PLC CONTROL OF SCRAP BATTERY AND LEAD RECLAMATION PROCESS

By

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Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
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CERTIFICATION OF APPROVAL

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UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

MAY 2004

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.

(LEE WAI YIN)

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This project would not have impossible without the help of a number of people, and the author would like to express her gratitude to all of them.

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Last but not least, the author would like to thank everyone who provided many comments and support to help the author to complete his project successfully.

ABSTRACT

A Programmable Logic controller (PLC) is a specialized computer, and designed to be used for industrial control. PLCs are used extensively in industrial control. Scrap battery process is an industry process required in recycling used batteries. This process involves scraping the used batteries and separated it to raw materials for new battery production. This process involves the industrial automation and chemical reaction process.

This project is to implement the PLC control of scrap battery process. Besides that, this project is aimed to design an optimum ladder logic program for the PLC controlling of scrap battery process and enhance the scrap battery process by upgrading the process to automation process. Nowadays, the manual operating system in the battery production, result a low quantity and quality production. The control systems used previously in battery industry are not user friendly and reliable. With this project, the author aim to design a reliable, user friendly, high productivity, smooth and advanced automated PLC controlling of scrap battery process.

The initial stage of the project involves feasibility studies of the scrap battery process, including the electrical, chemical and mechanical process. This continues by the literature review on the PLC and battery recycling process, which related to this project.

The scrap battery process is analyzed and implemented it in Microsoft Visio and Auto Cad. After analyzing the process, the scrap battery process is improved to a fully automated process. The PLC ladder logic diagram for the scrap battery process is designed and will be implemented in real PLC. Then the hardware circuitries, components of the scrap battery process is built and combined to construct a scrap battery process plant prototype. Finally, the scrap battery process plant prototype will be interfaced with PLC, and the scrap battery and lead reclamation process is controlled by the PLC. As a conclusion, the project is successfully done by PLC control of scrap battery and lead reclamation process. This PLC control has proved that it brought practical advantages to the battery recycling industry.

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CHAPTER 1
INTRODUCTION

1.1 BACKGROUND STUDY

A Programmable Logic controller (PLC) is a specialized computer, and designed to be used for industrial control. PLCs are used extensively in industrial control, because they are easy set up and program, behave predictably, and are tough enough to keep working in even the dirtiest production environment.

Programmable logic Controllers are sometimes called programmable controllers but are more commonly called PLCs. A PLC is different from a standard personal computer in two ways: (1) PLCs are constructed to make it easier for a user to put together a PLC-controlled system, and (2) PLCs come preprogrammed with an operating system and applications programs optimized for control. The programming used in PLC is the ladder logic program.

The PLC components consist of CPU module, input and output modules (I/O modules), power supply module, and a rack. The CPU module is containing the central computer and its memory. The input and output modules allow PLC to read sensors and control actuators. The power supply module provides the power to CPU and the I/O modules. The rack enables the CPU module exchanges data with I/O modules. However, a PLC automated system need a programming unit, to create the user-program to and send to CPU module's memory.

Scrap battery process is an industry process required in recycling used batteries. The input for the scrap process is the battery and the output is the raw materials for new battery production- lead, lead oxide, plastic and separator. The scrap battery process involves the industrial automation and chemical reaction process.

CX-Programmer 3.0 is a software that developed by OMRON PLC Company. This program is used to program the ladder logic program for PLC. In the CX-programmer, the ladder logic diagram is programmed in rung. The programming technique is that tracked the ladder logics and connected them according the program designed. The common ladder logics used in CX-programmer are the normally opened input, normally closed input, output, holding relay, timer and counter. Some additional functions in the CX-Programmed are comparing, adding and subtracting. After the ladder logic program is done, the CX-Programmer contains a server to interface the program to the PLC. Then the PLC read the specified program from the CX-Programmer and functioned to control the system according to the program.

1.2 PROBLEM STATEMENT

1.2.1 Problem Identification

In industrial area, the quantity and the quality of the production are very important. The manual operating system in the battery production, result a low quantity production. In addition, the quality of the manual operating system is not reliable. This is because the manual operating system is more time consuming and the production is not consistent, since the result depends on the human's skill. Therefore, smooth automation system needed in the battery production, and recycling process.

For the scrap battery process, the quantity of the battery scraped to raw materials will affected the whole battery recycling system. This is important to ensure the system is running smoothly. The control system of the scrap process must be user friendly, easy to optimize and manage to operate a smooth automation system. From previous industrial experience, the manual operating system results low quantity and quality production. In addition, current control system such as electromechanical control has high operating costs, modifications are difficult, unclear system layout, wear (maintenance therefore required), high space requirements and expensive components needed. Besides this, the personal computer system required high technology, high cost and not user friendly. Therefore, a suitable control system for scrap battery process must be applied.

1.2.2 Significance of the Project

This project serves an automation control system for an advanced scrap battery process in order to solve the problems identified. This project will implement the PLC in the scrap battery process. The PLCs will be interfacing will the scrap battery process hardware such as motors, sensors, conveyors, crushers, actuators, pumps, reactors and others industrial components. The ladder logic program will be design and suit the scrap battery process. The PLC control of the scrap battery process will result an automation process and solves the manual process issue.

The PLCs are constructed to make it easier for a user to put together a PLC-controlled system, and come preprogrammed with an operating system and applications programs optimized for control. This may lead the scrap battery process running smooth and in automated way. Hence, the quantity and quality of the production can be improved from this project.

1.3 OBJECTIVES AND SCOPES OF STUDY

1.3.1 Objectives

(i). To implement the PLC for controlling of the scrap battery process.

(ii). To design the optimum ladder logic program for the PLC controlling of scrap battery process for future features enhancement purposes.

(iii). To interface the PLC control system with the scrap battery process hardware.

(iv). To enhance the scrap battery process by upgrading the process to automation process.

(v). To design a reliable, user friendly, high productivity, smooth and advanced automated PLC controlling of scrap battery process.

(vi). To integrate and utilize the knowledge that is learnt throughout the 5-year of university program.

1.3.2 Scope of Study

The feasibility studies of the scrap battery process including electrical, chemical and mechanical process; has to be conducted before deciding the PLC controlling of the scrap battery process. The features of the hardware in the process such as motors, sensors, conveyors, crushers, actuators, pumps, reactors and others industrial components will be researched on the early stage of the project, from week 3 to week 8. Generally, the process flow of the scrap battery and lead reclamation process is studied and understood as well in order to program the ladder logic program for the process.

A profound study has to be conducted before deciding on the PLC controlling of scrap battery process. The scope of study may include the components, features, applications and programming of the PLC. In addition, the CX-Programmer software, which used to program the PLC ladder logic program will be learnt in this semester. This feasibility study will be carry on during the whole semester, from week 3 till week 14. The working and researching schedule will be concluded in the project Gantt chart.

CHAPTER 2

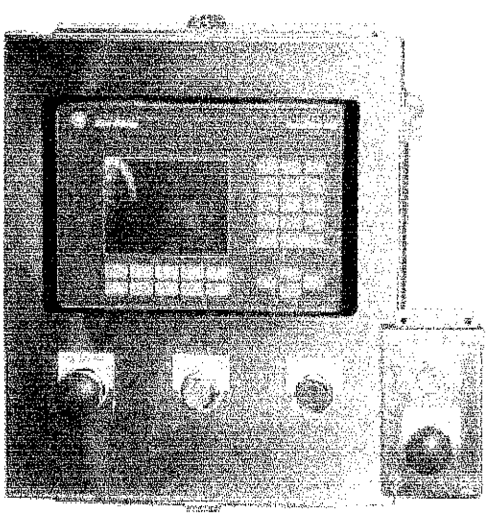
LITERATURE REVIEW AND THEORY

2.1 SUPPORTING INFORMATION

The literature review done by the author on the PLC control of scrap battery process had been divided into two major parts namely the PLC and scrap battery process.

For the PLC part, the author had collected some information from books and internet. These information are included the introduction, components, features, applications, programming and types of the PLC. For the scrap battery process part, the literature review of the input and output of the system had been done by the author.

2.1.1 The Introduction of Programmable Logic Controller (PLC)



Many-many years before PLC was invented, machine controllers using a combinational circuit, like combine of many relays, timers or any other devices, mechanical controller like cams shaft and drums, include of electronics circuits to made a sequence process (logic control system). With this old sequential controller, the circuit looks very crowded and usually it is hard to find the malfunction part, or even to modify the sequence, besides that it needs more time and cost too. The old sequential controller also implemented only in small scale or medium scale system and specific to a system or machine, because in large scales system, it is hard to test the ability and the efficiency of the entire system. This system also cannot be implemented in the process that needs a high-speed control. So that is why the PLC was invented.

Many new industries now a day already implemented PLC systems to control their machines.

PLC is operated by the instruction input from the input devices (like push button switch, selector switch, digital switch, etc. provided on the operation panel, or sensors input from the limit switch, proximity switch, etc.) used to detect the operation condition of the equipment, and serve to control the driving loads, output devices (such as solenoid valve, motor, electromagnetic clutch, etc. and indication loads such as pilot lamp, digital indicator, etc.). The transmission of output signal against these input signals is determined by the contents of program to be provided to the PLC. The light loads such as small type solenoid valve, pilot valve, pilot lamp, etc. can be directly driven by the PLC, however, the heavy loads such as 3-phase motor, large capacity solenoid valve, etc. need to be driven through the contactor or the intermediate relay. Such contactor, intermediate relay, power breaker, etc. are installed in the control panel together with the PLC. The PLC will play the important roles as a small type, high-reliability and flexible brain when designing the automated product machining, assembling, transfer, inspection, packing, etc.

The PLC is composed of electronic circuits with a micro-computer (micro-controller) centered, however, it can be equivalently regarded as an integrated body of ordinary relay, timer, counter, etc. The input relays built in the PLC; is driven by the external switch through the input terminal. The output relay built in the PLC is provided with various internal contacts in addition to the external output contact. Besides, it is incorporated with various types of elements such as timer, counter, auxiliary relay, state, coil and function block, etc. In addition, these elements are provided with many electrically normally-open contacts and normally-close contacts, and can be used optionally with in the PLC.

2.1.2 Components of PLC

The main components of PLC are stated as following:

- CPU module
- Input and output modules
- Power supply module
- Rack

2.1.3 Features of PLC

The literature review of the features of PLC had done according following function. These features must be familiarized before handling the PLC. The features of normal PLC are:

- Analog settings function
- Input function
- Quick-response inputs function
- High-speed counter
- Timer function
- Pulse output function
- Synchronized pulse control
- Marco function

2.1.4 Applications of PLC

There are so many applicants that PLCs are used in various industries. Some of these applications are:

- Material handling
- Conveyor system
- Food processing
- Tobacco industries

- Cement manufacturing
- Traffic light system
- Petrol chemical plant
- Power station plant

2.1.5 The programming of PLC

Ladder logic programming is used to program the PLC. The ladder logic diagram is a language that looks and acts like an electrical ladder diagram. Ladder-logic is not only a self-documenting-graphical language, but also the fastest way to get one-of-a-kind applications up and going. Ladder-logic also called self-documenting language because the copy of the ladder logic can be printed out directly. This is because it uses the same graphical representation that electricians call ladder diagrams with the same types of symbols they have been looking at for generations.

2.1.6 Types of PLC

There are two types of PLC had been reviewed: 'Brick' PLC and Rack PLC. A 'brick' PLC has a block shaped case (hence a 'brick') with terminal strips on it. They can be panel or DIN rail mounted but come in a model-number-determined set of I/O capabilities.

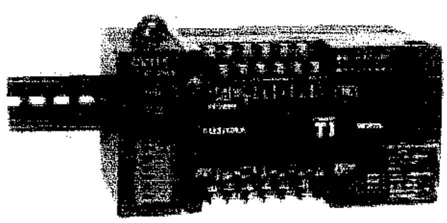


Figure 2.1: Picture of a Brick type PLC

A 'Rack' has one or more 'card racks' that individual circuit cards slide into so you can pick and choose your I/O to whatever number and/or type you need.

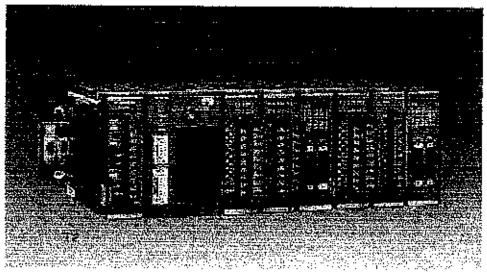


Figure 2.2: Picture of a Rack type PLC

2.1.7 Input and Output of The Battery Scrap Process

Basically the purpose of scrap battery process is to separate the materials of the battery as raw material for battery recycle. The inlet and outlets of the process is stated as flow chart below.

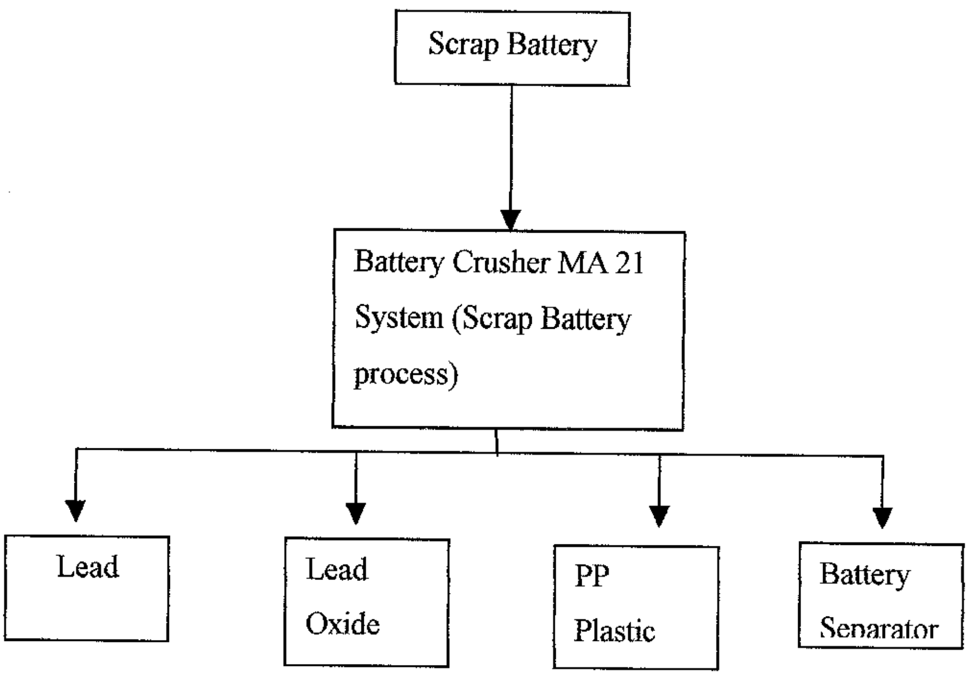


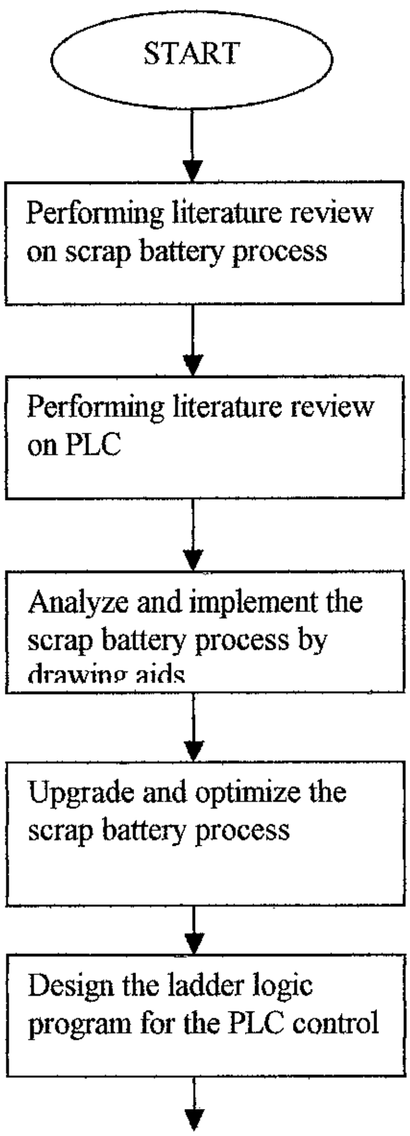
Figure 2.3: Flow chart of the inlet to outlets of the scrap battery process.

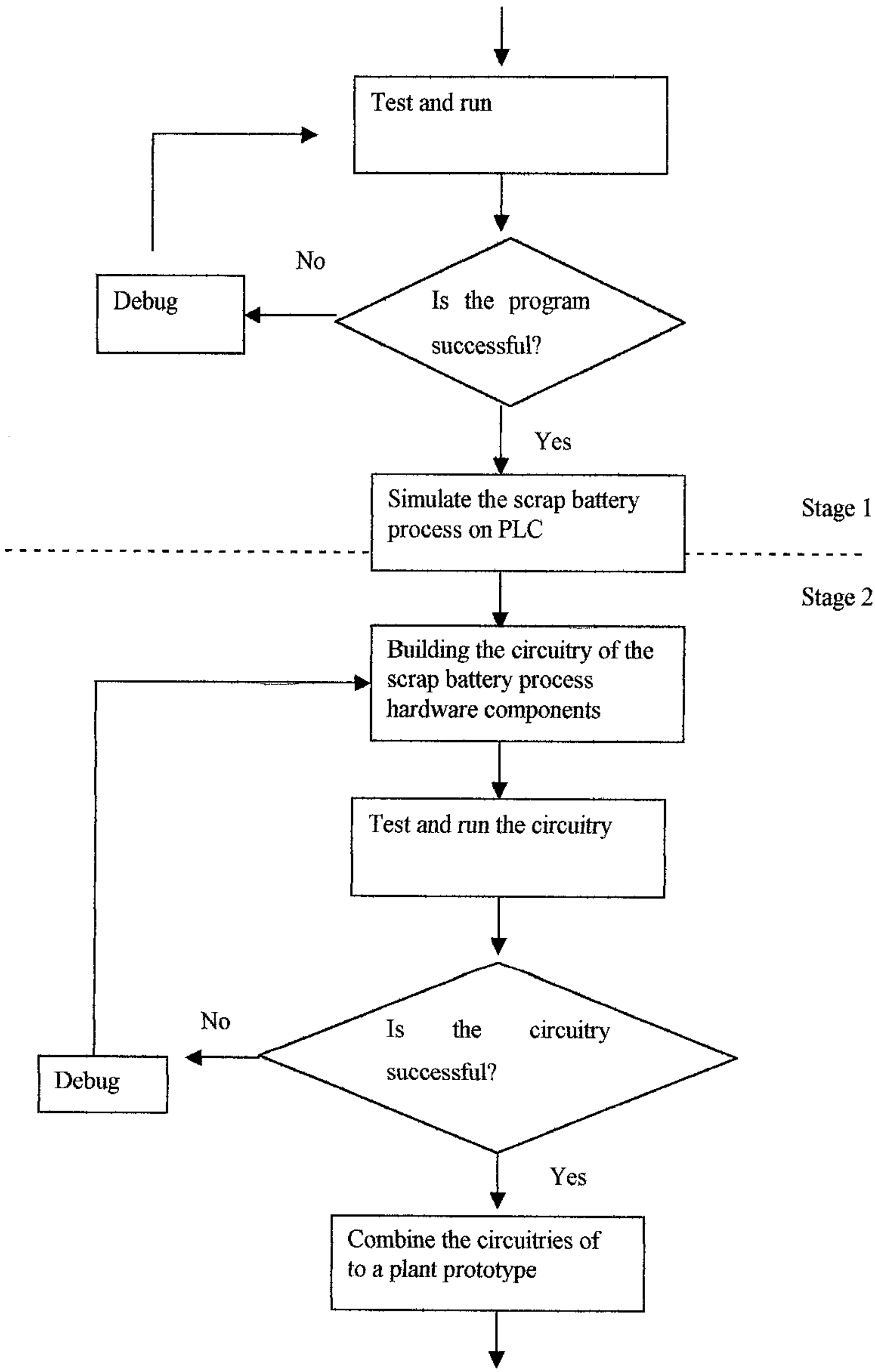
For the outlets obtained, the lead and lead oxide will be recycled in the lead reclamation process. The pp plastic will be packed for sales purpose and the battery separator will be disposed.

CHAPTER 3
METHODOLOGY/ PROJECT WORK

3.1 PROCEDURE IDENTIFICATION

The flowchart below shows the methodology of producing the PLC control of scrap battery process. The process is basically divided into 2 stages – stage 1 and stage 2, whereby, the tasks assigned in stage 1 is expected to be accomplished within the first semester, whereas, tasks assigned in stage 2 is planned to be completed in the second semester.




Test and run
No
Debug
Is the program successful?
Yes
Simulate the scrap battery process on PLC
Stage 1
Stage 2
Building the circuitry of the scrap battery process hardware components
Test and run the circuitry
No
Debug
Is the circuitry successful?
Yes
Combine the circuitries of to a plant prototype

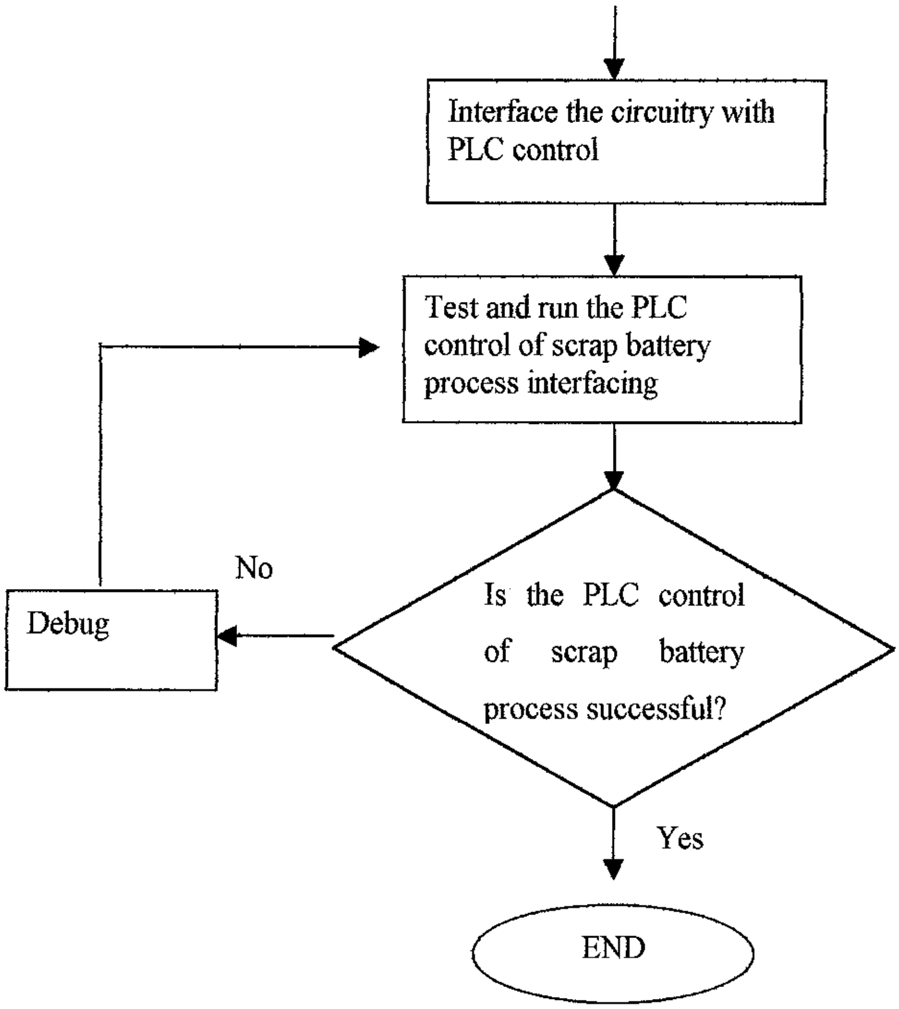


Figure 3.1: Flow chart of Methodology

3.2 WORKING SCHEDULE

The working schedule is divided to two stages, first stage is for first semester and second stage is for second semester. In the first semester, the author will due with the literature review and research on the PLC and scrap battery process. After mastering the process flow and PLC, the author will improve the scrap battery process to automated process and program the ladder logic program to control the manual and improved scrap battery process. After finishing the programming, the PLC simulation on the process will be done.

