AMATROL PLC
GUIDE

Inventory	Inspection	Distribution
Station 1	Station 2	Station 3

CHAP 1 - INTRO

1.1   Introduction

The "Amatrol Tabletop Mechatronics System" is a PLC-controlled automation system designed for academic use and student learning. PLC stands for programmable logic control. We will refer to this system with a shorter name - the "Amatrol PLC" system.

This is an automated system that is designed and programmed to inspect and sort pucks based on material type, size, and color. This system is composed of 3 different modules outlined below and an optional 4th system - a robot arm that pulls components from the storage chutes and re-loads them into the feeding tube.

1.   Inventory Station (87-TMS1)
2.   Inspection (or Gauging) Station (87-TMS2)
3.   Distribution Station (87-TMS3)
4.   Servo Robot (Pegasus) Station

The system is controlled by Allen-Bradley PLC (programmable logic control) controllers.

The system teaches students about industrial automation and PLC by demonstrating a real-world automated manufacturing system. Students will learn to operate the system. Students may also encounter hardware problems, requiring them to debug and problem-solve hardware. Students may also learn how the system is programmed using LADDER LOGIC programming. The system will also help students understand the basics of sensor input, control, processing, and actuators.

1.2   Intro to PLC's

Programmable logic controllers are computers that are designed to work in industrial environment and to provide automated control of machinery. They are typically used in manufacturing but also in infrastructural sectors as well (e.g., water resources). Modern manufacturing is a rapidly-advancing area, increasingly utilizing high technology like robotics and automation. These equipment are often controlled using PLC technology. PLC's are used to sense and control industrial machinery. Common PLC brands are Allen Bradley (in US) and Siemens (Europe).

PLC's are typically programmed using LADDER LOGIC. Ladder logic is a graphical programming language in the shape of a ladder. The graphical diagram is based on circuit diagrams of relay logic hardware. The term "ladder" is used because of the resemblance to a ladder. There are 2 vertical rails with a series of horizontal rungs between them. Often one thinks of the left rail as the HOT side of an electric circuit, and the right side as GROUND.

Such programming is useful for sequential control of a process or manufacturing operation.

A given rung may be seen as a set of connections between logical checkers (contacts) and actuators (coils). The logical checkers are often configured to operate as logic gates (AND or OR). If a path can be traced from the left side to the right side of the rung (usually the coil, lamp, or actuator), then the rung is TRUE and the output coil is energized.

1.3   Safety

The most important safety item is

NEVER REACH INTO THE MACHINE WHILE IT IS RUNNING!
(First turn it off! It is also possible to use a pen or short stick to dislodge something)

The Amatrol PLC system involves numerous moving parts driven by electric motors and air actuators. It is very easy to get a finger or hand caught in the moving parts of this machine. If this happens a person can become seriously injured. There are many places in this machine where fingers, hands, clothes, or jewelry can get caught (sometimes called PINCH POINTS). A particularly dangerous area is the ROTARY TABLE.

No loose clothing (long sleeves, dangling sleeves) that can get caught in the machine
Remove any jewelry (dangling necklaces, earrings, watches, rings, bracelets, etc.).
Tie back long hair into a bun.
Eye protection is also recommended.
DO NOT reach into the machine while it runs. Turn it off first.

If the machine malfunctions (for instance pucks fall out or are stacked on top of each other) DO NOT REACH INTO THE OPERATING MACHINE! First TURN OFF the machine before reaching for the pucks.

## *******BASIC OPERATION *******

CHAP 2 - BASIC OPERATION

In this chapter we will look at how to run or operate the Amatrol PLC system, including the sequence of steps needed to start up the system

2.1   Start Up

Here are the steps for starting up the Amatrol PLC system. Note that station 1 is on the far left, station 2 is in the middle, and station 3 is on the right.

