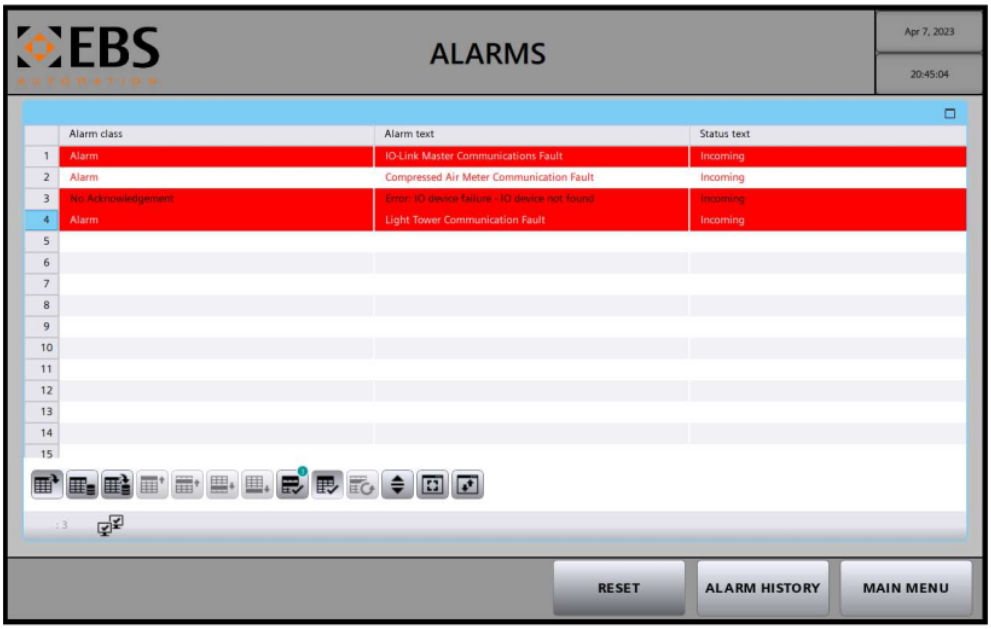


Figure 166 - Functional Test Evidence – Alarm 8 HMI (P.12)

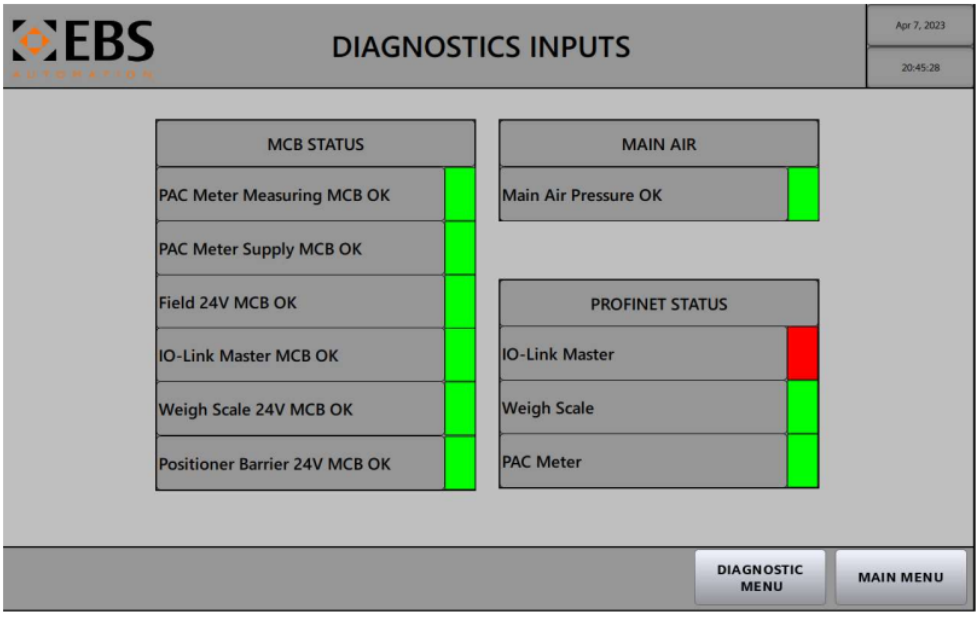


Figure 167 - Functional Test Evidence – Alarm 8 Fault on Diagnostic Screen (P.12)

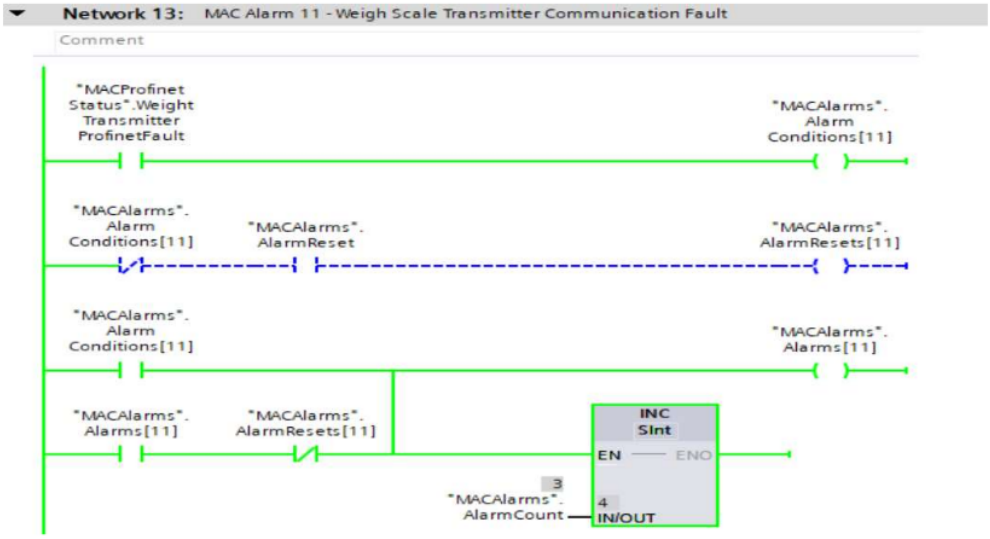


Figure 168 - Functional Test Evidence – Alarm 9 Network (P.12)