In the second semester, the author will build the electronics circuitry of the scrap battery process hardware components such as sensor, alarm, motor, pump and conveyor circuits. Then the author will combine this circuitry to a scrap battery and lead reclamation plant prototype. Finally, the PLC interfacing will be done on this plant prototype and control the scrap battery and lead reclamation process. The working schedules of the project are summarized as Gantt chart in *Appendix1* (first semester) and Ap*pendix 2* (second semester).

3.3 TOOLS/ COMPONENTS

(i) Programmable Logic controller (PLC)- OMRON PLC Training Kit
(ii) Dc motors
(iii) Stepper motors
(iv) Light Dependent Resistor (LDR) sensors
(v) High-low water level sensors
(vi) Ac Water pumps
(vii) Dc air pumps
(viii) 24Vdc Relay
(ix) Dc power supply
(x) Ladder logic programmer- CX Programmer Version 3.0
(xi) Microsoft Visio software
(xii) Auto Cad 2004
(xiii) Scrap battery process model components
(xiv) Soldering kits
(xv) Wire wrapper
(xvi) Jumper wires
(xvii) Perspex
(xviii) Plastic cup (tank)
(xix) Push button
(xx) Neon LED
(xxi) Buzzer

3.4 METHODOLOGY OF ELECTRONICS CIRCUITRY CONSTRUCTION

To construct the electronics circuitry, each electronics component must be stack and based on the PCB circuit board. Then the leg of the components will be soldered. In progressing the soldering, the author found out that there have short on the circuit. Then the troubleshooting work needed to correct the circuit.

Besides soldering circuitry, the author found out that there are better way to substitute this technique. The new method that will be tried to connect the electronics components to a circuitry is the wire wrapping techniques. To do this, the wire wrapper and the jumper wires are needed. Then each wire is wrapped on the component's leg and to the target leg. The advantage of this method is to simplify the circuitry work and less time consuming.

By trying the wire wrapping method in order to connect the electronics components to a circuitry is the. The wire wrapper and the jumper wires are the tools required in this technique. Then each wire is wrapped on the component's leg and to the target leg. By using this method, the author had successful complete to complete the LDR sensor and water level sensor circuit, which faced problem when the soldering method applied. The problem of soldering the circuit is that, time to complete and troubleshooting is much more longer than wire wrapping technique.

For the high-low water level sensor, the author built the circuitry by soldering the components on PCB board. The author did not applying the wire wrapping method because the author priority on the toughness of the circuitry.

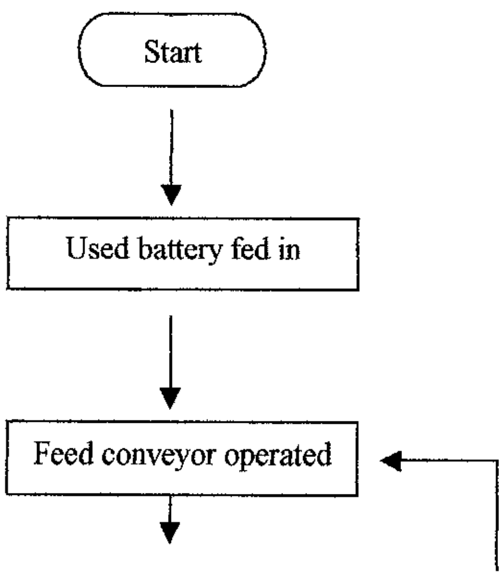
CHAPTER 4

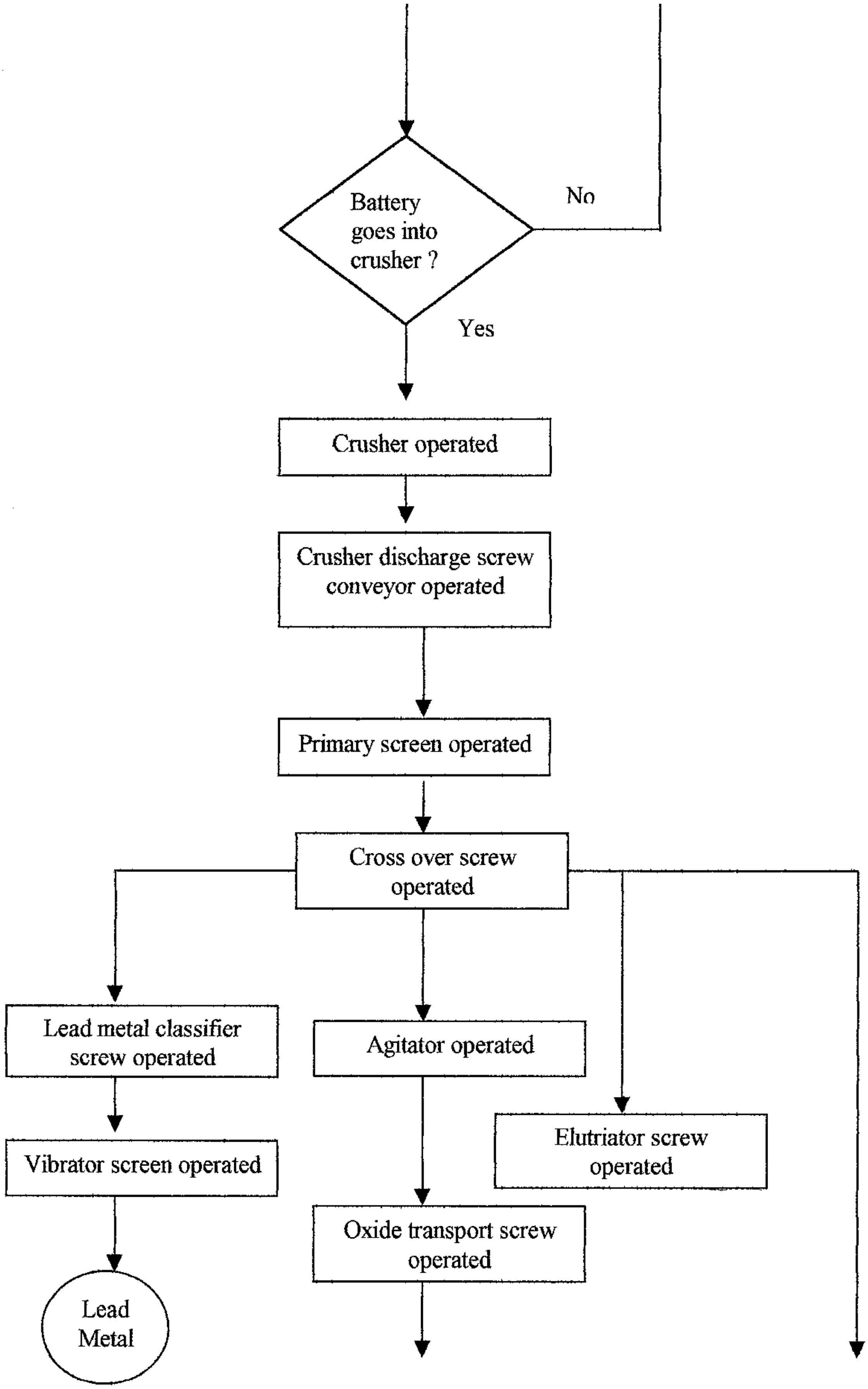
RESULTS AND DISCUSSION

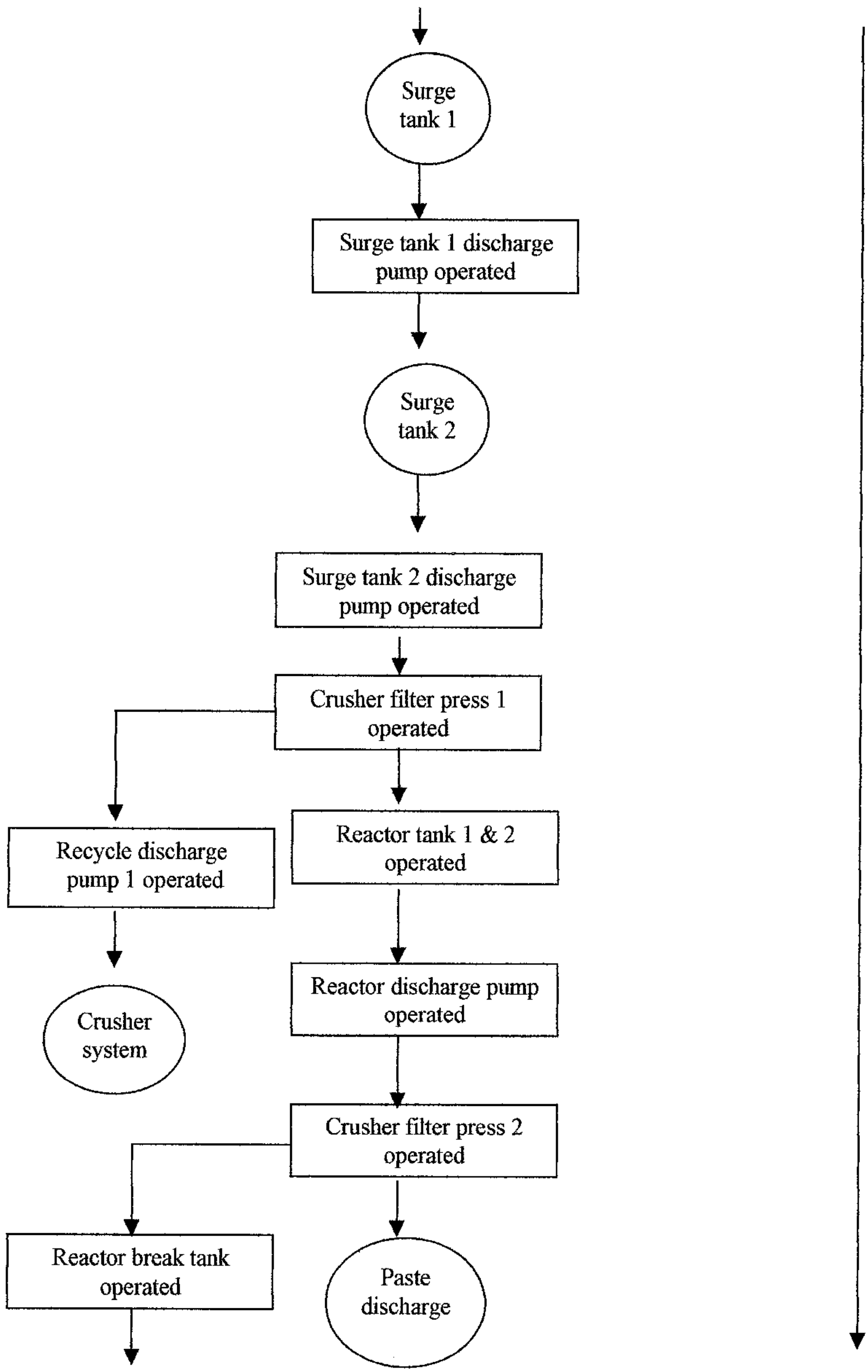
4.1 ANALYSIS ON PROCESS FLOW

The author had studied and analyzed the scrap battery process flow in the Yokohama Battery- Lead Reclamation Plant. The result of the analysis is the process flow drawing as process identification. The author had draw and implemented the plant process operation and process flow by Microsoft Visio and edited again in Auto Cad. The results of the drawing and the implementing of the Scrap Battery Process Flow are shown as the *Appendix 3* (Microsoft Visio) and *Appendix 4* (Auto Cad). To program the PLC ladder diagram of an industrial process, the understanding on the process flow is very important. This will affect the programming accuracy, if the process flow is not fully been mastered.

From the plant operation and process flow drawing, the author summarized it to a process flow chart. The ladder logic program will be designed according to the process flowchart, since the process flowchart provides the step-by-step sequence of the process. This provides a clear overview and sequence to the author or any programmer. The plant process flow of the scrap battery process is summarized as flow chart below.




Battery goes into crusher ?
No
Yes
Crusher operated
Crusher discharge screw conveyor operated
Primary screen operated
Cross over screw operated
Lead metal classifier screw operated
Agitator operated
Elutriator screw operated
Vibrator screen operated
Oxide transport screw operated
Lead Metal


Surge tank 1
Surge tank 1 discharge pump operated
Surge tank 2
Surge tank 2 discharge pump operated
Crusher filter press 1 operated
Recycle discharge pump 1 operated
Reactor tank 1 & 2 operated
Crusher system
Reactor discharge pump operated
Crusher filter press 2 operated
Reactor break tank operated
Paste discharge

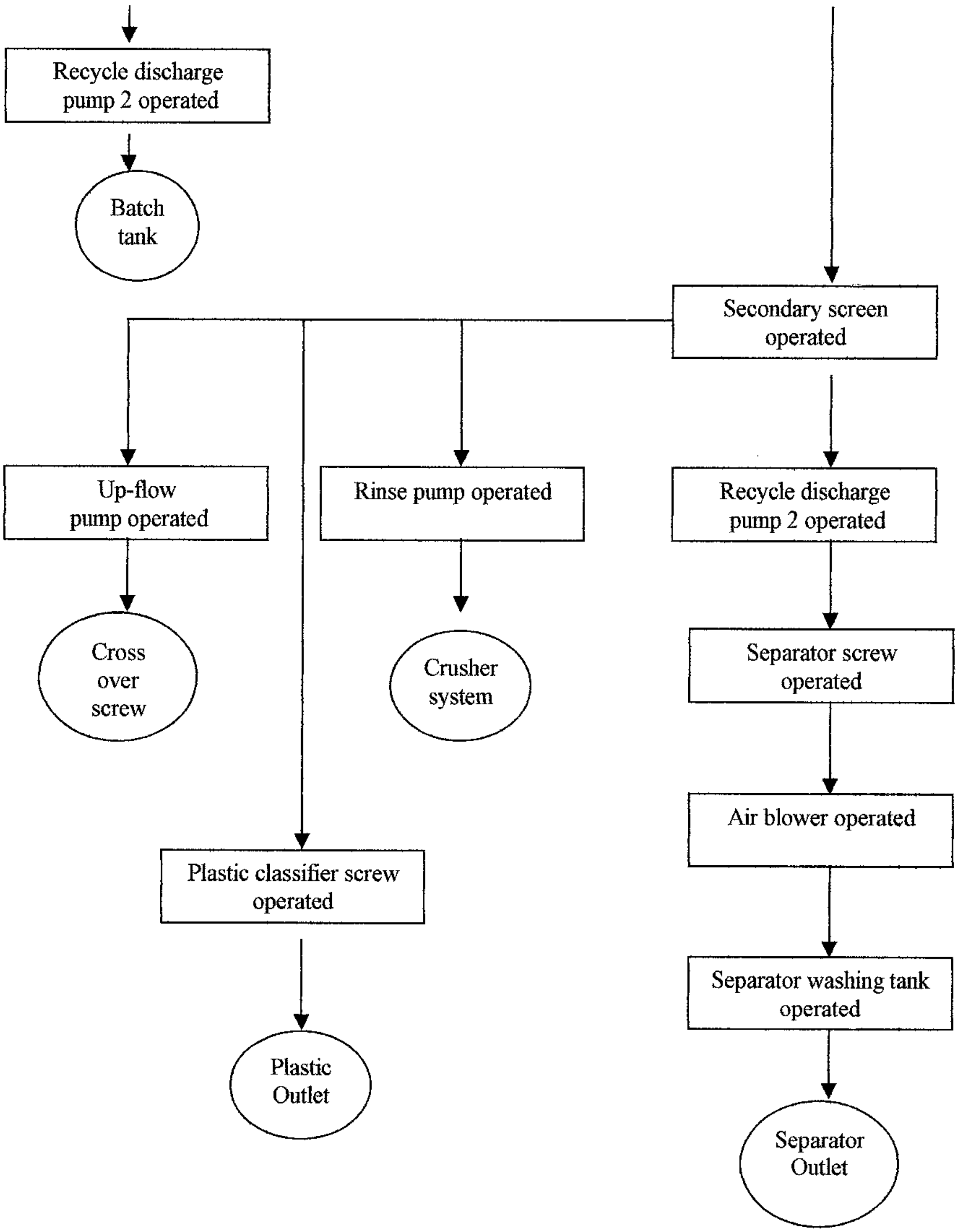


Figure 4.1: Flow chart of original scrap battery process.

4.2 DISCUSSION ON PROCESS FLOW

In the original scrap battery process, the process started with feeding in the used battery. Then the battery is fed to crusher by the feed conveyor. When the battery reach to the crusher, the crusher will crushes the battery to small particles. Then the small particles containing of lead metal, lead oxide, plastic and separator are moved to primary screen by crusher discharge screw conveyor.

In the primary screen, the lead oxide is separated by the cage, which inside the screen. The agitator is on and the lead oxide is vibrated to the elutriator screw and surge tank 1 by oxide transport screw. The lead oxide is moved to reactor tank 1 and 2 by the elutriator screw. The surge tank is to increase the capacity, slow down the incoming of lead oxide by increase the holding time. When the contents (lead oxide + water) of the surge tank are full, the surge tank discharge pump 1 will pump the contents to surge tank 2. The process of surge tank 2 is same as surge tank 1. The contents of surge tank 2 are pumped to crusher filter 1 by surge tank discharge pump 2. The lead oxide is pressed in the filter press 1 to remove the moisture. The moisture removed is pumped back to crusher system by recycle discharge pump 1. The lead oxide pressed is passed to reactor tank 1 and 2.

In reactor tank 1 and 2, the soda (NaOH) is adding to the tank as a desulphurization process.

$$PbO_2 + PbO + PbSO_4 + 2NaOH \longrightarrow PbO + Na_2SO_4 + H_2O$$

The Sodium Soleplate is discharged to the drain. The lead oxide and water is pumped to crusher filter press 2 by reactor discharge pump. The filter press presses out the moisture from lead oxide and sinks to reactor break tank. The reactor break tank moisture then is pumped to batch tank. The lead oxide is became paste discharge and will sent to electrolysis process.

4.3 LADDER LOGIC PROGRAM FOR MANUAL PROCESS

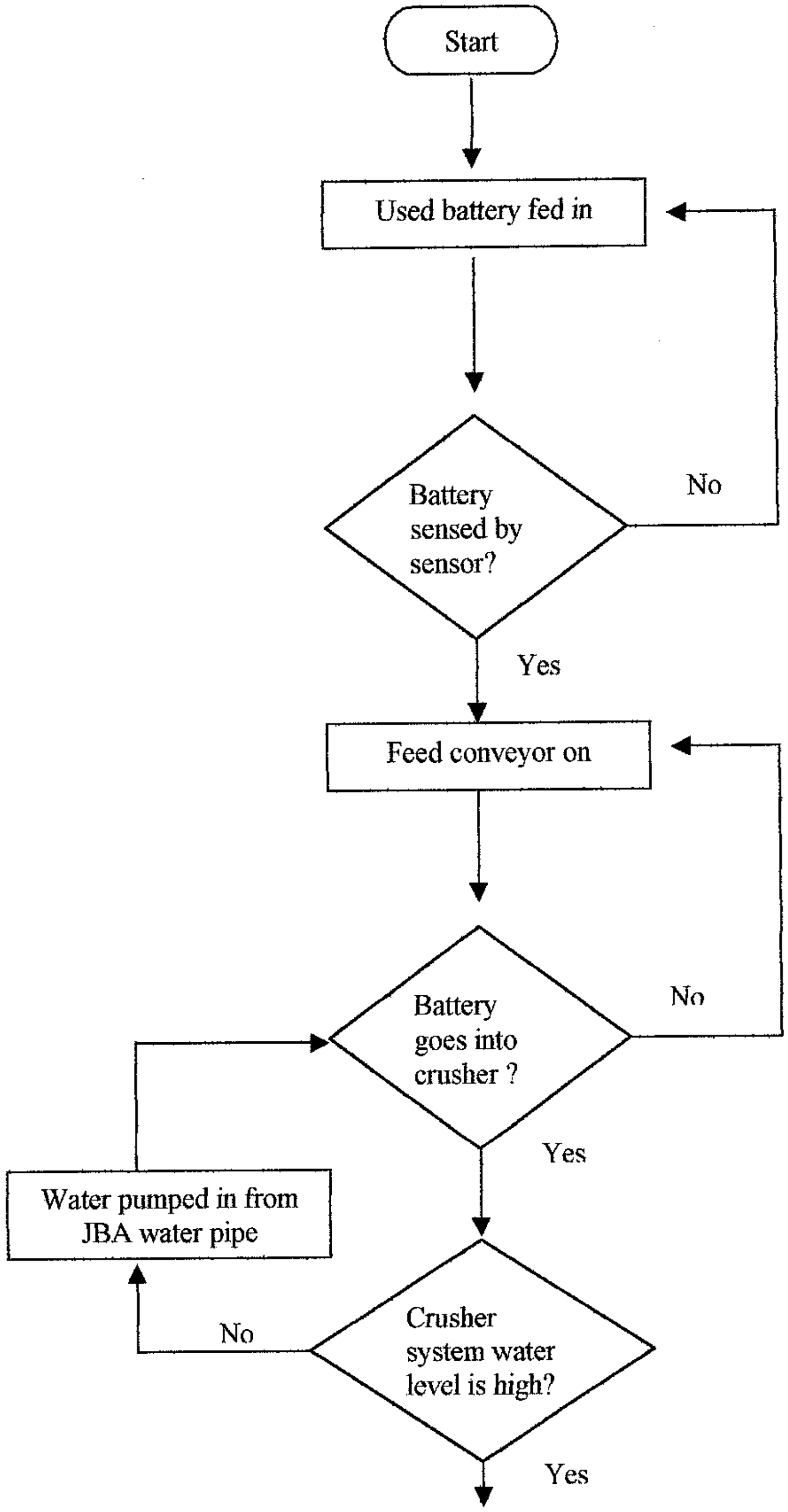
The control system techniques used in implementing this process is the Programmable logic controller (PLC). Referring to the flow chart developed in figure 4.1, the ladder logic diagram is designed by the author and attached in the *Appendix 5* (Ladder Logic Program for Manual Scrap Battery Process). Note that the original scrap battery process is same with the manual scrap battery process. Hence the manual scrap battery process ladder logic program is designed according to the original process flow.

