JUICE BLENDING/BATCHING SYSTEM

By

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FINAL PROJECT REPORT

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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Approved by,

(Dr. Josefina Barnachea Janier)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

RAJA PUTERI NORAZLINA BINTI RAJA ABDULLAH

ABSTRACT

The food manufacturing industry is always ripe for integration of major improvements in process control and intelligent processing. At this time, even though many new devices and systems are available for implementation in food processing industry, the majority of the routine processing steps are still controlled and performed by workers.

The report is on the design and implementation of the logic control functions on a single-product batch process. The aim is to utilize the digital Programmable Logic Controller (PLC) module to control the sequences in a batching process that produces fruit juices hence, making the system fully automated by creating the appropriate ladder diagram or program. Another aim of this project is to control and drive the control valve opening and closing from 0% to 100%. This project also demonstrates the advantages of using PLC in a plant.

The batching system is restricted to only four kinds of materials as the based of this case study. The illustrated batching system also includes 5 valves, one agitator motor, one pump and a batching tank. The end product of the batching system should be commercial product of fruit juices.

The OMRON PLC is being used for programming, in order to create a ladder diagram or program for the process of this project using the CX-Programmer Version 3.0 ladder diagram language. The PLC device type is the SYSMAC CQM1H-CPU21 with the network type of SYSMAC way.

ACKNOWLEDGEMENT

Firstly, I would like to grant my gratitude to God for giving me the strength and enlighten every step that I had taken in order for me to complete this project and also for making it possible in the first place.

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CHAPTER 1
INTRODUCTION

1.1 Background of Study

Batching system or batch process control is widely used in various kinds of industrial branches and the applications also vary in terms of its complexity. The simplest batching system produce only one end product and a more complex batching can produce up to two or more end products.

Juice blending that can be categorized into the food processing industry is one example that utilizes batching system to produce fruit juices as its end product. The market for this industry is quite large in Malaysia as well as worldwide and most of these industries apply Programmable Logic Controller (PLC) to control and monitor their plant including batching system, specifically for juice blending.

The first PLC systems evolved from conventional computers in the late 1960s and early 1970s. These first PLCs were mostly installed in automotive plants. In the 1980s, with more computer power per dollar available, the PLC came into exponentially increasing use.

A PLC is a microprocessor based, specialized computer that carries out control functions of many types and levels of complexity. It can be programmed, controlled and operated by a person. The PLC's operator essentially draws the line and devices of ladder diagrams. The resulting drawing in the computer takes the place of much of the external wiring required for control of a process. The PLC will operate any system that has output devices that go on and off. It can also operate any system with variable outputs.

A PLC consists of four major units. Refer to *Appendix C* for the PLC system layout and connections. The four major units are as stated below:

- *Central Processing Unit (CPU)*: The "brain" or heart of the system which composed of processor, memory and power supply.
- *Programmer Monitor (PM)*: The keyboard on which the program instructions are type by the user.
- *I/O Modules*: The input module has terminals into which the user enters outside process electrical signal. The output module has another set of terminals that send action signals.
- *Racks and Chasis*: The racks on which the PLC parts are mounted and the enclosures on which the CPU, PM and I/O Modules are mounted.

Other than PLC and batching system, there are also other current and emerging systems and technologies that is being used to process food. Some of them are:

1.1.1 Smart sensors

The enormous diversity of products in food processing industry is reflected in the diversity of the types of sensors in use. Few of the general areas where sensors are needed include: [8]

- *Subjective properties*: sensors to access appearance, taste, texture and aroma. [8]
- *Physical properties*: sensors for determining the size, shape, formness, density, texture, viscosity, color and orientation. [8]
- *Process parameter*: sensors for determining process temperature, humidity, pH, flow rates and contamination levels. [8]

A review of the open literature reflects a great deal of research in applying and developing sensors for the food industry. Some sensors must be used in combination to obtain a desired measurement. The smart sensors concept is aided by the trend away from analog control system toward digital control systems. The presence of a plant wide digital communication network (local area network) facilitates the bi-directional communication with widely distributed sensors throughout the plant.

Anticipated benefits of smart sensor technology to the food manufacturing include: [8]

- Higher accuracy measurement of process variables. [8]
- Faster measurements of process variables.[8]
- Fewer sensors. [8]
- More reliable sensors. [8]
- Universal sensors. [8]

1.1.2 Electron Beam Food Irradiation

This process uses a high energy electron beam to irradiate the food. The electron beam is generated by high voltage electricity and does not use radioactive material. The electron beam in this new plant is only use to kill insects, larvae and other pests in containers of fruit and vegetables. Other plants use higher energy beams to kill microorganism in meats and other foods. In these cases the beam need to be more penetrating. The technology from this process is not unlike a commercial large scale microwave oven with a conveyor belt running through it to carry containers. [4]

The process uses linear microwave accelerators, which are also known as radio frequency linacs. This accelerates electrons to 10MeV over the range of 1 meter. The electron beam is generated by alternating electron fields in the vacuum of the linac cavities, which consists of copper line tubes. The electron beam pulse generated is focused using electromagnets and then passes through a 3 mm titanium foil exit window before passing over the fruit and vegetables. [4]

1.1.3 Fieldbus (Plant Wide Communication Protocols)

For a variety of business reasons, manufacturing or processing companies now appear ready to embrace an industry-wide standard for what has become known as the fieldbus. It is an all digital communication network for connecting process instrumentation to controllers. One bus appears to be well positioned to become an industry standard. The foundation fieldbus presently under development by the

Fieldbus Foundation in Austin, Texas. The emphasis of the Foundation fieldbus is on interoperability; the ability of compliant field devices to share data and execute standard functions in a control system. [8]

1.2 Problem Statement

Some fruit processing industrial companies in the past and at present are still applying manual batching system in processing their product. One of manual batching system procedures is manual ingredients addition into the batching tank that required excessive labors and caused workers to bend over that can lead to back stress, injuries and accidents. Ingredients also frequently spilled hence; wasting material and causing a messy working environment. The manual ingredients addition also impaired proportional accuracy and reducing finished product consistency.

Many advantages are expected by applying fully automated batching system in fruit processing industry; specifically juice blending. Anticipated benefits to the juice blending industry deriving from the fully automated batching systems include:

- Increase product accuracy and quality control
- Lower ingredients costs.
- Reduce risk of injuries,
- Reduce labor requirements.
- Increase company productivity

1.3 Objective of the Study

The objective of this project is to design a PLC ladder diagram or program that is capable of controlling a fully automated batching system for juice blending by utilizing digital PLC module. The program will also utilize some timers to control the opening and closing of the control valves from 0% opening to 100% opening.

This batching system will benefit the users; industrial companies producing juice as their product. Reduction in risk of injuries and reduction in labor requirements will be considered in completing this project.

The objective of this project also includes PLC programming usage in modern manufacturing process system enhancement and creating an organized and systematic approach for PLC programming.

1.4 Scope of the Study

This project focuses in several aspects of the food manufacturing process system development. The aspects are as stated below:

- Research, design and develop the Juice Blending/Batching System overall operation.
- Flow chart construction for the operation of the overall Juice Blending/Batching System.
- Development of the ladder diagrams for the overall process of the Juice Blending/Batching System using the CX-Programmer version 3.0 with the assumption on the material transfer rate of 100 kg per minute on all materials.
- Simulation using the OMRON digital PLC module.
- Hardware connections between the PLC and the control valves.