1. Verify the system is plugged in.
2. Verify it is safe to turn on the system (no foreign objects, no people in the work area)

3. Plug in the quick connect compressed air line.
4. Adjust the air pressure regulator to **50 to 60 psi**.
5. Verify all toggle (3-position) switches on all 3 stations are AWAY from you.
6. Turn ON station 3 using the black rocker switch.
7. Watch the indicator lights on the PLC for station 3 & wait for the PLC's green RUN light to turn on.
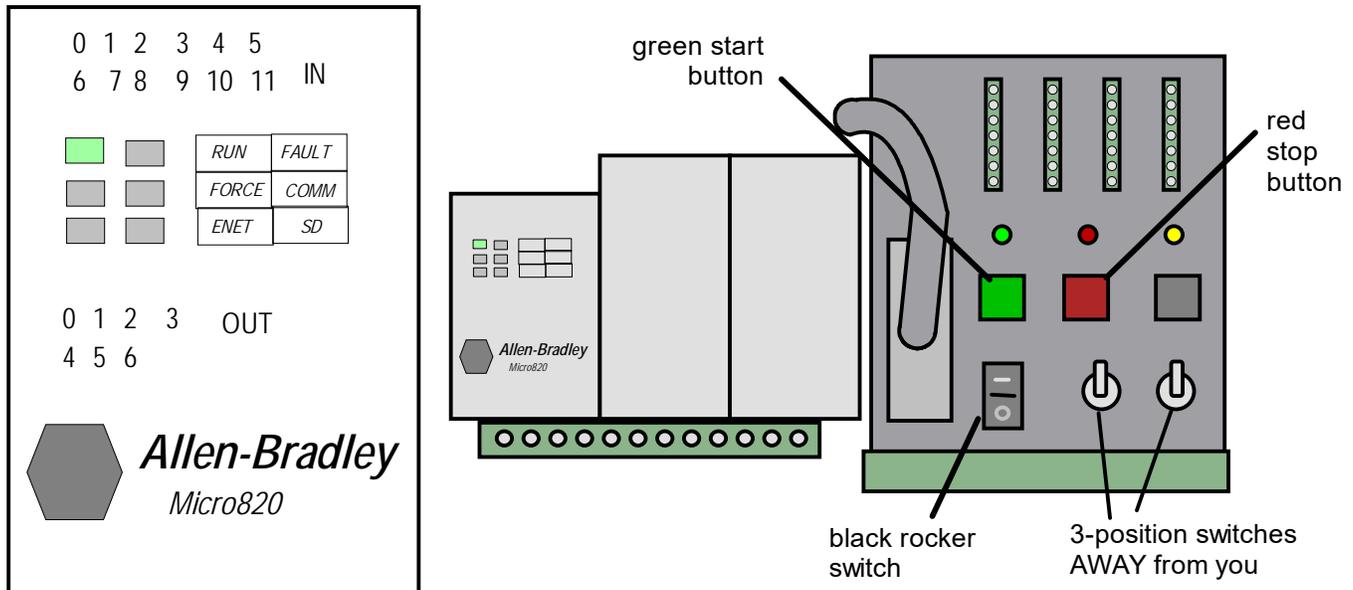
8. Turn ON station 2 just as you did with station 3.
9. Turn ON station 1 just as you did with station 3.
10. Return to station 3 (distribution) and press the GREEN BUTTON. The lights on the PLC will change.

    The lights for the sensors will light up.
    Test that the station is ON by breaking the part-presence beam (the conveyor will start)
    Then break the "chute-full" beam to stop the conveyor.

11. Now press the GREEN BUTTON for station 2.

    The rotary table will begin a homing sequence. Allow the homing sequence to complete.

12. Now press the GREEN BUTTON for station 1. This will begin the process.

KEEP YOUR FINGER OVER THE RED BUTTON OF STATION 1
IF ANYTHING GOES WRONG (eg - puck gets stuck), PUSH THE BUTTON!
**Do NOT reach into the machine for any reason at all!**

The system will continue to run until one of the chutes is full, or if the feeding tube is empty. Re-load the feeding tube and press the GREEN BUTTON FOR STATION 1 to re-start the process.

2.2   Errors

Sometimes a puck will get stuck or fall, or otherwise the machine will not operate as intended. If this happens perform this sequence of steps.

1. Stop the station 1 FIRST (right away) by pressing the RED button.
2. Then shut down the remaining stations if needed.
3. Address the issue or debug the hardware.
4. Restart the system from scratch as written in this document.