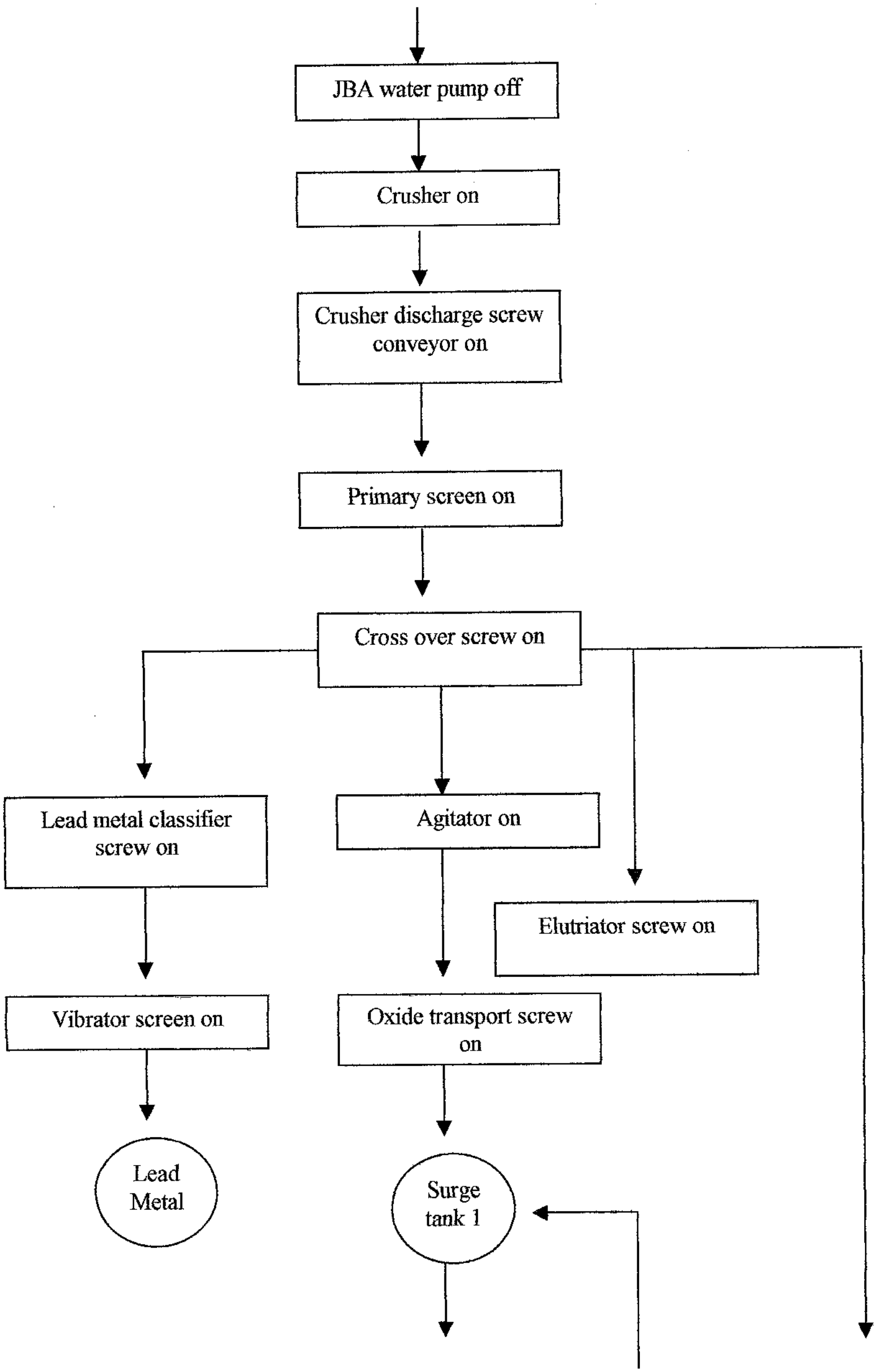
In this ladder logic programming, the push buttons (PB) work as the inputs for relevant output. Therefore, all push buttons will be ON before the battery is fed in, in order to start the scrap battery process. This may lead the waste on the electricity, water and life times of the equipment. In addition, the process is not a fully automated process. To optimize and improve the scrap battery process, the author had modified on the process flow.

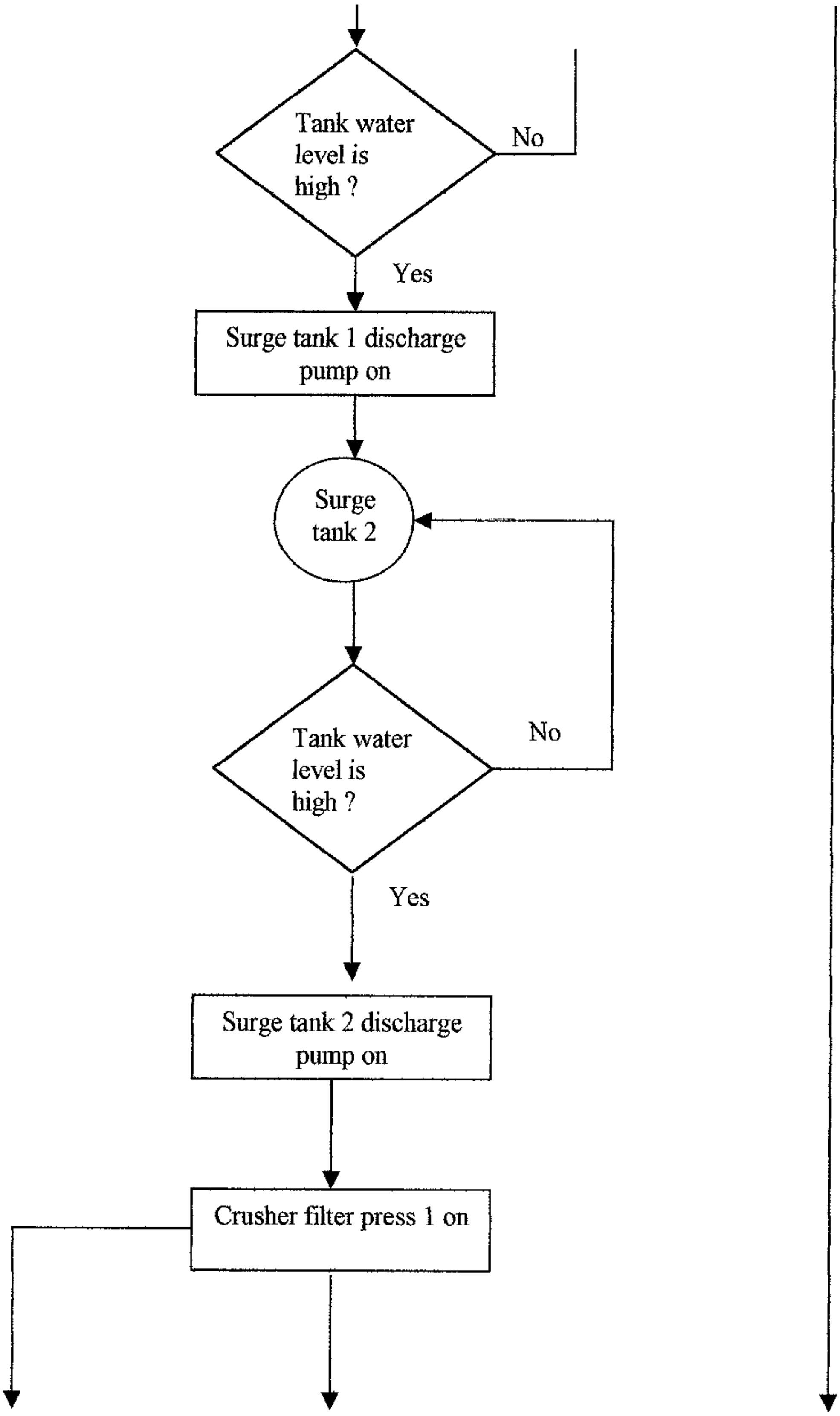
4.4 IMPROVEMENT ON SCRAP BATTERY PROCESS

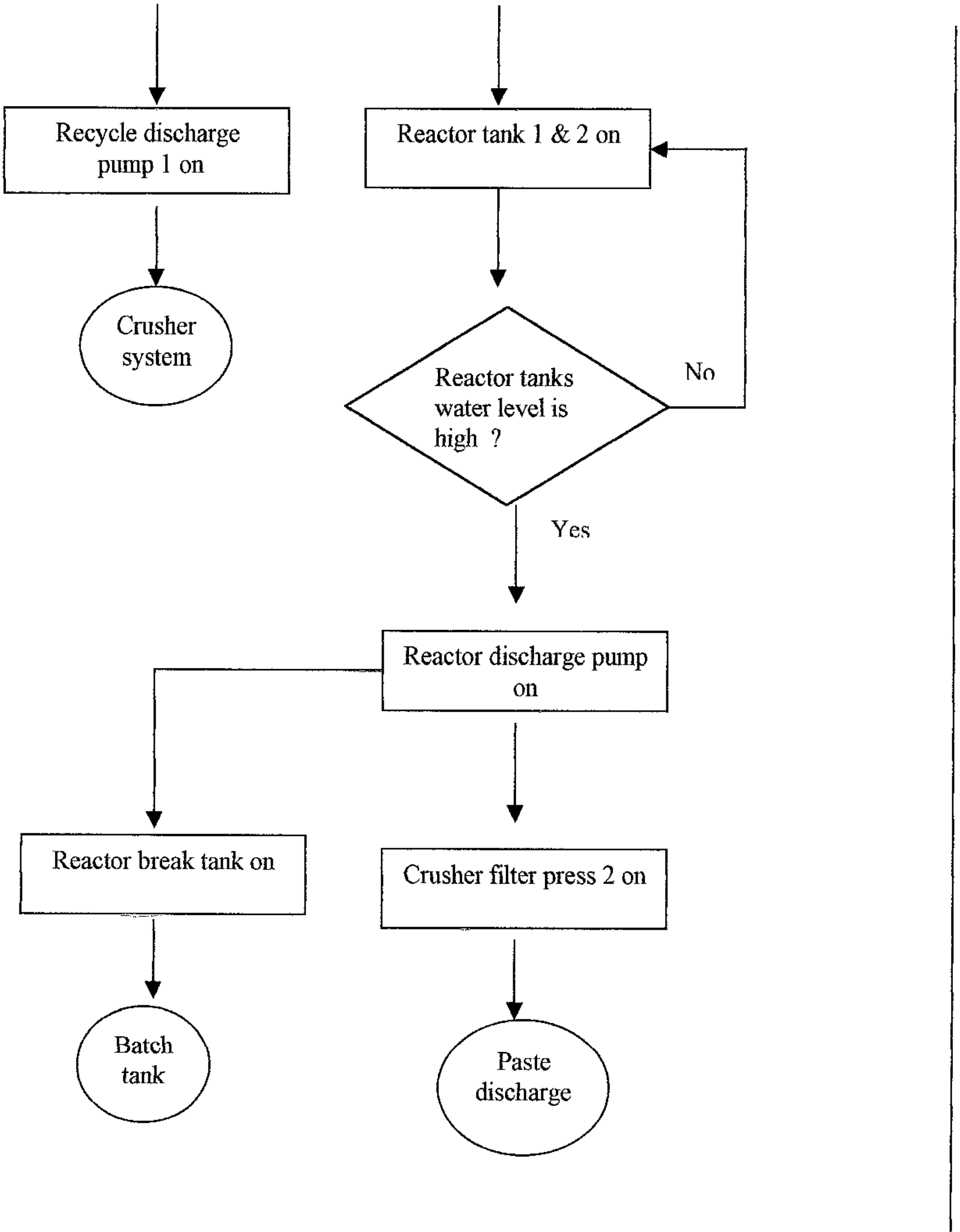
The author had upgraded and optimized process flow to an automation scrap battery process. In the upgraded process flow, the author had added in sensor, water level sensors and soda concentration meter. The sensor is sense to battery, if the battery is sensed then only the system will start. This can save the electricity and equipments' life times. The water level sensor is used to sense the tank water level, if the water level is high then only the water pump will pump the water to the system. This can save the water in this process. For the crusher, the water level sensor working is big different. When the water level is high, the crusher then only on, when the water level is low, the JBA water pump will pump the water into the crusher system. This is because the crusher system will be damaged if there is not enough water in the system. So the water level sensor will activated the JBA water to pump in the water when the water level is low.

The improvement and optimum process flow is summarized as flow chart below.




JBA water pump off
Crusher on
Crusher discharge screw conveyor on
Primary screen on
Cross over screw on
Lead metal classifier screw on
Agitator on
Elutriator screw on
Vibrator screen on
Oxide transport screw on
Lead Metal
Surge tank 1


Tank water level is high ?
No
Yes
Surge tank 1 discharge pump on
Surge tank 2
Tank water level is high ?
No
Yes
Surge tank 2 discharge pump on
Crusher filter press 1 on


Recycle discharge pump 1 on
Crusher system
Reactor tank 1 & 2 on
Reactor tanks water level is high ?
No
Yes
Reactor discharge pump on
Reactor break tank on
Crusher filter press 2 on
Batch tank
Paste discharge

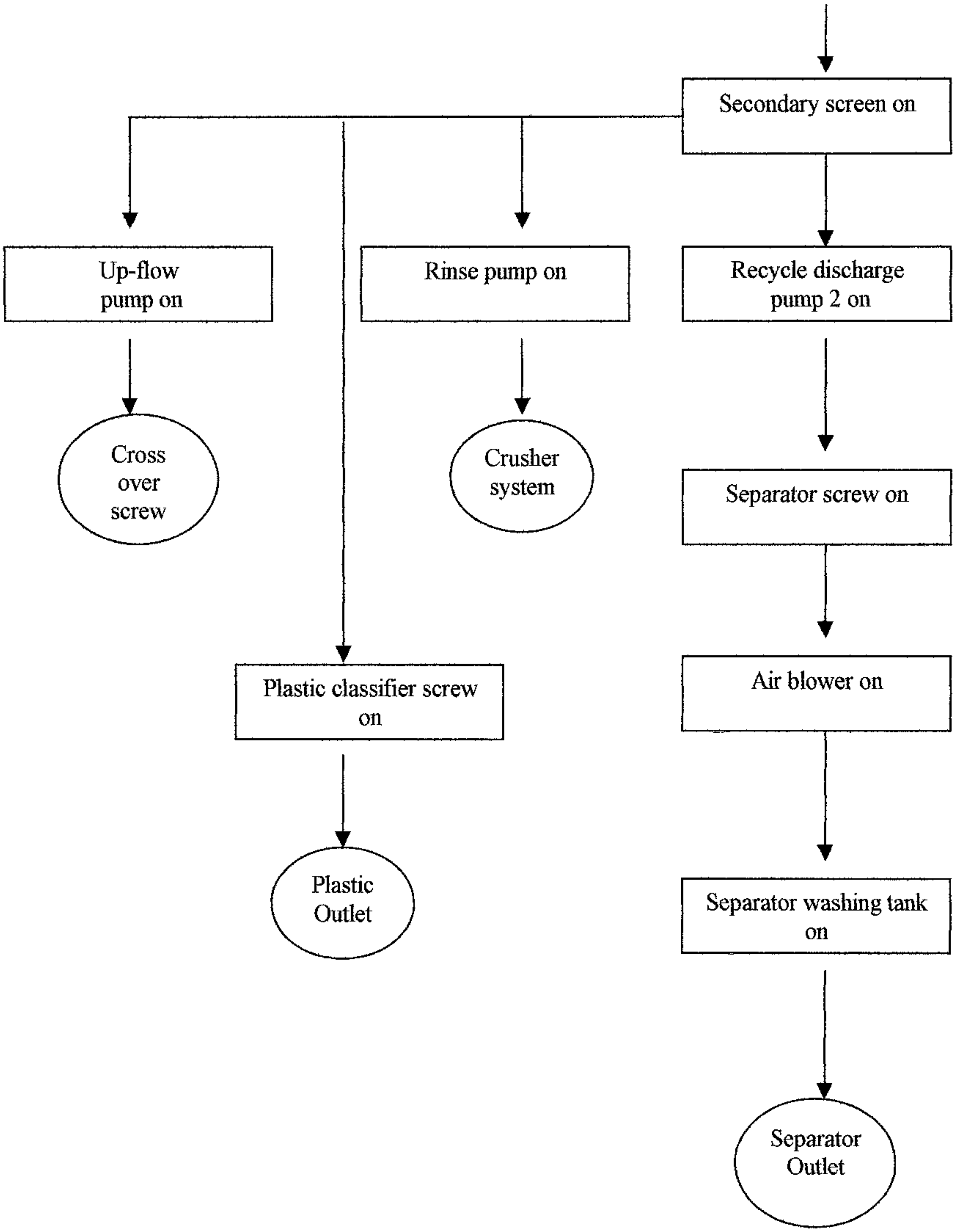


Figure 4.2: Flow chart of improved scrap battery process.

4.5 IMPROVEMENT ON THE VALVE CONTROL LOOPS

In the scrap battery process, it has seven valves that controlled the amount of water in and out and a reactor valve that controlled the soda concentration. These valves are operated manually in the original scrap battery process. The author had modified these valves to automated valves by adding the water level sensor and soda concentration sensor. There have total of seven valves that control the amount of water discharge to the system; the measure elements are the water level sensor. But the modification is done on the output activated by the water level sensor. When the water level is high, the water level sensor will activate the pump and the control valve. Then the water is discharged to the system and the valve controls the amount of water out. The water will be discharged to the system until the water level is low. When the water level close to low level, the valve is close smaller and smaller until the water level is low then the valve is totally closed. In this control loop, the measure element is the water level sensor and the final element is the water level in low. The valves that involve of this control algorithm are:

- Up flow valve- discharge water to cross over screw
- Rinse valve- discharge water to crusher
- Surge tank 1 valve- discharge water surge tank 1
- Surge tank 2 valve- discharge water surge tank 2
- Recycle discharge valve 1- discharge water to crusher
- Recycle discharge valve 1- discharge water to batch tank
- Reactor discharge valve- discharge water to crusher filter 2

The control loop of this type of controller is shown as next page.

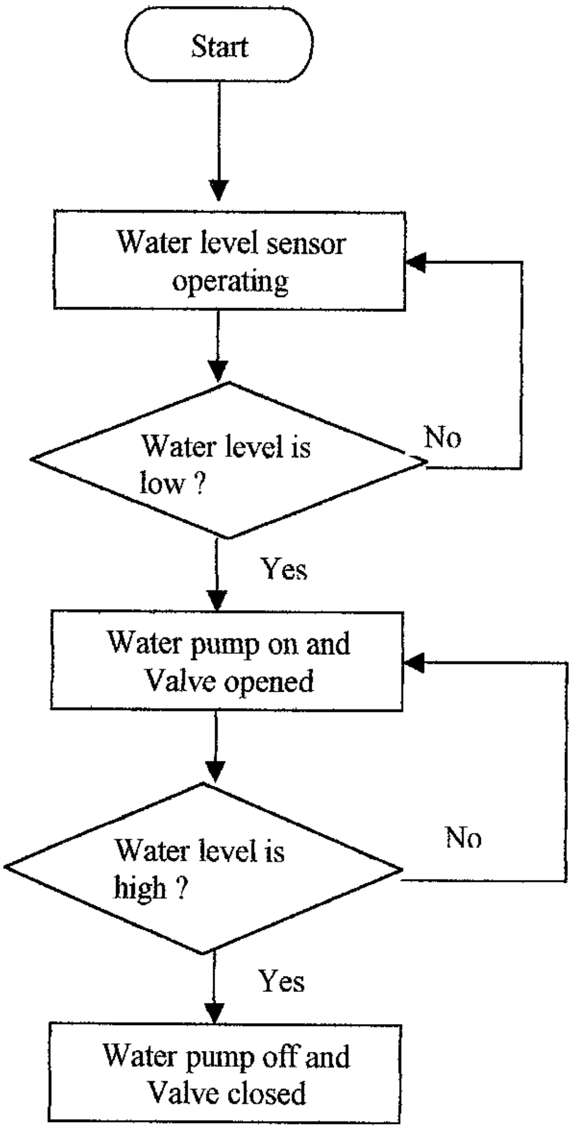


Figure 4.3: Flow chart of improved water valve control loop

For the reactor valve, control loop, a soda (NaOH) concentration sensor is added inside the reactor tank. This sensor operating principle is that the sensor will detect the conductivity of the OH^+ ion. If the conductivity of the OH^+ ion is high then the concentration of the soda is high. When the soda concentration is low, the concentration sensor will activate the pump and the control valve. Then the soda is pumped in to the system and the valve controls the amount of soda pumped into the reactor tank. The soda will be pumped into the system until the concentration level is high. When the concentration level close to high level, the valve is close smaller and smaller until the soda concentration level is high then the valve is totally closed. In this control loop, the measure element is the soda concentration sensor and the final element is the soda concentration is in high or the conductivity of the OH^+ ion is high. The control loop of this type of controller is shown as below.

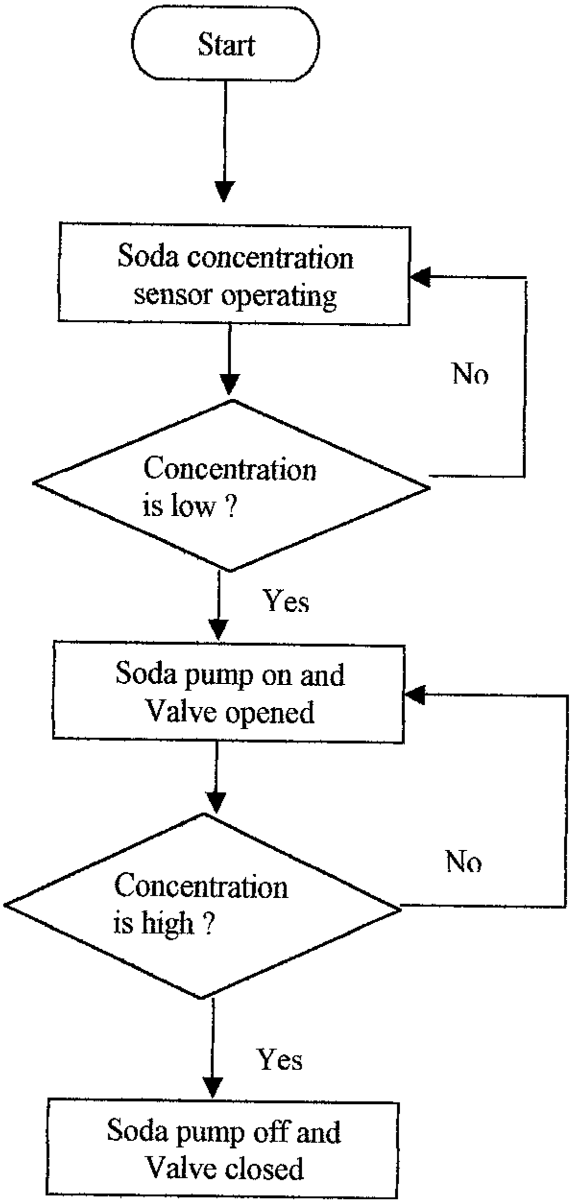


Figure 4.4: Flow chart of improved Soda valve control loop

4.6 LADDER LOGIC PROGRAM OF IMPROVEMENT PROCESS

Referring to the flow chart developed in figure 4.2, the upgraded and improved process flow ladder logic program is designed by the author and is attached in the *Appendix 7* (Ladder Logic Program for Improvement Scrap Battery Process). In the ladder logic programming, the sensor is the input for the whole process. The process output is operating in a sequence. That is the first output will activate the next output. That means the next output will not be activated when the previous output is jammed. This can lead the process to a fully automated process and increases the safety measure of the process. In addition, the whole process can be stopped or reset by the emergency push button (PB0) in order to increase the safety measure and avoid the accident.

4.7 SCRAP BATTERY PROCESS ELECTRONCS CIRCUITRY

4.7.1 Light Dependent Resistor (LDR) Sensor

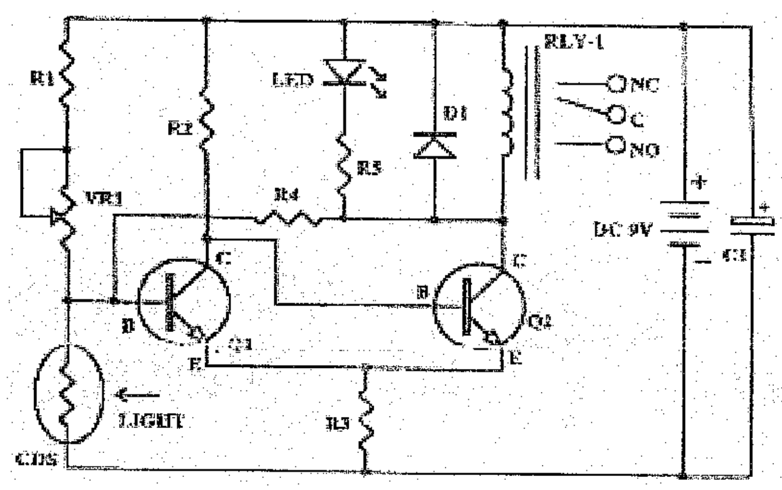


Figure 4.5: LDR sensor electronics circuit diagram.