CHAPTER 2
LITERATURE REVIEW

As a result by some reading throughout the internet, books and thesis, the author had gained some information in food processing and batching system field. The results are as listed and stated below:

2.1 Food Processing Industry

2.1.1 Effects on the Economy

Many researches had been made regarding fruit processing industry effects on the economy. Availability of quality fruits and advancement of processing technologies in the recent past have lead to the production of top quality hygienic fruit products like fruit juices and concentrates, jams and jellies, fruit slices and tidbits. These superior quality fruit products retain the original taste of the fresh natural fruit as well as full flavor and aroma and thus satisfy the taste of ever-demanding consumers through-out the year. This phenomenon of retaining the original taste and flavor has not only created a considerable interest around the world for natural, pure and healthy products but also has given a new dimension to the fruit processing industries. Today a number of fruits like citrus, stone fruits and tropical fruits are being processed in the developing countries in a very economical way, providing very good profit margin as well as substantial foreign exchange. [2]

However, while the fruit processing industries have shown a substantial growth potential, they are very much dependable on production of good quality fruits and easy availability. There are many countries that are producing quality fruits but cannot process them due to the lack of adequate industrial development in the related field and end up exporting all the fruits. [2]

2.2 The Batch Process

2.2.1 The Advantages of Batch Process

Automated batching system is a viable option to increase production while also improving the quality. This automated system provides a more consistent product while generating more controlled data. Other advantages of the system include reduced risk of back injuries and lower raw material costs due to the bulk packaging. Production can be increased up to 70 percent, while labor costs can be decreased to only 30 percent. [5]

The automated batching system is also a simple fail-safe system. It is more user-friendly and easier to program by the programmer. The system also produced significant benefits in improving the batching time to nearly 1/3 of the time taken by using manual batching system. [5]

2.2.2 The ISA S88 Batching Standards

The ISA S88 batching standards provide a vision and framework for flexible batching in which processes and recipes are defined at a higher level, divorced from the actual equipment and operating software. A Unit-based approach (where a Unit is a vessel or piece of process equipment and its associated devices) allows the recipe to define a set of operations or Phases that take place using whatever Units are required. Ingredient sources and product destinations are flexible, as ingredient additions and product transfers are phases within the recipe and may be specified in any combination or order. [9]

2.2.3 Flexible Batching System

In most batching applications, dedicated production lines lend themselves to very user-friendly batching systems and interfaces. With a set sequence of ingredient additions, ingredient sources, cooking cycles, and transfer to dedicated use or storage tanks, the batching sequence is predicable and can be highly automated. Minor ingredient hand-adds can be made in a structured manner through operator prompts or confirmations, and the recipe consists of quantitative data such as ingredient and temperature set points. Similarly, a standard Batch Record or report can easily be generated, because the ingredients, sequences, and operations are predictable. The only deviation from the set batching sequence might be a Semi-Auto mode that would allow adjustment of set points or execution order. [9]

Today's fast-paced manufacturing environments, however, can demand flexible production lines capable of making a variety of products with a minimum of equipment or software adjustment. This presents problems to the process control programmer, as all possible combinations of equipment and ingredients must be possible, and the recipe becomes less predictable in size and structure. [9]

2.3 Programmable Logic Controller (PLC)

2.3.1 What is PLC?

A programmable logic controller, PLC, or programmable controller is a small computer used for automation of real-world processes, such as control of machinery on factory assembly lines. The PLC usually uses a microprocessor. The program is usually created by a skilled technician at an industrial site, rather than a professional computer programmer. The program is stored in battery-backed memory. [11]

2.3.2 History of PLC

The PLC was invented in response to the needs of the American automotive industry. Before the PLC, control, sequencing, and safety interlock logic for manufacturing automobiles and trucks was accomplished using relays, timers and dedicated closed-loop controllers. The process for updating such facilities for the yearly model change-over was very time consuming and expensive, as the relay systems needed to be rewired by skilled electricians. In 1968 GM Hydramatic (the automatic transmission division of General Motors) issued a request for proposal for an electronic replacement for hard-wired relay systems. [11]

2.3.3 PLC I/O

The main difference from other computers is the special input/output arrangements. These connect the PLC to a process's sensors and actuators. PLCs read limit switches, dual-level devices, temperature indicators and the positions of complex positioning systems. Some even use machine vision. On the actuator side, PLCs drive any kind of electric motor, pneumatic or hydraulic cylinders or diaphragms, magnetic relays or solenoids. The input/output arrangements may be built into a simple PLC, or the PLC may have external I/O modules attached to a proprietary computer network that plugs into the PLC. [11]

2.3.4 PLC Evolution Throughout the Years

PLCs were invented as less-expensive replacements for older automated systems that would use hundreds or thousands of relays and cam timers. Often, a single PLC can be programmed to replace thousands of relays. Programmable controllers were initially adopted by the automotive manufacturing industry, where software revision replaced the re-wiring of hard-wired control panels. [11]

The functionality of the PLC has evolved over the years to include typical relay control, sophisticated motion control, process control, Distributed Control Systems and complex networking. [11]

The earliest PLCs expressed all decision making logic in simple ladder logic inspired from the electrical connection diagrams. The electricians were quite able to trace out circuit problems with schematic diagrams using ladder logic. This was chosen mainly to reduce the apprehension of the existing technicians. [11]

Recently, inspired from Grafcet, the PLC has integrated the Sequencial Function Charts: a new graphical language which allows now to directly program the sequencial nature of processes. Today, the line between a programmable computer and a PLC is thinning. With the IEC-1138 standard, it is now possible to program these devices using structured programming languages (such as C language), and logic elementary operations. [11]

CHAPTER 3

METHODOLOGY/PROJECT WORK

3.1 Studies on Batch Process Control and PLC

3.1.1 Preliminary Research

Preliminary research is the initial and main stage of the project development process. At this stage, firm understanding and planning on the project is considered. Thus, this stage aids the author to predetermine the problem, objectives, scope of study, tools, and development flow as well as problem analysis throughout the project execution.

3.1.2 Problem Analysis and Data Gathering

Problem analysis and data gathering is a continuation stage of preliminary research. The identified problem is analyzed at this stage. Data gathering offers better understanding and help in problem solving as well as decision making process. At this stage, the author able to determine the tools required for the development process.

3.2 A Systematic Approach to PLC Ladder Diagram Design

3.2.1 Operation Flow Development

Operation Flow is essential in designing a PLC program and it can also make the batching system / juice blending process clearer. Thus, the process steps were listed based on the batching system / juice blending operation. The Operation Flow was then created based on the process steps listed. Refer to *Figure 3* for the Operation Flow diagram on page 18.

3.2.2 PLC Input/Output (I/O) Identification

The identification of PLC I/O can only be done after completing the operation flow of the batching system/juice blending. By knowing the operation flow, the devices that will be used to build up the program or the ladder diagram can be identified. Hence, they will be converted into PLC I/O.

3.2.3 Tools Identification

The required tools for this project were identified at this stage. The PLC unit that will be used is OMRON CQM1HCPU21. This PLC can handle up to 16 inputs and 16 outputs compatible with the project design proposed. It utilizes CQM1 – PA203 power supply that can provide maximum capacity of 3.6 A, 18 (W) current based on 5 V dc. For the ladder diagram programming part, CX-Programmer version 3.0 will be used as the software. This CX-Programmer software is not only suitable for OMRON CQM1HCPU21 PLC, but it is suitable for most of the OMRON PLCs.

The tools and parts required to complete the physical part of the project had also been identified. The physical part of the project will use control valves to demonstrate the opening and closing the valves from 0% to 100%.

3.2.4 Develop PLC Ladder Diagram

The ladder diagram was developed based on the Operation flow and the PLC I/O that had been listed before. Ladder diagram is the standard PLC programming language which consists of symbols to represent components and functions. A ladder diagram consists of one line running down the left side with lines branching off to the right. The line on the left is called the bus bar. The branching lines are called instruction lines or rungs. Along the instruction lines are placed conditions that lead to other instructions on the right side. The logical combinations of these conditions determine when and how the instructions at the right are executed.

3.2.5 Programming into Memory

Now, the power to the PLC can be applied. Depending on the type of PLC used, the system configuration need to be generated. Then, the program is entered into memory by a computer aided ladder software tool. Once completed, program and any coding errors should be checked by means of a diagnostic function.

3.2.6 Simulation and Troubleshooting

It is important to simulate and troubleshoot the whole system ladder diagram or program to validate the system behavior after the compiling completed. This is also to make sure that the program runs according to the intended process sequences.

3.3 Hardware Connection

Once the program has been developed and tested, the implementation of the project can be realized. The implementation involves the connection of the digital input module and also the control valves. The digital input is from the switches that will be used to energize the process sequence.