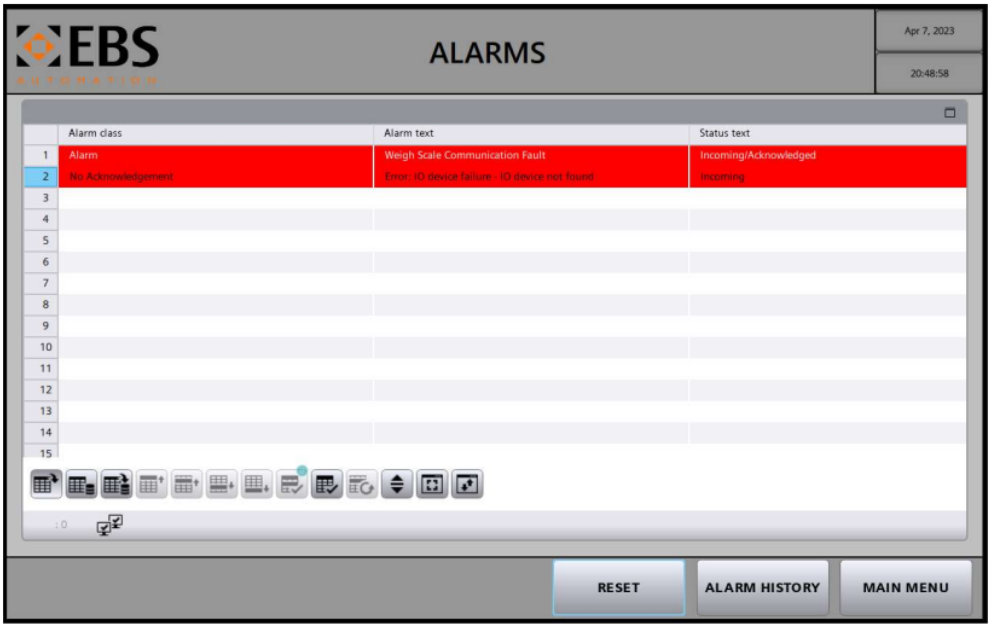


Figure 169 - Functional Test Evidence – Alarm 9 HMI (P.12)

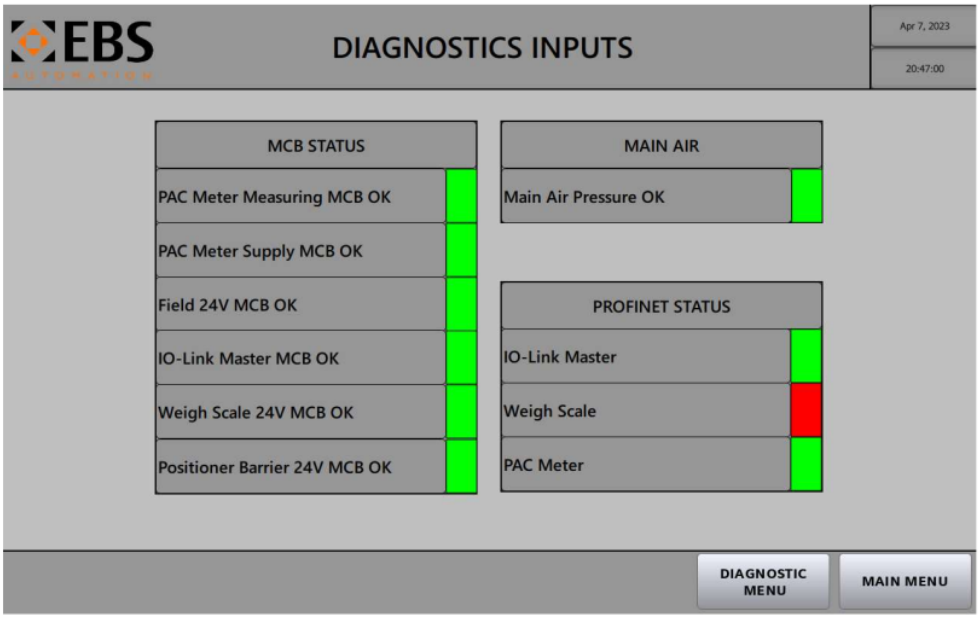


Figure 170 - Functional Test Evidence – Alarm 9 Fault on Diagnostic Screen (P.12)