From figure 4.5, we can see that there have 5 resistors, 1 diode, 2 NPN transistors, 1 relay and 1 light dependent resistor (LDR) to build up this LDR sensor circuit. The LDR acting as a receiver to detect the battery, once the battery had been detected, the signal will be sent to the relay. In this project, the relay will be connected to PLC as an intelligent input. The LDR sensor will act as battery sensor, which will be installed in the feed conveyer and crusher. In the feed conveyor, the sensor will sense the battery to activate the conveyor. However, the sensor will sense the battery in the crusher to activate the crusher.

4.7.2 Water Level Sensor

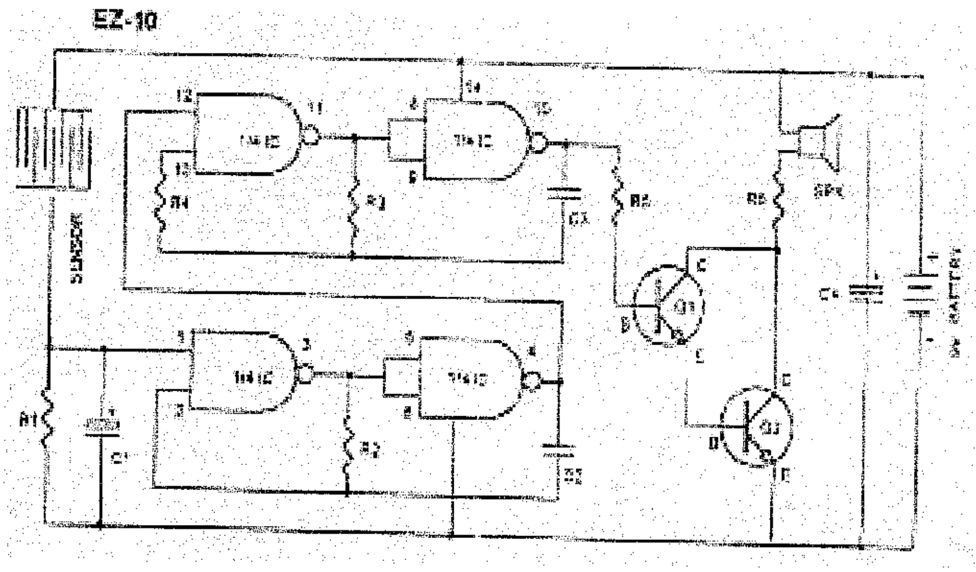


Figure 4.6: Water level sensor electronics circuit diagram.

From figure 4.6, we can see that there have 6 resistors, 2 NPN transistors, 4 capacitors, 1 4011 IC, 1 speaker and copper wire to build up this water level sensor circuit. The copper wire acting as a receiver to detect the water level, once the water had been detected at the desire level, the signal will be sent to the speaker. In this project, instead of the speaker, the output of the sensor will be connected to PLC as an intelligent input. The water level sensor will operate in the surge tank and reactor tank. When the water is at the high level, the sensor will detect the level and send signal to PLC as an intelligent input. Then the discharge pump will be activated and discharge the water out from the tank.

4.7.3 High-Low Water Level Sensor

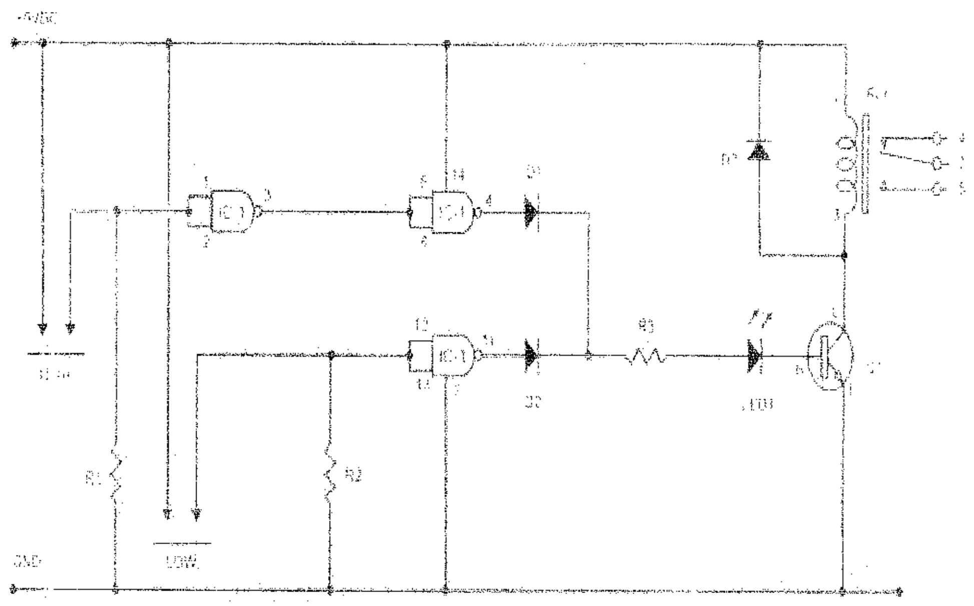


Figure 4.7: High-Low water level sensor electronics circuit diagram.

From figure 4.7, we can see that there have 3 resistors, 1 NPN transistors, 3 Diodes, 1 4011 IC, 1 relay and 1 copper water detector to build up this high low water level sensor circuit. The copper detector acting as a receiver to detect the water level, once the water had been detected at the desire level, the signal will be sent to the speaker. In this project, the High-low water level sensor is used, instead of the water level sensor, which used previously. This is because the Hi-low water level sensor can detect high water level and low water level of the tank in chemical process. This is more practical than the previous water level sensor since it can send two signals out. The output signals of the sensor will be connected to PLC as an intelligent input. The water level sensor will operate in the surge tank and reactor tank. The high signal will operate the discharge pump to pump out the water from the tank. However, the low signal will reset or stop the water pump operation.

4.8 SCRAP BATTERY PROCESS PLANT PROTOTYPE CONSTRUCTION

In the scrap battery process plant prototype, the author used the Perspex as the base of the prototype. There have four phases of the plant prototype. The author had planned out the lay out of the plant prototype in order to construct the plant successful. The lay out of each phase are shown as below.

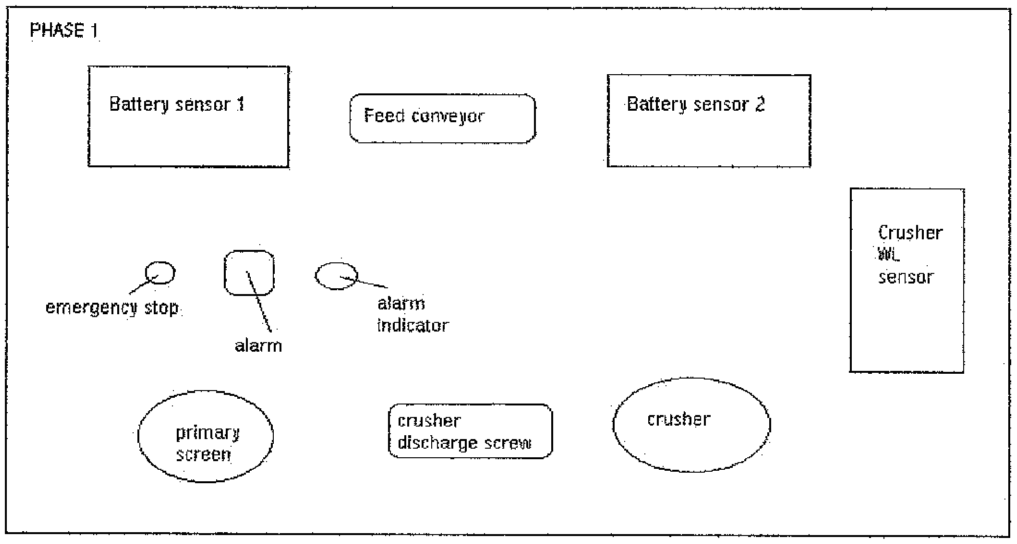


Figure 4.8: Phase 1 of scrap battery plant prototype.

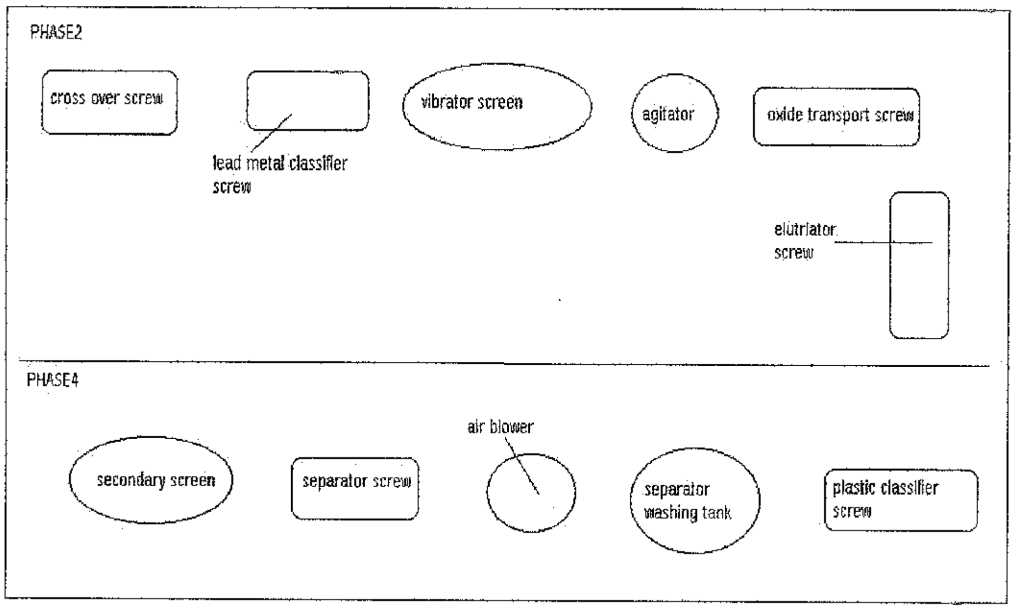


Figure 4.9: Phase 2 and 4 of scrap battery plant prototype.

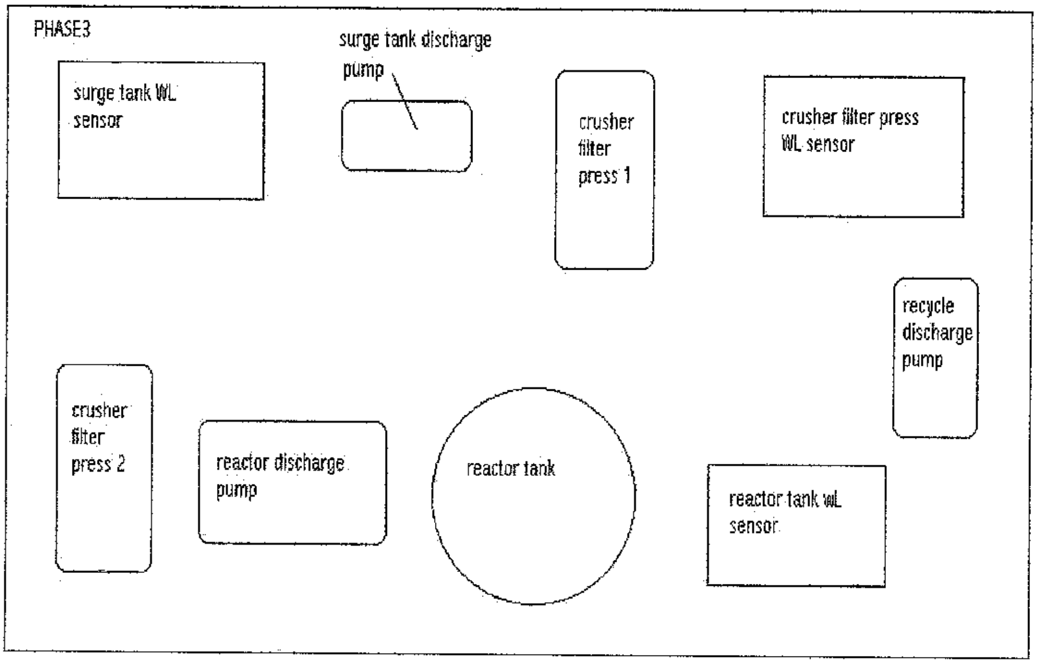


Figure 4.10: Phase 3 of scrap battery plant prototype.

Note that Phase 2 and 4 of the plant prototype are combined in same Perspex. After produced the layout of the plant prototype, the author had started to install the hardware components on the perspex. The hardware components such as sensor circuit, motor, tank, and water pump are stacked on the perspex by double-sided tape. This can be graphically shown as picture in *Appendix 8*.

After installing the hardware components, the terminals are installed on the perspex. These including the positive, negative, load and common ground terminals. The terminals are screwed and clamed on the perspex. Then the relevant hardware components' wires are soldered to the leg of the terminals. Each wire is soldered to the relevant terminals according to the PLC interfacing techniques. This will be discussed in the following section. Refer to figure in *Appendix 8* for graphically showing the installation of the terminals and the hardware components.

4.9 PLC INTERFACING

4.9.1 PLC Input Interfacing

The input interfacing do not have special connecting path. It is just interface the output of the input components such as sensor by connecting the output signal to the PLC input. Then the ground of the input components is connecting to the common ground of the PLC input module. This can be graphically shown as figure 4.11.

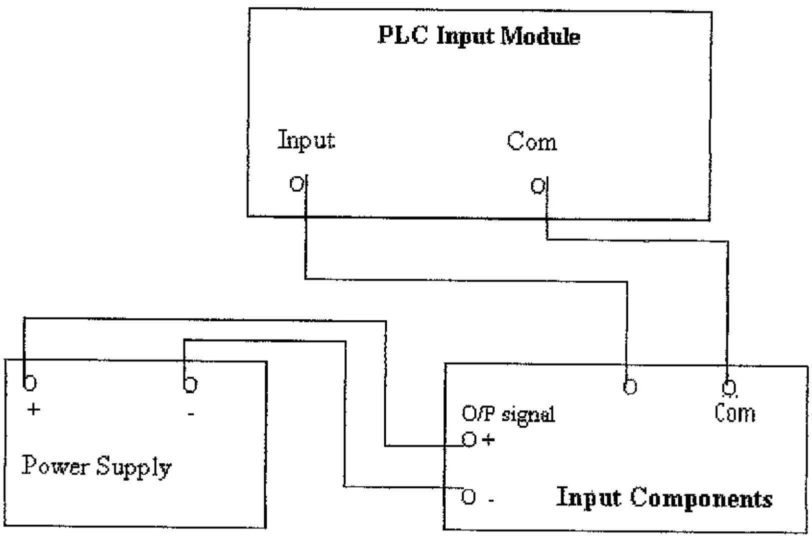


Figure 4.11: PLC input interfacing.

Note that the push button switches need not power supply when interface with PLC.

4.9.2 PLC Output Interfacing

However, the output interfacing is different from input interfacing. The power supply needed to supply to the output components/load such as motor and alarm negative terminal. Then the PLC output module is connected to the positive terminal of the load. The ground of the power supply is grounded to the PLC output common ground. This can be graphically shown as figure 4.12.

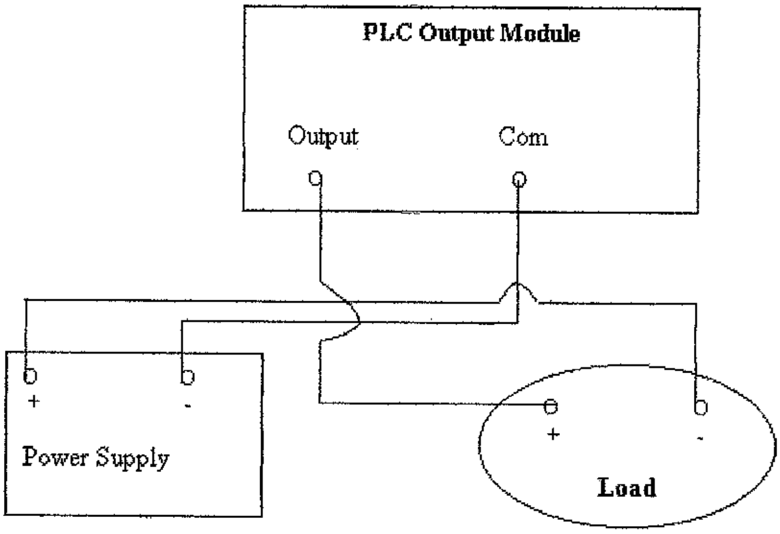


Figure 4.12: PLC output interfacing.

4.9.3 AC Voltage Interfacing

Besides the input and output interfacing, the author produced another feature, which is the Ac voltage interfacing. This feature is to interface the Ac water pump that used in the scrap battery process. This may interface the Ac source and Dc source. The water pump operated to discharge the water from the reactor tank and known as reactor discharge pump. The author had modified the adapter of the Ac water pump. The blue colour wire of the adapter is cut out. The first end of the wire, which connected to the Ac power, will be connected to pin 9 of the 24Vdc relay. The second end of the wire, which connected to the water pump, will be connected to the pin 5 of the 24Vdc relay. However, the brown colour wire of the adapter is remained the same.

In addition, the PLC output is connected to the pin 13 of the 24Vdc relay. Then a 24Vdc is supply to the relay, and the positive terminal is connected to the common ground of the PLC. The negative terminal of the power supply is connected to the to the pin 14 of the 24Vdc relay. This can be graphically shown as figure 4.13.

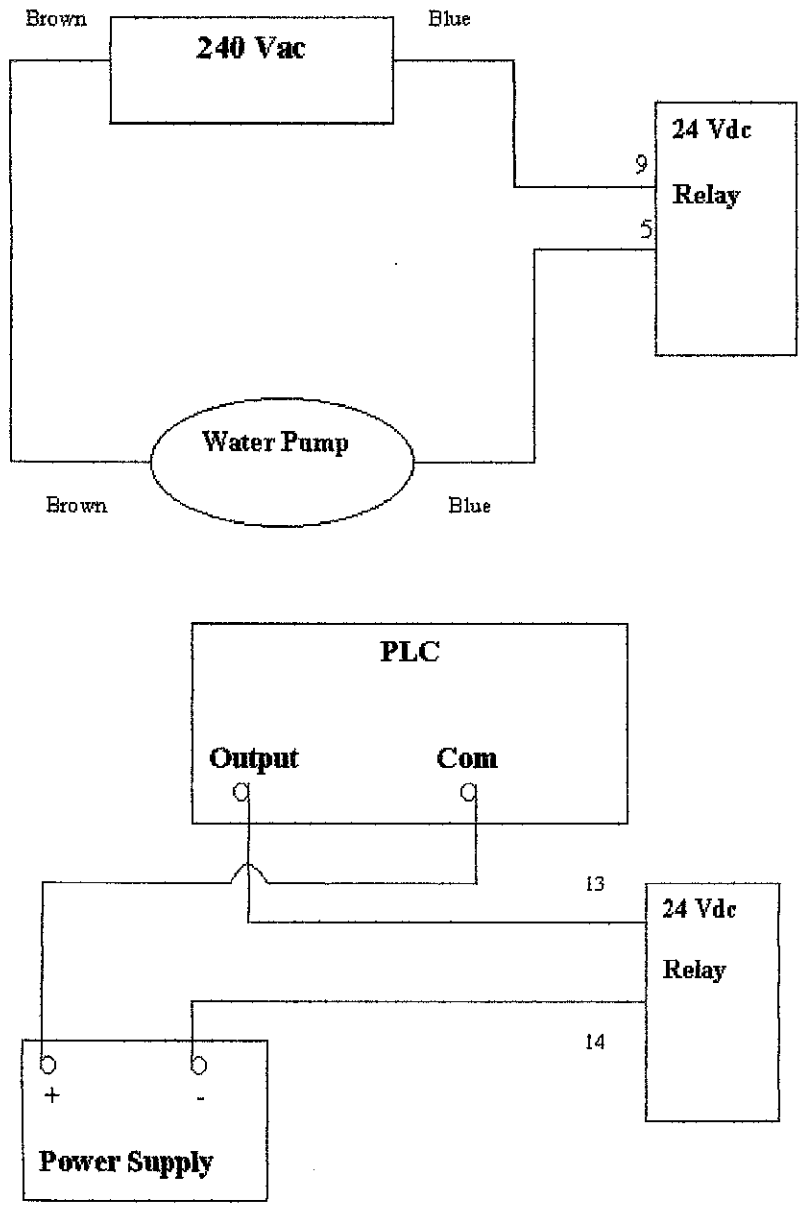


Figure 4.13: AC water pump interfacing by using 24Vdc relay.

By using the PLC interfacing theory, the author success to interface the PLC with the scrap battery plant prototype. This including the input, output, and Ac power interfacing. The interfacing of the components is done one by one. Refer to figure in *Appendix 9* for graphically showing the end product of the PLC interfacing with the scrap battery process plant prototype.

4.10.2 Failure Indicator

The second feature is the failure indicator for each hardware components. This indicator will be functioned when there have problem on the hardware components. The indicator can be a neon light or buzzer alarm. The problems may be detected when the hardware equipment is jammed or stuck. Figure 4.14 shows the ladder logic program of the failure indicator.

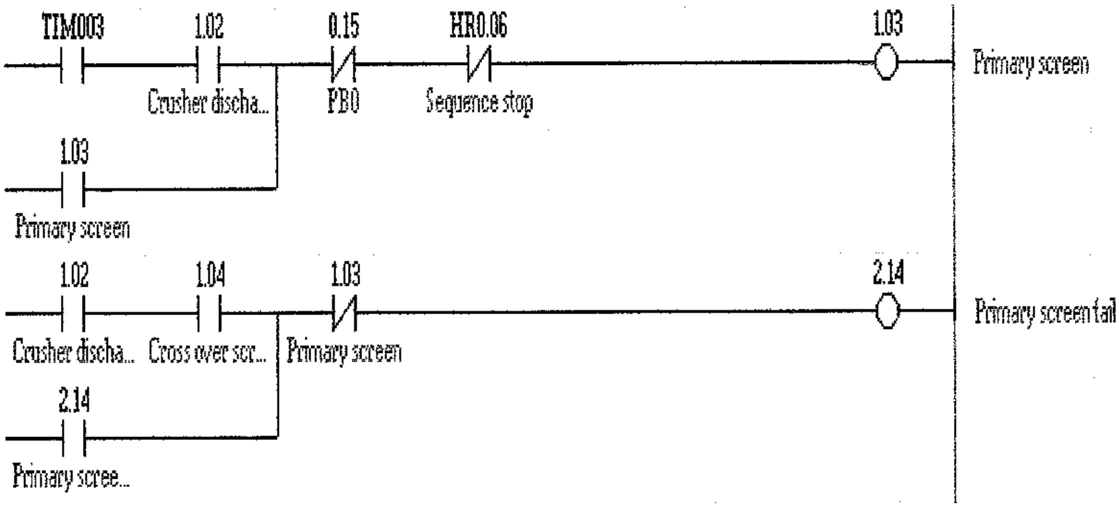


Figure 4.15: Ladder logic program for the failure indicator.