Figure 1 on the next page shows the flow chart of the whole work flow of the project:

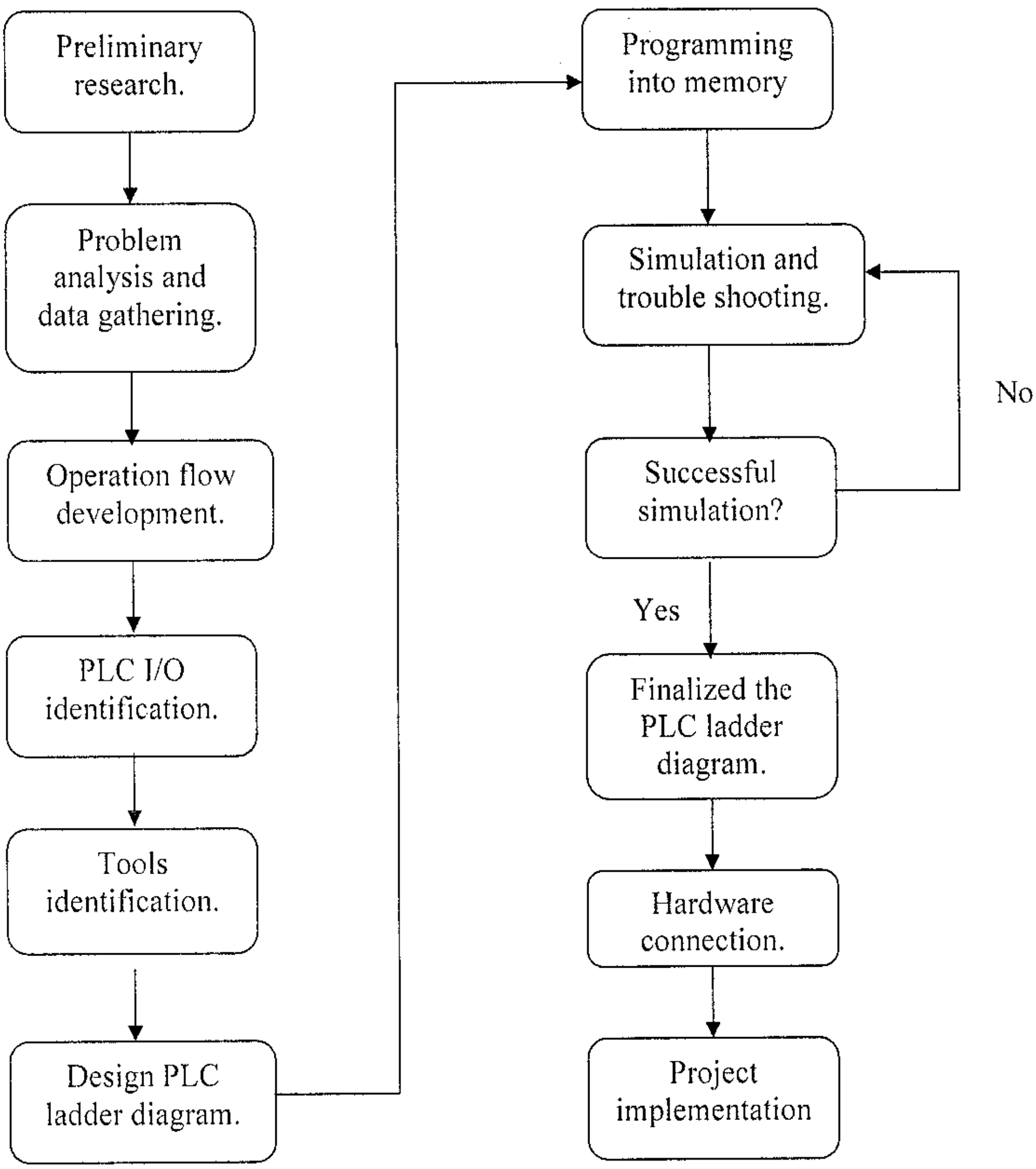

Figure 1: Project work flow flowchart

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Data Comparison

Juice blending is part of food processing industry and there are many technologies applied in food processing industry including PLC implementation in batching system. However, not all batching systems are fully automated. Some of them are manually handled or semi-automatic during operation. *Table 1* below shows the differences between these three variations of batching system being used in industrial world:

Table 1: the differences between three variations of batching system

Manual batching system	Semi-Automatic batching system	Fully automated batching system
Required the highest number of workers. (up to 4 person per batching system or more)	Required medium range of workers. (2-3 person per batching system)	Can be handle by only one worker per batching system.
Product quality depends on the workers integrity.	Product quality not necessarily depends on workers integrity but some parts of the system process are depending on the workers.	Product quality does not depend on workers integrity.
Workers are exposed to danger most of the time.	Parts of the works expose the workers to danger.	Many causes of injuries can be eliminated.
Switches act as the PLC input most of the time. Load cells and sensors only act as indicator to the workers.	Utilize switches, sensors and load cells as the PLC input and also indicator.	Minimum amount of switches required as the PLC input. Sensors, switches and load cells act as the input most of the time.

4.2 Digital PLC Module Advantages and Benefits

As stated before, this project will be applying the digital PLC module instead of the analogue PLC module. This decision was made based on some research on the internet and also from the books related to the project. Stated below are the reasons why this decision was made:

- Digital PLC module is much cheaper than the analogue module.
- The programming for digital PLC module is easier to understand and the PLC ladder diagram is easier to compose.
- The basic operation of a digital PLC module is simpler than the basic operation of an analogue module.
- The specified project that is the Juice Blending/Batching System project is only applying 0% and 100% valve opening that is within the capability of a digital PLC module.