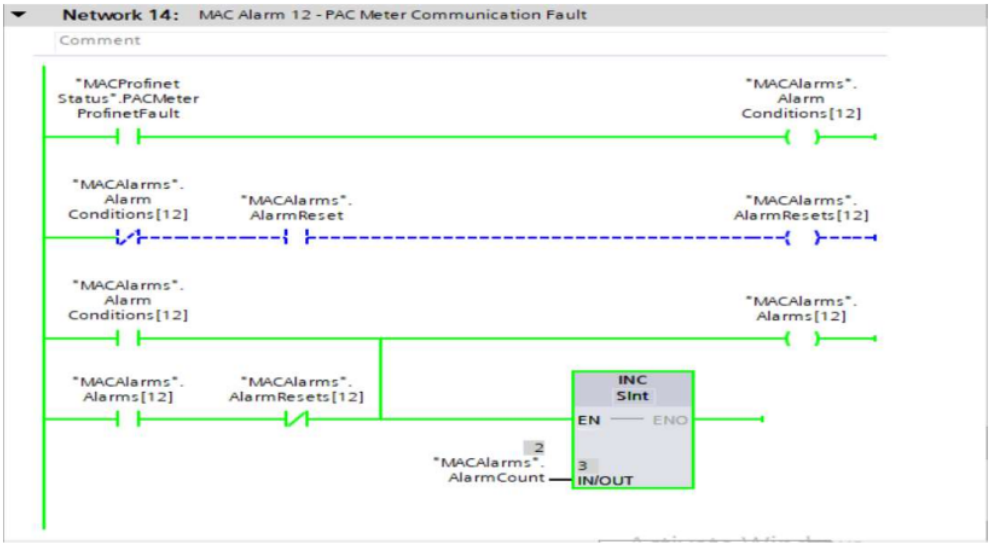


Figure 171 - Functional Test Evidence – Alarm 10 Network (P.12)

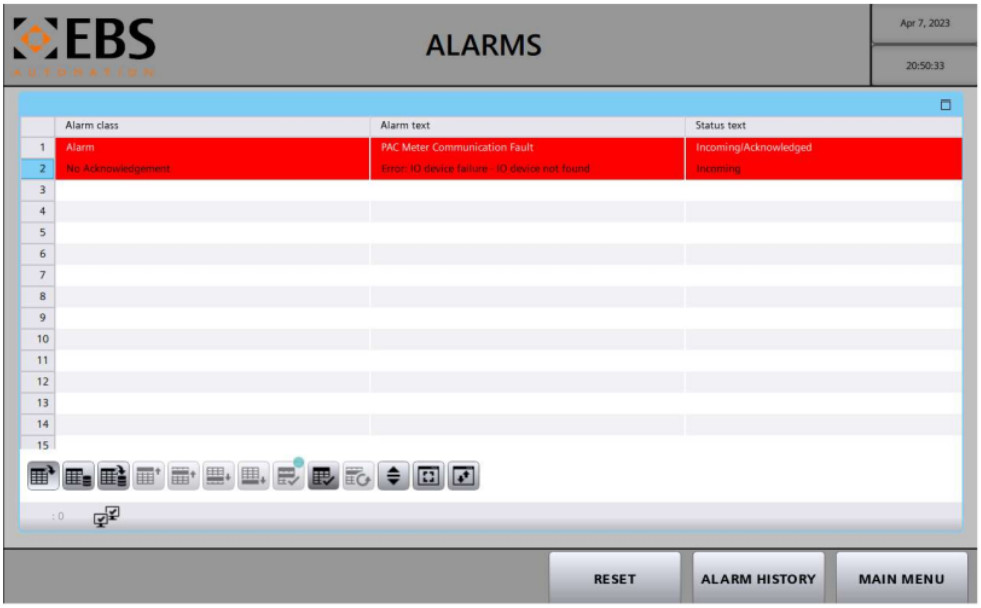


Figure 172 - Functional Test Evidence – Alarm 10 HMI (P.12)

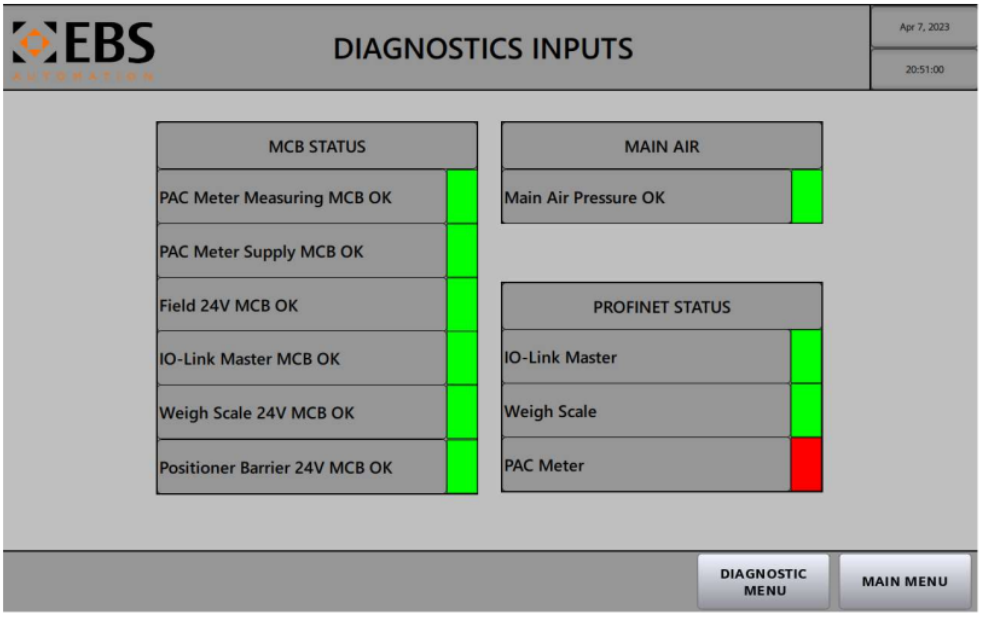


Figure 173 Functional Test Evidence – Alarm 10 Fault on Diagnostic Screen (P.12)