From figure 4.14, the primary screen fail will can be a neon light or alarm to indicate the failure of the primary screen. As we know in the scrap battery process, the crusher discharge screw is the equipment before the sequence of primary screen and the cross over discharge screw is after the sequence of primary screen. When the primary screen is jammed, this means the crusher discharge screw and cross over discharge screw is running but the primary screen is not run. Then the failure indicator will be activated. However, the primary screen will reset or not activate the failure indicator, if the primary is running as normal. This can be shown in second line of ladder logic program in figure 4.14. When the indicator is activated, the operator will inform the technician for repairing purpose.

4.11 CONTROLLING THE SCRAP BATTERY PROCESS PLANT PROTOTYPE BY PLC

After finishing the PLC interfacing, the author run the PLC ladder logic program and finalized the project with controlling the scrap battery plant prototype by PLC. Before running the PLC, the voltage supply to the hardware components must be set to correct value. There have 4Vdc and 9Vdc supplied to the Dc motor, 1.5Vdc supplied to air pump, 24Vdc supplied to the stepper motor and relay. For the LDR and water level sensor, 9Vdc is supplied, and the water pump is supplied by 240Vac. Then the control process is started with sensing battery by the LDR sensor. As a conclusion, the scrap battery process could be controlled by the PLC smoothly. Refer to figure in *Appendix 10* for graphically showing the PLC control of scrap battery process plant prototype.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The PLC control of scrap battery process is a project, which serves for research and application purposes. It is a perfect platform that provides a good learning and practical process for the students, whereby; students are given the opportunity to utilize knowledge that they have learnt so far. The PLC control of scrap battery process expected to be upgraded from time to time in the future – that is, to improve it's intelligence and advances by adding additional functionalities. By working on the project, students would be able to achieve some hand on experience on PLC controlling and interfacing in industrial process. Thus, students would be able to get familiarized with programming using ladder logic programming language, building circuitry for motors and sensors, etc.

As a conclusion, the author had analyzed for the whole scrap battery process and implemented it in Microsoft Visio and Auto Cad. After analyzing the process, the author had upgraded and optimized the scrap battery process to a fully automated process. Thus, the optimized process could solve the problem stated in problem statement. From the process flow implemented, the author had design two ladder logic program- manual scrap battery process and improved scrap battery process. These two ladder logic programs had been simulated in OMRON PLC, the simulation is successful and the programs were running smooth. Hence the process is upgraded and improved to a reliable, user friendly, high productivity, smooth and advanced automated PLC controlling of scrap battery process.

For the second semester, the author had built the electronics circuitry of the scrap battery process hardware components such as LDR sensor, high-low water level sensor, alarm, motor, and conveyor. After that, the author combined this circuitry to a scrap battery and lead reclamation plant prototype. Finally, the PLC was interfaced with plant prototype and controlling the scrap battery and lead reclamation process successfully.

5.2 RECOMMENDATIONS

This section presents some recommendations for future expansion and continuation work to improve the PLC control of scrap battery and lead reclamation process.

For the hardware part, the LDR sensor can be replaced by the ultrasonic sensor, because of the sensitivity of the ultrasonic sensor is greater. The sensed distance and accuracy of the ultrasonic sensor is higher.

To adjust the soda valve opened accurately, we can have an analogue valve positioner. The valve positioner is controlled by different level of current source. If the valve can have step level of 20%, we need 5 level of current to operate to valve to open from 0%, 20%, 40%, 60%, 80% and 100%. The relevant current source may be 4mA, 8mA, 12mA, 16mA and 20mA. The soda concentration sensor may detect the percentage of the valve opened needed. Then the signal is sent to the current source and the relevant current level will activate the valve to open to desire level.

The PLC input and output module (I/O module) should have more input and output. The PLC I/O module currently used by the author in the laboratory is the 16 inputs and 16 outputs module. This is not enough for the scrap battery process that have 30 inputs and 30 outputs. The author needed to add another I/O module to solve this problem, which may not lead the optimum result. The scan time of the PLC is longer and more wiring needed. Therefore, the risk of error is higher.

The design of soda concentration sensor in the market should be more user-friendly and economically. In this project, the author can get a suitable soda concentration sensor, since the price and the size of the sensor is totally out of the project affordability.

For the software part, the ladder logic program can be more simplified and optimized by adding some digital logic such as AND, OR, NAND and NOR gate. The timing and behaviours of each hardware component should applied more research and study. These behaviours will change from time to time. The maintenance needed to adjust the ladder logic program to suite the hardware components.

CHAPTER 6
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<http://www.icsti.su/rbd/eng/teche/0010e.html>

APPENDIX 1

Gantt Chart For Final Year Project- Semester 1

No	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Selection of Project Topic															
	-Propose Topic, Topic Awarded															
2	Preliminary Research Work															
	-Introduction/ objective															
	-List of references/ literature review															
	-Project planning															
3	Submission of Preliminary Report				●											
4	Project Work															
	-Literature review (Process Flow & PLC)															
	-Analyze and implement the process flow															
	-Upgrade and optimize the process flow															
5	Submission of Progress Report								●							
6	Project work continue															
	-Design PLC ladder diagram															
	-PLC simulation															
8	Submission of Interim Report														●	
9	Oral Presentation															●

Proposed Process

Actual Process

APPENDIX 2

Gantt Chart For Final Year Project- Semester 2

Gantt Chart For Semester 2 (PLC control of Scrap Battery & Lead Reclamation Process)

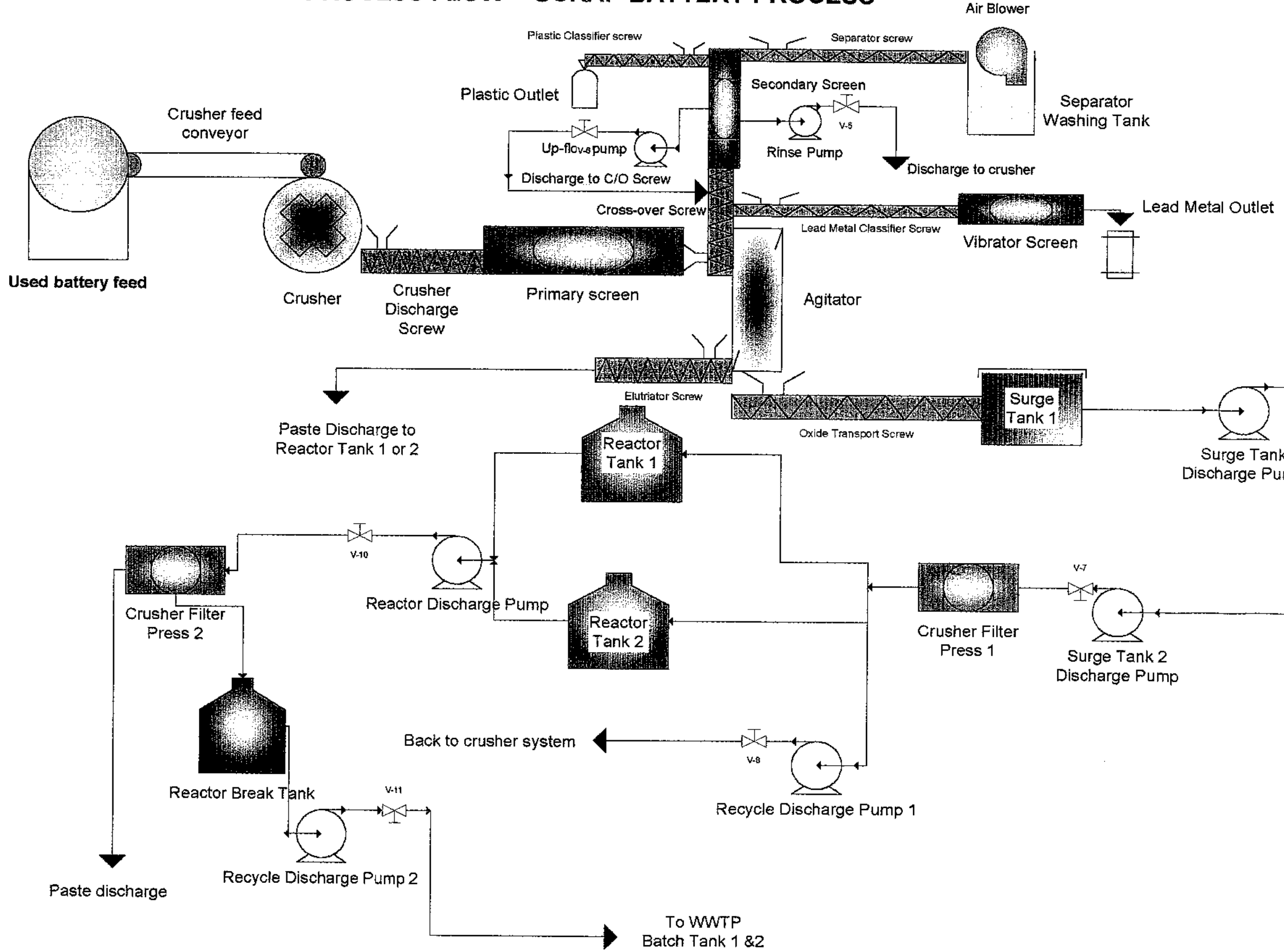
No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Project Work Continue															
	- Collect the components for PLC interfacing															
	- Build the circuitry of the scrap battery process hardware components															
2	Submission of Progress Report 1															
3	Project Work Continue															
	- Build the circuitry of the scrap battery process hardware components															
4	Submission of Progress Report 2															
5	Project work continue															
	- Combine the circuitry to build the scrap battery plant prototype															
	- Interface the scrap battery plant with PLC control															
6	Submission of Dissertation Final Draft															
7	Submission of Project Dissertation															
8	Oral Presentation															

Proposed Process   Actual Process

APPENDIX 3

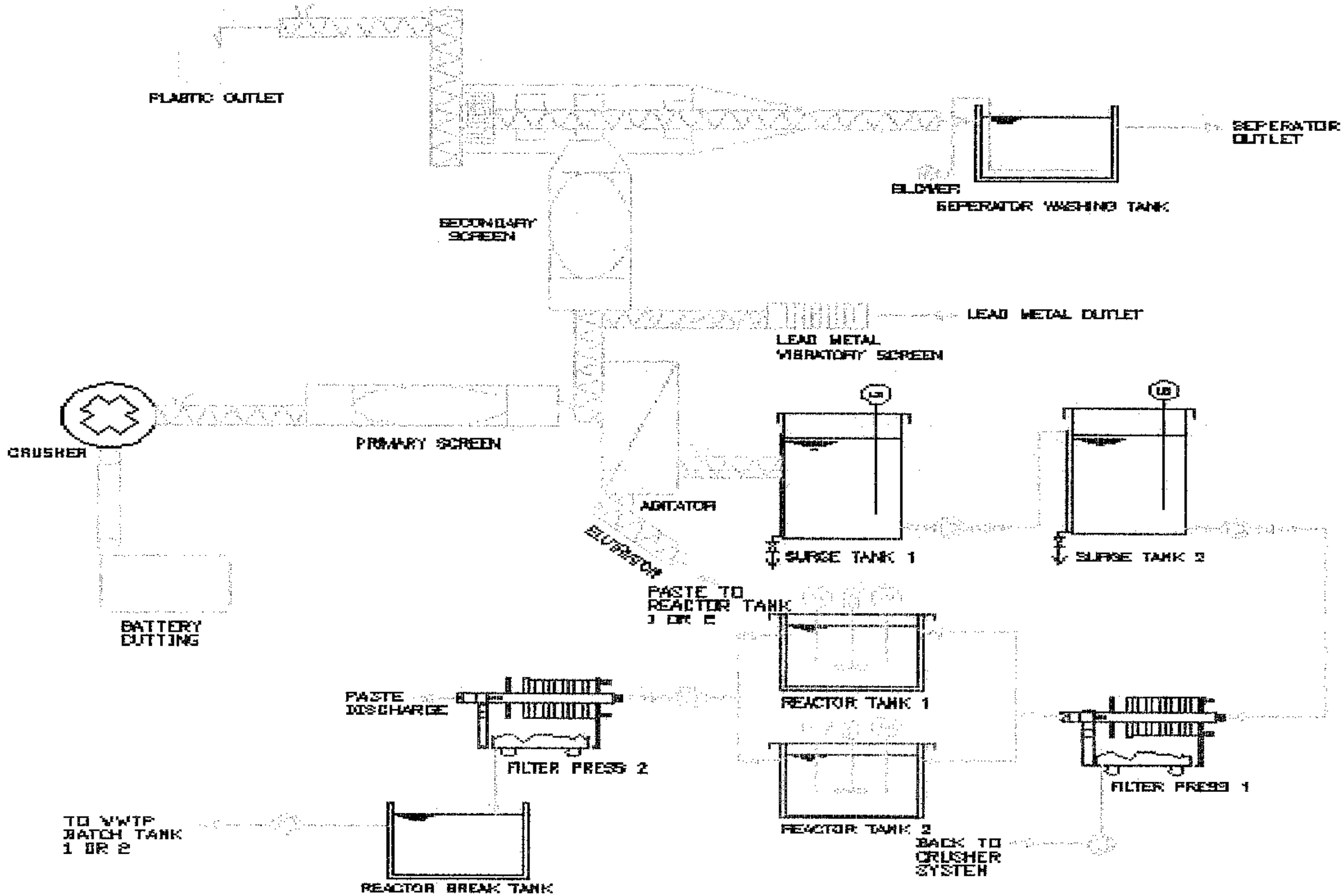
Scrap Battery Process Flow- Implemented In Microsoft Visio

PROCESS FLOW -- SCRAP BATTERY PROCESS



APPENDIX 4

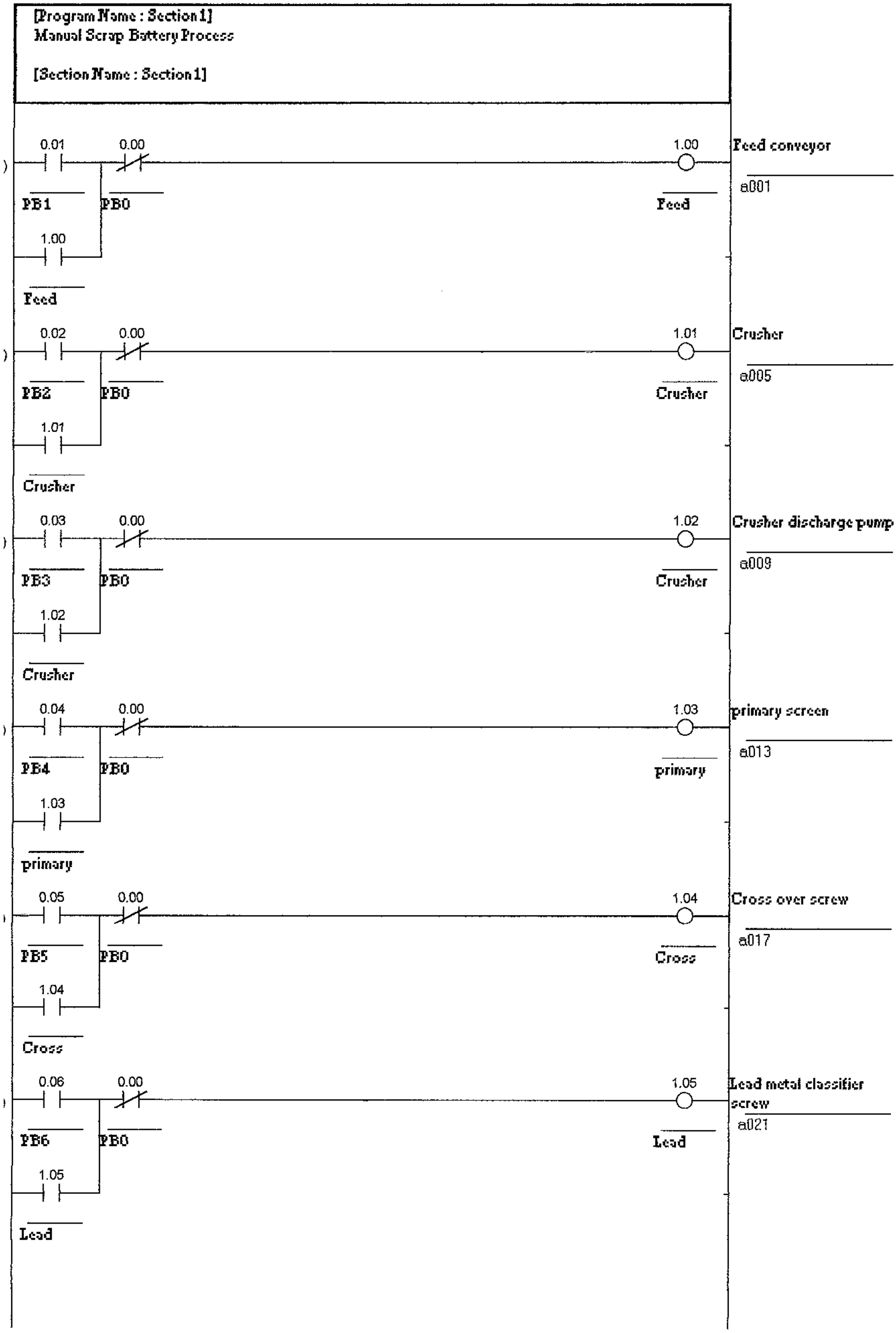
Scrap Battery Process Flow- Implemented In Auto Cad