2-axis pick & place

Powered
parts
feeder
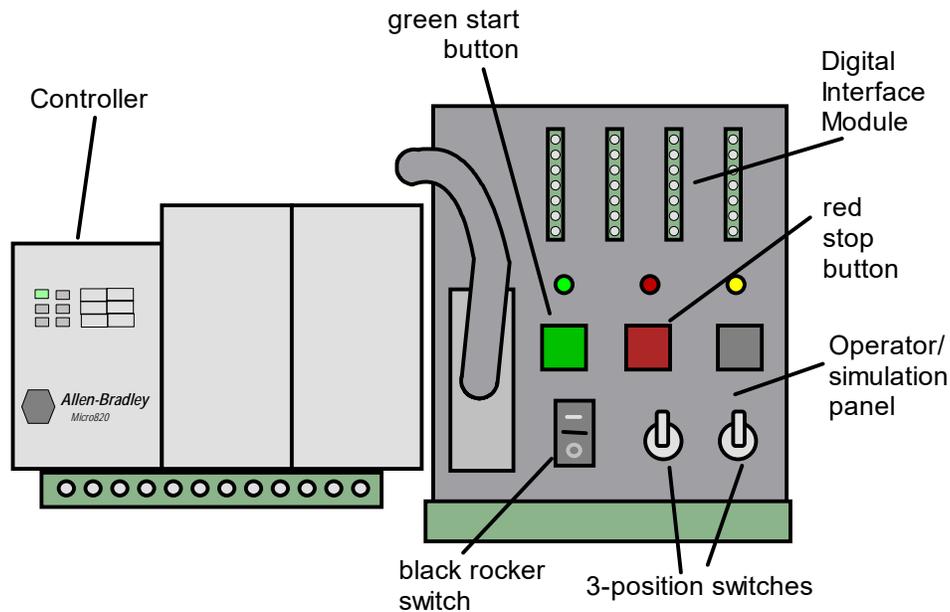
Electro-pneumatic
valve manifold
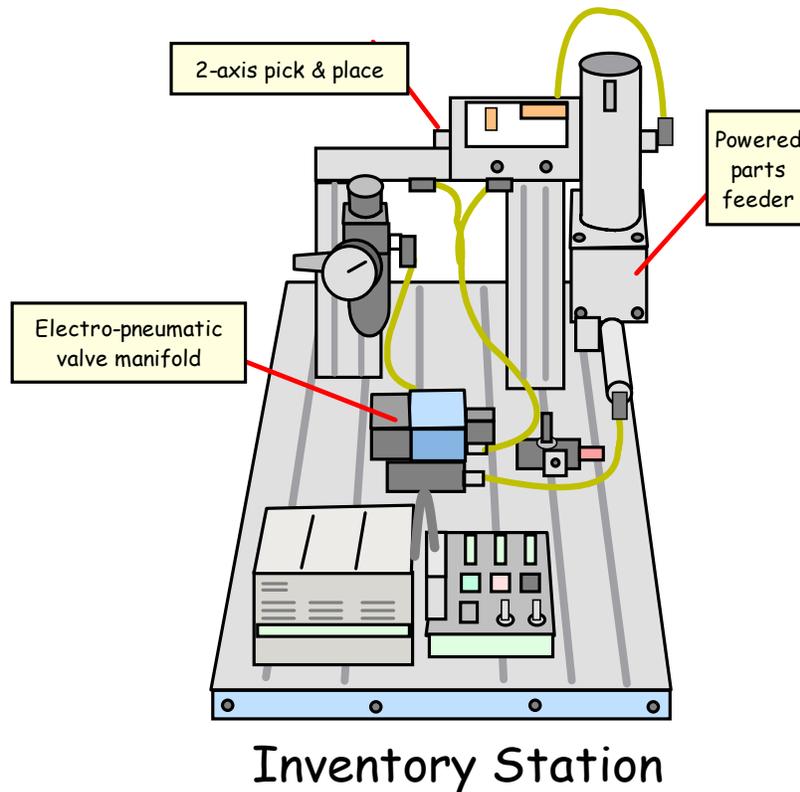
Inventory Station

CHAP 3 - INVENTORY STATION

The INVENTORY STATION primarily stores parts that a ready to be processed and moves the parts to the inspection area. The POWERED PARTS FEEDER has a gravity parts feeder (a vertical "feeder" tube) and an air cylinder at the base that pushes parts to the pick-up location. A second air cylinder mounted to a linear travel rail picks up the part and places it onto a rotary table in the inspection station.