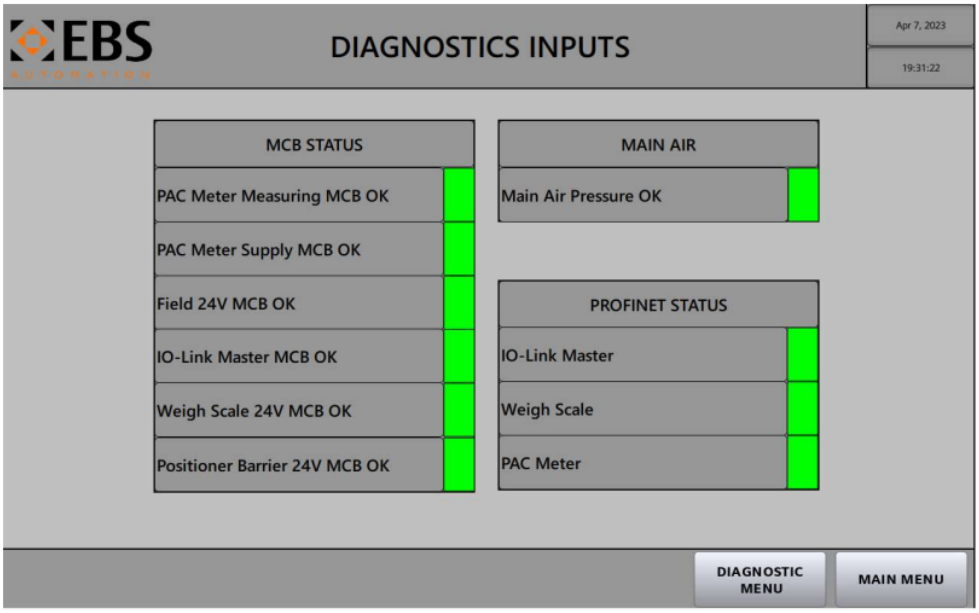


Figure 174 - Functional Test Evidence – Diagnostic Input Screen (D.0)

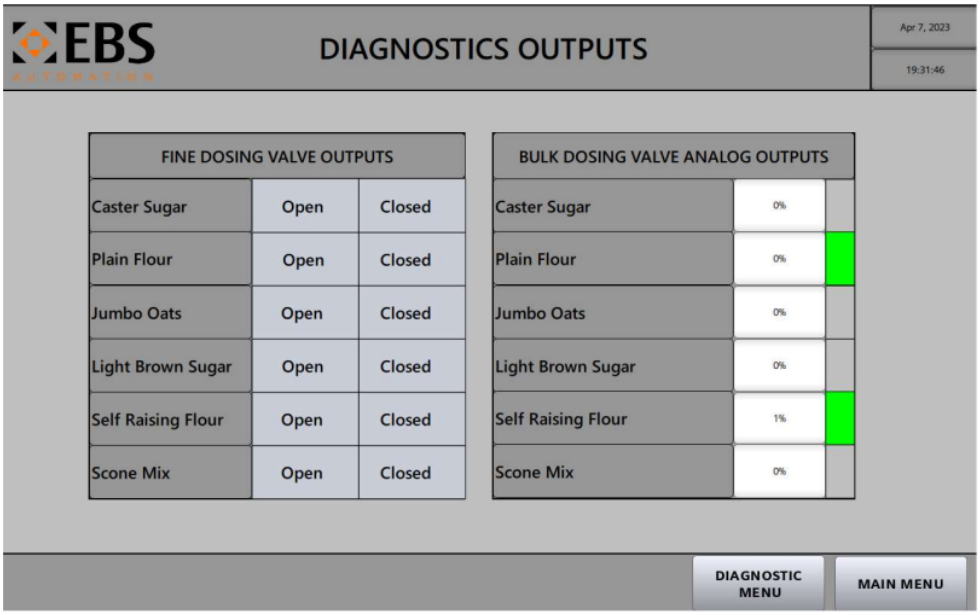


Figure 175 – Functional Test Evidence – Diagnostic Output Screen (D.0)

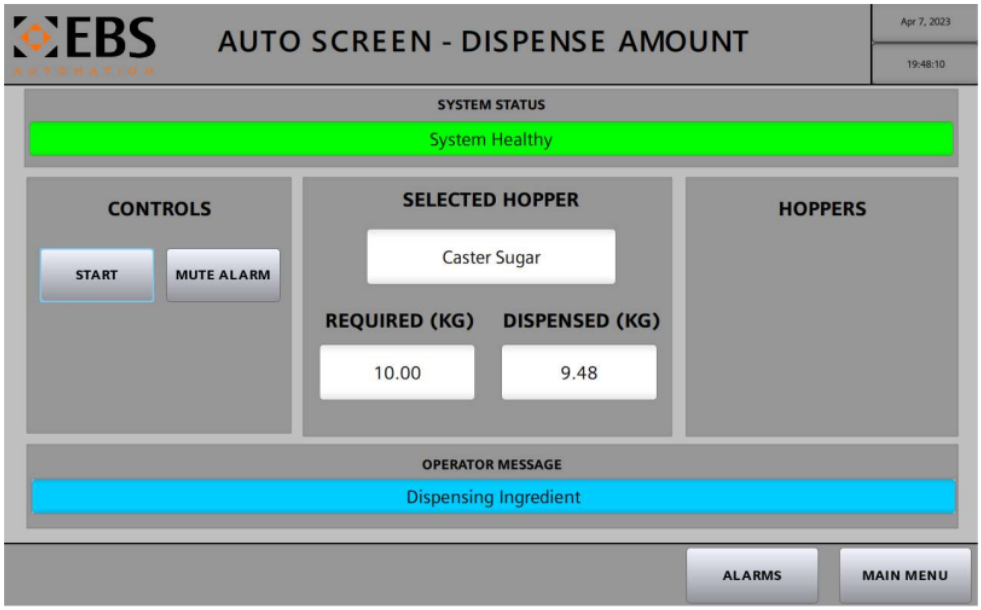


Figure 176 - Functional Test Evidence – Auto Screen Current Step Message (D.1)