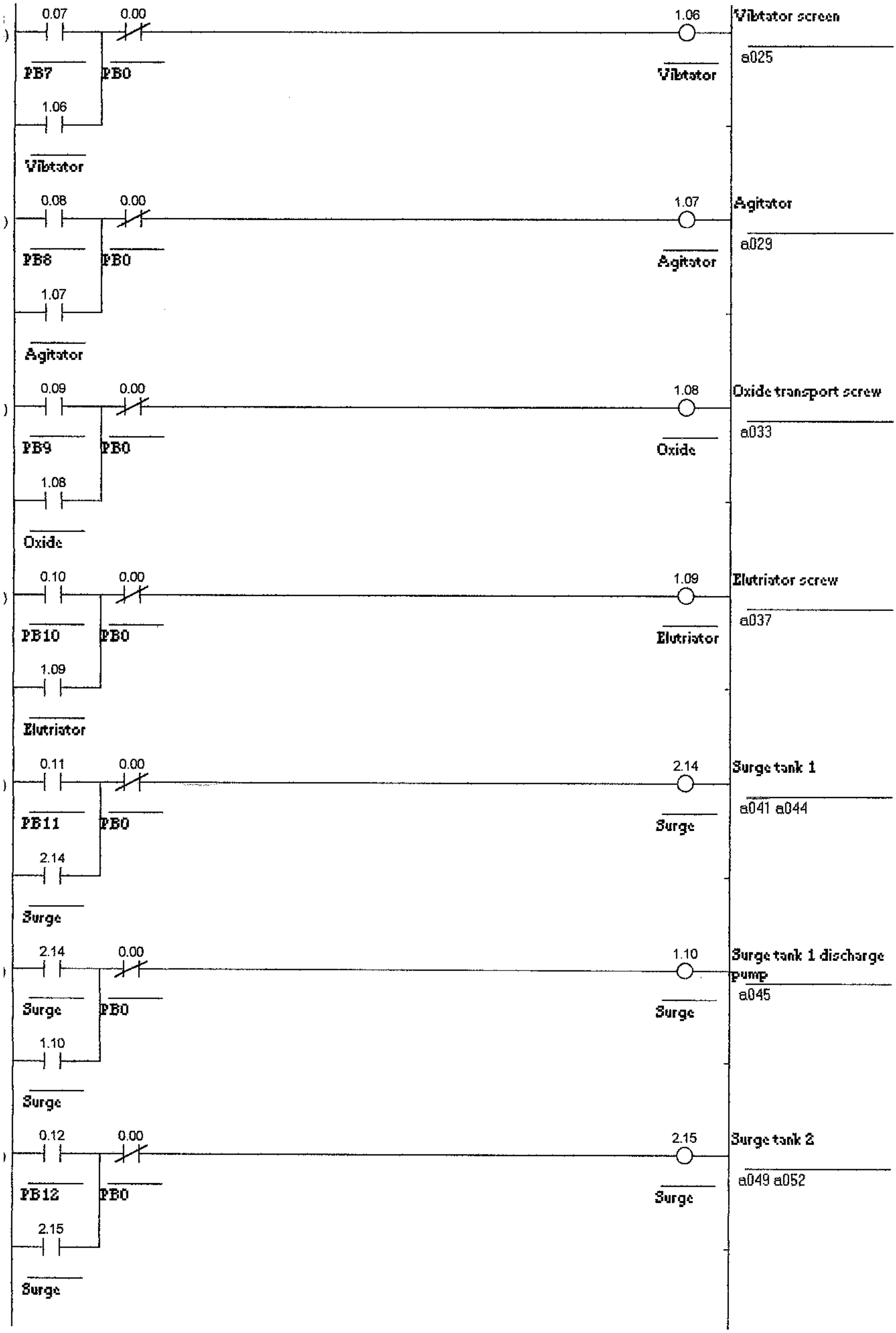


PROCESS FLOW DIAGRAM -- SCRAP BATTERY PROCESS

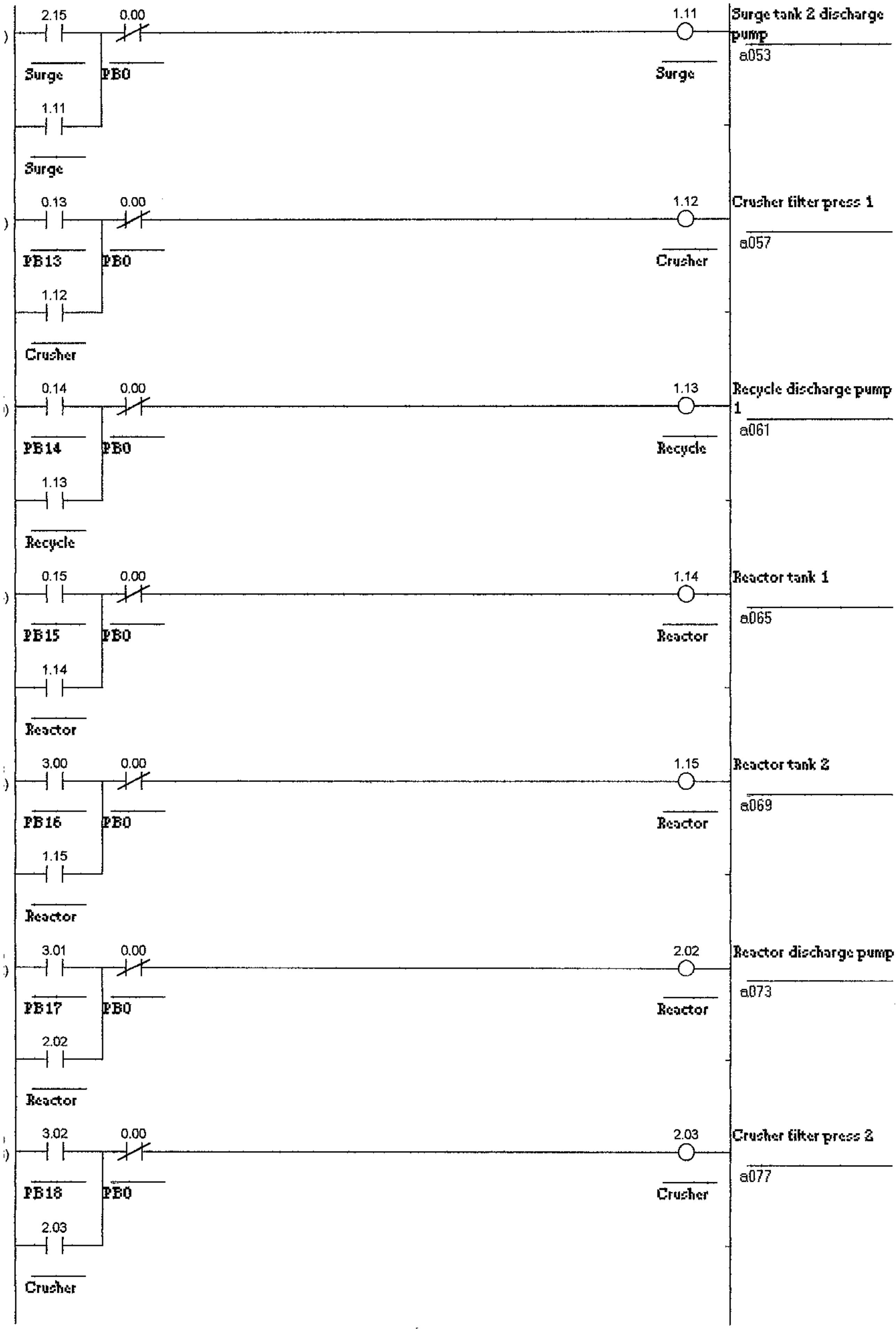
APPENDIX 5

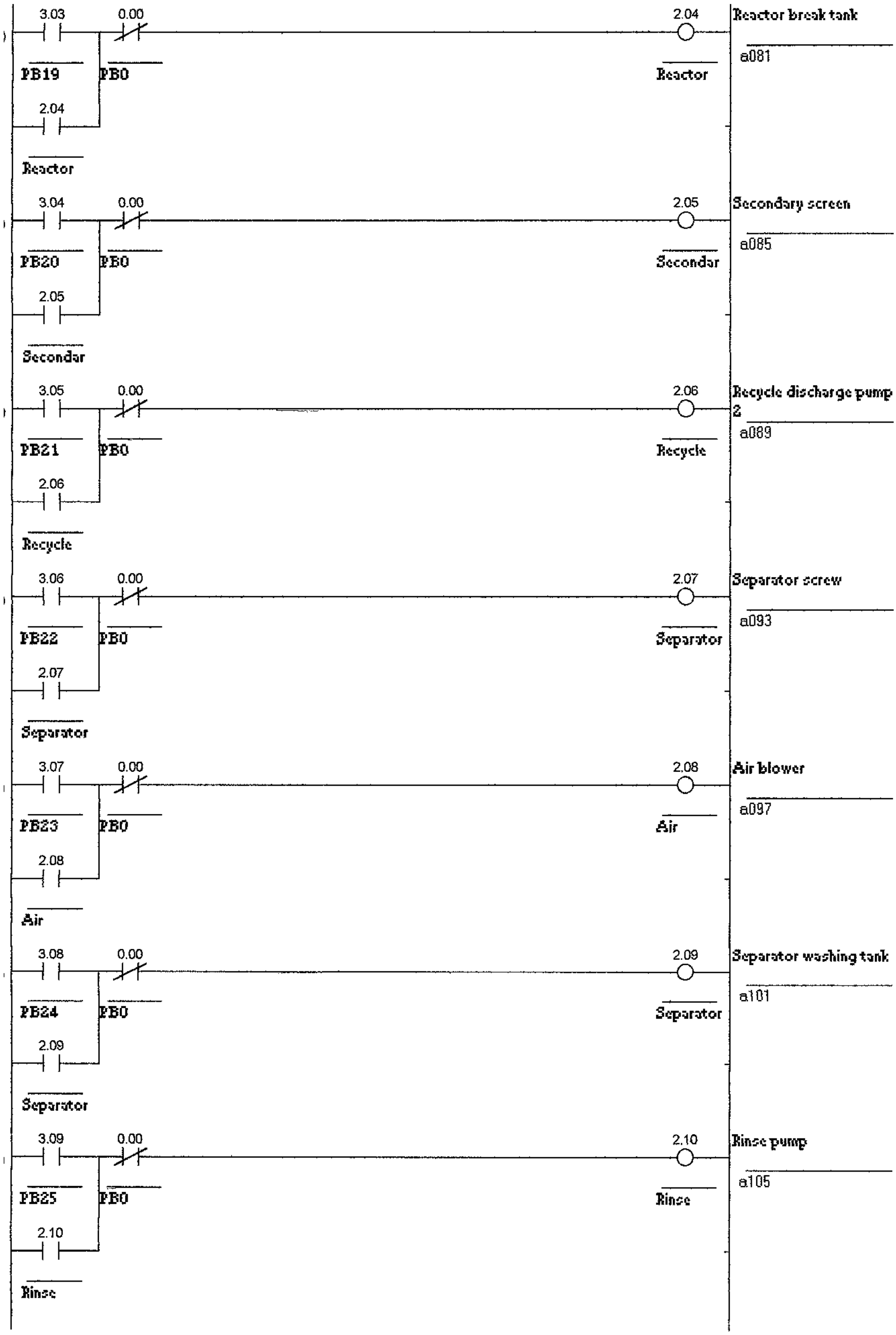
Ladder Logic Program for Manual Scrap Battery Process

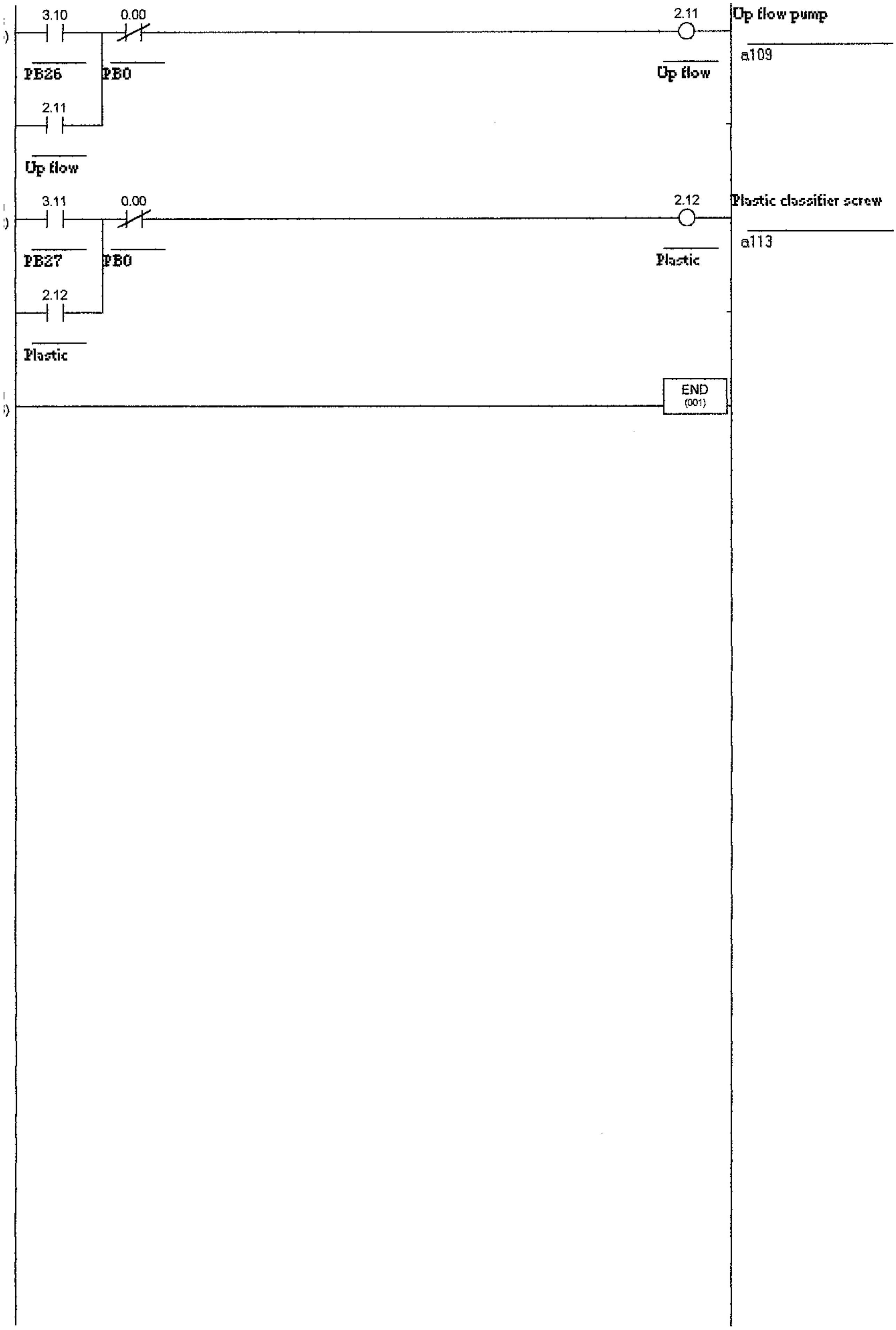

[Program Name : Section1]
Manual Scrap Battery Process
[Section Name : Section1]
0.01
0.00
1.00
Feed conveyor
a001
PB1
PB0
Feed
1.00
Feed
0.02
0.00
1.01
Crusher
a005
PB2
PB0
Crusher
1.01
Crusher
0.03
0.00
1.02
Crusher discharge pump
a009
PB3
PB0
Crusher
1.02
Crusher
0.04
0.00
1.03
primary screen
a013
PB4
PB0
primary
1.03
primary
0.05
0.00
1.04
Cross over screw
a017
PB5
PB0
Cross
1.04
Cross
0.06
0.00
1.05
Lead metal classifier screw
a021
PB6
PB0
Lead
1.05
Lead



0.07
0.00
1.06
Vibtator screen
PB7
PB0
Vibtator
a025
1.06
Vibtator
0.08
0.00
1.07
Agitator
PB8
PB0
Agitator
a029
1.07
Agitator
0.09
0.00
1.08
Oxide transport screw
PB9
PB0
Oxide
a033
1.08
Oxide
0.10
0.00
1.09
Elutriator screw
PB10
PB0
Elutriator
a037
1.09
Elutriator
0.11
0.00
2.14
Surge tank 1
PB11
PB0
Surge
a041 a044
2.14
Surge
2.14
0.00
1.10
Surge tank 1 discharge pump
Surge
PB0
Surge
a045
1.10
Surge
0.12
0.00
2.15
Surge tank 2
PB12
PB0
Surge
a049 a052
2.15
Surge


2.15
Surge
0.00
PB0
1.11
Surge
1.11
Surge
Surge tank 2 discharge pump
a053
0.13
PB13
0.00
PB0
1.12
Crusher
1.12
Crusher
Crusher filter press 1
a057
0.14
PB14
0.00
PB0
1.13
Recycle
1.13
Recycle
Recycle discharge pump 1
a061
0.15
PB15
0.00
PB0
1.14
Reactor
1.14
Reactor
Reactor tank 1
a065
3.00
PB16
0.00
PB0
1.15
Reactor
1.15
Reactor
Reactor tank 2
a069
3.01
PB17
0.00
PB0
2.02
Reactor
2.02
Reactor
Reactor discharge pump
a073
3.02
PB18
0.00
PB0
2.03
Crusher
2.03
Crusher
Crusher filter press 2
a077


3.03
0.00
2.04
Reactor break tank
a081
PB19
PB0
Reactor
2.04
Reactor
3.04
0.00
2.05
Secondary screen
a085
PB20
PB0
Secondar
2.05
Secondar
3.05
0.00
2.06
Recycle discharge pump 2
a089
PB21
PB0
Recycle
2.06
Recycle
3.06
0.00
2.07
Separator screw
a093
PB22
PB0
Separator
2.07
Separator
3.07
0.00
2.08
Air blower
a097
PB23
PB0
Air
2.08
Air
3.08
0.00
2.09
Separator washing tank
a101
PB24
PB0
Separator
2.09
Separator
3.09
0.00
2.10
Rinse pump
a105
PB25
PB0
Rinse
2.10
Rinse


3.10
0.00
2.11
Up flow pump
a109
PB26
PB0
Up flow
2.11
Up flow
3.11
0.00
2.12
Plastic classifier screw
a113
PB27
PB0
Plastic
2.12
Plastic
END
(001)

APPENDIX 6

List of Inputs and Outputs for the Ladder Logic Program
(Improvement Scrap Battery Process)

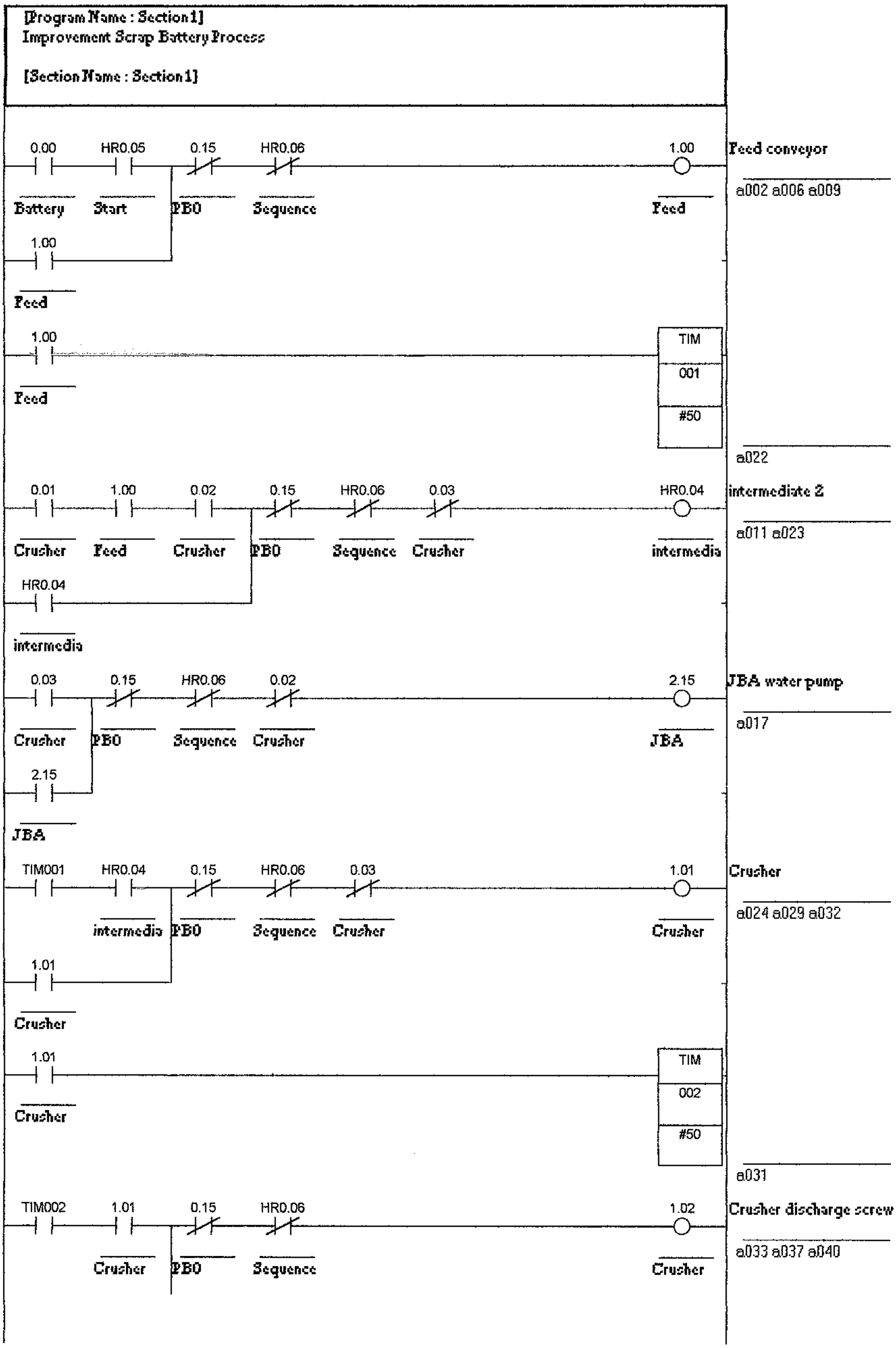
Inputs
Battery sensor
Crusher sensor
Crusher water level sensor
Surge tank 1 water level sensor
Surge tank 2 water level sensor
Soda concentration meter
Reactor tank water level sensor
Crusher filter press 1 WL sensor
Crusher filter press 2 WL sensor
Reactor break tank water level sensor
Secondary screen water level sensor
Emergency reset

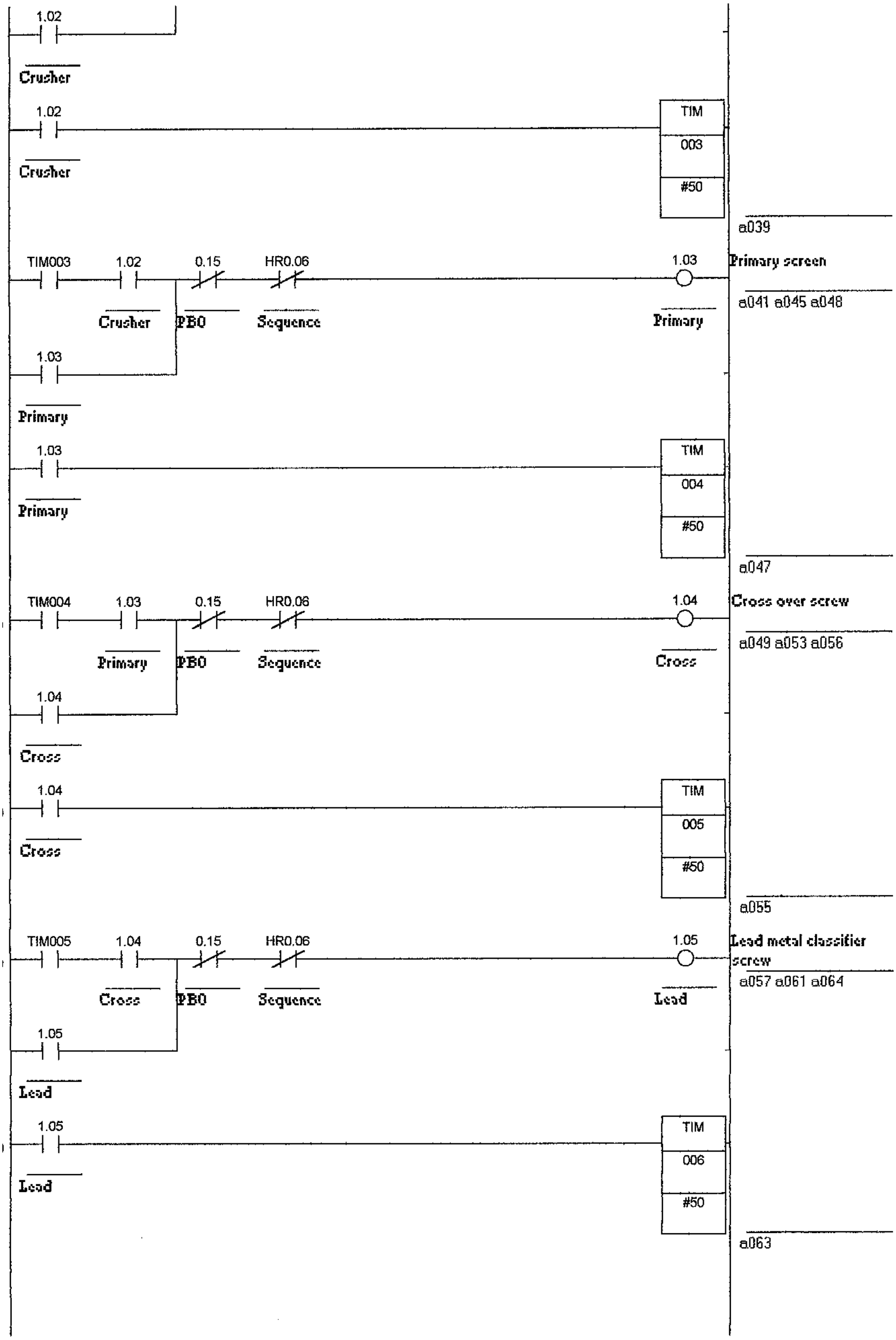
Outputs
Conveyor
Crusher
Crusher discharge screw
Primary screen
Cross over screw
Lead metal classifier screw
Vibrator screen
Agitator
Oxide transport screw
Elutriator
Surge tank 1
Surge tank 1 discharge pump
Surge tank 2
Surge tank 2 discharge pump
Crusher filter press 1
Recycle discharge pump1
Reactor tank 1
Reactor tank 2
Recycle discharge pump1
Crusher filter press 2
Reactor break tank
Secondary screen
Recycle discharge pump 2
Separator screw
Air blower
Separator washing tank
Rinse pump
Up flow pump
Plastic classifier screw
JBA water pump
Alarm

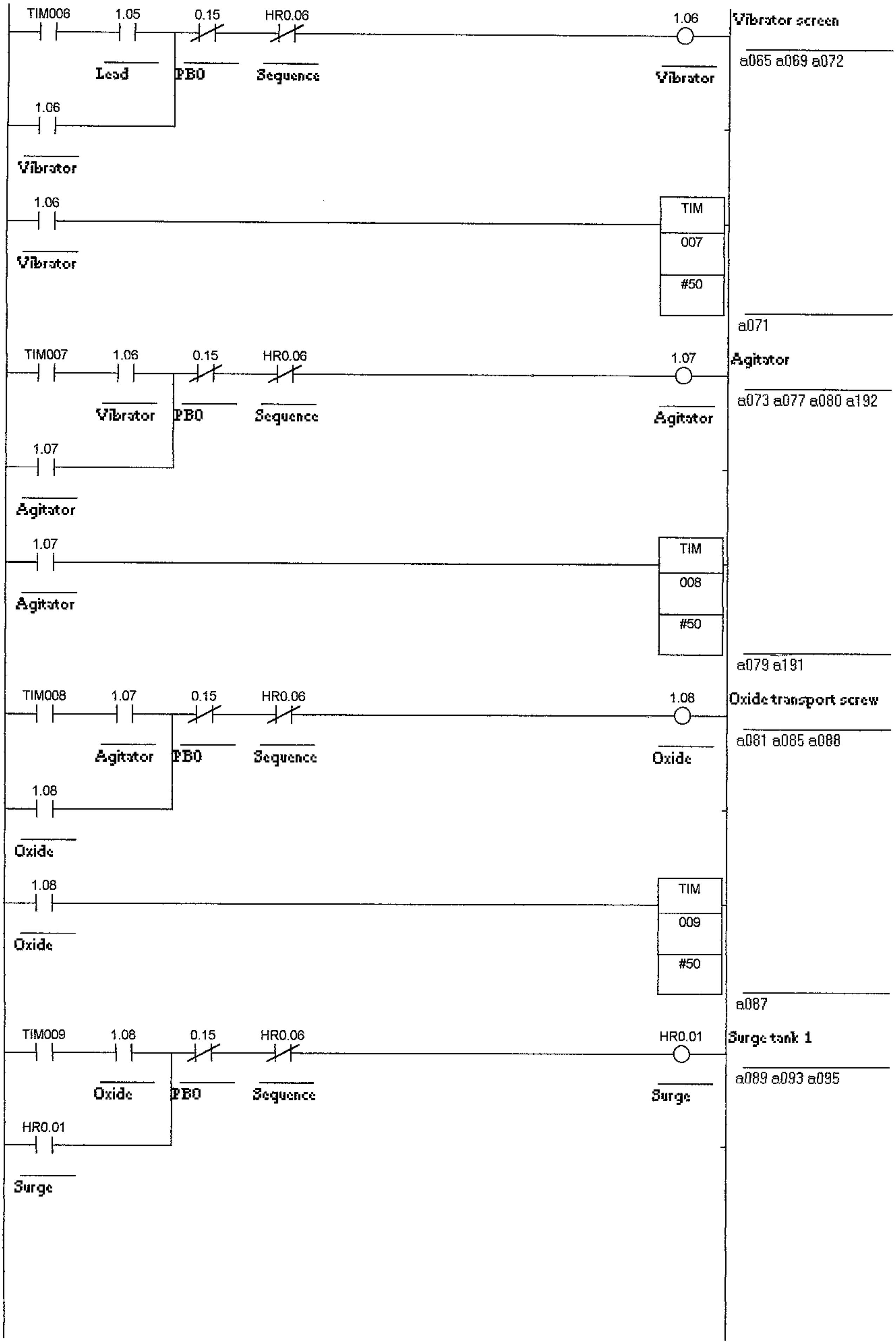
Table 7.1: List of Inputs and Outputs for the ladder logic program (Improvement Scrap Battery Process)