4.3 Juice Blending/Batching System Physical Design

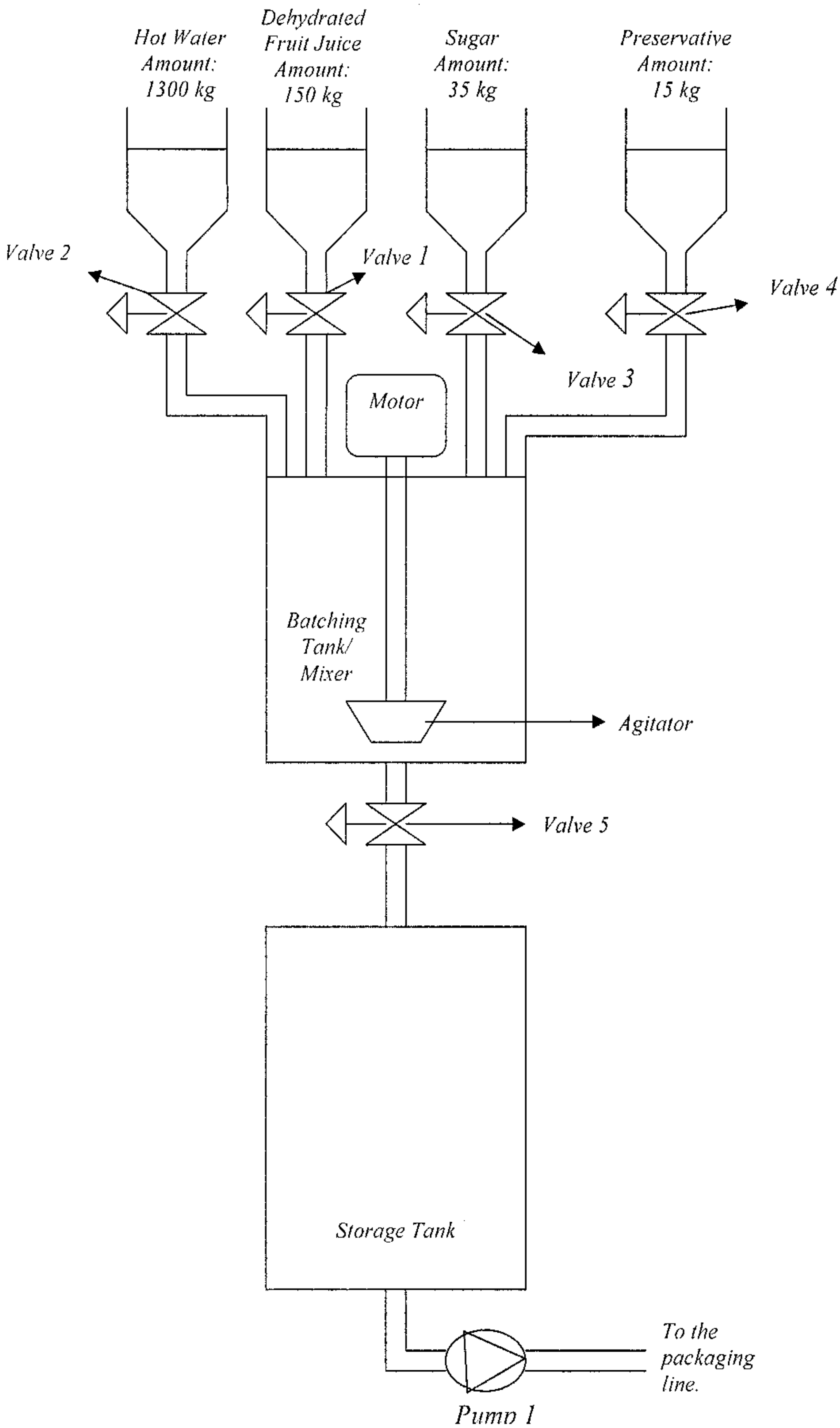

Figure 2: Juice Blending/Batching System diagram

4.4 Computations for Batching Time Operation

$$\text{Time duration of an equipment to operate} = \frac{\text{Mass of the material in kg}}{\text{Material transfer rate}}$$

Example:

Time duration for valve 1 to open = 150 kg / 100 kg

= 1.5 minutes

= 90 seconds

Table 2: Time duration of the Juice Blending/Batching System Outputs

	Mass of the material (kg)	Operation time
Valve 1	150	1.5 minutes
Valve 2	1300	13 minutes
Valve 3	35	21 seconds
Valve 4	15	9 seconds
Valve 5	1500	15 minutes
Agitator	-	10 minutes
Pump 1		-

Table 2 above shows each of the equipment operation time based on the equation derived above. However, the pump 1 operation time is depending upon the inputs switch 2 and switch 4 that is controlled by the user. Thus, the total batching time per batch cycle is:

Total time taken per batch cycle = $\sum$Operation time for each equipment in seconds

90 + 780 + 21 + 9 + 900 + 600

+ pump 1 operation time

= 2400 seconds + pump 1 operation time

= 40 minutes + pump 1 operation time

Based on *Figure 2* and *Table 2*, the operation flow of the Batching System/Juice Blending will be:

1. Trigger switch 1 to start the whole process.
2. Valve 1 will open to load the batching tank/mixer with dehydrated fruit juice.
3. After 1 minute and a half, valve 1 will close and valve 2 will open to load the batching tank/mixer with hot water.
4. After 13 minutes, valve 2 will close and valve 3 will open to load the batching tank/mixer with sugar.
5. After 21 seconds, valve 3 will close and valve 4 will open to load the batching tank/mixer with preservative.
6. After 9 seconds, valve 4 will close and the agitator will start operating to mix the content of the batching tank/mixer.
7. After 10 minutes, agitator automatically stops moving. Valve 5 will open to unload the content of the batching tank/mixer into the storage tank.
8. After 15 minutes, valve 5 will close.
9. When switch 2 (Pump ON) is being triggered, pump 1 will pump the juice from the storage tank to the packaging line.
10. When switch 4 (Pump OFF) is being triggered, pump 1 will stop pumping the juice from the storage tank to the packaging line.

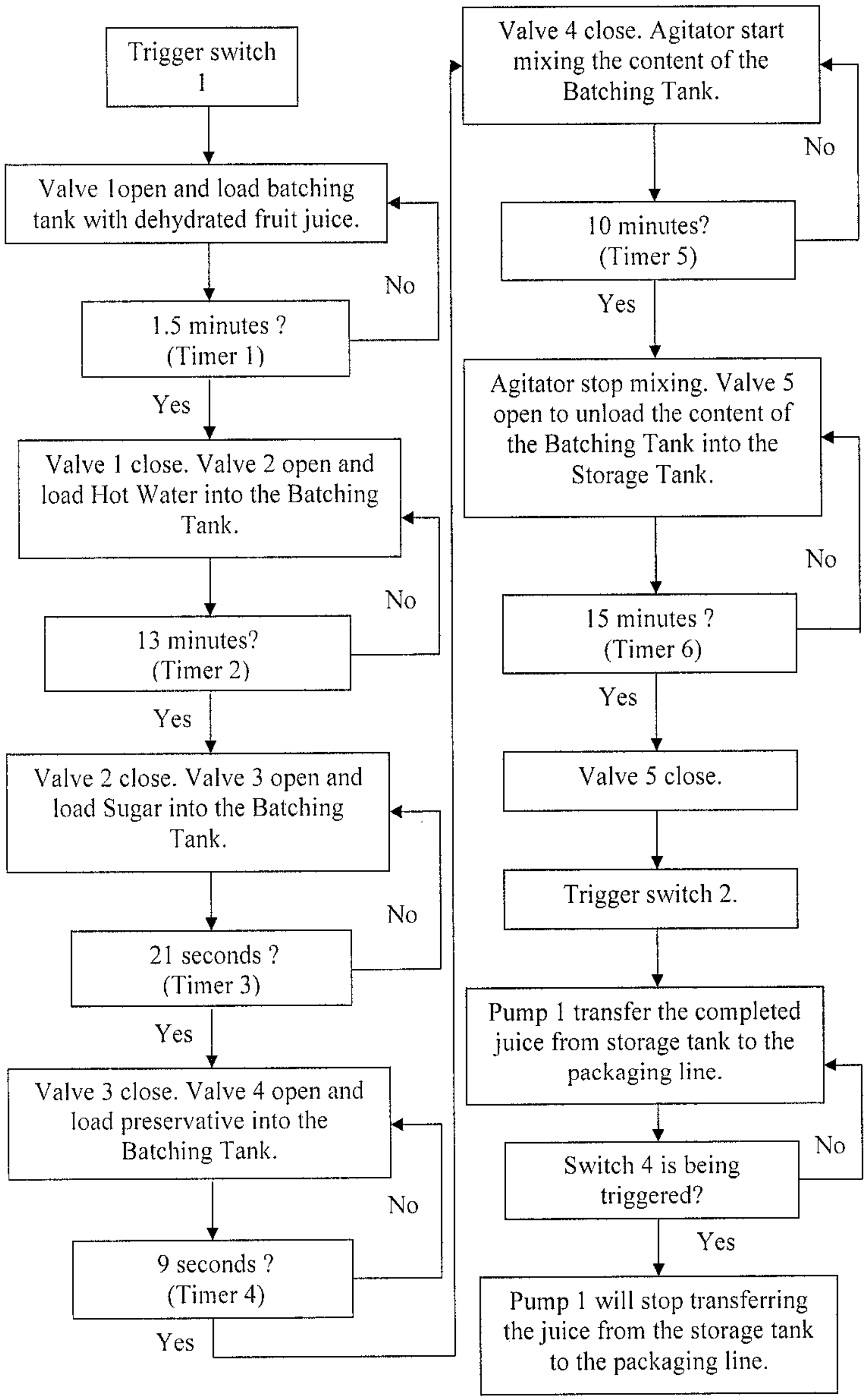

Figure 3: Juice Blending/Batching System Operation Flow Chart

4.5 PLC Programming

PLC programming can be divided into three major stages which are determining the operation flow, PLC I/O identification and developing the ladder diagram. The operation flow of the Juice Blending/Batching System had been determined and is shown in *Figures 2* and *3*.

4.5.1 Identification of PLC Input/Output

OMRON CQM1HCPU21 implements digital input/output modules. Digital input modules accept either an ON or OFF state from the real world. The module inputs are attached to devices such as switches or digital sensors. Meanwhile, digital output modules are used to turn real-world output devices either on or off. Digital output modules can be used to control any two-state devices or any other devices by converting the signal into analog output.