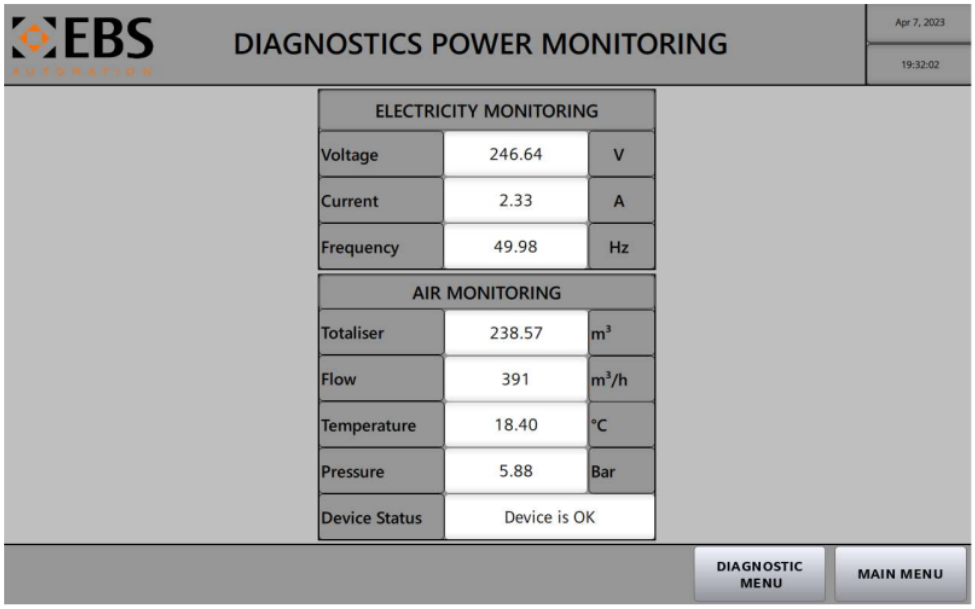


Figure 177 - Functional Test Evidence – Diagnostic Power Monitoring Screen (E1 & E2)

SGEL6000

Independent Project

Log Book

Thomas Grennan

Ingredient Dosing System

2022-2023

Summary of Entries

Log Entry	Date	Brief Description of Activity	Duration (hrs)	Accumulated time (hrs)
1	30/09/22	Customer Meeting	3	3
2	07/10/22	Initial Concept Meeting	6	9
3	14/10/22	ATEX Research	2	11
4	21/10/22	Research / Supplier Visit	10	21
5	28/10/22	Project Scope Development	6	27
6	04/11/22	On-site	0	27
7	11/11/22	Concept Review / Project Scope Review	12	39
8	18/11/22	Literature Review	20	59
9	25/11/22	Comparison of 3 Solutions	6	65
10	02/12/22	Contacting Suppliers	9	74
11	09/12/22	Work Breakdown Structure & Gantt Chart	16	90
12	16/12/22	Resource Plan & Costing Spreadsheet	10	100
13	23/12/22	Report Writing	9	109
14	06/01/23	Panel Layout Design & Power Circuit Design	32	141
15	13/01/23	Completion of Electrical Schematics & SISTEMA	36	177
16	20/01/23	Ordering of Electrical Components, Sequence & Software Design	48	225
17	27/01/23	Software Design	30	255
18	03/02/23	HMI Screens / Issues with DF2101	22	277
19	10/02/23	Panel Build / Mechanical Assembly	30	307
20	17/02/23	Contingency - PAC3220/Weight Transmitter Setup	48	355
21	24/02/23	Mechanical Assembly & Machine Wiring	48	399
22	03/03/23	Machine Wiring / Commissioning Start	30	429
23	10/03/23	Completed Electrical Commissioning / Start Software Commissioning	40	469
24	17/03/23	Software Commissioning / Hopper Issues	25	494
25	24/03/23	Finish Software Commissioning / Test Plan	40	534

26				
27				
28				
29				
30				

Log Entry Sheet

Log Number	14
Date	06/01/2023
Duration (hrs)	32
Accumulated time (hrs)	141

Record of activities and achievements

Week 14 saw the first stages of the implementation phase. This week saw the panel layout for the main electrical panel completed and the electrical schematics has been started, completing the power circuits.

The mechanical general assembly has also started, with both myself and Wojciech compiling information for the machinery directive and technical file.

Plans for next week

The plan for week 15 is to complete the electrical schematics & SISTEMA report, and for the electrical parts list and requisition forms to be completed.

Signed _____ Signed

_____

Log Entry Sheet

Log Number	15
Date	13/01/2023
Duration (hrs)	36
Accumulated time (hrs)	177

Record of activities and achievements

Week 15 saw the completion of the electrical schematic diagrams, the control circuits, PLC circuit and cable sizing has been completed, the SISTEMA report was completed confirming that the components chosen are suitable for performance level B.

The mechanical design has also seen progress in line with the Gantt chart plan.

Plans for next week

The plan for Week 16 is to order all electrical & control components, complete the sequence design and to begin the first stage of the software design.

Signed _____ Signed

_____

Log Entry Sheet

Log Number	16
Date	20/01/2023
Duration (hrs)	48
Accumulated time (hrs)	225

Record of activities and achievements
Week 16 saw all electrical components ordered, the sequence design has also been completed and the software design has begun. All I/O has been mapped internally, and the system alarms have also been completed and the “System Empty Run” sequence has also been completed. The mechanical general assembly design is also still underway. Time this week has also been spent planning towards the presentation.

Plans for next week
The plan for the following week is to complete the software design element of the project. The mechanical engineer plans on completing the general assembly design, and to start the detailed design.