3.1   Inventory Station Components

CONTROLLER, OPERATOR/SIMULATION PANEL, DIGITAL INTERFACE MODULE

Each station has the controller (the PLC), an operator/simulation panel, and digital interface module. The simulation panel allows a mode where a user can use the PLC in a simulation mode. The digital interface module has a set of screw terminals which are the interface between the PLC and the automated components. Each of the 3 stations has these components.

ELECTRO-PNEUMATIC VALVE MANIFOLD

"Shop air" (a source of air pressure) is routed to this component through a quick connect. This system is responsible for routing pressurized air to the air actuators (air cylinders). The MANIFOLD directs the high pressure air to the different control valves as needed. This system has 3-stations having two single-acting, and 2 position DCV's (directional control valves) equipped with manual overrides. The PLC controls the DCV's by commanding electricity to energize the solenoid coils. The DCV's control the air cylinders by determining which half of the air cylinder receives the high pressure air. This determines whether the air cylinder extends or retracts.

This system also has a VENTURI to produce a VACUUM from flowing air. Air blowing over a venturi produces vacuum via the VENTURI EFFECT. The vacuum is used as a means for the pick-and-place manipulator to pick up parts. There is also a VACUUM SENSOR that tells the system if the pick up manipulator does not have a part available. This works because vacuum will be lost if this manipulator tries to pick up a part and there is none there.

POWERED PARTS FEEDER

This system has 2 main components: (1) a gravity parts feeder (a vertical "feeder" tube) and (2) a FEEDER AIR CYLINDER that pushes parts to a pick up location. The gravity feeder is a simple vertical tube that stores parts that are ready to be processed. The tube has a micro-switch sensor that senses when it is FULL. This information is needed when using the Pegasus robot arm to re-load the feeder. If the PLC senses a full feeder, it will not command the robot arm to place parts in the feeder. The FEEDER AIR CYLINDER at the base pushes parts to a pick up location.

2-AXIS PICK-AND-PLACE MANIPULATOR

A black vertically-mounted air cylinder is mounted to a 2nd transverse-mounted twin-bore cylinder which provides side to side movement. This 2-axis system drops down, grabs a part, pulls back up (retracts), translates sideways (the twin-bore cylinder extends), drops down again, and finally releases the part onto the rotating platform. The twin-bore cylinder is a cylinder with double bores controlled by solenoid-operated DCV's (directional control valves). The gripper uses vacuum to pick up the parts. If no part is present, the rubber seal gripper cannot seal against the grooved base and vacuum will be lost. The loss of vacuum is sensed and sent back to the PLC.

The transverse actuator (dual bore) has LIMIT SENSORS on it to sense when the air cylinder is actuated out or retracted.
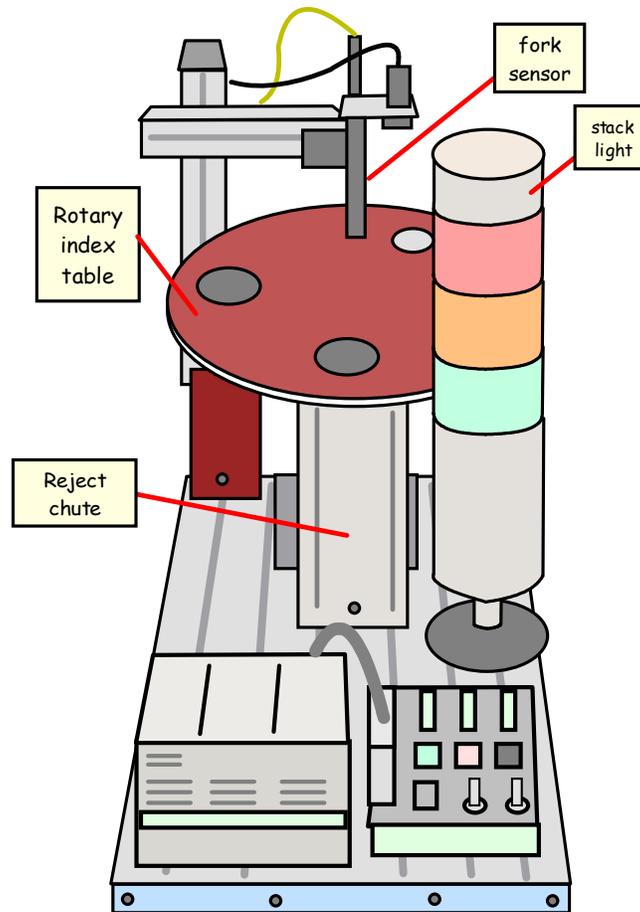
3.2 Air Manifold