To identify the PLC input/output, the lists of devices which give the electrical signal and perform the desired output operation were listed. All these devices were labeled with the corresponding addresses (PLC Operand) in order to construct the ladder diagram. The list of devices and their PLC Operand are shown below:

4.5.1.1 PLC Input

- Switch 1 (00000)
- Switch 2; Pump ON (00001)
- Switch 3; Reset (00003)
- Switch 4; (Pump OFF) (00004)

4.5.1.2 PLC Output

- Valve 1 (10000)
- Valve 2 (10001)
- Valve 3 (10002)

- Valve 4 (10003)
- Valve 5 (10004)
- Agitator (10005)
- Pump 1 (10006)
- Holding Relay 1 (10007)
- Holding Relay 2 (10008)
- Holding Relay 3 (10009)
- Holding Relay 4 (10010)
- Holding Relay 5 (10011)
- Holding Relay 6 (10012)

4.5.2 Developing PLC Ladder Diagram

Developing the ladder diagram plays an important part in PLC programming. Ladder diagram is a symbolic representation of an electrical circuit. PLC ladder diagram can be developed based on the operation flow and the PLC I/O listed before. The following are the expected conditions of valves, pumps and agitator's motor while the system is operated according to the operation flow described in section 4.2:

Table 3: Digital output for the Juice Blending/Batching System

	Valve 1	**Valve 2**	**Valve 3**	**Valve 4**	**Valve 5**	**Agitator (Motor)**	**Pump 1**
Step 1	ON	OFF	OFF	OFF	OFF	OFF	OFF
Step 2	OFF	ON	OFF	OFF	OFF	OFF	OFF
Step 3	OFF	OFF	ON	OFF	OFF	OFF	OFF
Step 4	OFF	OFF	OFF	ON	OFF	OFF	OFF
Step 5	OFF	OFF	OFF	OFF	OFF	ON	OFF
Step 6	OFF	OFF	OFF	OFF	ON	OFF	OFF
Step 7	OFF	OFF	OFF	OFF	OFF	OFF	ON

The time duration for the operating devices such as the valves and agitator's motor operation, will be controlled via the timers that will be introduced in the PLC program. This operating duration is varied according to the amount of materials used as computed before in the previous section based on an assumption that the materials transfer rate will be at 100 kg per minute as stated in the scope or limitation of the study.

The valve working standard voltage is between 1V to 5V. 1V corresponds to 0% opening of the valve while 5V indicates that the valve is fully opened (100%). Normally with digital control, the valve is limited to open and close only. However, adjustment can be made so that the valve can still be flexible.

This can be done by assigning a different output address to open the valve and also a different output to close. In other words, the operation of the control valves controlled by digital controllers can be similar to the analog control. But, it cannot be denied that digital control will never be as good as the analog control implementation.

The "Open" and "Close" of the valves is done by simply latched and unlatched the output address. This means that the output is latched when being triggered and the same output is unlatched after some delay time provided via the timer. *Figure 4* below is a sample program for latched and unlatched the Valve 1 output:

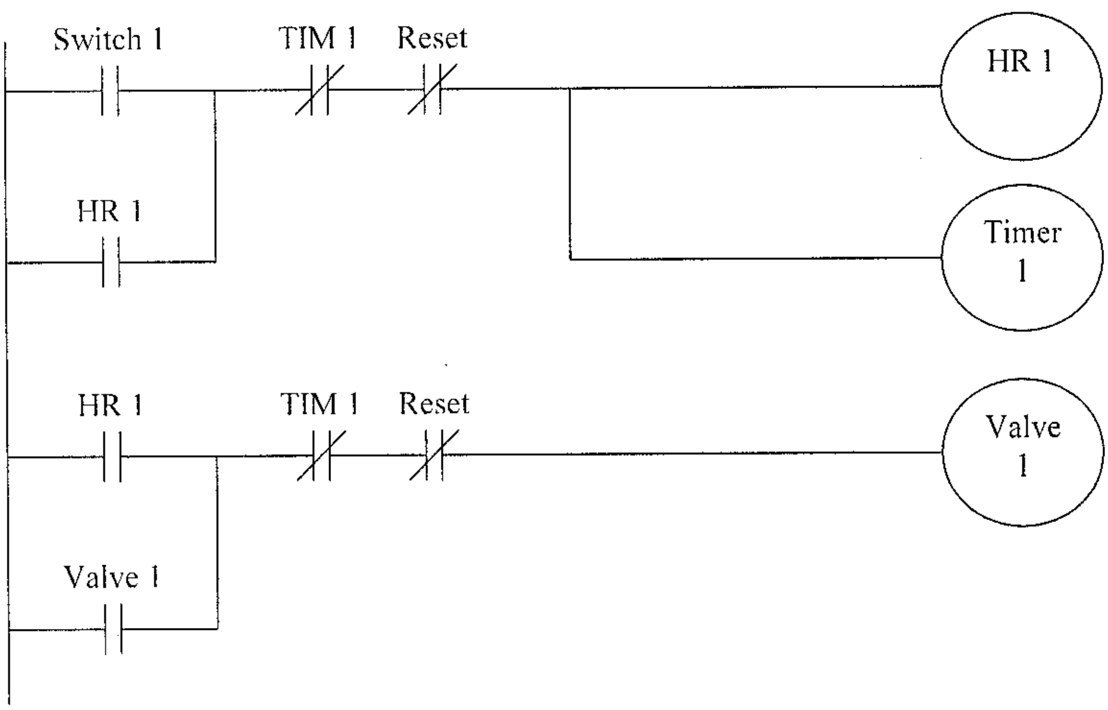

Figure 4: Sample program for latched and unlatched the output

Switch 1 is acting as the input switch to trigger the whole program cycle. Once it has been triggered, timer (TIM 1) and the holding relay (HR 1) will ON simultaneously. HR 1 output is latched so that it will stay in ON state and timer 1 will start counting. At the same time, HR 1 will trigger the next rung in which Valve 1 output will open to 100% opening. Valve 1 is also latched to make sure that it stays in 100% open state. After certain time specified in the ladder diagram, Timer 1 will stop counting and all the latches will be unlatched.

The ladder diagram also includes a Reset function for emergency cases. Whenever this reset button is being pressed, the Juice Blending/Batching System will stop its process instantaneously.

Meanwhile, the ladder diagram for controlling the ON and OFF state of the Pump 1 is different from the ladder diagram that controls the opening and closing of the valves. *Figure 5* below is the ladder diagram that controls the ON and OFF state of the Pump 1:

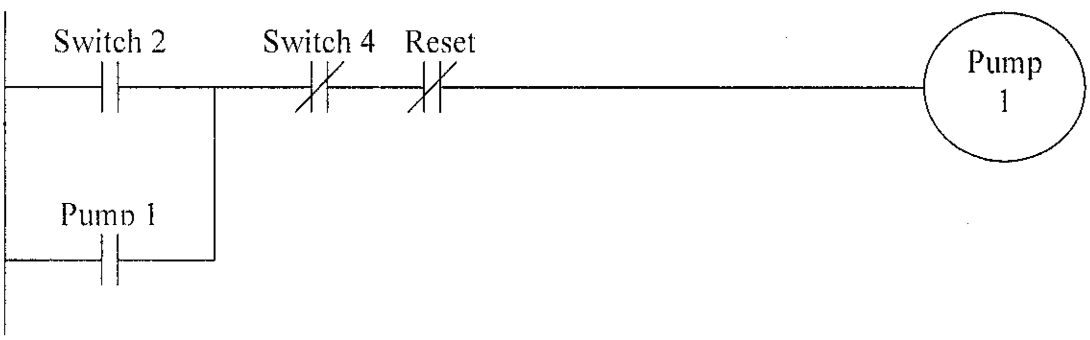

Figure 5: Ladder diagram for latched and unlatched the pump 1

Pump 1 will only operates when switch 2 (Pump ON) has been triggered. The Pump 1 will keep on operating because it has been latched. Pump 1 will only stop operating when switch 4 (Pump OFF) has been pressed.

Refer to *Appendix D* for the complete ladder diagram of Juice Blending/Batching System.

4.6 Control Valve Characteristics

Even though digital control won't be as good as analog controller, the operation of the control valve by digital controller can be as similar as the analog controller. The flexibility of the control valve can be achieved by utilizing extra devices such as relays because control valve opening is directly proportional to the input signal current. The higher the input signal, the higher the percentage of the valve opening will be. *Figure 6* below shows how the valve reacts corresponds to the input signal.