Signed _____ Signed

_____

Log Entry Sheet

Log Number	17
Date	27/01/2023
Duration (hrs)	30
Accumulated time (hrs)	255

Record of activities and achievements
Week 17 saw the Software design task completed, in line with the gantt chart plan, the tasks are currently completed on schedule, a brief start has also been made on the HMI design. The mechanical general assembly has also been completed and the detailed design stage has begun.

Plans for next week
The plan for the following week is to complete the HMI design.

Signed _____ Signed

_____

Log Entry Sheet

Log Number	18
Date	03/02/2023
Duration (hrs)	22
Accumulated time (hrs)	277

Record of activities and achievements
Week 18 saw the completion of the HMI design for the Ingredient Dosing System, this includes Diagnosis, Manual, Alarm, Automatic and Recipe screens. An update was received from the supplier of the IFM DF2101, this will not be received until July 2023, therefore it must be removed from the project, this will fail one of the FDS points. **ADD PHOTO OF HMI SCREENS**

Plans for next week
The plan for the following week is to tag the HMI screens into the PLC & to start the panel build.

Signed _____ Signed

_____

Log Entry Sheet

Log Number	19
Date	10/02/2023
Duration (hrs)	30
Accumulated time (hrs)	307

Record of activities and achievements
Week 19 saw extensive progress made in line with the Gantt Chart plan. The main control panel has been built, wired and installed on its plinth with an Icotek also installed for cable entry.



Progress has also been made on the mechanical aspects of the project, 3 of the 6 hoppers have been delivered and were mounted on the frame including the two-stage valves to ensure they fit.



Plans for next week

The plan for the following week is to begin machine wiring, however, this is looking unlikely as the machine frame has not been powder coated.

Signed _____

Signed _____

Log Entry Sheet

Log Number	20
Date	17/02/2023
Duration (hrs)	48
Accumulated time (hrs)	355

Record of activities and achievements

The machine frame has been sent out for powder coating, this has restricted machine wiring & mechanical tasks planned for this week, delaying the project plan by a week.

A contingency has been introduced to recover the timing plan. As the panel has been completed, 1 day electrical commissioning was brought forward to test and power up the panel, this allowed for 2 days commissioning to be brought forward.

The 2 days of Software Commissioning have been spent networking and setting up the weight transmitter and PAC3220, all IO has been mapped and tested. The frame is due to be delivered from powder coating on 20/02/2023.

Plans for next week

The plan for Week 21 is to begin the machine wiring.

Signed _____

Signed _____

Log Entry Sheet

Log Number	21
Date	24/02/2023
Duration (hrs)	48
Accumulated time (hrs)	399

Record of activities and achievements

The machine frame has been received from powder coating, allowing project progression to re-start, a week delay is now evident due to the delays.

The mechanical assembly aspects have been completed. The Valves received from Mucon were assembled with the valve mounted in the wrong direction of flow, this was found after they had been installed on the machine resulting in re-work being required.

Progress has been made on the machine wiring, the positioner valves & manifold have been wired completing 65% of the machine wiring.

Plans for next week

The plan for Week 22 is to complete the remaining electrical wiring tasks.

Signed _____

Signed _____

Log Entry Sheet

Log Number	22
Date	03/03/2023
Duration (hrs)	30
Accumulated time (hrs)	429

Record of activities and achievements

Week 22 saw the completion of the machine wiring. Electrical Commissioning tasks have begun ensuring all IO is wired to the correct addresses. The mechanical commissioning of the system is complete.



Plans for next week
The plan for Week 23 is to complete all electrical commissioning tasks including wiring to the positioner valves, 5/3 valve manifold, HMI, Weigh Scale & IO-Link Master. Due to the delays, Week 23 expects to see the Software Commissioning tasks to be started.

Signed _____

Signed _____

Log Entry Sheet

Log Number	23
Date	10/03/2023
Duration (hrs)	40
Accumulated time (hrs)	469

Record of activities and achievements

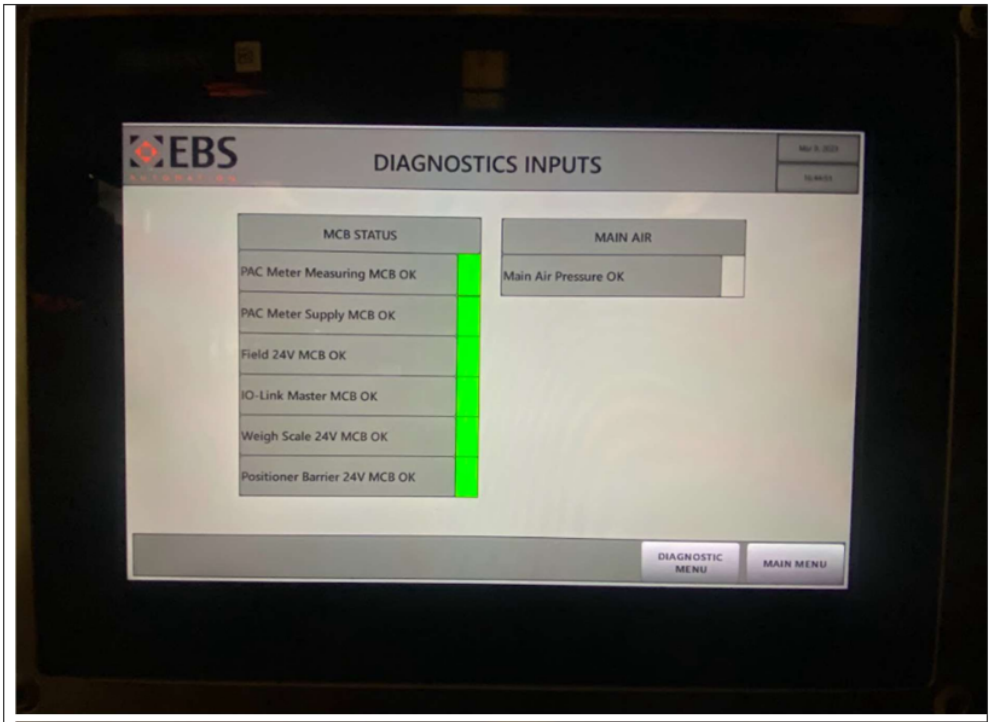
Week 23 saw extensive progress made on the software commissioning; the electrical commissioning is complete. The PLC & HMI programs have been downloaded. All Inputs, Outputs & Profinet statuses have been tested and confirmed, with the statuses displayed on the HMI.