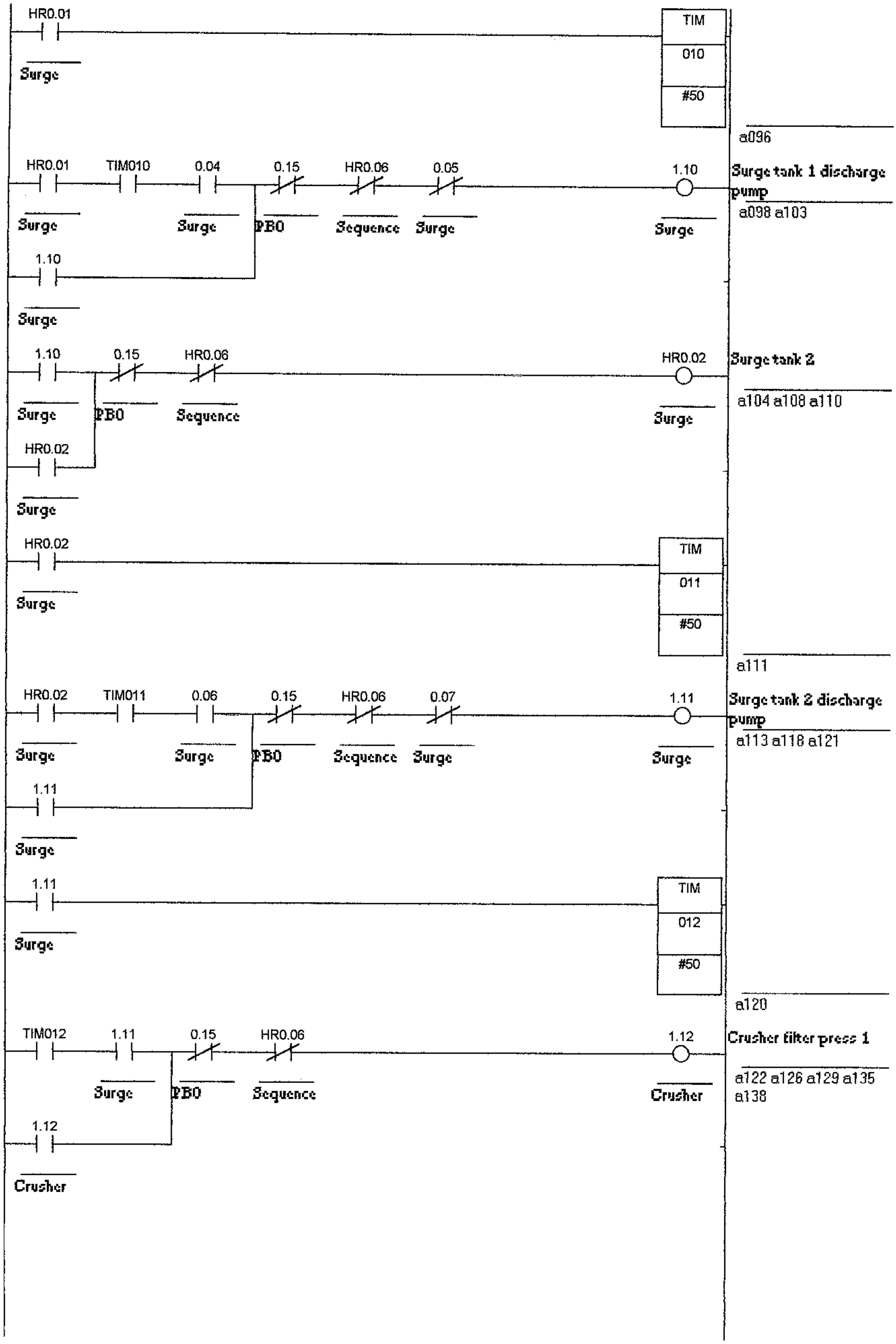
APPENDIX 7

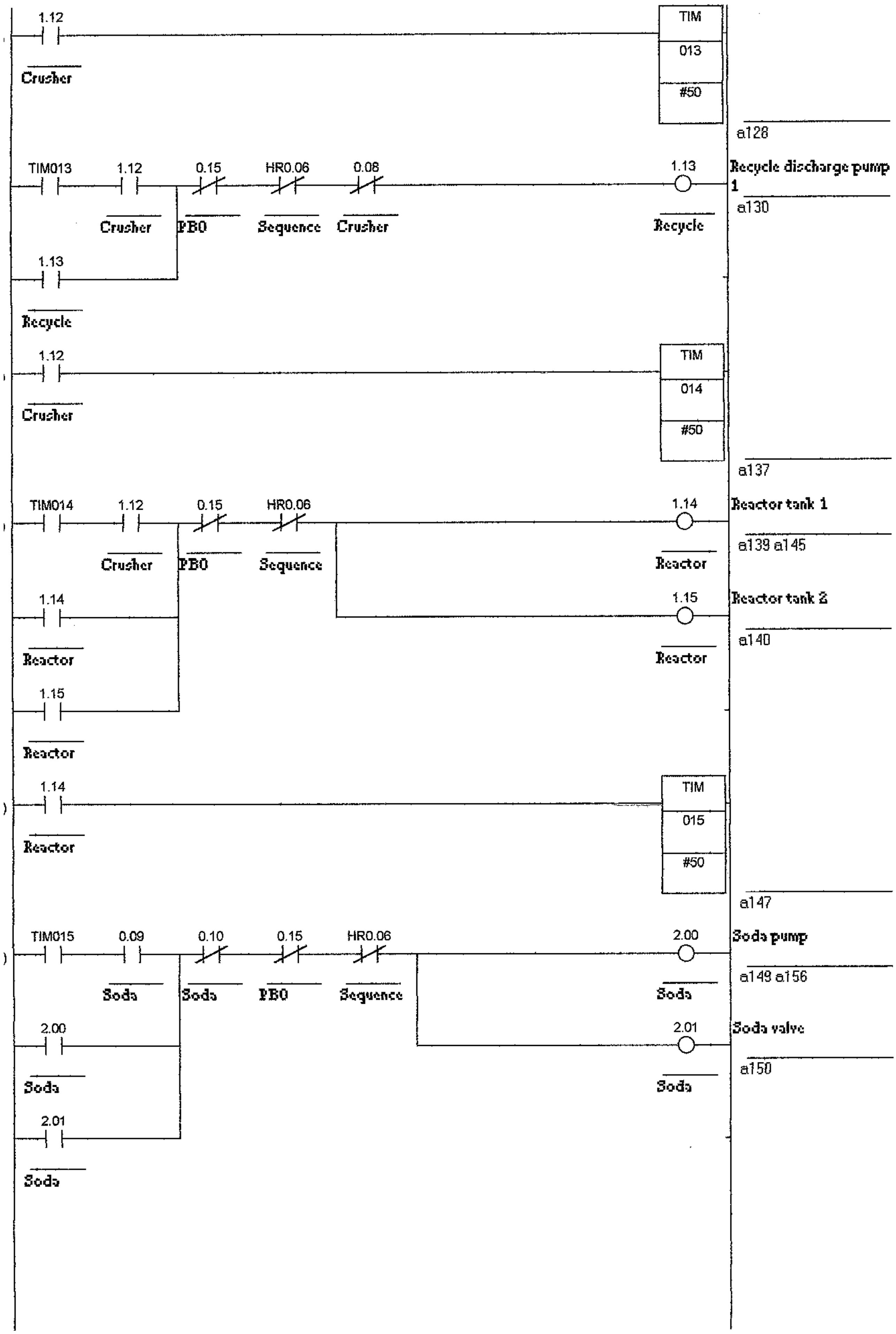
Ladder Logic Program for Improvement Scrap Battery Process


[Program Name : Section1]
Improvement Scrap Battery Process
[Section Name : Section1]
0.00
HR0.05
0.15
HR0.06
1.00
Feed conveyor
a002 a006 a009
Battery
Start
PB0
Sequence
Feed
1.00
Feed
1.00
Feed
TIM
001
#50
a022
0.01
1.00
0.02
0.15
HR0.06
0.03
HR0.04
intermediate 2
a011 a023
Crusher
Feed
Crusher
PB0
Sequence
Crusher
intermedia
HR0.04
intermedia
0.03
0.15
HR0.06
0.02
2.15
JBA water pump
a017
Crusher
PB0
Sequence
Crusher
JBA
2.15
JBA
TIM001
HR0.04
0.15
HR0.06
0.03
1.01
Crusher
a024 a029 a032
intermedia
PB0
Sequence
Crusher
Crusher
1.01
Crusher
1.01
Crusher
TIM
002
#50
a031
TIM002
1.01
0.15
HR0.06
1.02
Crusher discharge screw
a033 a037 a040
Crusher
PB0
Sequence
Crusher

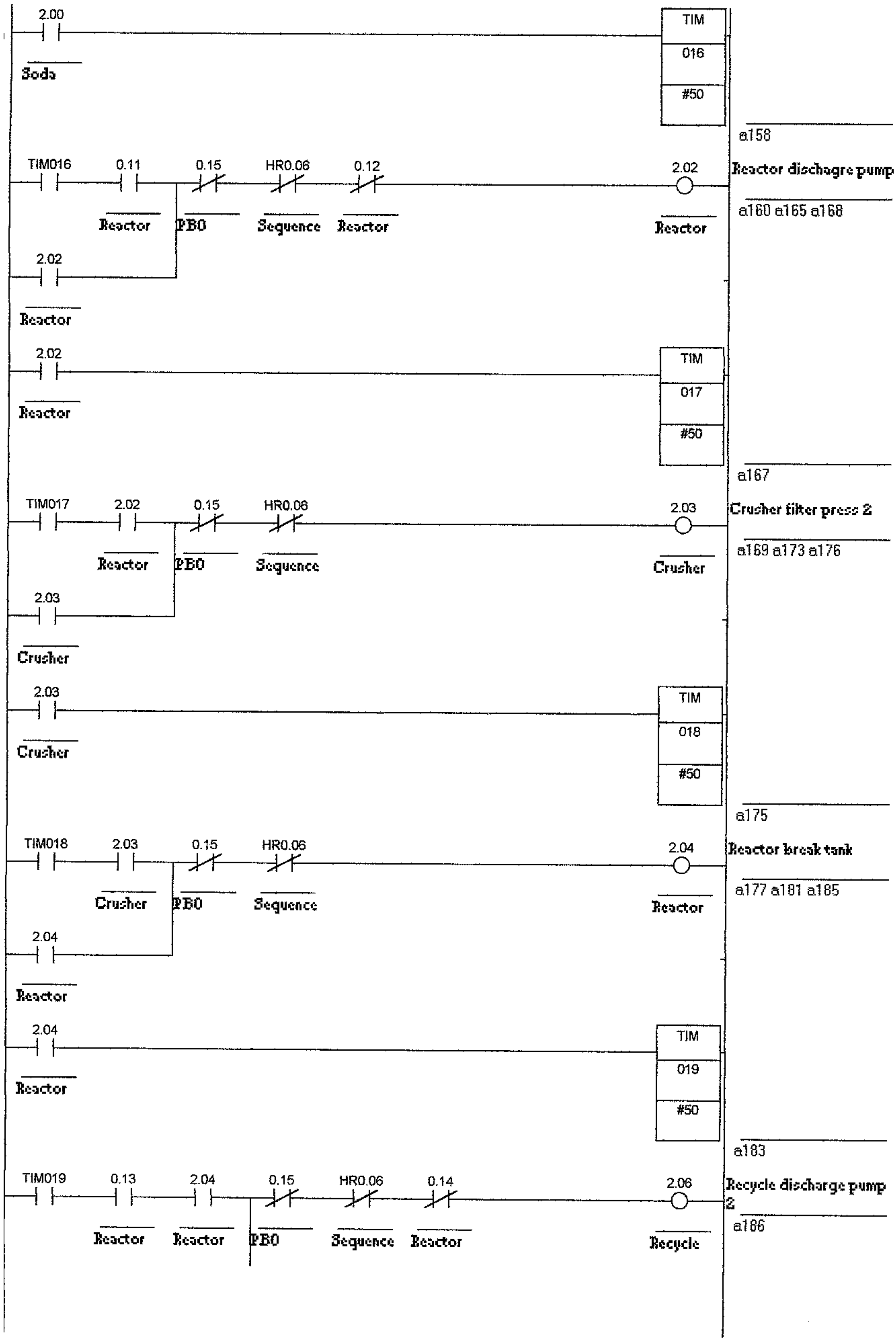

1.02
Crusher
1.02
Crusher
TIM
003
#50
a039
TIM003
1.02
0.15
HR0.06
1.03
Primary screen
Crusher
PB0
Sequence
Primary
a041 a045 a048
1.03
Primary
1.03
Primary
TIM
004
#50
a047
TIM004
1.03
0.15
HR0.06
1.04
Cross over screw
Primary
PB0
Sequence
Cross
a049 a053 a056
1.04
Cross
1.04
Cross
TIM
005
#50
a055
TIM005
1.04
0.15
HR0.06
1.05
Lead metal classifier screw
Cross
PB0
Sequence
Lead
a057 a061 a064
1.05
Lead
1.05
Lead
TIM
006
#50
a063

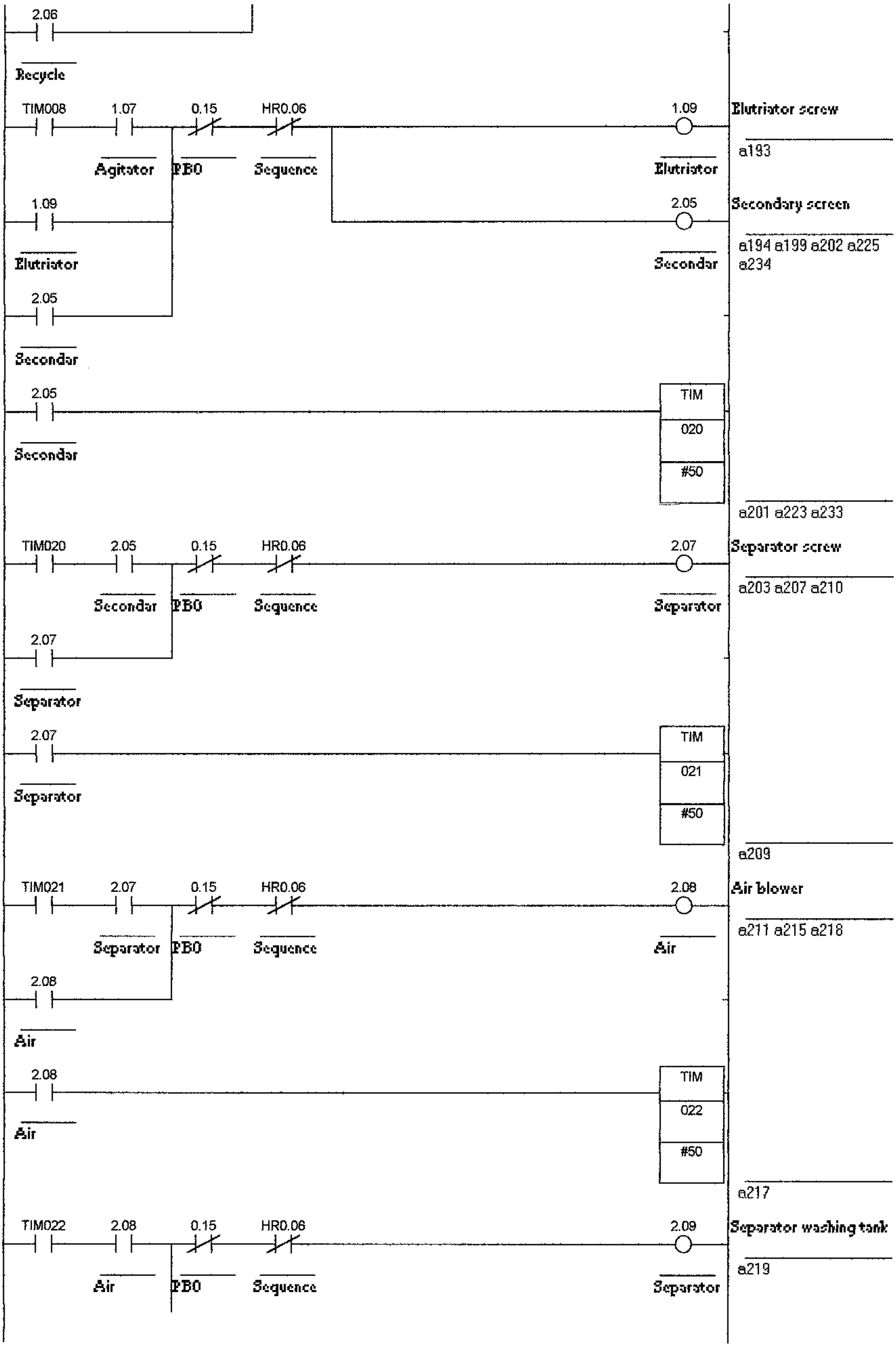

TIM006
1.05
0.15
HR0.06
1.06
Vibrator screen
Lead
PB0
Sequence
Vibrator
a065 a069 a072
1.06
Vibrator
1.06
TIM
007
#50
Vibrator
a071
TIM007
1.06
0.15
HR0.06
1.07
Agitator
Vibrator
PB0
Sequence
Agitator
a073 a077 a080 a192
1.07
Agitator
1.07
TIM
008
#50
Agitator
a079 a191
TIM008
1.07
0.15
HR0.06
1.08
Oxide transport screw
Agitator
PB0
Sequence
Oxide
a081 a085 a088
1.08
Oxide
1.08
TIM
009
#50
Oxide
a087
TIM009
1.08
0.15
HR0.06
HR0.01
Surge tank 1
Oxide
PB0
Sequence
Surge
a089 a093 a095
HR0.01
Surge

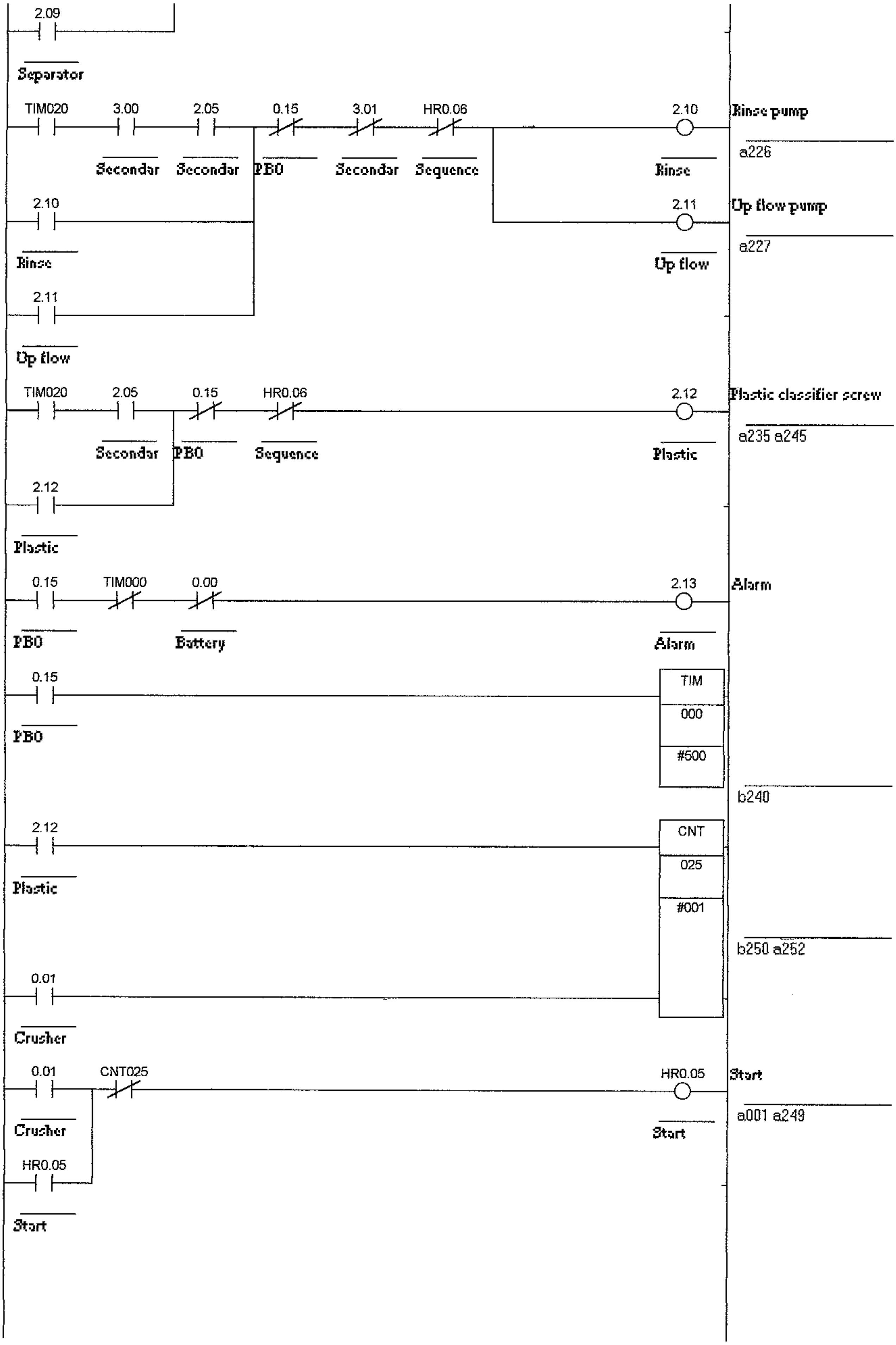

HR0.01
Surge
TIM
010
#50
a096
HR0.01
TIM010
0.04
0.15
HR0.06
0.05
1.10
Surge
Surge
PB0
Sequence
Surge
Surge
Surge tank 1 discharge pump
a098 a103
1.10
Surge
1.10
0.15
HR0.06
HR0.02
Surge
PB0
Sequence
Surge
Surge tank 2
a104 a108 a110
HR0.02
Surge
HR0.02
Surge
TIM
011
#50
a111
HR0.02
TIM011
0.06
0.15
HR0.06
0.07
1.11
Surge
Surge
PB0
Sequence
Surge
Surge
Surge tank 2 discharge pump
a113 a118 a121
1.11
Surge
1.11
Surge
TIM
012
#50
a120
TIM012
1.11
0.15
HR0.06
1.12
Surge
PB0
Sequence
Crusher
Crusher filter press 1
a122 a126 a129 a135 a138
1.12
Crusher