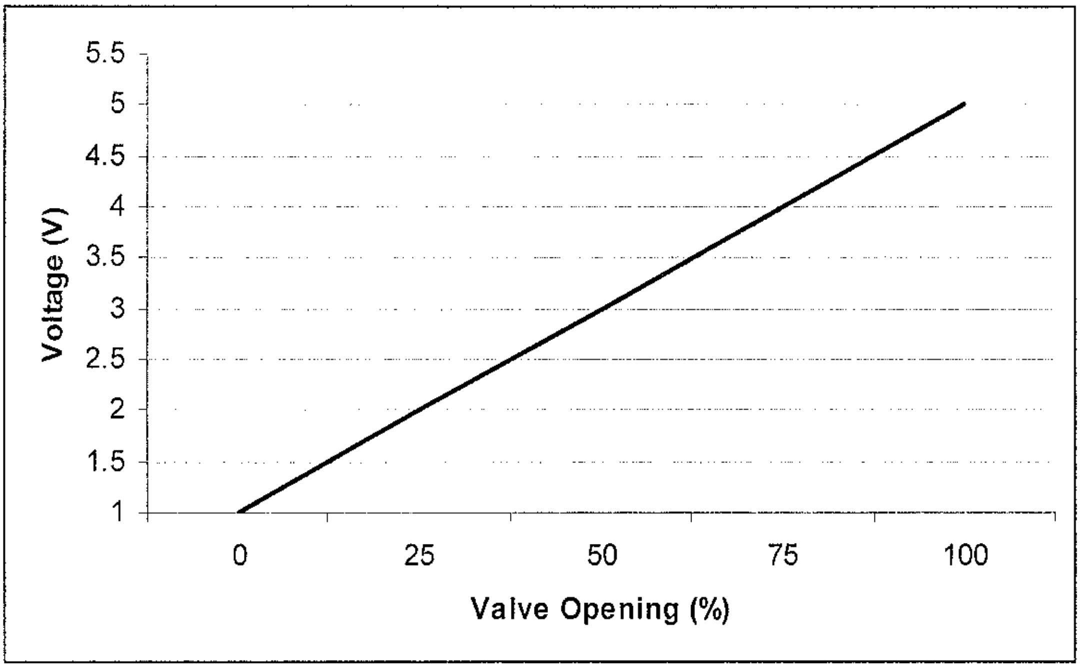

Figure 6: Input signal (V) vs valve opening (%) graph

Notice that from *Figure 6,* various range of control valve opening can be achieved by varying the input signal. For digital controller, the input signal can be assorted by using relays to vary the voltage supply. For example, to have 25% control valve opening, relays are connected along with other equipments to have 2V voltage supply. However in this specific project, the control valves are specified to have 0% opening and 100% opening only.

4.7 Hardware Connections

The real fact is, control valve will not simply respond to the voltage supply from the digital PLC units straight away. The voltage signal must be converted into the form of pressure value that will actually drive the valve. From the controller, the signal is 1V to 5V which is corresponding to 4mA to 20mA. A converter known as the I/P Converter (I= current, P= pressure) or Valve Positioner will then convert the current signal to pressure between 3psi to 15psi. *Figure 7* below will clarify the connection between the I/P converter, controller and valve.

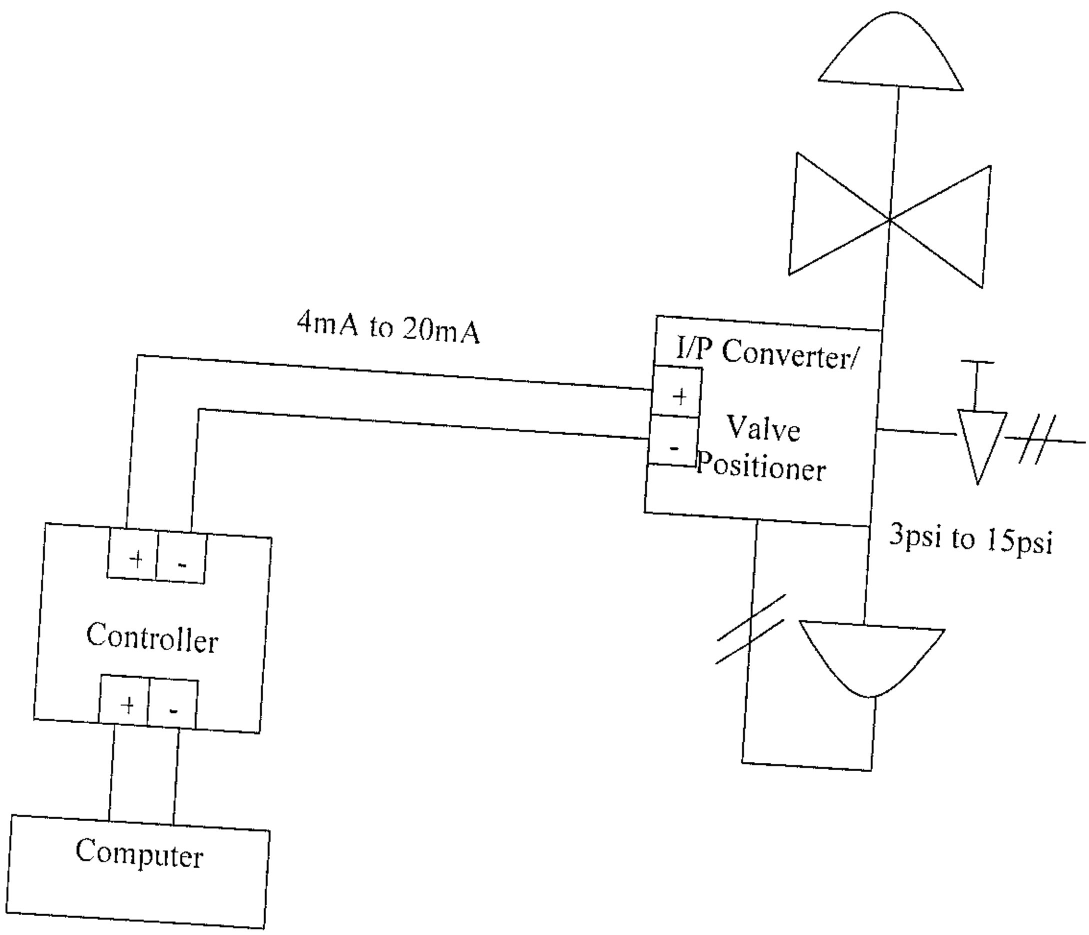

Figure 7: The connection between I/P converter, controller and valve

PLC with complete digital or analogue input and output module can be regarded as a controller to a plant. After all, PLC is commonly known as the heart of the control system and it will control the operation of the output devices in the plant. Thus, it needs to be connected properly to the devices that it needs to control. *Figure 8* below is the layout diagram of the connection between the computer, the digital PLC module and the juice blending/batching system.