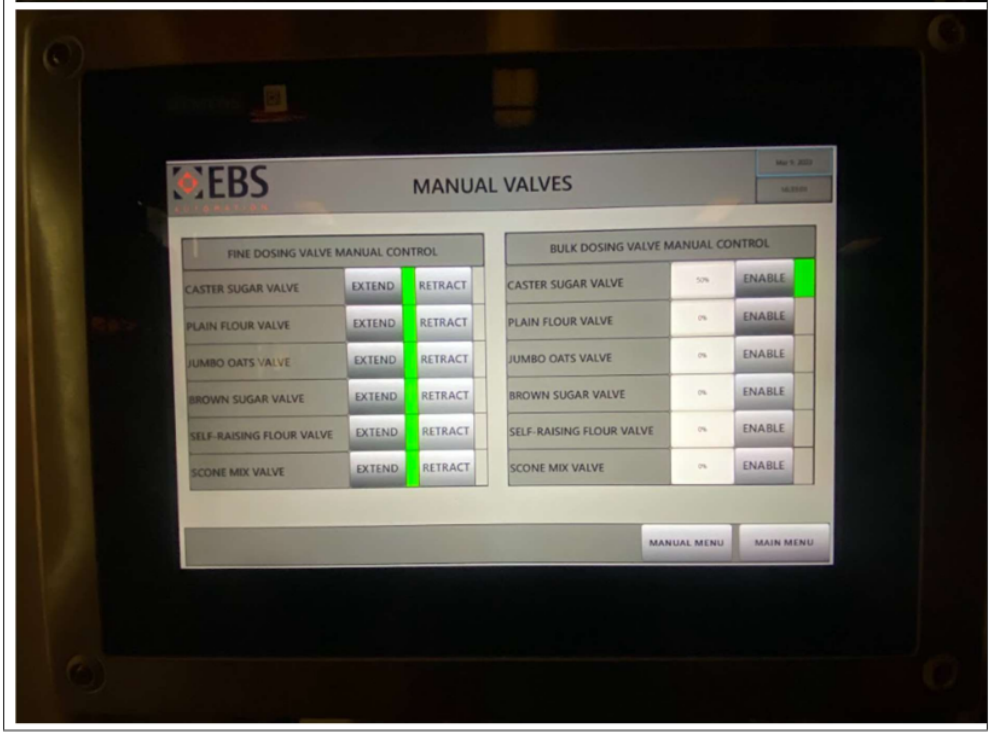
The analog scaling from a 16-bit Integer to a percentage was tested, upon inspection it was clear that the valve was offset by 10% when manually actuating the valve (At 30% Position when 20% is set, At 60% position when 50% is set). The valve was disconnected and a 250 Ohm resistor was connected as the load. At 0% (4mA) it is expected that a voltage of 1VDC will be dropped across the resistor (V = I x R= 0.004 x 250 = 1V), and at 100% (20mA) it is expected 5VDC will be dropped across the resistor (V = I x R= 0.020 x 250 = 5V).

This was successfully tested proving the scaling was correct. Upon inspection it was noticed that the valve was not fully shut in the 0% position, being the root-cause of the 10% offset. The Mucon manual was studied, showing that the valve stroke can be adjusted to allow for movement over 90 degrees, utilising feeler gauges the stroke was adjusted to ensure the closed gap was smaller than a grain of sugar.

The alarms function was also tested. Each Alarm condition was set to trigger the PLC alarm. The HMI message for each condition was verified to ensure correlation, the reset function was tested to ensure all alarms can be reset once the condition is cleared.

All manual functions were successfully tested, and all IO is correctly configured.





Plans for next week

The plan for week 24 is to complete the software commissioning.

Signed _____

Signed _____

Log Entry Sheet

Log Number	24
Date	17/03/2023
Duration (hrs)	25
Accumulated time (hrs)	494

Record of activities and achievements

Week 24 saw further commissioning of the Ingredient Dosing System. The hoppers were filled with ingredients, both caster sugar and oats flowed freely into the mixing bowl when the valve was manually actuated, performing as required. However, Plain Flour, Self-Raising Flour, Scone Mix & Light Brown Sugar did not dose correctly. Upon inspection of the hopper it was found that the consistency of these ingredients caused cohesive bridging in the hopper, whereby the particles of the ingredient had bonded together and compressed creating a bridge of material strong enough to cause a blockage. The four hoppers required agitation via a Hide Mallet to allow for the ingredient to partially dose.

A meeting was held with the mechanical project engineer, the author & the valve supplier. It was decided that agitation is required in the form of High Frequency Impact Vibrators (HFIV) to relieve the cohesive bridge.

Lead time of the HFIVs is 6 weeks, therefore it was decided that the system would be commissioned only using oats and caster sugar. All three automatic modes were successfully tested proving the systems functionality and operation meets the requirements of the FDS. Minor fault finding was required for the Recipe Mode Sequence as the Valves were not firing, this was found to be a coil being written to twice in the PLC program.

Plans for next week

The plan for Week 25 is to complete the test plan for the project.

