CHAPTER 1
INTRODUCTION

1.1 Background of Study

An air knife is a tool used to blow off liquid or debris from products as they travel on conveyors. Air knives are normally used in manufacturing as the first step to separate lighter or smaller particles from other components for use in later or subsequent steps, post manufacturing parts drying and conveyor cleaning. The knife consists of a high intensity, uniform sheet of laminar airflow.[1]

In the 1950s and 60s, the term “air doctor” was first used to refer to the non-contact method of debris blow-off using compressed air. The printing and textile industries were some of the largest users of air doctors at that time. They often needed wide paths of air from a compressed air system to control the thickness of liquids on a surface, or to blow debris off the surface of materials prior to the next process. Other terms used were air bar, air squeegee, air curtain, air jet, air blast, air blow off, air nozzle, air comb, air blade and air doctor blade. Today the most commonly used term is simply, air knife. [1]

Air knives remove liquids, dry the liquid coatings, remove foreign particles, cool product surfaces or create a hold down force to assist in the mechanical bonding of materials to the surface. Air knives are often the most efficient method of removing or controlling unwanted or foreign substances on any surface.

A programmable logic controller (PLC) is used to control the prototype of Air Knife Drying (AKD) machine. PLC consists of solid-state system designed to perform the logic functions previously accomplished by components such as electromechanical relays, drum switches, etc. for the control and operation of manufacturing process equipment. A typical PLC can be divided into four major components consists of CPU module, power supply, the input output section and a rack.

Early PLCs were designed to replace relay logic systems. These PLCs were programmed in "ladder logic", which strongly resembles a schematic diagram of relay logic. This program notation was chosen to reduce training demands for the existing technicians. Other early PLCs used a form of instruction list programming, based on a stack-based logic solver.

CX-Programmer is the software used to program the ladder diagram for the PLC. In the CX-Programmer, the ladder diagram is programmed in rung. The programming technique is that the PLC scans the ladder diagram rung by rung from the first to the end and connected them according to the program designed. The common ladder logics used in CX-Programmer are normally open input, normally closed input, output, holding relay, timer and counter. There are some additional functions such as comparing, adding, and subtracting and others.

Once the ladder diagram has been developed, the CX-Programmer has a server to interface the program with the PLC. The program is sent to the PLC. Then the PLC read the program from the CX-Programmer and implemented to control the system according to the ladder diagram.

1.2 Problem Statement

In many manufacturing process, moisture or particle can become deposited on products. These need to be continuously removed quickly and cleanly. In food industries, an air knife is used to dry the fruits and vegetables that are travel on conveyor system before packing. Application of air knife can be extended to remove the pesticides residue on the skin of fruits. The system will not only clean and remove foreign particles from the fruit, it also remove the toxin such as pesticides. This idea will reduce the human risk from the dangerous chemical from the fruits.

1.3 Objectives

The following are the main objectives to be achieved in this project:

1. To build a prototype of air knife drying (AKD) machine.
2. To design ladder diagram for the PLC to control the AKD machine.
3. To interface the PLC control system with the AKD machine hardware.
4. To extend the application of AKD system that can dry the fruits and remove the pesticides residue on the skin of the fruit.

1.4 Scope of Project

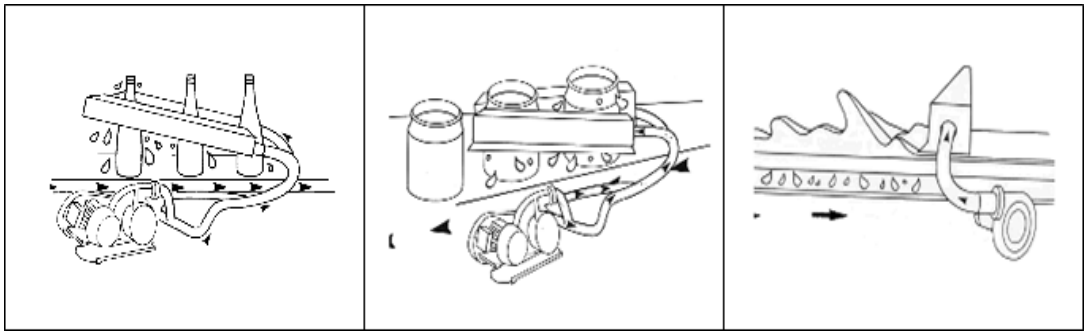
A profound study has been conducted before deciding on the PLC controlled the AKD machine. A unit of OMRON PLC is programmed to build a reliable control system to the AKD machine. Familiarization on the using of CX-Programmer software is an important part of the work. The feasibility studies of the AKD system includes the electrical and mechanical aspects of the system such as features of the hardware used such as motor, relays, solenoid valve, power supply and other materials to build the prototype.

The next phase requires the PLC interfacing between all components of the machine and confirms the validity of the system. In addition, it is important to make a research on the suitable product of pesticide remover to be applied on the AKD machine.

CHAPTER 2
LITERATURE REVIEW

2.1 Air Knife

Air Knives deliver a continuous sheet precisely controlled velocity air for stripping away moisture and debris. The applications of air knife in industries are wide-raging. Figure 1 proves that an air knife is the most efficient method for drying, cleaning or cooling applications. Air knives are normally used in manufacturing to separate lighter or smaller particles from other components for use in later or subsequent steps, part of component cleaning.



Drying Bottles Drying Jars Drying Flat Conveyors

Figure 1: Application of Air Knives in Industries

As in the food and beverage industries, the uses for air knives in other industrial sectors are almost as long as the list of potential problems. In the manufacture of rolled aluminum foil, for example, air knives are used to dry the roll after washing, preventing water marks, and in cement works and quarries, air knives are effective at removing dust and gravel from conveyors, preventing the

rollers from becoming jammed and worn. Many seemingly intractable problems can actually be solved quite easily with air knives. Their modular construction allows them to be positioned in the most awkward and inaccessible places, where other devices may not easily fit in.

In food industries, fruits and vegetables that are processed throughout a washer are required to be dried. As in Figure 2, the air knife drying machine is used to dry the tomatoes before packing. An Air Knife Drying (AKD) machine blows high-velocity air over the products to remove the water.

An industrial air knife is a pressurized air plenum containing a series of holes or continuous slots through which pressurized air exits in a laminar flow pattern. The exit air velocity then creates an impact air velocity onto the surface of whatever object the air is directed. [1]

Figure 2: Drying of Tomatoes before Packing

However, the application of AKD system can be extended to remove pesticides residue on the skin of fruits. In this project, the machine will be used first to remove pesticide on the skin of fruits and then to dry the fruits. Instead of clean and remove foreign particles, it also removes the pesticides residue on the skin of the fruit. This idea will reduce the human risk from the dangerous chemical from the fruits.

2.1.1 Types of Air Knives

There are two types of air knife in industries that are straight and circular air knives. The air exists through a narrow aperture producing a highly effective "knife" effect. The more narrow the aperture, the more powerful the effect. Figures below show the most common air knives that being used:

1. Straight Air Knives

Figure 3: Straight Air Knives

Figure 3 shows the straight air knife that being used in industries. Straight air knives is the ideal choice for most application for drying a wide variety of sheet materials such as printed circuit boards, bottles, jars, cans, components. [1] They have adjustable slot widths for optimum power and a unique air diffuser system.

2. Circular Air Knives

Figure 4: Circular Air Knives

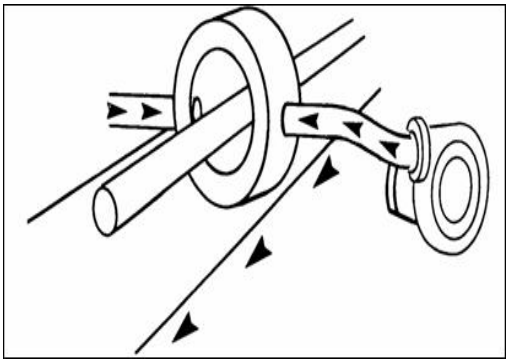


Figure 5: Airflow in Circular Air Knives

In certain cases such as for drying cables, tubes and rods, circular air knives are more suitable compare to straight air knives, as shown in Figure 4 and Figure 5. A circular air knife placed at the exit of the forming tool strips the cutting fluid from the surface to produce a dry tube. The cutting oil is collected and returned to the tank.

2.1.2 Standard Operation of AKD Machine

Figure 6 shows the standard operation diagram of AKD machine for drying fruits in food manufacturing industries. Fruits that are processed throughout a washer are required to be dried. After the fruits undergo with washing section, they will be transported to the drying section by a conveyor system.

At this section, the blower will supply enough air to the air knives nozzles. The air knives direct the air against the fruits. If the stream of air is properly directed, it will remove most of the superfluous liquids adhering to the fruits. After the fruits are completely dried, they will be transported to the other section to be packing. [2]

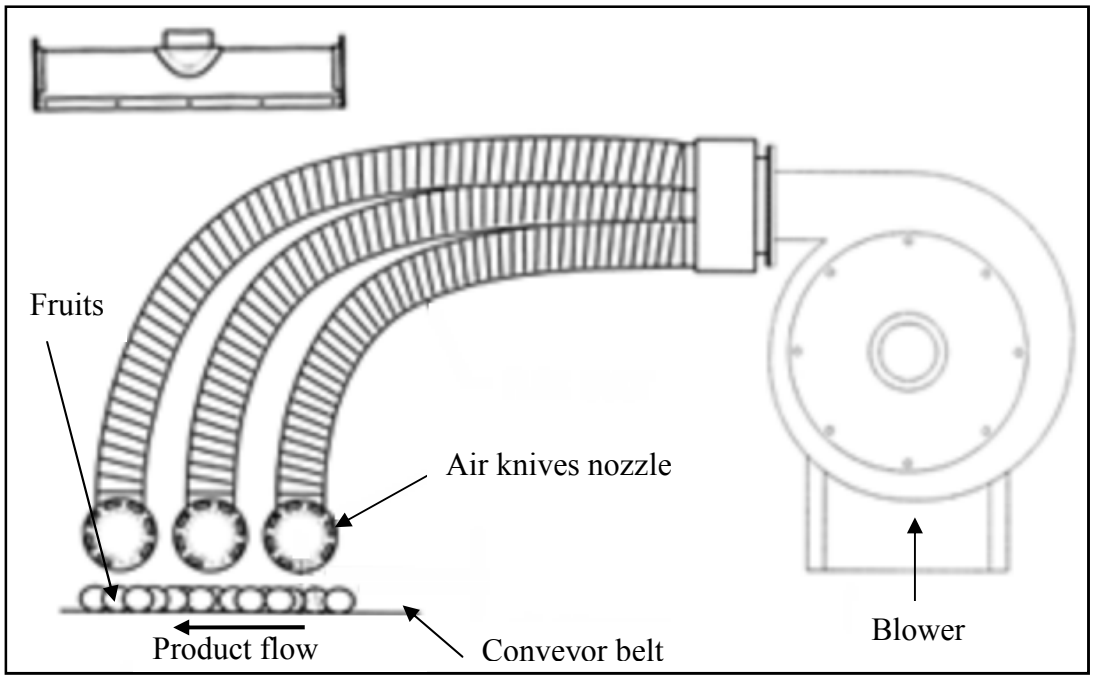


Figure 6: Diagram of AKD Machine in Food Industries [6]

2.2 Programmable Logic Controller (PLC)

Proper planning and studying of the PLC system will ensure the success of the end of project. PLC is a solid-state system designed to perform logic function such as sequencing, timing, counting and arithmetic to control machine and processes which is previously done by hardwired relay system. [9]

Figure 7: PLC OMRON CPM 1A

Figure 7 shows one example types of PLC. PLC is operated by the instruction input from the input devices such as push button, switches, sensors and other used to detect the operation condition of the equipment, output devices such as solenoid valves, motor and so on. PLCs are used in many industries and machines.