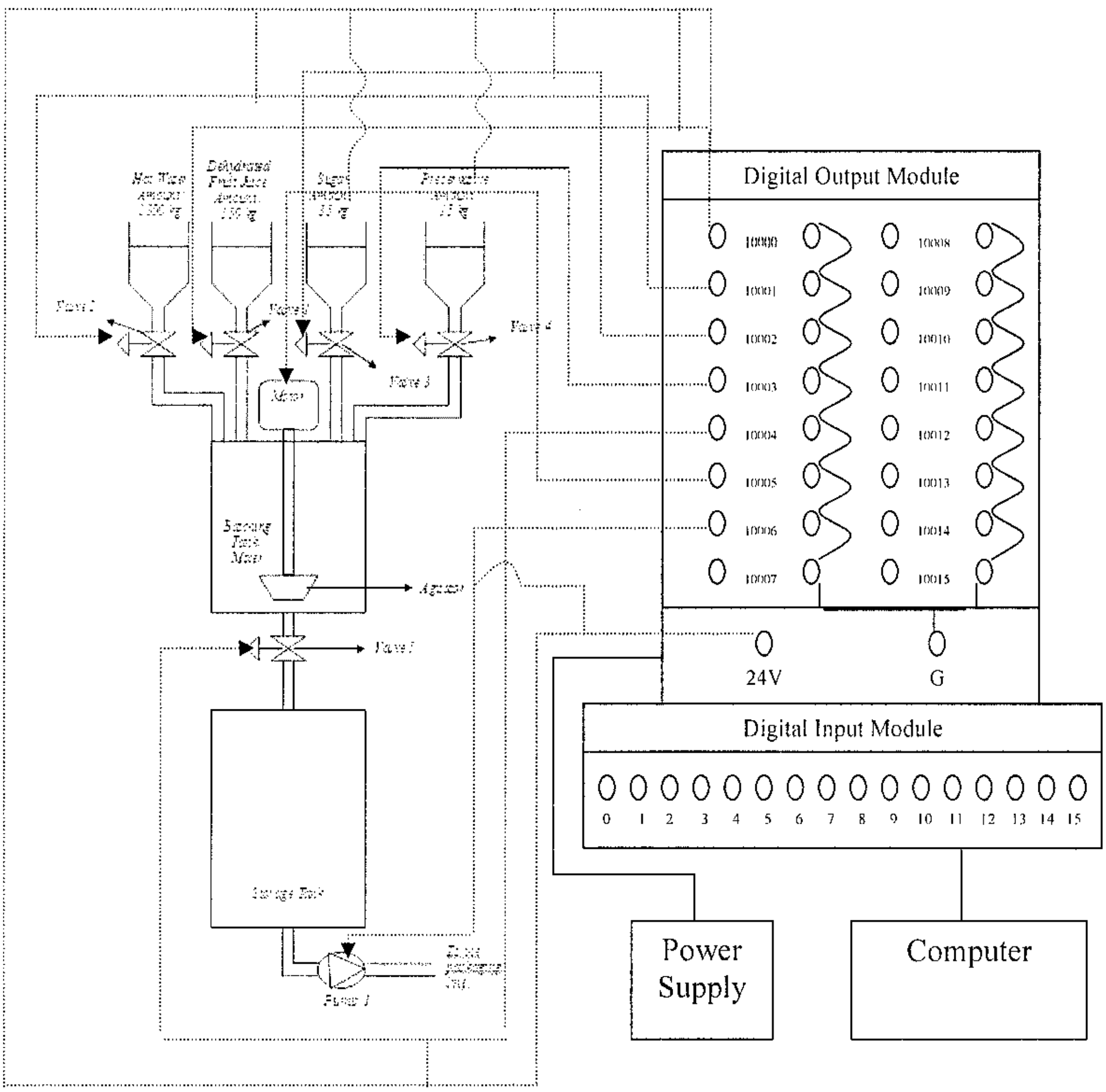

Figure 8: The connections between computer, PLC and plant

CHAPTER 5
CONCLUSION AND RECOMMENDATION

The food manufacturing industry including fruit processing; specifically juice blending is always in need of major improvements in process control. At this time, many new devices and system are available for food processing implementation. But, the fact is that the majority of the routine processing steps are still performed by workers and this includes manual batching system.

Manual batching system is not only time consuming, but it also increase labor costs, increase cause of injuries, non-consistent product quality and decrease productivity of a fruit processing industrial company. Manual batching system also creates a messy working environment for the employees. Lots of benefits can be derived by making the batching system fully automated as the author had been planning to do.

In creating a batching system for juice blending, PLC is an essential tool. A PLC is a user-friendly, microprocessor based, specialized computer that carries out control functions of many types and levels of complexity. PLC had been used in industries for a long time because PLC has many major advantages such as flexibility, implementing changes and correcting errors, large quantities of contacts, lower costs, pilot running, visual observations and many other advantages.

The final product of this project is a design of a PLC program or ladder diagram by utilizing digital PLC module that is capable of controlling an automated batching system for juice blending for industrial purposes. In order to complete the final design, this project demonstrates the appropriate steps taken in developing a ladder diagram by applying applicable concepts in ladder diagram development. This project also proves the benefits of using PLC to control the sequences in a plant.

Although the used of digital PLC module is compatible with this project, analog PLC module that can produce analog signal is still more flexible in terms of its application. Thus, this project can be upgraded by using the analog control as well as to get better product quality because PLC analog output signals can be varied accordingly hence, varying the control valve percentage opening such as 25% and 75 % valve opening depending upon the system and the users requirement.

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APPENDIX A: FINAL YEAR PROJECT PART I GANTT CHART

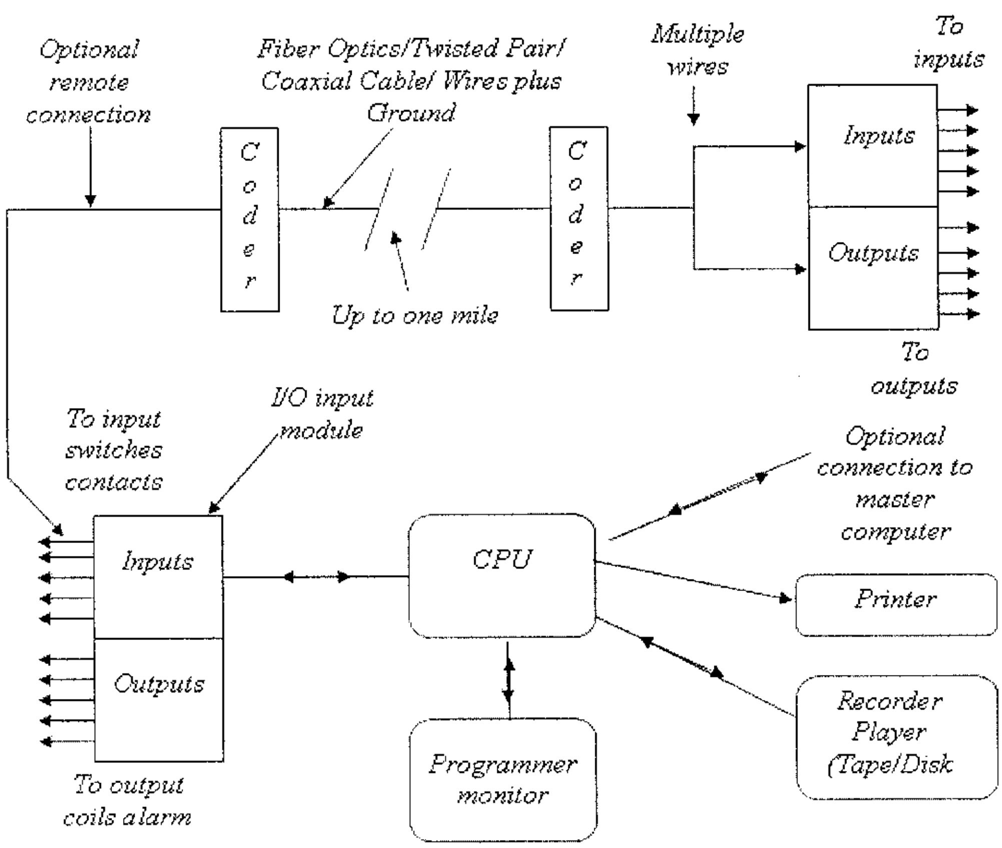
No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of Project Topic	■													
	-Propose Topic														
	-Topic assigned to students														
2	Preliminary Research Work		■	■											
	-Introduction														
	-Objective														
	-List of references/literature														
	-Project planning														
3	Submission of Preliminary Report			●											
4	Project Work				■	■	■	■							
	-Reference/Literature														
	-Learning on PLC module														
5	Submission of Progress Report								●						
6	Project work continue								■	■	■	■			
	-Learning on basic ladder diagram														
7	Submission of Interim Report Final Draft												●		
8	Oral Presentation													●	
9	Submission of Interim Report														●

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Project Work Continue		▒	▒											
	-Ladder diagram construction														
2	Submission of Progress Report 1			●											
3	Project Work Continue				▒	▒	▒	▒							
	-Ladder diagram construction														
4	Submission of Progress Report 2								●						
5	Project work continue								▒	▒	▒	▒			
	-Hardware connections (control valve)														
6	Submission of Dissertation Final Draft												●		
7	Oral Presentation													●	
8	Submission of Project Dissertation														●