Signed _____

Signed _____

Log Entry Sheet

Log Number	25
Date	24/03/2021
Duration (hrs)	40
Accumulated time (hrs)	534

Record of activities and achievements

Week 25 saw the completion of the commissioning with only two hoppers. The testing plan requirements of the FDS was then completed, successfully meeting 30 out of the 36 requirements. The 6 requirements that failed completion are direct results of the supply-chain issues currently faced in the automation sector, these are:

- The DF2101 Fuse Modules have not been fitted due to supply chain issues
- Emergency Stop not integrated due to Pilz Relay & ATEX E-Stop components not delivered.
- Technical File is not complete as the system has not been fully tested due to components not being delivered.
- The project is currently within budget and is likely to be delivered within budget, this cannot be confirmed as the project is still underway.
- Ability to undertake maintenance activities cannot be confirmed due to the new requirement for HFIVs which have not been designed and installed.
- The HFIVs require high air consumption, it has been decided to delay the air saver mode function as the system could be potentially dumping large amounts of air regularly, a better control method could be looked into by the SD6500 Air Meter by monitoring the totaliser flow when air consumption is not expected to find leaks.

Other than these failures, 30 of 36 requirements have been achieved within the time frame, successfully meeting 83% of the test plan.

Plans for next week

The plan for the following week is to have an update meeting with the HFIV supplier and write the report.

Signed _____

Signed _____

Log Entry Sheet

Log Number	26
Date	31/03/2023
Duration (hrs)	8
Accumulated time (hrs)	542

Record of activities and achievements
Week 26 saw an update meeting with the HFIV supplier, the delays are still in place and the HFIVs are expected to be received by 05/05/2023. Time has been spent writing up the major project report.

Plans for next week

Signed _____

Signed _____

1809799

GRADEMARK REPORT

FINAL GRADE

87 /100

GENERAL COMMENTS

Instructor

PAGE 1

PAGE 2

QM **Good Structure**

Report is structured exactly as stated in the assignment brief.

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10

Text Comment. Very detailed but far too long for a summary

Text Comment. The brief asked you to write this in 300 words

PAGE 11

QM **Punctuation Error**

Punctuation error

PAGE 12

PAGE 13

PAGE 14

PAGE 15

PAGE 16

PAGE 17

Text Comment. should be Harvard referenced

QM

Punctuation Error

Punctuation error

Text Comment. a long quotation

PAGE 18

Text Comment. don't instruct your reader

PAGE 19

PAGE 20

Text Comment. This is an excellent analysis for choice of safety related parts

PAGE 21

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Text Comment. out of

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PAGE 30

QM

Punctuation Error

Punctuation error

PAGE 31

PAGE 32

Text Comment. This shows the importance of better planning and purchasing earlier

PAGE 33

PAGE 34

Text Comment. Why doesn't the customer receive the technical file?

PAGE 35

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PAGE 37

Text Comment. What is the difference between this figure and figure 8?

PAGE 38

Text Comment. Derivative

Text Comment. CV

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PAGE 44

Text Comment. These belong in the log-book

PAGE 45

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PAGE 47

Text Comment. You were asked not to include datsheets in the report

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PAGE 125

Text Comment. A useful planning chart but a key would be helpful

PAGE 126

PAGE 127

PAGE 128

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PAGE 130

Text Comment. This information did not need to be included

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GRADING FORM: NEW CSG-RUBRIC

THOMAS GRENNAN	**87**

1. ENGAGEMENT WITH LITERATURE

✎	Section 3: Judicial use and critical evaluation of technical literature in the design of the project There is very good evidence of this in the report.	**9**

However, many datasheets have been included in the appendix without need. Information should have been cited instead. (4/5)
Section 8: Extent of reading, range of credible sources and use of Harvard method
Excellent range of reading and use of Harvard. (5/5)

2. KNOWLEDGE AND UNDERSTANDING

Sections 3 and 4: Advanced knowledge and critical understanding demonstrated in the design and implementation of the project
There is excellent evidence of this throughout and particularly in the design and implementation of the project. (8/5)

8

3. COGNITIVE AND INTELLECTUAL

Section 5: Testing and analysis of results
Excellent and thorough testing and analysis. (10/10)
Section 5: Critical evaluation of the project outcomes
A very thorough and critical evaluation presented. However, you are spending too many words lamenting over the delays and blaming circumstances for not achieving all the outcomes. (8/10)
Section 6: Conclusions and recommendations
Mostly excellent, though you are in part telling a story and are giving reasons for failing to meet all the outcome with is unnecessary. (7/10)

25

4. PRACTICAL APPLICATION

Section 4: Deployment method, use of material, tools, equipment and techniques in the construction of the project
Excellent methods, professionally executed. (10/10)
Section 4: Quality of the final product or system
High quality to professional standards. (10/10)
Sections 5, 6 and appendix: Management of the design process including use of plans, costing spreadsheet and log book
Excellent evidence of management methods and contingencies to overcome unforeseen delays that prevent 100% completion. However, better planning may have enabled an even better outcome. (8/10)

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5. TRANSFERABLE SKILLS

Section 1: Acknowledgements, executive summary and introduction
Generally good but summary is far too long, should be 300 words. (4/5)
All Sections: Presentation quality of the report, diagrams, charts, tables, figure numbering, page and section numbering etc
Excellent quality, structure and presentation. However, against the advice of the brief, you have included datasheets and manuals whereas they should have been referenced. (4/5)
All Sections: Quality of the writing style, use of punctuation and grammar
Generally good but you have a tendency to repeat yourself and can be overly specific. You are also telling a story rather than explaining the final system. Too much space was given to lamenting

17

over unforeseen delays. (4/5)
Word count limit not exceeded (5/5)