Unlike general-purpose computers, the PLC is designed for multiple inputs and output arrangements, extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact. Programs to control machine operation are typically stored in battery-backed or non-volatile memory. The PLC plays an important role as the brain of the automated manufacturing process.

2.2.1 Components of PLC

The typical PLC contains four major components as following:

- CPU module
- Power supply
- Rack/ bus
- Input/ Output modules

2.2.2 Applications of PLC

PLC can be applied in so many industries such as below:

- Bottling and filling industry
- Food industry
- Automotive industry
- Conveyor system

2.2.3 PLC Ladder Diagram

Ladder logic diagram is a programming language that represents a program by a graphical diagram based on the circuit diagrams of relay-based logic hardware. It is primarily used to develop software for PLC used in industrial control applications.

Ladder logic is widely used to program PLCs, where sequential control of a process or manufacturing operation is required. Ladder logic is useful for simple but critical control systems or for reworking old hardwired relay circuits. Ladder logic can be thought of as a rule-based language rather than a procedural language.

A "rung" in the ladder represents a rule. A ladder diagram consists of horizontal rungs between two vertical rails which represent the power rails. Each rung contains instruction elements that examine memory bits and at least one output element that control a memory bits. Each rung must start with an input(s) and end with at least one output. Figure 8 shows an example of simple PLC ladder diagram.

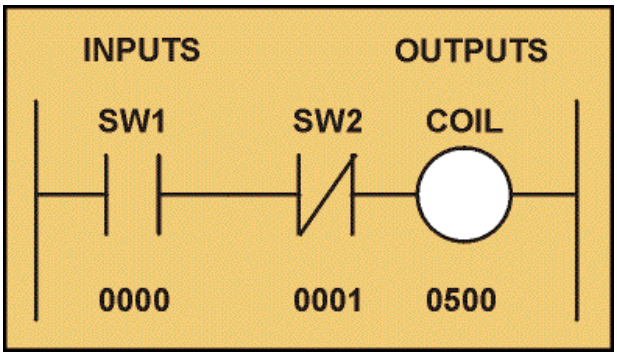


Figure 8: An Example of Ladder Diagram

2.3 Pesticides

Pesticides are chemicals used to protect crops from insects, weeds and fungal attack and rodents. The use of pesticides allowed growers to produce crops in otherwise unsuitable locations, extend growing seasons, maintain product quality and extend shelf-life.

Most chemicals used as pesticides however are toxic and the major argument against their use is the health risk factor and the danger of environmental pollution. These concerns, including the potential chronic effects, form the basis of all regulations that control the use of pesticides, the setting of safety standards and the monitoring of residues on foods.

In 2006, at least three people were killed and more than 200 others in all over the world became sick after consuming spinach. Tests later revealed that samples of cattle manure from pasture surrounding the spinach field tested positive for the same strain of E. coli that lead to the outbreak. Fruit and vegetables usually come from fields where there are birds and animals that can contaminate them through their droppings. People get sick from eating fruit and vegetables that have been contaminated with E. coli all the time.

Surveys have shown 8 out of 10 people wash their fruit and vegetables with water, which isn't enough to remove all of the potentially harmful chemicals, pesticides and bacteria. Independent laboratories, certified by the National Association of Testing Authorities (NATA), have conducted tests that found fruits & vegetable rinse product can removes up to 100 times more contaminants than water alone.

Pesticides can be broadly divided into a number of groups which relates to their functionality and structure. Examples of some groups and pesticides within the groups are: [5]

- Organochlorine pesticides, eg. dieldrin, chlordane, endosulfan
- Organophosphorus pesticides, eg. Parathion, dimethoate
- Synthetic pyrethroid insecticides, eg. deltamethrin, methomyl
- Triazine herbicides, eg. simazine, atrazine, DDT
- Carbamate pesticides, eg. aldicarb, propoxur, carbofuran

2.3.1 Research on Pesticide Remover

Although, nowadays there are numerous producers of organically grown food, but even these have some type of chemicals on them. People normally mislead to think that if it says "organically grown" that it truly is chemical free. In some instances it is possible that they didn't use chemicals, but in most cases they did.

There are many tips in the internet or websites on how to remove pesticide and wash fruit at home. However, there is no proving that the pesticides have been totally removed from the fruit. In fact, people who washed the fruits using soap will face with the dangerous chemical left by the soap itself.

In this project, research need to be done to find a perfect solution for pesticide remover on the skin of fruit to be applied in agriculture food industry. In fact, liquid or soluble form of pesticide remover is needed to be applied to the AKD machine.

CHAPTER 3
METHODOLOGY

3.1 Procedure Flowchart

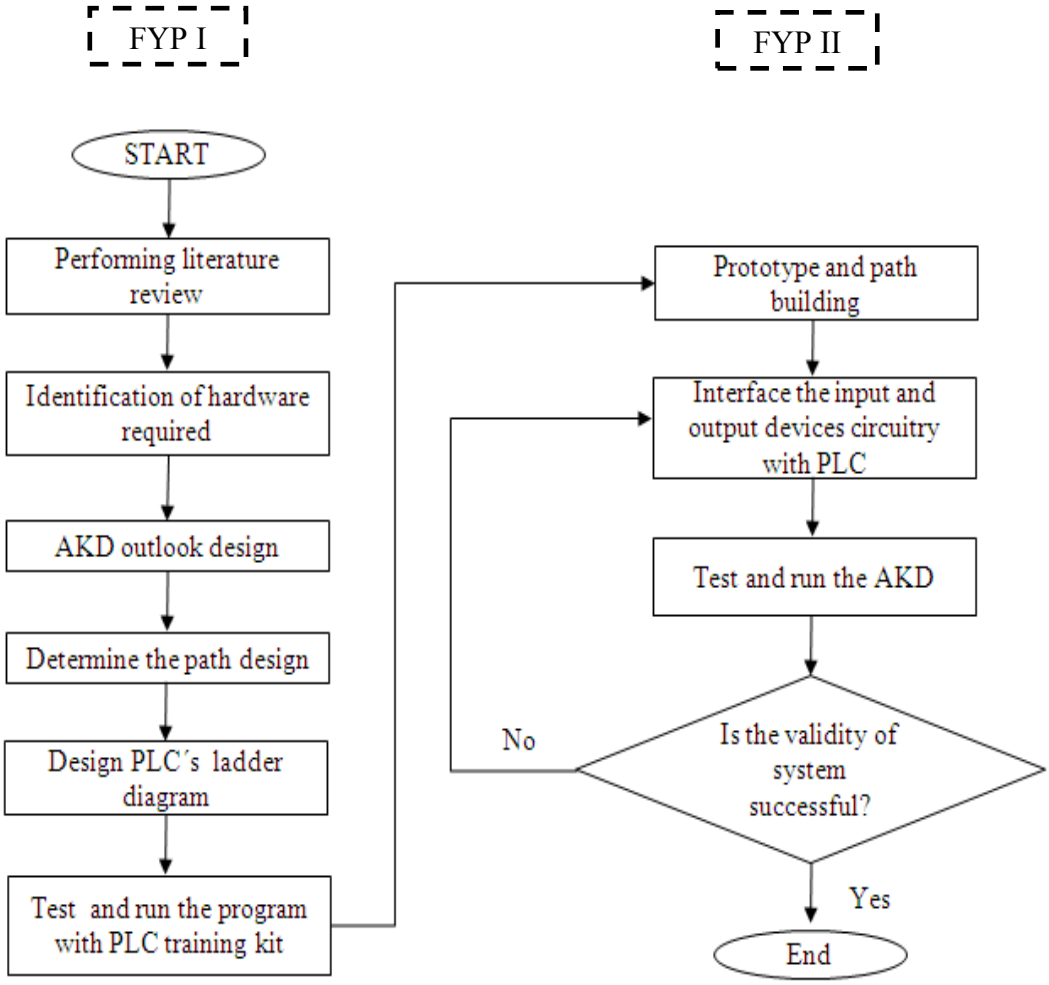


Figure 9: Procedure Flowchart

3.2 Procedure Identification

The procedure identification explains the procedure flowchart as in Figure 9. In this project, the few steps identified were used as a guide on completing the project for the whole process.

Step 1: Literature review (AKD system and PLC)

Step 2: Identification of hardware required

- Identify for suitable equipment needed for the prototype such as solenoid valve, relays, PLC and blower.

Step 3: AKD outlook design

- Draft the design of AKD machine including the dimension and size.

Step 4: Determine the path design

- Identify the path design of every equipment

Step 5: Design the PLC ladder diagram

- Obtain the desired operation of AKD machine based on the path such as the sequence of each equipment

Step 6: Test and run the program with PLC training kit

Step 7: Prototype and path building

Step 8: Interface the I/O devices circuitry with PLC

- Wiring connection of I/O devices with PLC

Step 9: Test and run the AKD

- Make improvement (if necessary)

3.3 Tools and Equipment Used

3.3.1 Equipment and Tools Used

To be mentioned on this section are the hardware and software being used in this project. These software and hardware are the most commonly used application. The tools and component required to build an AKD machine are as follow:

1. Programmable Logic Controller (PLC) – OMRON CPM 1A
   - Output: 24 V-dc
   - Purpose: Control the sequences of AKD machine

2. Power supply 24 V-dc
   - Figure 10 shows the OMRON Power Supply 24 V-dc.
   - Purpose: Supply 24 V-dc power to the output of PLC such as switch, indicator lights.

Figure 10: OMRON Power Supply 24 V-dc

3. Indicator equipment
   - START & STOP button switch, MAIN indicator light, and indicator light for solenoid valve 1&2.
   - Output: 24 V-dc.

4. Solenoid valve (x2)

Figure 11: Solenoid Valve

- Figure 11 shows the solenoid valve that being used in this project. The solenoid converts electrical energy into mechanical energy which, in turn, opens or closes the valve mechanically. [3]
- Purpose: Control water and pesticide remover flow.

5. Air Knives Nozzle

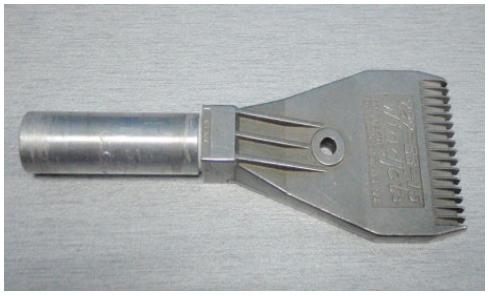


Figure 12: Air Knives Nozzle

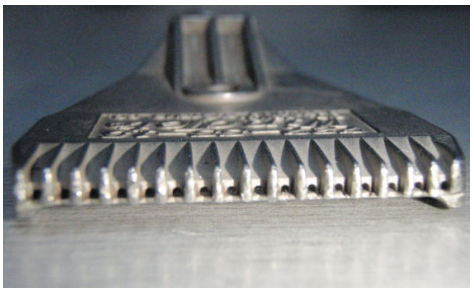


Figure 13: Nozzle´s Hole

- Figure 12 and Figure 13 shows the air knives nozzle that contains uniform sheet of laminar airflow.
- The air exits through a narrow, producing a highly effective “knife” effect.[1]
- Purpose: Directs air against fruits to be dried.