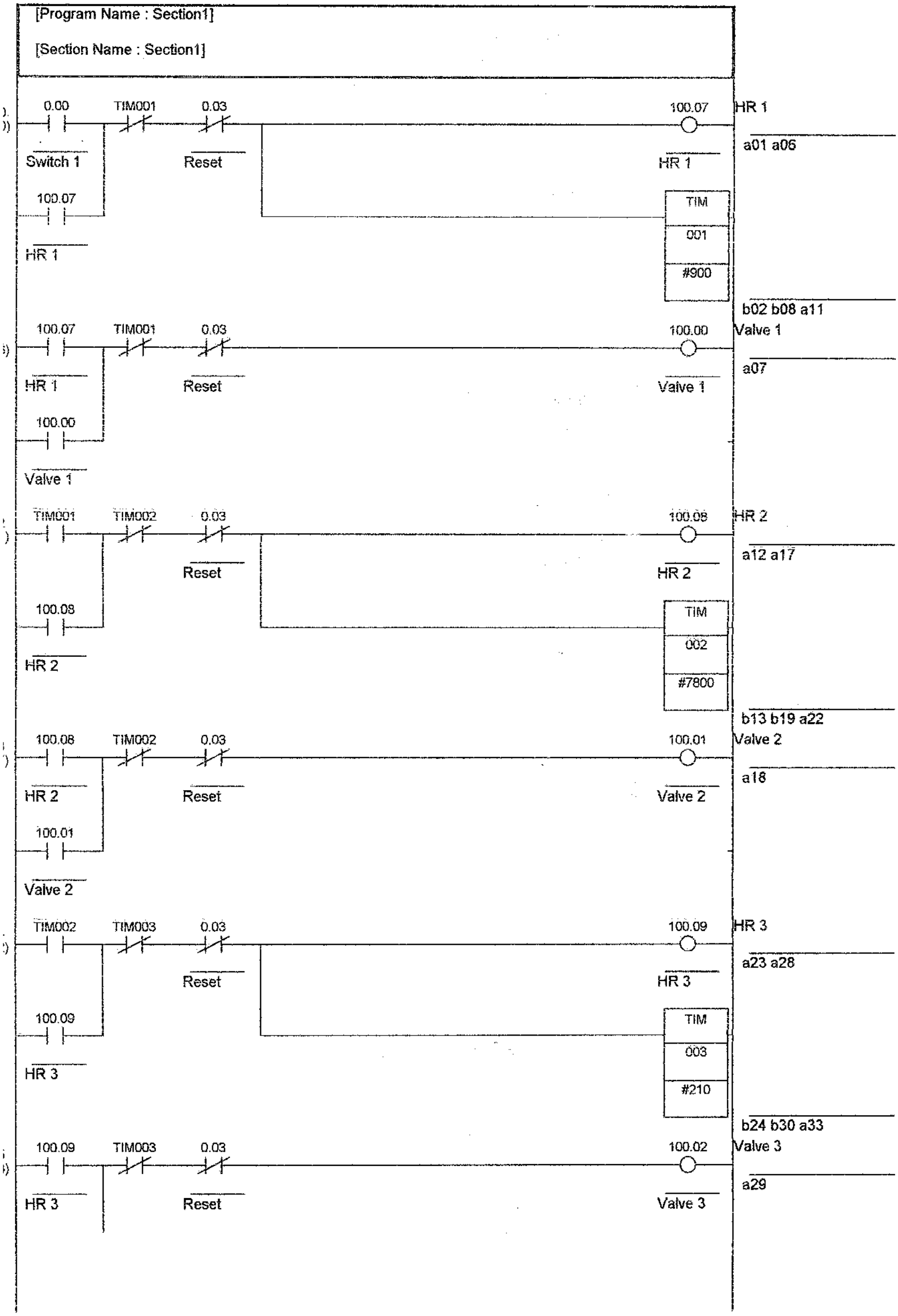
● Suggested milestone

▒ Process

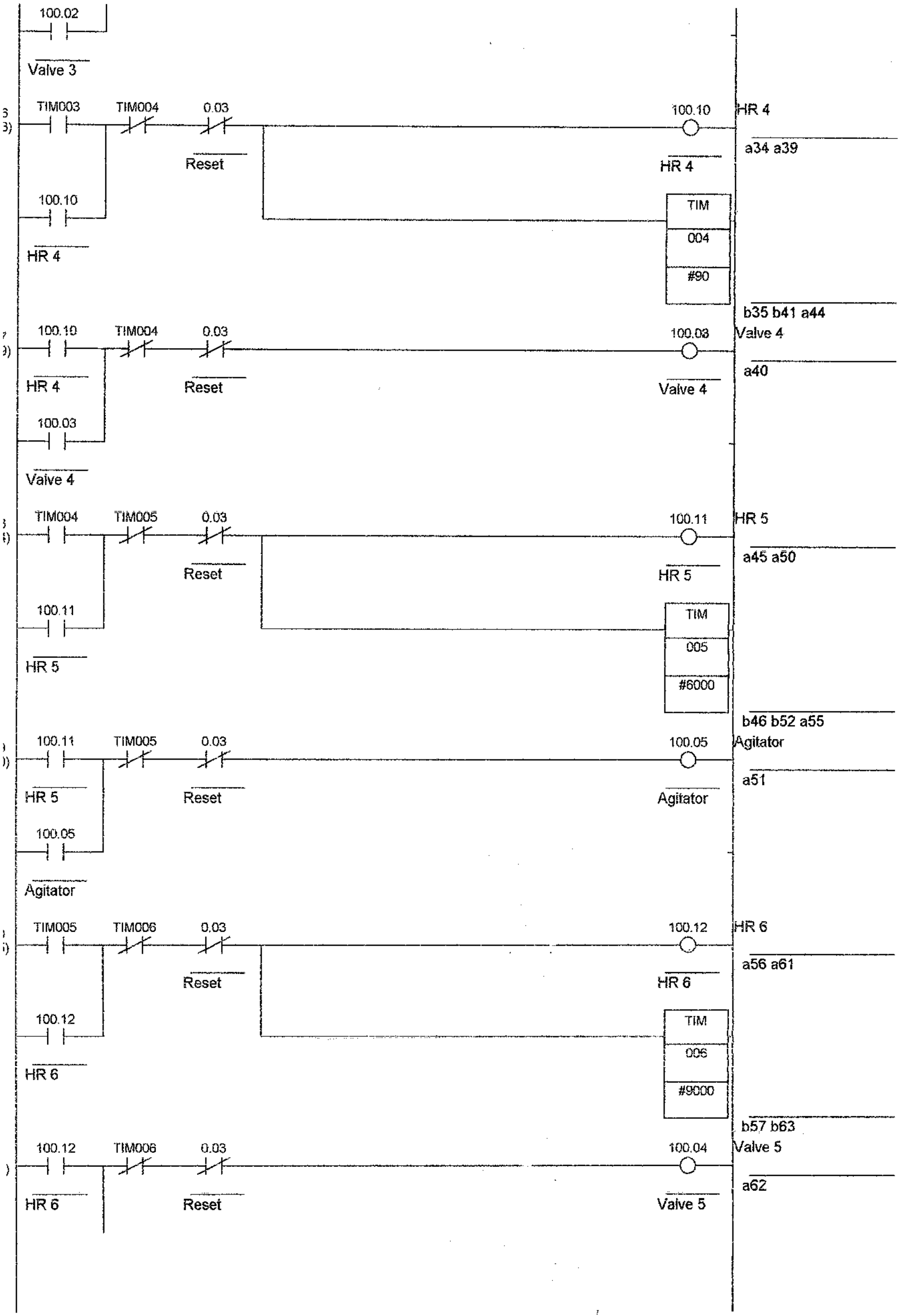
APPENDIX C: PROGRAMMABLE LOGIC CONTROLLER SYSTEM LAYOUT AND CONNECTIONS



X D: JUICE BLENDING/BATCHING SYSTEM LADDER DIAGRAM



IX D: JUICE BLENDING/BATCHING SYSTEM LADDER DIAGRAM



IX D: JUICE BLENDING/BATCHING SYSTEM LADDER DIAGRAM