There are manual overrides on the valves. Use a small screwdriver to push them
There is an additional unused port on the back side in case you wish to add another air powered actuator.

Back valve - for vacuum
Front valve - to push part out to receiving area

Inspection station

CHAP 4 - INSPECTION STATION

The INSPECTION STATION will perform some basic inspection steps.

First the puck is placed onto the rotary index table, where a PARTS PRESENCE SENSOR senses it. The table rotates clockwise to move the part to a FORK SENSOR which checks the puck's height. If it is rejected, the platform rotates anti-clockwise to deliver the part to the reject bin. If the height is accepted, the platform rotates clockwise to deliver the part to the next station.

4.1   Inspection Station Components

This station also has a PLC, operator/simulation panel, and interface module.

ROTARY TABLE

The rotary table is used to move parts to different locations: the fork sensor, the reject chute, or the conveyor system of Station 3. It is controlled with stepper motors whose controller resides under the reject chute. The rotary table has a reflector on it. This is used in conjunction with a rotary table homing sensor, a photo-electric sensor that is looking for a reflection of light. During the homing process the table will turn slowly until the reflector is underneath the beam emitter. By doing this, the PLC can know the position of the rotary table.

PART PRESENCE SENSOR

The part is placed on the rotaty table over a CAPACITIVE sensor. This electronic device senses the presence of a solid (or liquid) object without physical contact. These sensors emit an electric field from the sensing end of the sensor. An object placed in this field will disrupt the electric field. This disruption is sensed and the signal is sent to the controller. If an object is sensed, the PLC will cause the system to proceed.

FORK SENSOR

Once an object is sensed, the rotary table turns clockwise to move the part to the FORK SENSOR. The fork sensor uses a through-beam photoelectric sensor used as a HEIGHT SENSOR. An overly high part blocks the beam, and the part is rejected. An acceptable part does not block the beam, and it is accepted. If accepted the rotary tables turns CW and drops the puck onto the conveyor (Station 3).

REJECT CHUTE

If the part is rejected, the rotary table turns CCW to move the part to the reject chute. is where rejected parts are stored. It uses a photo-electric retro-reflective sensor (has a turquoise cap) to indicate when the chute is full. If full, the top puck will block the beam, and the signal sent to the PLC. The PLC will command the station operation to stop until the chute is emptied.

STACK LIGHT

The stack light indicates the status of the inspection station.