6. Water and Pesticide Remover Nozzle (x3)

- Purpose: Directs the water and pesticides remover against the fruits for washing purpose.

7. Transformer

- Purpose: Converts 240 V-ac to 24 V-ac

8. Relay (x4)

- OMRON LY2N-D2 & OMRON MY2 (SSR)
- Purpose: Act as switching mechanism
- Figure 14 shows the terminal arrangement/internal connections of LY2N-D2

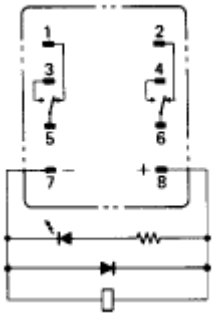


Figure 14: LY2N-D2 Terminal Arrangement

9. Blower

- Hair dryer will be used as blower for drying purpose.
- Purpose: Supply sufficient air to air knife nozzle.

10. Manual Circuit Breaker

- Purpose: Manually protect the circuit from damage caused by overload or short circuit.

11. Conveyor

- Purpose: Transfer the fruit from washing section to drying part.
- Output: 240 V-ac

12. Pesticide Remover

- Sunsmile Fruit & Vegetable Rinse product
- Non-toxic, safe enough to swallow without harmful effects.
- Ensure fruits stay fresher for a longer period of time.
- Purpose: Destroy pesticides or germs that existed prior to the wax application, harmful organisms, and oily contaminants and neutralize the carcinogenic sprays. [5]

Other tools:

- PVC pipe
- Mini tank (x2)
- Perspex
- Fitting 1/2" and 3/8"
- Water
- Wire
- RS 232 Cable

Software: CX-Programmer version 3.1

3.3.2 Air Knives Nozzle Specification

The type of air knives nozzle that will be used in this project is AA27 WindJet Nozzle. Figure 15 below shows the AA27 WindJet nozzles.

Figure 15: AA27 WindJet Nozzles

AA727 features and benefits:

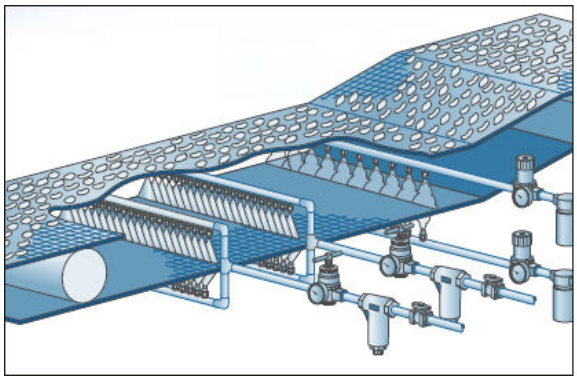
- Designed to maintain spray pattern integrity
- Available in materials that withstand high temperatures
- Low noise levels
- Can be mounted side-by-side for air curtain applications

Table 1 below indicates the AA27 WindJet nozzle specifications. [10]

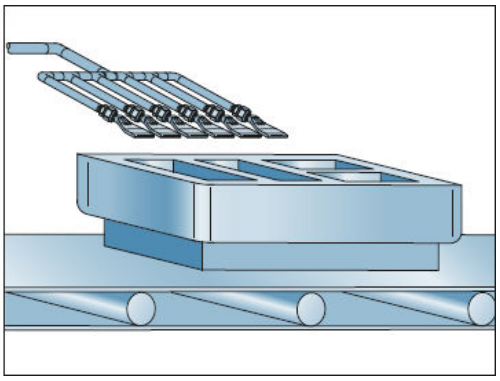
Table 1: AA27 WindJet Nozzles Specifications

Weight	ABS – 0.7 oz (20 g), PPS – 1.0 oz (28 g), aluminum – 2 oz (56 g), stainless steel – 4.1 oz (116 g)
Materials	ABS, PPS (polyphenylene sulfide), aluminum or stainless steel
Diameter	3/16” (4.8 mm) diameter mounting hole for fixed positioning
Maximum operating pressures	ABS – 100 psi at 170° F (7 bar at 77° C) PPS – 100 psi at 180° F (7 bar at 82° C) Aluminum – 100 psi at 450° F (7 bar at 230° C) Stainless steel – 150 psi at 500° F (10.3 bar at 260° C)

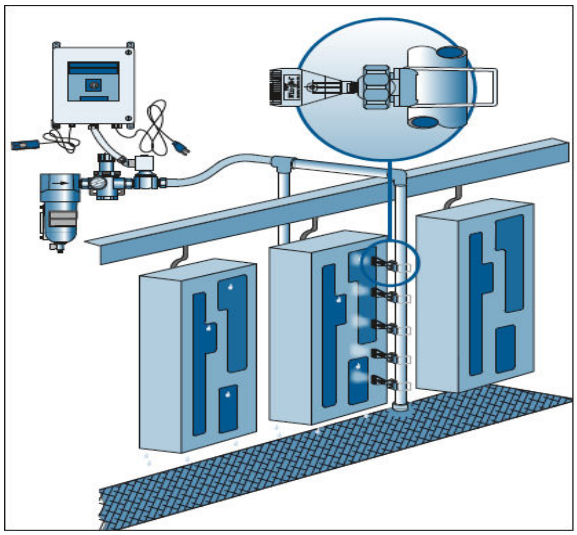
WindJet nozzles are widely used in industries. Figure 16 below shows those examples of solving typical application problems with AA27 WindJet Air Nozzles.



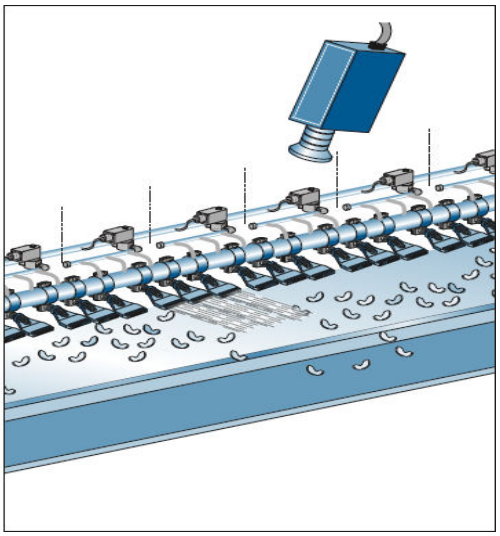
Conveyor belt blow-off using AA27 WindJet® air nozzles.



Blowing sand out of molds with WindJet AA27 air nozzles.



Air blow-off system dries plastic packing trays after washing. WindJet AA27 air nozzles are installed in Clip-Eyelet® nozzle bodies for easy installation and adjustment.



Potato chips that don't pass QC inspection are blown off the conveyor with WindJet AA27 air nozzles.

Figure 16: AA27 Solving Typical Application Problems with Air Nozzles

3.4 Chassis Construction

The chassis or body of the AKD machine is made from Perspex. It is cut into some pre-determined dimension based on the design. Since the AKD will carry quite heavy load, the suitable thickness for the Perspex is 4mm and the major dimension are 25 cm x 25 cm. The Perspex is cut to the shape as Figure 17 below:

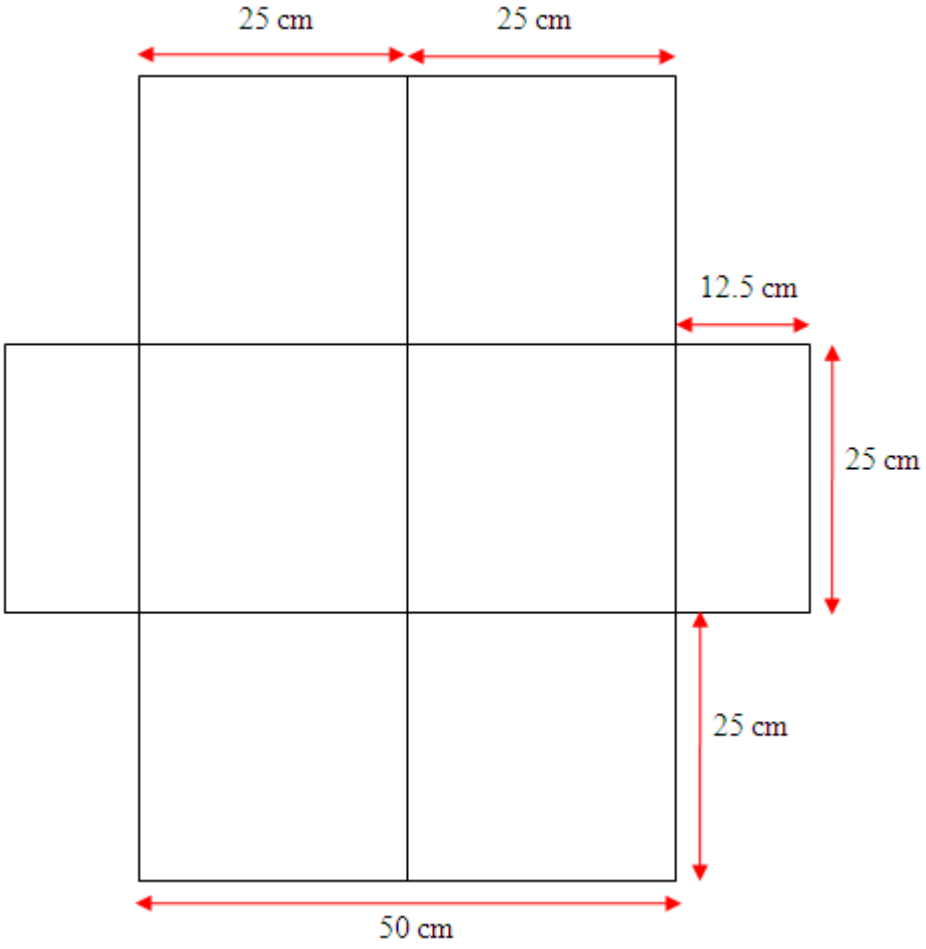


Figure 17: The Dimension of Perspex

CHAPTER 4
RESULTS AND DISCUSSION

4.1 AKD Machine

4.1.1 AKD Machine Block Diagram

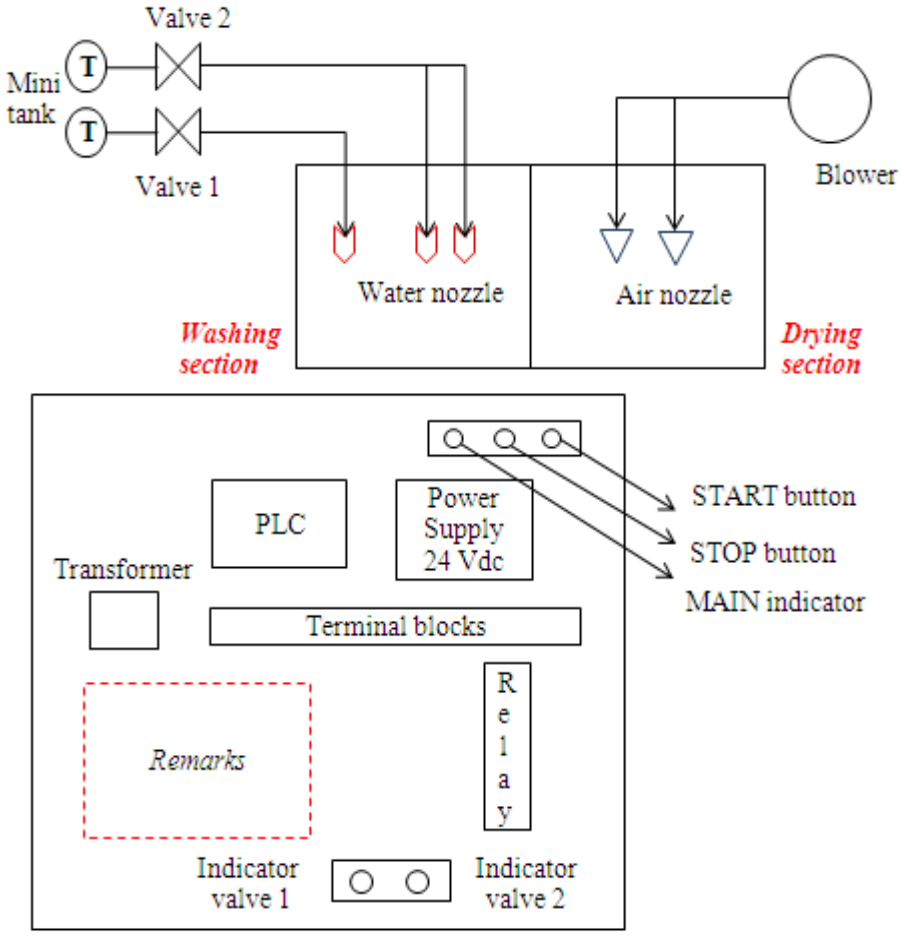


Figure 18: AKD Machine Block Diagram

Figure 18 shows the block diagram for AKD machine in this project. The purpose of using transformer is to convert the 240 V-ac to 24 V-ac as the output for solenoid valve is 24 Vac. As outputs of PLC are 24 V-dc such as switch button and indicator light, power supply 24 V-dc is needed. Shows in figure, washing section and drying section are being separated.

Figure 19 below shows the real AKD machine with the controller board. Only the conveyor system did not attached yet to the machine. The AKD machine will be used first to remove pesticide on the skin of fruits and then to dry the fruits. After the conveyor transport the fruit to drying section, the blower that is the hair dryer will produce sufficient air through air knives nozzle to dry the fruit. Then, the fruit is now dry, clean and safety to be eaten. Still this is not the final version which means that there are rooms for improvement.

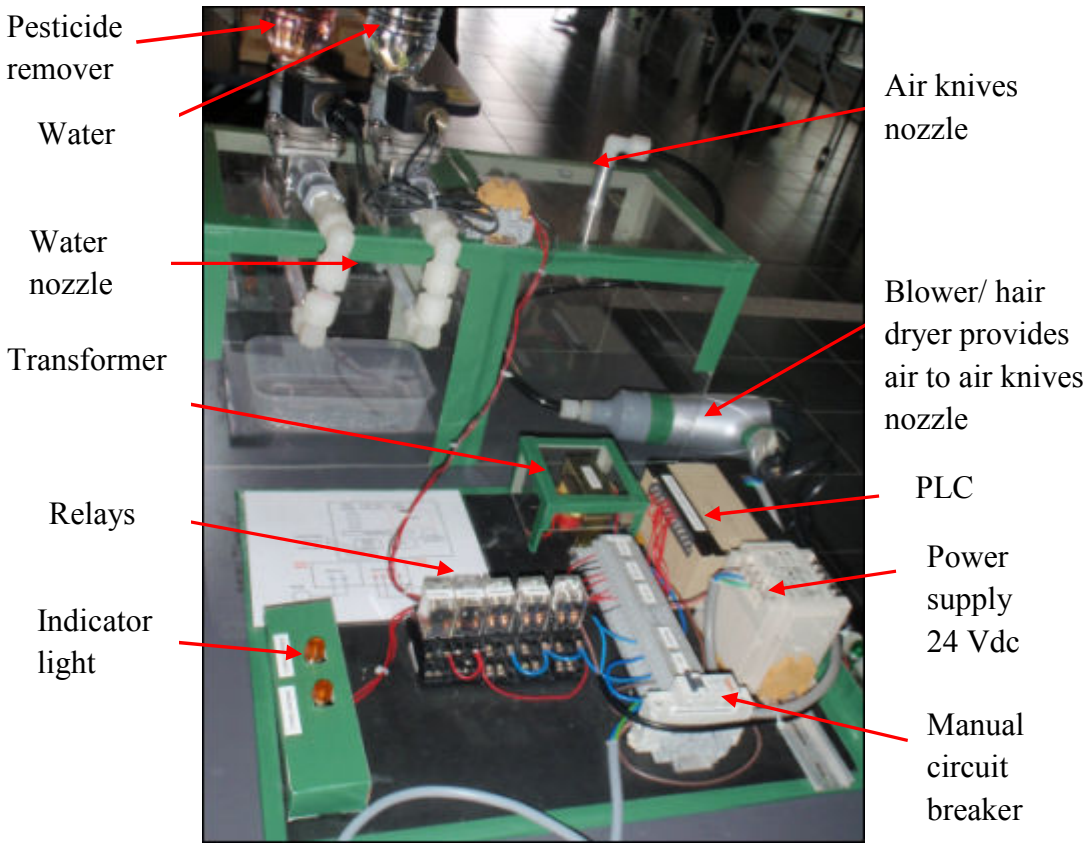


Figure 19: AKD Machine and the Controller Board

4.1.2 AKD Machine Control Board

Figure 20 below shows the design for monitor or control board for AKD machine. The control board controls the sequences of the outputs of PLC such as indicator light, solenoid valve, conveyor and blower. The IO interface between the PLC and hardware will illustrated like below.

The indicator light 1 is ON when the output Spray PR is triggered. This is to show that the solenoid valve 1 is functioned. Same goes to indicator light 2 to shows that solenoid valve 2 is functioned. The transformer is covered by Perspex as a protection to the transformer itself.

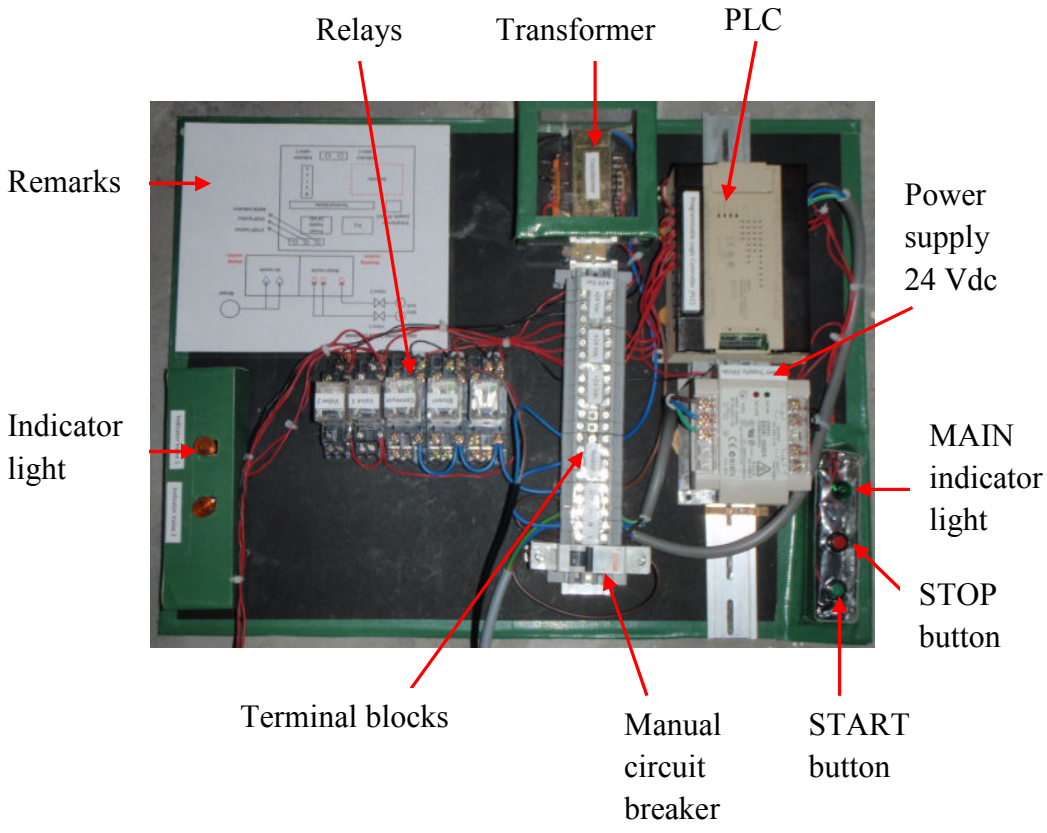


Figure 20: AKD Machine Control Board

4.1.3 Safety Feature

In the AKD machine control board, the manual circuit breaker was installed to provide safety mechanisms to the machine. This safety feature may enhance not only the safety of the plant but also the hardware equipment. The circuit breaker is an absolutely essential device in the modern world. Whenever the wiring has too much current flowing through it, these simple machines cut the power.

Figure 21 below shows the circuit breaker that being used in this AKD machine project. C60N Manual Circuit Breaker (MCB) is an all new high performance current limiting device with the ability to disconnect short circuits of up to 10kA which is the newest model in 21st century. [10]