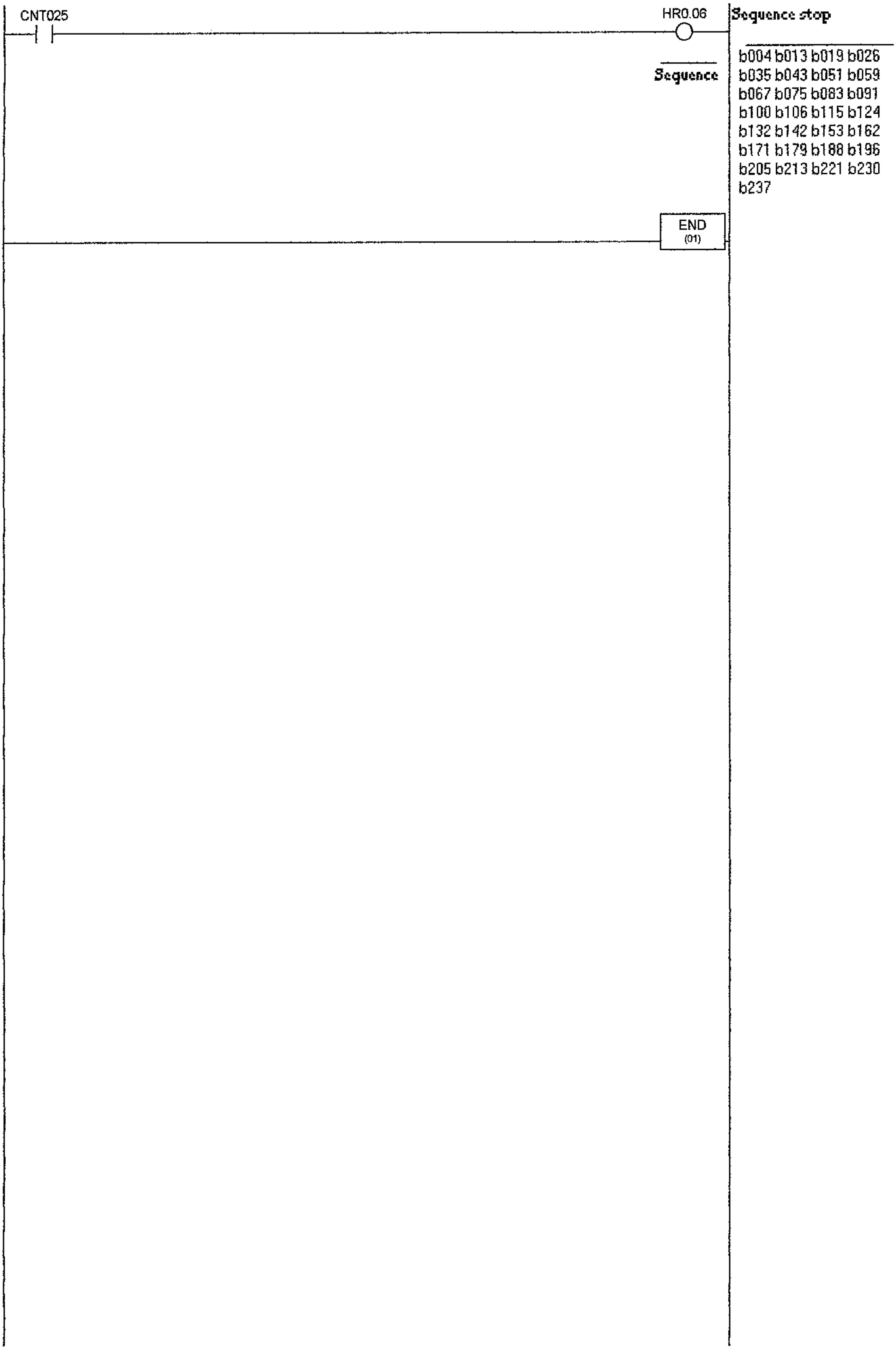


1.12
Crusher
TIM
013
#50
a128
TIM013
1.12
0.15
HR0.06
0.08
1.13
Recycle discharge pump 1
a130
Crusher
PB0
Sequence
Crusher
Recycle
1.13
Recycle
1.12
Crusher
TIM
014
#50
a137
TIM014
1.12
0.15
HR0.06
1.14
Reactor tank 1
a139 a145
Crusher
PB0
Sequence
Reactor
1.14
1.15
Reactor tank 2
a140
Reactor
Reactor
1.15
Reactor
1.14
Reactor
TIM
015
#50
a147
TIM015
0.09
0.10
0.15
HR0.06
2.00
Soda pump
a149 a156
Soda
Soda
PB0
Sequence
Soda
2.00
2.01
Soda valve
a150
Soda
Soda
2.01
Soda


2.00
Soda
TIM
016
#50
a158
TIM016
0.11
0.15
HR0.06
0.12
2.02
Reactor discharge pump
Reactor
PBO
Sequence
Reactor
Reactor
a160 a165 a168
2.02
Reactor
2.02
Reactor
TIM
017
#50
a167
TIM017
2.02
0.15
HR0.06
2.03
Crusher filter press 2
Reactor
PBO
Sequence
Crusher
a169 a173 a176
2.03
Crusher
2.03
Crusher
TIM
018
#50
a175
TIM018
2.03
0.15
HR0.06
2.04
Reactor break tank
Crusher
PBO
Sequence
Reactor
a177 a181 a185
2.04
Reactor
2.04
Reactor
TIM
019
#50
a183
TIM019
0.13
2.04
0.15
HR0.06
0.14
2.06
Recycle discharge pump 2
Reactor
Reactor
PBO
Sequence
Reactor
Recycle
a186


2.06
Recycle
TIM008
1.07
Agitator
0.15
PB0
HR0.06
Sequence
1.09
Elutriator
Elutriator screw
a193
1.09
Elutriator
2.05
Secondar
Secondary screen
a194 a199 a202 a225 a234
2.05
Secondar
2.05
Secondar
TIM
020
#50
a201 a223 a233
TIM020
2.05
Secondar
0.15
PB0
HR0.06
Sequence
2.07
Separator
Separator screw
a203 a207 a210
2.07
Separator
2.07
Separator
TIM
021
#50
a209
TIM021
2.07
Separator
0.15
PB0
HR0.06
Sequence
2.08
Air
Air blower
a211 a215 a218
2.08
Air
2.08
Air
TIM
022
#50
a217
TIM022
2.08
Air
0.15
PB0
HR0.06
Sequence
2.09
Separator
Separator washing tank
a219


2.09
Separator
TIM020
3.00
2.05
0.15
3.01
HR0.06
2.10
Rinse pump
a226
Secondar
Secondar
PB0
Secondar
Sequence
Rinse
2.10
2.11
Up flow pump
a227
Rinse
Up flow
2.11
Up flow
TIM020
2.05
0.15
HR0.06
2.12
Plastic classifier screw
a235 a245
Secondar
PB0
Sequence
Plastic
2.12
Plastic
0.15
TIM000
0.00
2.13
Alarm
PB0
Battery
Alarm
0.15
TIM
000
#500
PB0
b240
2.12
CNT
025
#001
Plastic
b250 a252
0.01
Crusher
0.01
CNT025
HR0.05
Start
a001 a249
Crusher
Start
HR0.05
Start


CNT025
HR0.06
Sequence stop
Sequence
b004 b013 b019 b026
b035 b043 b051 b059
b067 b075 b083 b091
b100 b106 b115 b124
b132 b142 b153 b162
b171 b179 b188 b196
b205 b213 b221 b230
b237
END
(01)

APPENDIX 8

Pictures of Scrap Battery Process Plant Prototype Construction

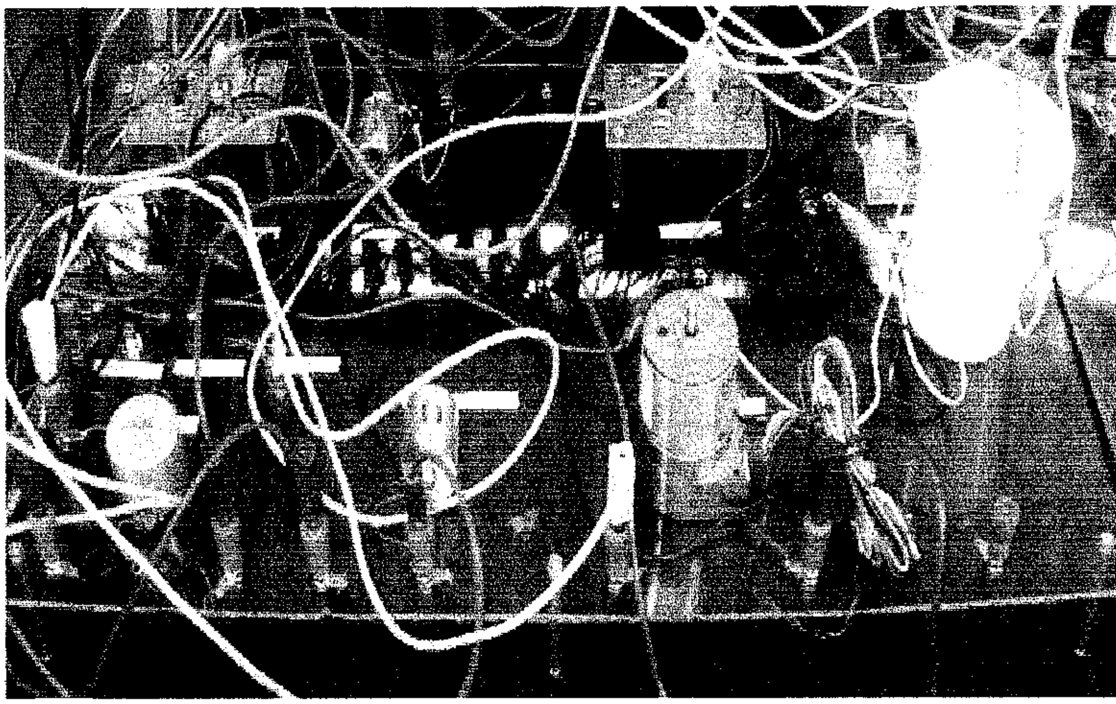


Figure 7.1: Scrap battery process plant prototype- phase 1.

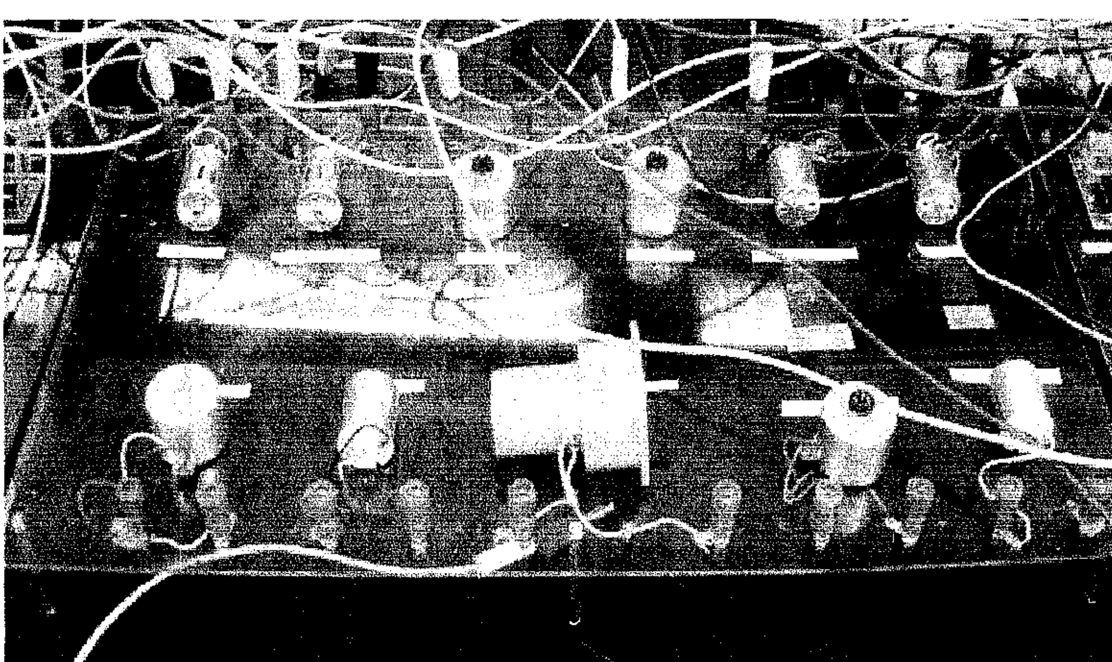


Figure 7.2: Scrap battery process plant prototype- phase 2 & 4.

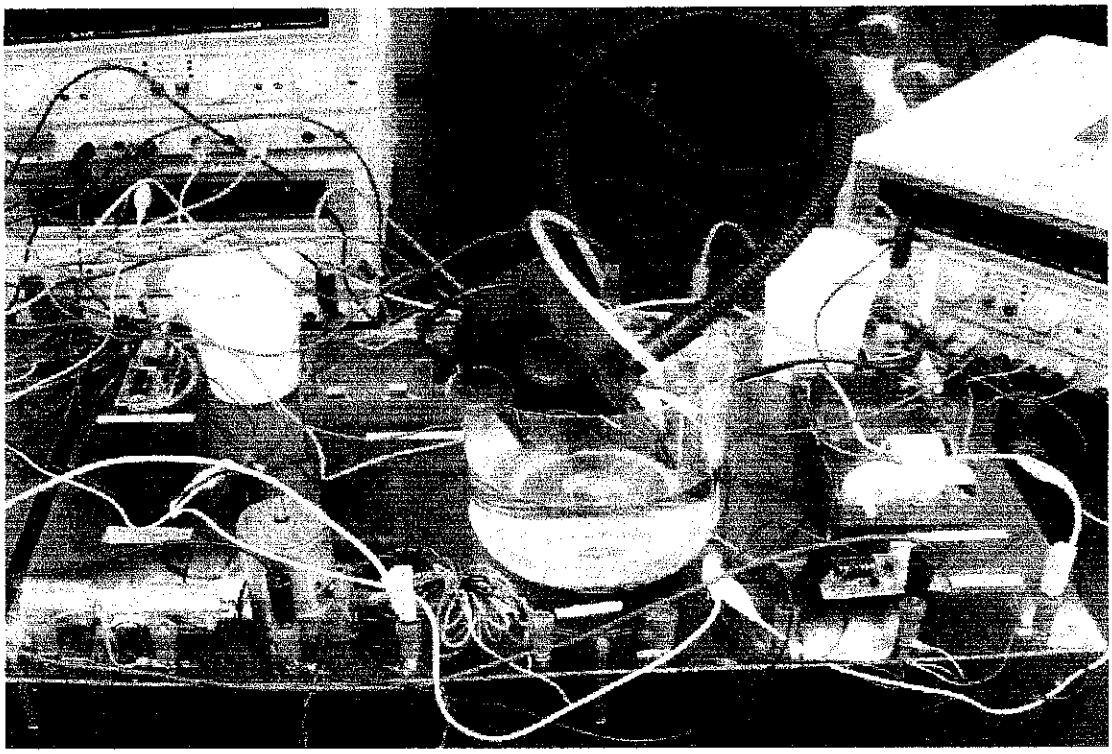


Figure 7.3: Scrap battery process plant prototype- phase 3.

APPENDIX 9

Pictures of PLC Interfacing With Scrap Battery Process Plant Prototype

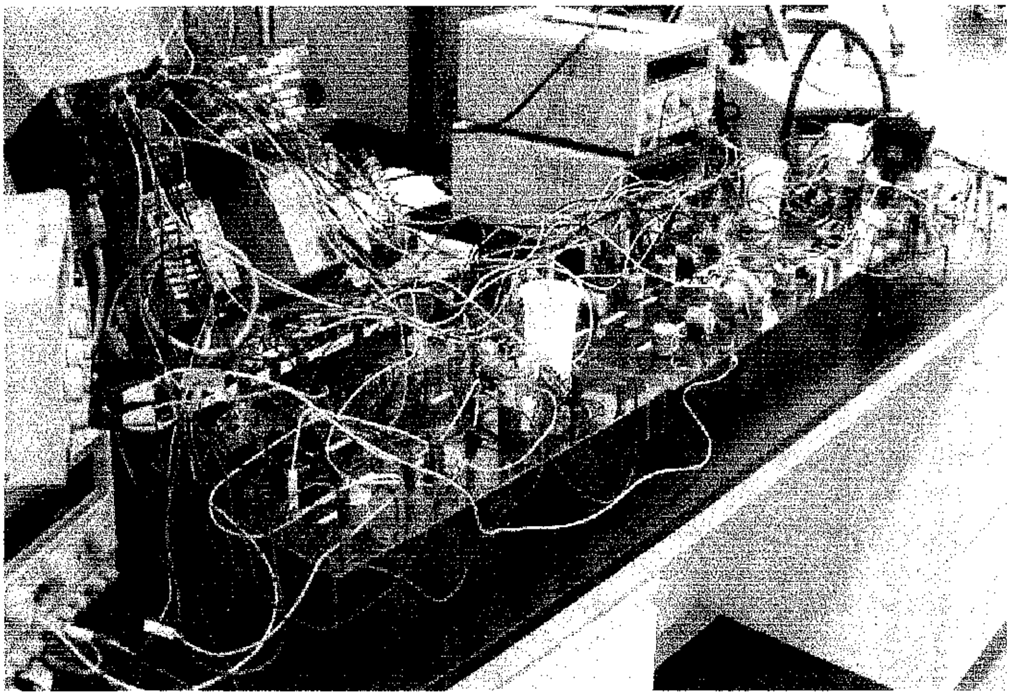


Figure 7.4: Picture of PLC interfacing with the scrap battery process plant prototype.

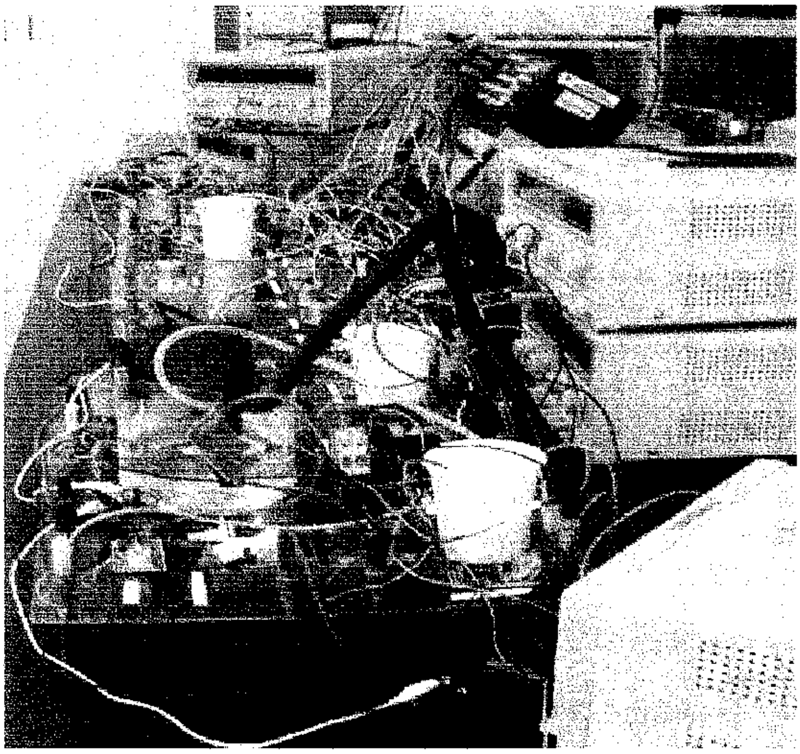


Figure 7.5: Picture of PLC interfacing with the scrap battery process plant prototype.

(Side view)

APPENDIX 10

Pictures of PLC Control of Scrap Battery Process Plant Prototype

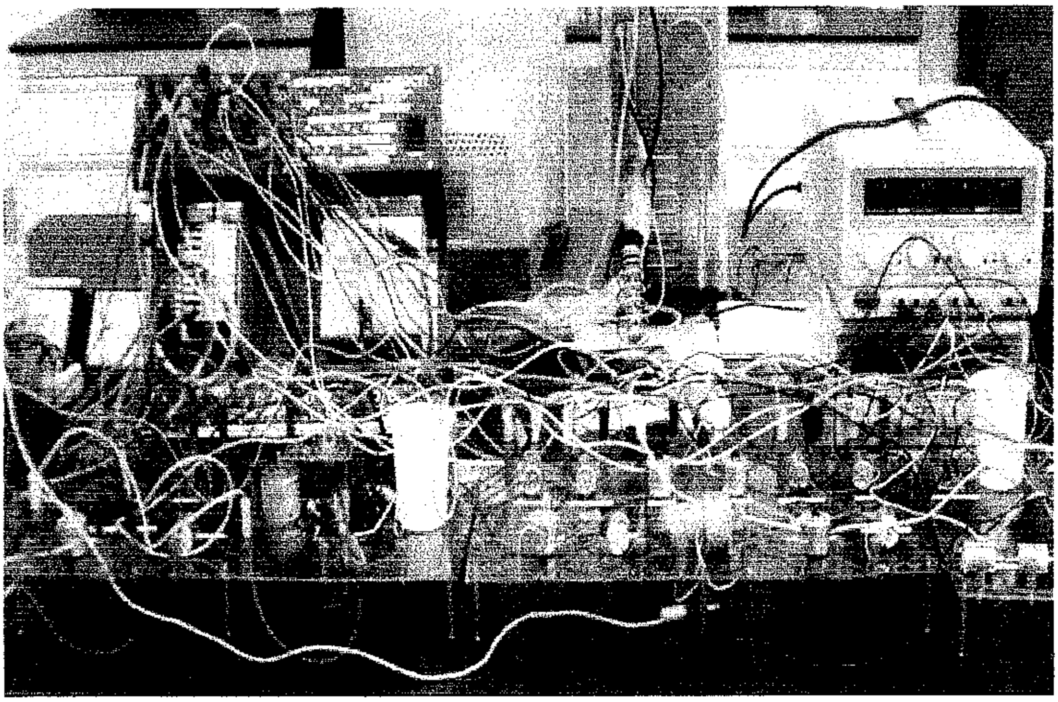


Figure 7.6: PLC control of scrap battery process plant prototype.

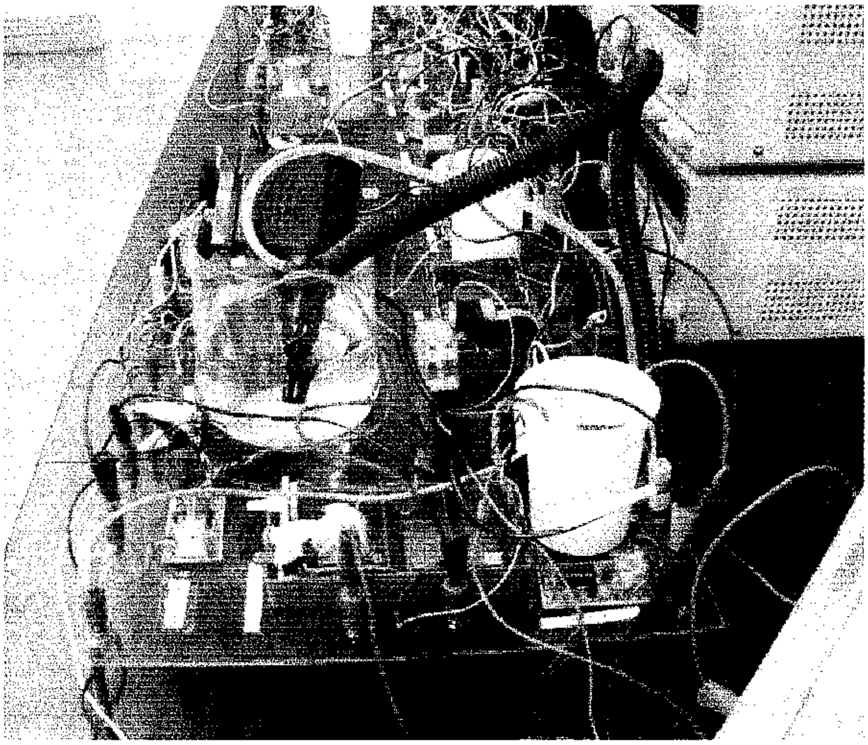


Figure 7.7: PLC control of scrap battery process plant prototype.

(Side view)