GREEN	Station is ready for a part
YELLOW	Station is processing a part
RED	Reject chute is full
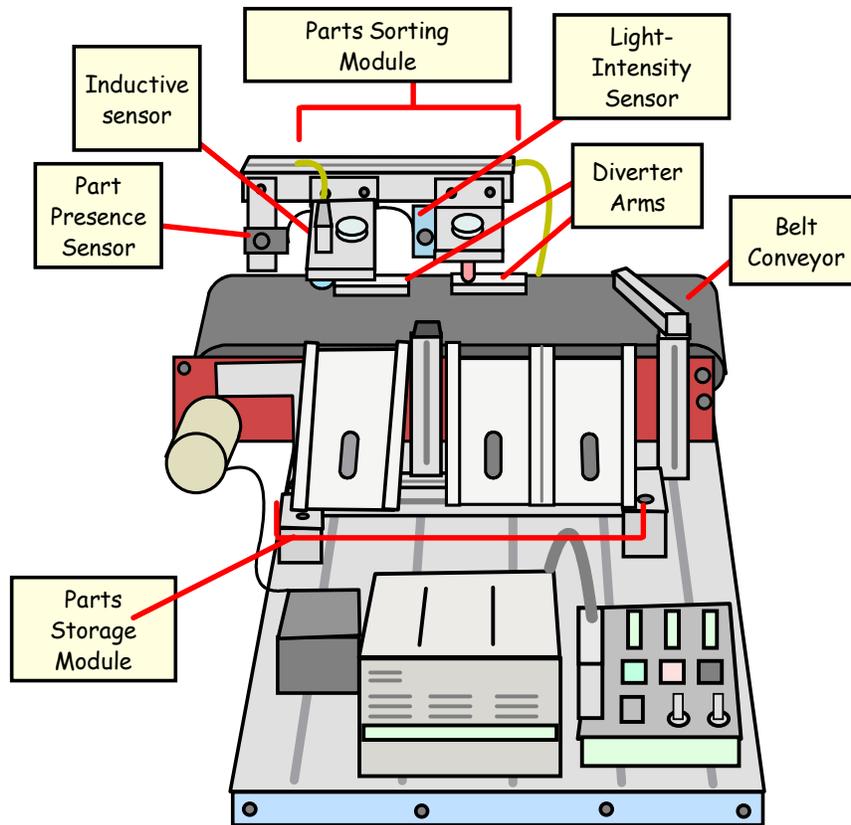
Distribution Station

CHAP 5 - DISTRIBUTION STATION

The DISTRIBUTION STATION will separate the pucks based on their material type and color. It has a conveyor belt to move parts through PART SORTING MODULE, which senses the part type. Then the conveyer moves the parts until diverter arms divert parts into the appropriate storage chutes.

5.1   Distribution Station Components

BELT CONVEYOR

The belt conveyor system moves parts through a part sorting module and onto the storage chutes. A relay is used to control the switching on and off of the conveyor. The conveyor will turn on when a part is sensed at the start. A photo-electric part presence sensor is used to detect when a part has been placed on the start

point of the conveyor (the beam is broken). This signals the conveyor to start. Once started, the conveyor moves the part to the PARTS SORTING MODULE.

PARTS STORAGE MODULE

The parts storage module will sense whether the part is metallic and the lightness of the part using the following sensors:

INDUCTIVE SENSOR - senses metal
LIGHT INTENSITY SENSOR - so the black reflects different light intensity from white

An inductive sensor at the start of the conveyor system checks for metallic pucks. An inductive sensor produces a magnetic field (usually via an electro-magnet - a magnet produced by passing electric current through a coil of wire). Metallic objects placed in the field will disrupt the field based on FARADAY'S LAW OF INDUCTION. If a metallic part is sensed the FIRST DIVERTER ARM will divert the aluminum parts into the first storage chute.

The LIGHT INTENSITY sensor senses whether the part is very dark (black) or very light (white). If a BLACK part is sensed the SECOND diverter arm is extended to divert the black parts into the 2nd chute. A white part will cause no diverter arms to actuate, and the white parts will fall into the last (3rd) chute.

CHUTE FULL SENSOR

Micro-switches in chutes sense presence of pucks in chute.
A through-beam photoelectric sensor senses if the chutes are full. This is a single sensor for all 3 chutes. So if any chute is full, the beam is broken.

CHAP 6 - PEGASUS ROBOT

The Pegasus is a **5-axis** robot arm. This robot arm is programmed to pull pucks from the storage chutes and re-load them into the feeding tower. When using this option, you are able to make the system fully automated because a user no longer needs to manually load the feeding tower.

The robot controller is housed under the table and appears like a tower computer. There are multiple LED lights, electrical wires, and a large red e-stop button.

The Pegasus robot is controlled with the local computer connected to the Amatrol PLC system. The computer must be on and the robot software must be running.