Figure 21: C60N Mini Circuit Breaker

4.1.4 AKD Work Flow

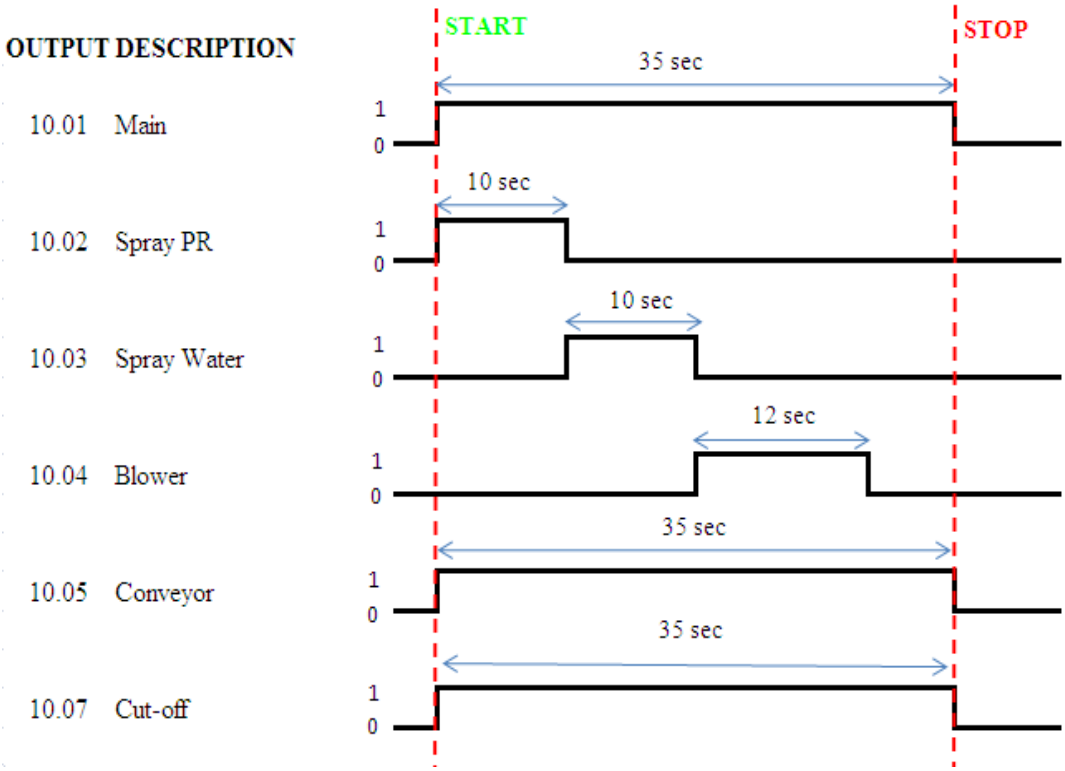


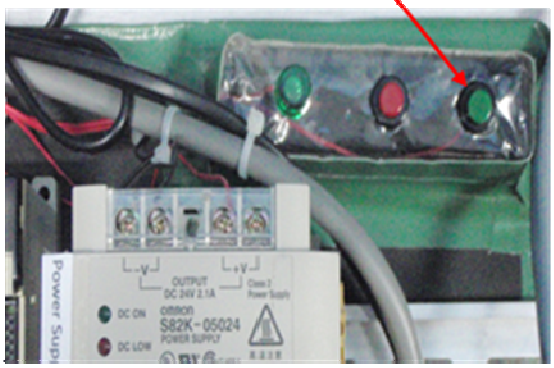
Figure 22: AKD Workflow

Figure 22 above shows the work flow of the AKD machine and the PLC output description. After the Start button is pushed, the output Main, Spray Pesticide Remover, Cut-off and Conveyor will be ON. The output Main here indicates that the indicator light will be on for the entire system until the machine stop operates. After 10 seconds, the machines will trigger the Spray Water command. Now, the AKD machine stops spray the pesticides remover. It will spray water to wash and cleans the fruit for 10 seconds.

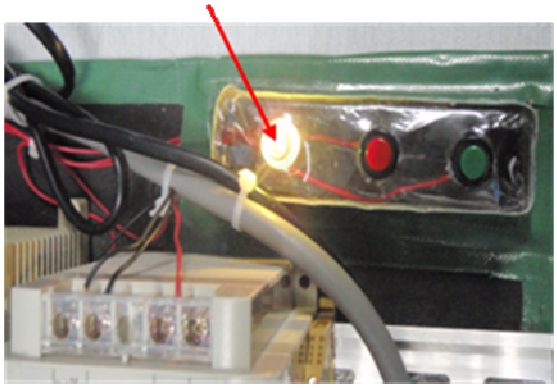
After complete 10 seconds, the Spray Water command stops and the Blower command will be trigger for 12 seconds. This is the part where air knives will be applied. After complete 12 seconds, the machine will delay for 3 seconds and automatically stops. The fruit is now clean, dry and contain non-pesticide.

For better understanding, refer Figure 23 below that shows step-by-step AKD workflow.

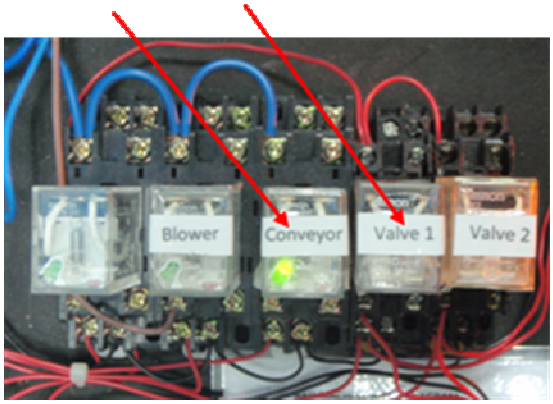
1. Push the START button

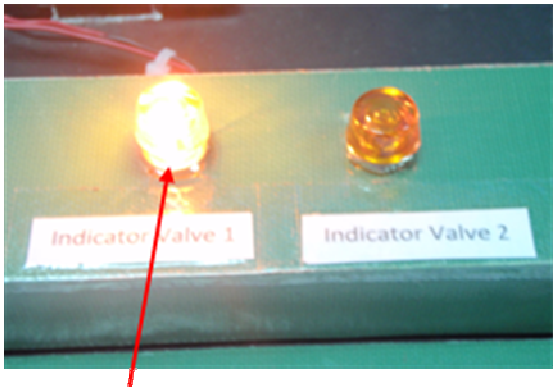


MAIN indicator light is activate.

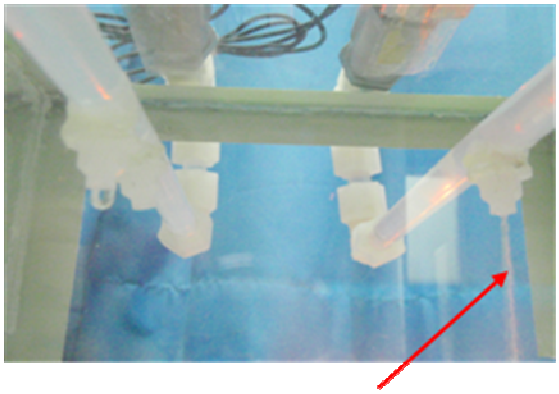


Conveyor and Valve 1 will be activate.





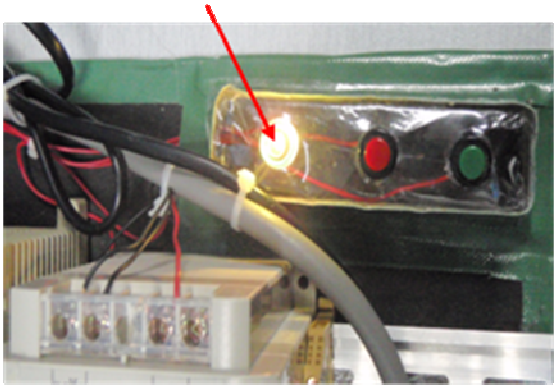
Indicator light Valve 1 is ON - this means solenoid valve 1 ON for AKD machine to spray pesticide remover.



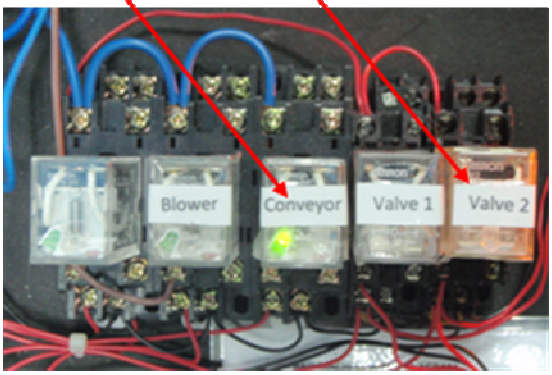
AKD machine will spray pesticide remover on the fruit.

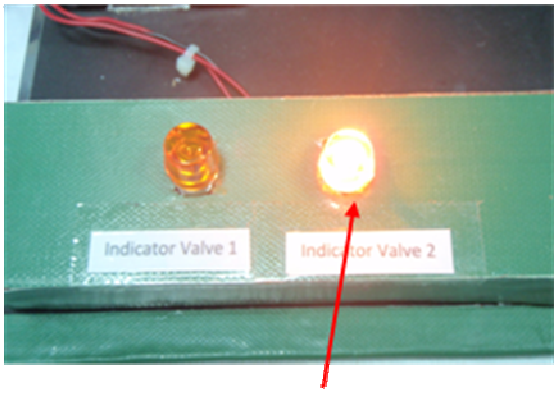
2. After 10 seconds

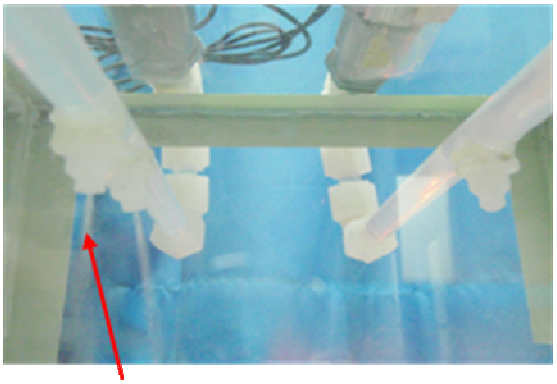
MAIN indicator light still ON.



Conveyor and Valve 2 are ON







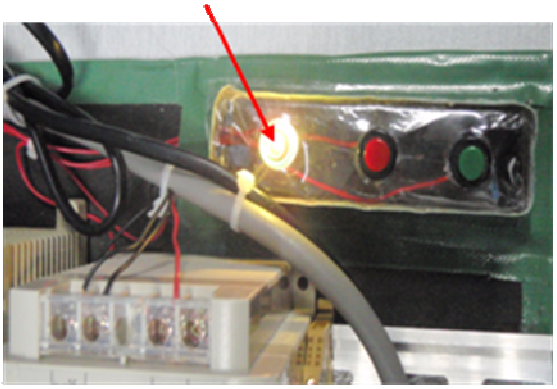
Indicator light Valve 2 is ON - this means solenoid valve 2 ON for AKD machine to spray water.

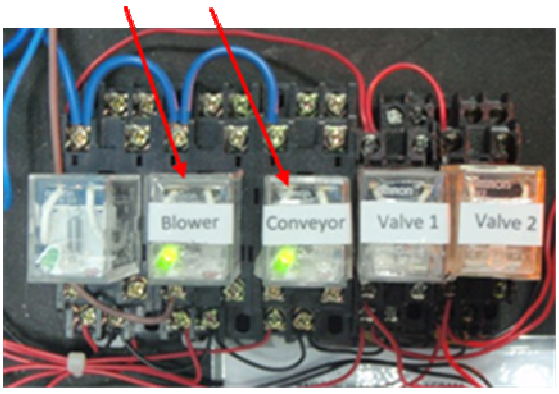
AKD machine will spray the water for rinsing purpose.

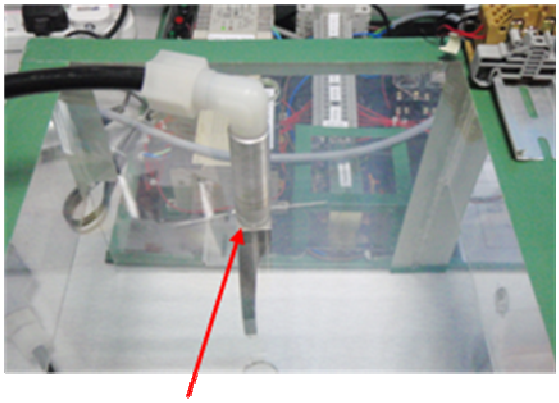
3. After 10 seconds

MAIN indicator light still ON.

Blower and Conveyor are ON.







Blower will produce sufficient air to air knives nozzle to dry the fruit.

4. After 15 seconds

AKD machine will automatically STOP. The fruit is now dry, clean and contain non-pesticide.

Figure 23: Step-by-step AKD Workflow

4.2 CX-Programmer OMRON PLC

For this project, the study is focuses on the use of OMRON CPM 1A. Proper planning and studying of the PLC system will ensure the success of the end product. CX-programmer is used for programming purpose. It provides comprehensive programming environment, testing and debugging of any automation system. Using the CX-programmer, the ladder diagram for the PLC program was constructed. On line capabilities are also available such as program uploading, downloading and multi rung editing.

4.2.1 Ladder Diagram

The software used in the design of the ladder diagram in CX-Programmer version 3.1. The ladder diagram was developed based on the flow chart created. Once the simulation with the PLC training kit is completed, the ladder diagram is loaded into the OMRON PLC CPM 1A with cable RS 232.

Figure 24 and Table 2 below show the ladder diagram of AKD machine and the list of input and output used for the PLC ladder diagram. Using the CX-Programmer, the ladder diagram was being constructed. The program can be further improved for future purpose. Basically, the ladder diagram attached is a working system. The PLC ladder diagram was uploaded into the CPM 1A OMRON PLC modules and tested for verification of the program.

The ladder diagram for AKD machine in Figure 24 has been developed to the following requirement:

- START command 0.01 initiates the sequence and a STOP command 0.02 to reset the sequence.

- This means that the motor will run when there is START command and the STOP command and faults are clear.

- When the Main command operates, the Indicator light will turn on as the output 10.01. It will show that the motor operated according to the commands.

- Then, the output 10.02, 10.05 and 10.07 operate as the machine will spray the pesticides remover towards the fruits. The timer has been set to 10 sec for the AKD machine to spray the pesticides remover on the fruits.

- After 10 sec, the machine will start spray water for 10 sec to the fruits. While the machine sprays the water, the Spray PR command will stop operating.

- The command normally closed (NC) for Spray PR and Blower ensure that only Spray Water commands normally open (NO) will runs during the operation.

- After 10 sec, the Spray Water and Spray PR commands will stop to allow the output 10.04 Blower operates to blow off the fruit for 12 sec.

- After all output operates, then the AKD machine will stop as STOP command 0.02 reset the sequences.

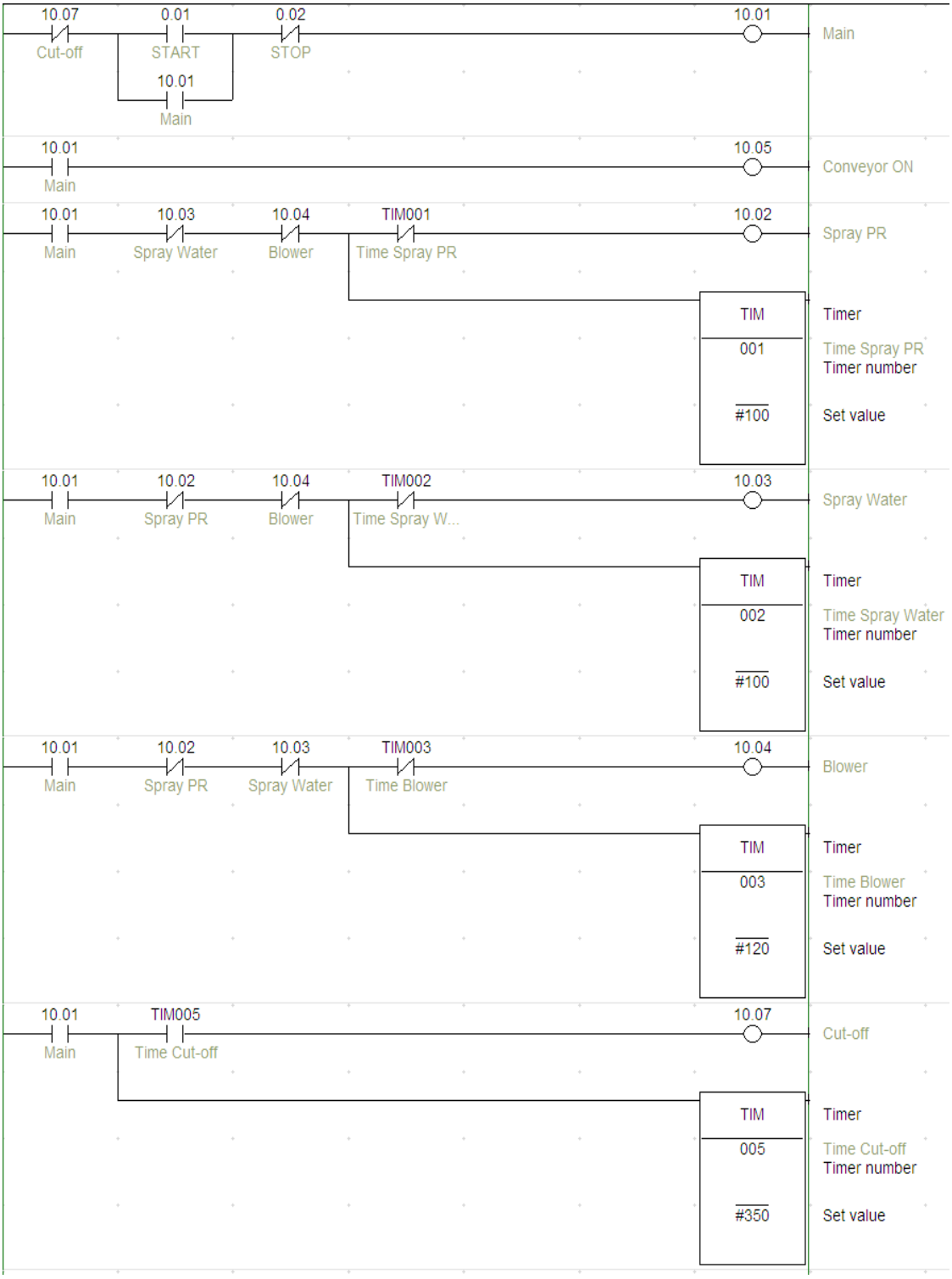


Figure 24: Ladder Diagram for AKD Machine

Table 2: List of Inputs and Output

Input	Description	Output	Description
0.01	Start Push Button	10.01	Main
0.02	Stop Push Button	10.02	Spray PR
		10.03	Spray water
		10.04	Blower
		10.05	Conveyor
		10.07	Cut-off

4.3 Pesticide Remover

4.3.1 Pesticide Remover

Fruit can pass through more than 20 pairs of hands between the farm and the consumer, adding bacteria to chemical and pesticide residue. Contaminants such as pesticides and waxes are designed to be waterproof, so while rinsing in water will remove some impurities, using a fruit and vegetable wash can remove 100 times more contaminants.

National Academy of Science (NAS) says, the real concerns are: [11]

- The cumulative effect of herbicide and insecticide toxic substances on all ages.
- This cumulative effect is serious, but especially to children since they pass through critical phases of development.
- There is an even higher level of carcinogenic sprays used in some countries that are not under the control of the ministry of agriculture.
- In addition there are various germs and parasites that exist on these fruits that we are unable to wash away.

Thus, it is very important for fruits that contain high pesticide level to be washed out first by the pesticide remover. In this project, the fruit will be washed out by a product of pesticide remover named SunSmile Fruit & Vegetable Rinse. It is naturally derived from coconut and corn, and powerfully formulated with herbal ingredients to clean gently all fruits and veggies. The primary cleansing agent is biodegradable surfactant derived from corn starch and coconut oil which is edible and does not contain harmful residue.

4.3.2 Pesticide Remover Case Study

Study by US Food and Drug Administration Pesticides Program (NTIS), 10 samples of apples were collected from supermarkets and a number of fruits which already being washed by pesticide remover product from this survey were also analyzed for pesticide residues and the results are included in this report. Table 3, Figure 25 and Figure 26 below shows the result of percentage residue reduction of fruits using three methods:

$$\text{Pesticide Residue Reduction (RR)} = 100 - \left[\frac{\text{residue of rinsed fruit}}{\text{[Residue of unrinsed fruit]}}\right] \times 100$$

Table 3: Percentage Residue Reduction [12]

Product	DDT		Methomyl	
	Parts per million	Residue Reduction	Parts per million	Residue Reduction
Unrinsed	0.5	---	0.87	---
Water only	0.1	81%	0.71	18%
Water + Fruits & Veggie Wash	0.053	90%	0.53	39%

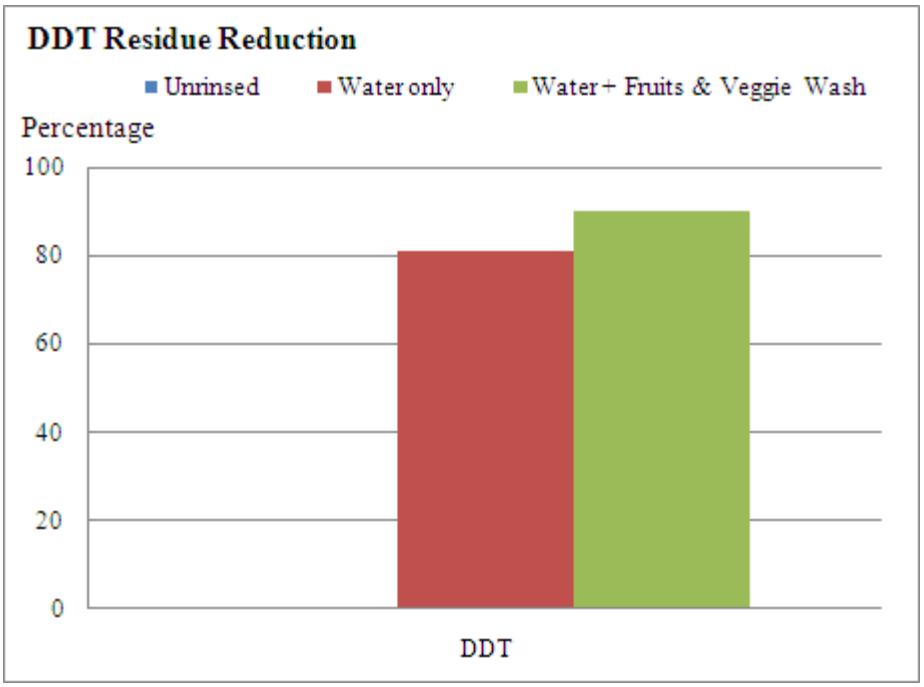


Figure 25: Percentage DDT Residue Reduction [12]

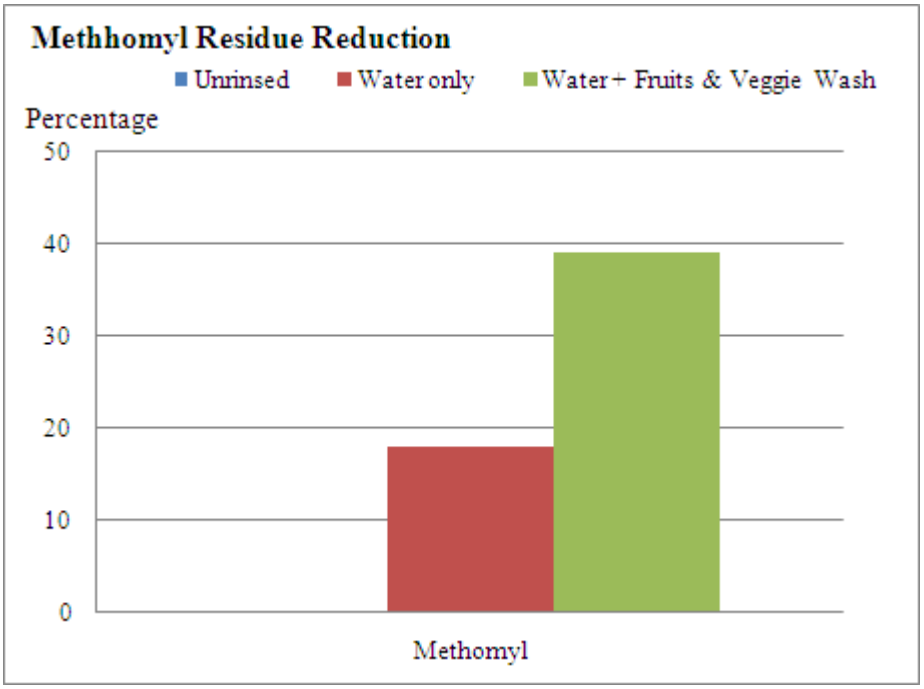


Figure 26: Percentage Methomyl Residue Reduction [12]

CHAPTER 5
CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This Air Knife Drying (AKD) Machine Application on Removing Pesticide on the Skin of Fruits using PLC as project that provides student a good learning and practical experience in working with hardware and software. It provides student with the opportunity to interfacing the devices as well as working with protocol. The construction of the prototype starts from the chassis design and implementation, hardware assembly and wiring interfacing between input/output devices with PLC. The operation of AKD is controlled by the PLC through the designed ladder diagram. Changes of the ladder diagram or modification of the hardware and path were done accordingly to obtain optimum performance.