6.1   Start Up

The Pegasus robot is powered up separately from the other 3 systems.

1. Plug in computer via USB
2. Turn on robot controller (black rocker switch in front). Error LED (red) will light.
3. Click on "CONTROLLER" (this is the Pegasus software). Error light should turn off.
4. In the robot software, press the ENABLE button.
5. Ensure the robot is in a safe position to HOME.
       - the arm is rotated in line with the traverse linear rail
       - the robot elbow will suddenly BEND in the homing procedure (keep that in mind).
6. In the robot software, press HOME. Allow the robot to home for a few minutes.
7. (Note - whenever you restart the Pegasus robot, you must re-home it)

6.2   Jogging Robot

You can now use the software to jog the robot and its "TRAVERSE" by pressing the arrows on the image.

Note is you jog the traverse to the hardware limit, the system will sense an over-current condition and shut down the robot. If this happens, reset and re-enable the robot.
x
x
  1.

6.3   Robot Simulator

The Pegasus software includes a graphical simulator.
It also includes a virtual teach pendant.

   Robot (menu) > [x] Interface with robot simulation software

If this is un-checked, the software will control the Pegasus HARDWARE.

6.4   Robot Programs

You can write programs or run pre-written programs.

To run a pre-written program, open the program and then RUN it.

Note is you jog the traverse to the hardware limit, the system will sense an over-current condition and shut down.

6.5   Modifying Program

Job robot > teach point

******* LADDER LOGIC *******

CHAP 7 - LADDER LOGIC

PLC's are normally programmed using LADDER LOGIC. This is a graphical programming language that has its origins in relay circuitry. Ladder logic programs are configured with 2 rails that could represent power rails like power and ground. The power rail is the LEFT rail and ground is the RIGHT rail. Ladder logic follows the sequence of left to right, and top down. Each row of the ladder is called a RUNG.

The programmer sets up a set of discrete elements that represent circuit elements like switches. Those switches, for instance, can be NORMALLY OPEN (NO) or NORMALLY CLOSED (NC). Depending on the configuration of the switches and their state (are they being pushed or not), then electricity MAY or MAY not flow through the output "COIL" (often this is a light or motor) and to the right rung.

With switches, FALSE means not being pushed and TRUE means they are being pushed.

7.1   Amatrol System Programs

The Amatrol System programs are saved onto micro-SD cards and they can be reloaded onto the PLC's if necessary. The Allen Bradley PLC's have a micro-SD card slot on the side. Note you will likely have to remove the data cable to access the card slot.

New Allen Bradley PLC ladder logic programs may be written as well. This is done using the CONNECTED COMPONENTS WORKBENCH Allen Bradley software.

(HOW DO YOU PUSH THOSE PROGRAMS ONTO THE PLC?)

7.2   LOGIC

Often ladder logic programs are configured to follow logic gates. The main 3 logic gates are: AND, OR, and NOT.

******* REFERENCE *******

CHAP 8 - REFERENCE

The system, like any other hardware system, will sometimes run into problems. In addition, there are some small maintenance tasks required.

8.1   System Repair

When the system malfunctions, most of the time the problem is with a SENSOR. Often a sensor must be adjusted or something like that.

8.2   System Maintenance

In general there is very little maintenance required on the Amatrol PLC system.

STORAGE CHUTES

Add PLEDGE or WAX to the chutes to ensure the pucks slide easily.

8.3   System Information

Purchase: July 2020
Cost: $58k
Vendor: Klein Tools (Joe Ray)

<div style="background-color: yellow; text-align:center;">

******* ALL FORMATS *******

</div>

CHAP 9 - ALL FORMATS

ct_text1 - Interesting text goes **here**.
   ct_text2
       ct_text3
           ct_text4
                   ct_text5

           X
           X
   1.   Renumbers after 1.1
   2.   YES!

9.2   Section 1.1

9.2.1 - Section 1.1.1

This is ct text 2.

```
// ctz_programg
   // ctZ_programg2
```

9.3   Section 1.1

ct_text1 - Interesting text goes **here**.
   ct_text2
      ct_text3
         ct_text4
         ct_text5