The main objectives of this project had been successfully achieved. The main contributions of this work are as follows:

- Develop a program for an Air Knife Drying system with PLC.
- Build an Air Knife Drying prototype that can be extended to dry the fruits and remove the pesticides residue on a skin of fruits.
- Interface all the main components of the project.
- Handle important tasks in proposing a project up until the completion process.

This AKD machine to remove pesticides residue on the skin of fruits hopefully can be implemented in the food industry manufacturing so that

consumer have a better choice when dealing with the organic and non-organic fruits.

5.2 Recommendations

This section presents recommendations for future improvement of this project. Although this project has achieved its objectives which include constructing the proper PLC programming and AKD machine construction, it still has a long way to go. There are a lot of aspects that can be further improved:

- Compressor can be used instead of blower for drying purpose. It will provide sufficient air pressure so the time to dry the fruits will decrease. Moreover, the performance of hair dryer as a blower in this project is poor compare to compressor. The hair dryer will easily overheat. Thus, making the life-span is shorter. In this project, hair dryer was chose because the limitation of cost as the compressor is very expensive and the size is big compare to hair dryer.

- More research about the most suitable pesticide remover is needed if this project were taken into big scale of industry. This is because SunSmile Fruits & Vegetable Rinse is suitable for home application.

- For future development, the measuring equipment can be install on the project so that the percentage residue reduction on the fruits can be calculate precisely. Thus, we can compare the results of residue reduction on the fruits with and without using the pesticides remover. In this project, the data of residue reduction are based on the research done by US Food and Drug Administration.

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[2] CG Gauden and Leible, RC: “*Air Knives for Energy Efficiency”*, Energy World, 1st ed, Vol. 1, Wiley, New York, 1998, pp. 6–10.

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[10] “WindJet Application ”, http://www.spray.com/applications, [retrieved 16 October 2010, 9.45 am]

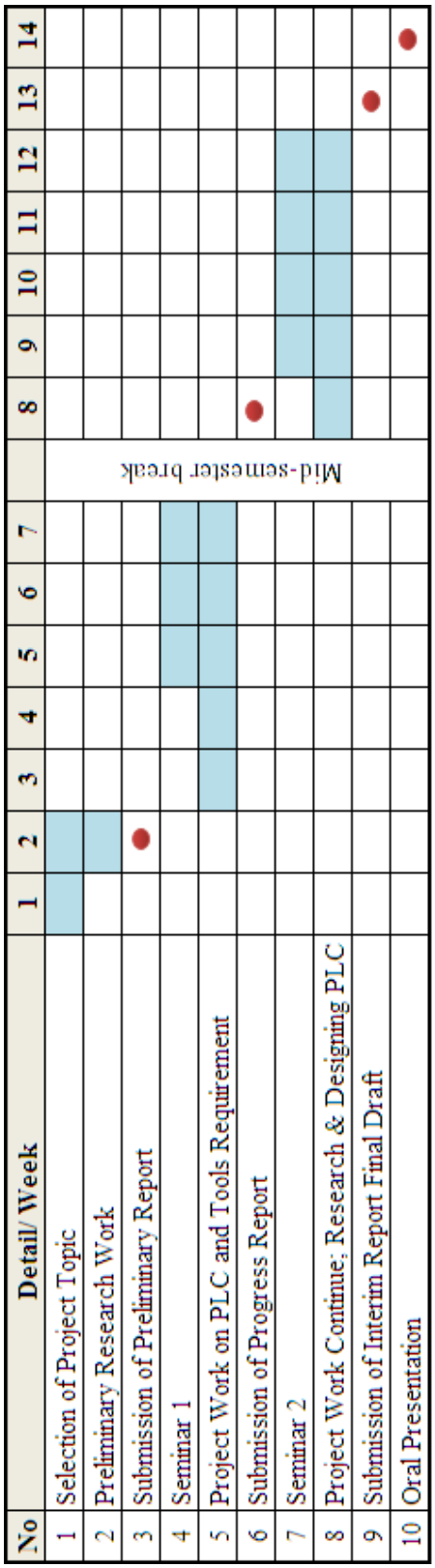
[11] “The Food and Drug Administration Program on Pesticide Residues in Food”, http://pubs.acs.org, [retrieved 14 October 2010, 5.54 pm]

[12] “FDA U.S Food and Drug Administration's”, http://www.fda.gov, [retrieved 14 October 2010, 6.15 pm]

APPENDIX

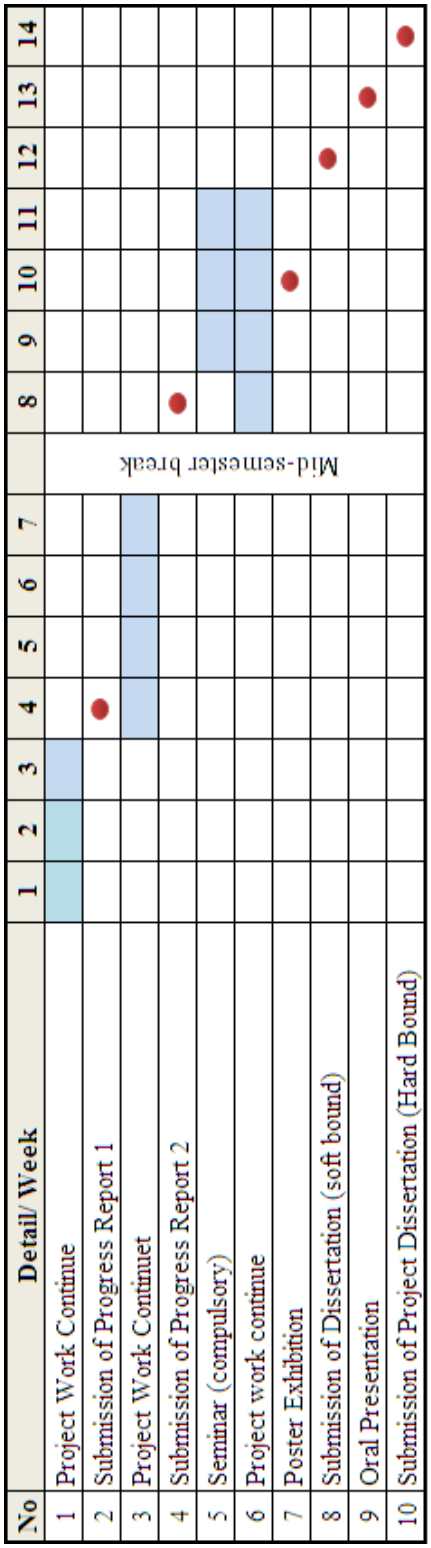
APPENDIX A

Gantt Chart for FYP I



APPENDIX B

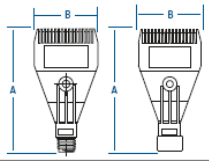
Gantt Chart for FYP II



APPENDIX C

Air Knives Specifications

Dimensions & Weights



Nozzle Type	A	B	Weight
AA727 (M)	3-9/16" (91 mm)	2" (51 mm)	4.1 oz (.12 kg)
AA727-F (F)	3-9/16" (91 mm)	2" (51 mm)	0.7 oz (.02 kg)

Air Control Nozzles

Model Type	Max. Coverage at 6" (150 mm) from nozzle	Max. Capacity	Max. Pressure	Inlet Conn NPT or BSPT	Available Materials
AA727	2-1/4" (57 mm)	43.4 scfm (1198 Nl/min)	100 psi (7 bar)	1/4 (M or F)	ABS Plastic, Aluminum, PPS, Stainless Steel
AA707	Produces a concentrated targeted pattern	45 scfm (1237 Nl/min)	125 psi (8.6 bar)	1/4 (M)	ABS Plastic, Aluminum, PPS, Stainless Steel, PVDF
UniJet® Blow-off	16-1/2" (419 mm)	61 scfm (1591 Nl/min)	100 psi (6 bar)	1/8, 1/4, 3/8 (M or F)	Brass, 303 Stainless Steel
UniJet TK	15-1/2" (349 mm)	31.1 scfm (881 Nl/min)	60 psi (4 bar)	1/8, 1/4, 3/8 (M or F)	Brass, 303 Stainless Steel
FloodJet® K	15-1/2" (349 mm)	31.1 scfm (881 Nl/min)	60 psi (4 bar)	1/8, 1/4, 3/8 (M)	Brass, 303 & 316 Stainless Steel, PVC
46760 Manifold	67-3/4" (1720 mm)	888 scfm (24480 Nl/min)	90 psi (6 bar)	3/4, 1, 1-1/4 (M)	Aluminum
39190 Manifold	16" (406 mm)	10.7 scfm (293 Nl/min)	100 psi (7 bar)	1-1/2 (M)	Nylon

WindJet® Low Flow Air Knives

Model Type	Max. Coverage at 6" (150 mm) from nozzle	Max. Capacity	Max. Pressure	Inlet Conn NPT or BSPT	Available Materials
WindJet Low Flow Air Knives	3" (76 mm)	11.1 scfm (314 Nl/min)	200 psi (13.8 bar)	1/4 (M)	Aluminum or 316 Stainless Steel
	6" (152 mm)	22.2 scfm (629 Nl/min)	200 psi (13.8 bar)	1/4 (M)	Aluminum or 316 Stainless Steel
	12" (305 mm)	44.4 scfm (1257 Nl/min)	200 psi (13.8 bar)	1/4 (M)	Aluminum or 316 Stainless Steel
	18" (457 mm)	66.6 scfm (1886 Nl/min)	200 psi (13.8 bar)	1/4 (M)	Aluminum or 316 Stainless Steel
	24" (610 mm)	88.8 scfm (2515 Nl/min)	200 psi (13.8 bar)	1/4 (M)	Aluminum or 316 Stainless Steel

APPENDIX D

S82K-05024 OMRON Power Supply Operations

OMRON

Operation

■ UNDERVOLTAGE ALARM INDICATOR AND OUTPUT FUNCTION (ALL MODELS EXCEPT S82K-24024/P24024)

If the output voltage at the output terminal drops to 75% to 90% of the rated voltage, the red indicator of the S82K (DC LOW indicator) will be lit. In the case of the 90-W, 100-W and S82K-24024T, a voltage drop alarm will be output via the relay available in the models (DC LOW output).

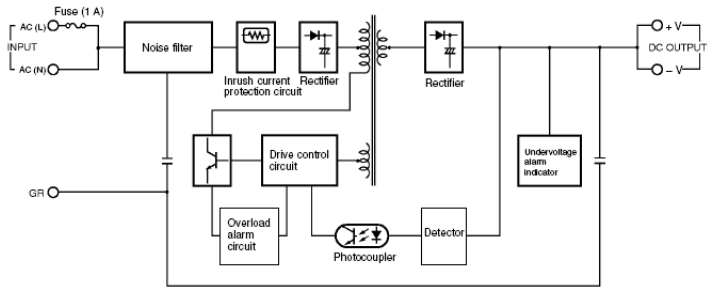
This function detects the voltage at the output terminal of the Power Supply. To check the precise output voltage, measure the voltage at the terminal of the load.

Indicator	Voltage	Operation of 90-W, 100-W, S82K-24024T's output (DC LOW output) (See Note 2.)
Green: ✱ DC ON Red: ○ DC LOW	If the voltage at the output terminal is more than 82% of the rated voltage and operation is normal, the green indicator will be lit and the red indicator will not be lit.	
Green: ✱ DC ON Red: ✱ DC LOW (See Note 1.)	If the voltage at the output terminal drops to below 82% of the rated voltage, the red indicator will be lit. (See Note 3.)	
Green: ○ DC ON Red: ○ DC LOW	If the voltage at the output terminal is 0 V, both the green and red indicators will not be lit.	

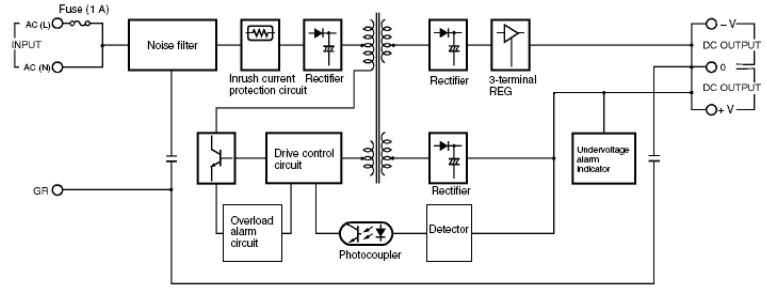
Note: 1. The more the voltage at the output terminal drops, the darker both the green and red indicators will be.
2. The relay contacts have a capacity of 0.1 A at 24 VDC.
3. The red indicator will actually first light at a voltage between 75% and 90% of the rated voltage.

■ BLOCK DIAGRAMS

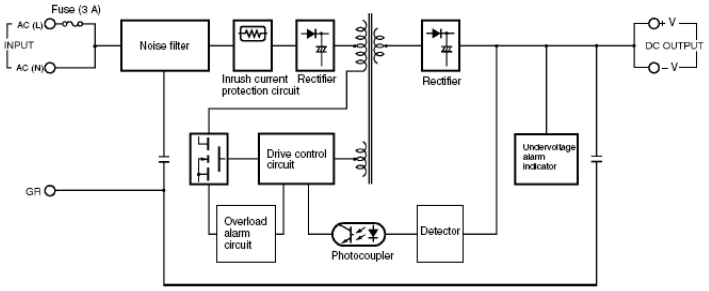
S82K-003□□ (3 W)
S82K-007□□ (7.5 W, Single Output)



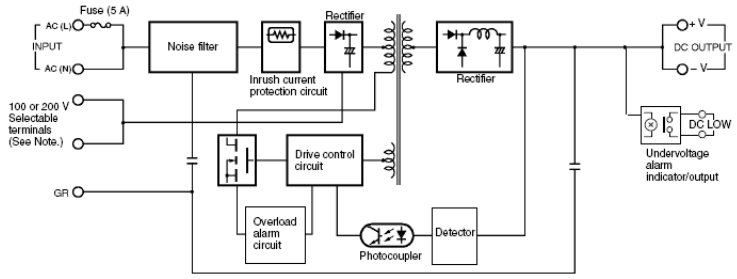
S82K-007□□ (7.5 W, Dual Outputs)



S82K-015□□ (15 W)
S82K-030□□ (30 W)
S82K-05024 (50 W)

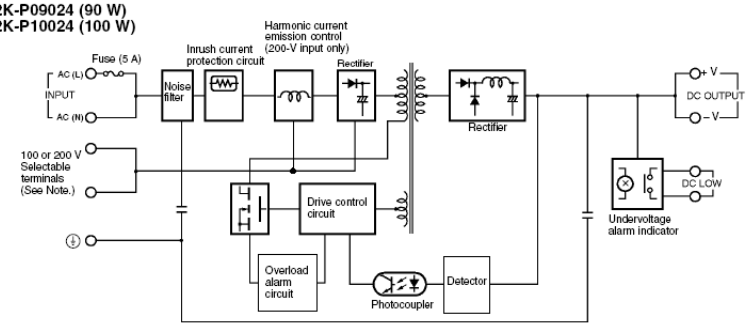


S82K-09024 (90 W)
S82K-10024 (100 W)



Note: Use the short bar to short-circuit terminals 7 and 8 to select 100 to 120 VAC and remove the short bar to select 200 to 240 VAC.

S82K-P09024 (90 W)
S82K-P10024 (100 W)



Note: Use the short bar to short-circuit terminals 7 and 8 to select 100 to 120 VAC and remove the short bar to select 200 to 240 VAC.

APPENDIX E

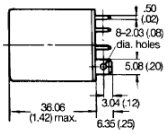
LY2 OMRON Relays Dimensions

Dimensions

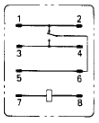
Unit: mm (inch)

■ **RELAYS**

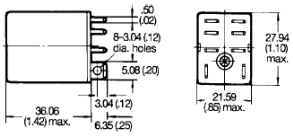
LY1



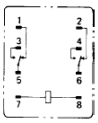
Terminal arrangement (Bottom view)



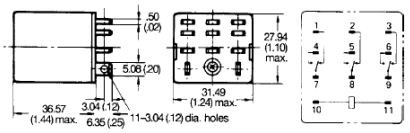
LY2



Terminal arrangement (Bottom view)

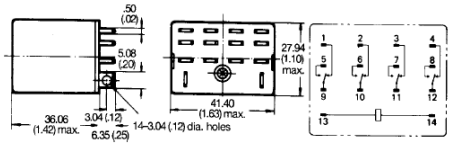


LY3



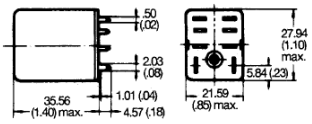
Terminal arrangement (Bottom view)

LY4



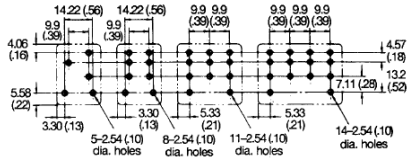
Terminal arrangement (Bottom view)

LY1-0, LY2-0, LY3-0, LY4-0



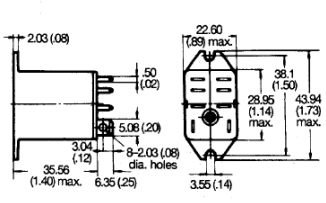
Note: The above drawing shows LY2-0. With LY1-0, dimension "*" should read as 6.35 (.25).

Mounting holes for LY1-0, LY2-0, LY3-0, LY4-0 (Bottom view)

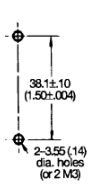


SPDT DPDT 3PDT 4PDT

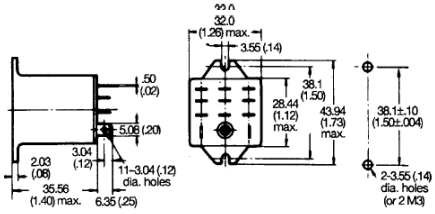
LY1F, LY2F



Mounting holes



LY3F



Mounting holes

Note: The above drawing shows LY1F. With LY2F, dimension "*" should read as eight 3.05 mm (0.12 in) dia. holes.

APPENDIX F

Produce with Highest Levels of Pesticide Residues

Fruit/Vegetable	Nutrients	Substitutions (approx. nutritional equivalent)
Strawberries	Vitamin C	Blackberries, raspberries, blueberries, kiwi, orange, cantaloupe
Bell Peppers		
...Green	Vitamin C	Green peas, broccoli, romaine lettuce
...Red	Vitamins A, C	Carrots, broccoli, Brussels sprouts, tomatoes, asparagus, romaine lettuce
Spinach	Vitamins A, C, Folic acid	Broccoli, Brussels sprouts, asparagus, romaine lettuce
Cherries (US)	Vitamin C	Grapefruit, blueberries, raspberries, cantaloupe, oranges
Peaches	Vitamins A, C	Nectarines, canned peaches, cantaloupe (US), tangerine, grapefruit, watermelon
Cantaloupe (Mexico)	Vitamins A, C, Potassium	Watermelon, cantaloupe (US)
Celery	Carotenoids	Carrots, broccoli, radishes, romaine lettuce
Apples	Vitamins A, C, Potassium	Oranges, nectarines, bananas, kiwis, watermelon, tangerines
Apricots	Vitamins A, C, Potassium	Nectarines, cantaloupe (US), watermelon, tangerines, grapefruit
Green Beans	Carotenoids	Green peas, broccoli, cauliflower, Brussels sprouts, asparagus
Grapes (Chile)	Vitamin C, Potassium	Grapes (US), in season
Cucumbers	Vitamin A, Potassium	Carrots, romaine lettuce, broccoli, radishes
Pears	Vitamins A, C, Folic acid	Canned pears, canned peaches, oranges, nectarines
Winter Squash (US)	Vitamins A, C. Folic acid, Potassium	Winter squash (Honduras, Mexico), sweet potatoes (US)
Potatoes (US)	Vitamin C, Folic acid	Sweet potatoes (US), carrots, winter squash (Honduras, Mexico)

Source : Environmental Working Group, using data from the U.S. Food and Drug Administrati

APPENDIX G

Produce with the Least Levels of Pesticide Residues

Avocados - Vitamins A, C, Folic acid	Grapes (US, Mexico) - Vitamin C
Corn - Carotenoids, Folic acid	Bananas - Potassium, vitamin C
Onions - Trace vitamins, carotenoids	Plums - Vitamin C
Sweet Potatoes - Potassium, vitamins A, C	Green Onions - Vitamins A, C
Cauliflower - Vitamin C, Potassium	Watermelon - Potassium, vitamins A, C
Brussels Sprouts - Folic acid, vitamins A, C	Broccoli - Potassium, vitamins A, C

Source : Environmental Working Group, using data from the U.S. Food and Drug Administration