Integrated Manufacturing Systems Troubleshooting (IMST) – Level 1

INSTRUCTOR DAY BY DAY

Instructor's Day by Day: 40 to 48 Contact Hours

Duration	Instructor Activities	Student Activities
N/A	**Instructor Note:** Homework: Significant in the beginning of the course. At the end of the course, mostly labs on troubleshooting the integrated systems.	N/A
N/A	**Instructor Note:** This course is an introduction to Integrated Manufacturing Systems and to the related technology. Henry Ford CC has used it in the first term of the Mechatronics program, to introduce the student to the technology that they will be encountering in their program of study. Thus all following classes can be taught in context. Secondly, this course introduces the students to a troubleshooting methodology that can be used on any sequencing machine. This methodology could be used by a maintenance worker to solve 80% of the problems faced on the plant floor that uses sequencing machines. This methodology relates to the automotive industry (OEMs, Tier 1 and Tier 2 suppliers) and similar industries. This methodology will not work for Process control or electronics board level repair. Different methodologies have to be employed in these industry segments. Therefore, two assumptions are made: 1) The student entering this course has no prior knowledge of the technologies, components and systems discussed. 2) The Instructor is versed in Fluid power, basic electrical principles, relay logic, motor controls, the reading of working drawings, Programmable Logic Controllers (PLCs), Robotics, and has some (limited) background in variable frequency drives, servos, and integrated systems. The robotic background is especially helpful since many of the institutions delivering similar courses have faced problems with the Fanuc robot utilized on the AMTEC Simulator*. The Instructor background is assumed and there will be minimum of support documentation in these areas and the emphasis of this document will be to expand on the study of sequencing machines (Integrated Manufacturing Systems), Sequence Diagrams, and Troubleshooting Methodology.	N/A

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Duration	Instructor Activities	Student Activities
	This course will provide the students with a basic understanding of how the PLC is used to control the operations of a machine. The students will not actually utilize the logic to troubleshoot the machine. This will follow in Level 2 training; however, to familiarize the student with the PLC control, Logix Pro 500 (From Learning Pit) is issued to the students and, they will be given homework assignments to complete. This is a simulator that can teach the student how the PLC works and provide an introduction to programming. This course as instructed utilized 2 AMTEC simulators* and 2 SMC Integrated systems. Note, the AMTEC simulators* expose the students to more diversified technologies and HMIs, whereas the SMC trainers exposed the students to a more complicated sequence and multiple stations. There are other systems that could be used in place of the SMC's. (Festo and AMATROL are two examples.) The challenge of using the AMTEC simulator* is the number of students that can be placed in lab at one time. The course has been run with only the SMCs but the lack of the HMI and associated diagnostics made a significant impact on the student's ability to effectively troubleshoot integrated systems. All students had laptops. This enabled them to access websites for some courseware and reference material. The opportunity to use downloaded information or reference material passed out on a flash drive for the students to load on their computer is referenced in red. An overview of the AMTEC Simulator* can be seen on the YouTube Video entitled: AMTEC Integrated Manufacturing Simulator*. An overview of the SMC Trainers can be seen on http://www.smctraining.com/webpage/indexpage/431/C1548330629	

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INSTRUCTOR DAY BY DAY

<table>
<tr><th>Duration</th><th>Instructor Activities</th><th>Student Activities</th></tr>
<tr><td>30 min. to 1 Hr.</td><td>Start of Class:
Introductions
Sign in Sheet
Housekeeping
Cell Phones
Breaks and facilities
Class Hours
Safety Glasses must be worn at all times when working in the lab
Watching Videos or other entertainment on the Laptops is only allowed during Lunch.
PPE must be worn when inside of the AMTEC trainer* with unit powered (Note: for level one training, the students were not allowed in the AMTEC simulator* with power applied)
The first day or two has significant lecture with exercises. This will change throughout the course.
Local Internet log in was reviewed
ID: XXXXX (Fill in for College)
PW: XXXXX (Fill in for College)
Note: Each day there may be downloads for the students’ laptops that they will need to complete the exercises and labs.

Course Objectives:
Hand out course objectives or include in flash drive download.
Attachment 1-1
Review course objectives and Q & A.
Some activities can be performed as a team (such as becoming familiar with the operation of a trainer). Some activities will be individually completed and assessed. The students will be told which applies.

Discuss Student tracking spreadsheet and Rubric.
Note: the referenced tracking spreadsheet in Attachment 1-2</td><td>N/A

N/A</td></tr>
<tr><td></td><td></td><td></td></tr>
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2 to 3 Hrs.	**System Overview – Instructor Demonstrations** 1) Gathered around the SME trainer, Instructor discussed (show and tell): • Pneumatic actuators – Hosing – • Mechanical Conveyor –and drives • Electrical pick-ups • Optical pick-ups • Controlling PLC and how the PLC is the coordinator of the actions • Discussed the sequence of the station broadly • Power up and operate station Note: emphasize the start-up… including air supply and application of electrical power. Note what to check to ensure that electrical power (Processor lights) and air (Pressure gauge) are available to the station. As the station is operating name the steps in the sequence. It would be easier to step through in manual mode, as the each step is discussed. • Point out Ethernet communications and switch. • Discuss how to reset faults. 2) Repeated with the AMTEC trainer*, Discussed (Show and Tell) and identified: • Pneumatic actuators – and controls – Hosing • Hydraulic - controls and Hosing • Mechanical Conveyor –and drives • Electrical pick-ups • Optical pick-ups • With Power off and locked out show Controlling PLC and how the PLC is the coordinator of the actions, discuss main enclosure contents – Disconnect – fuses - circuit breakers – circuit protectors and motor starters – HMI – Servo – VFD – PLC – I/O Note only give a brief overview at this time. (E.g. *This is a Variable Frequency drive which you will study in a later course. It controls the speed of the motor which drives the load conveyor*.	Instructor Demonstrations Instructor Demonstrations

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	That is the extent of the overview explanation) Point out Ethernet communications and switch. • Show and briefly discuss the robot controller power, Estop and Auto switch • Show and briefly discuss the Robot Teach Pendant Estop and Teach switch • Show Load and Unload junction boxes (also look inside) • Discussed the sequence of the machine... broadly; however, do emphasize the proper names – Load Conveyor – Transfer Station (either robotic or servo) – Unload Conveyor – Pusher area • Power up and operate station (remember 5 Disconnects – 5 Safety Gates – 3 E-Stops, one pull cord and light screen clear.) • Demonstrate how to power-up the machine and how to reset faults from the HMI • Operate in Auto • Operate in Manual (Remember that the manual screen changes when the robot is bypassed to reflect the transfer servo controls) • With robot enabled and disabled (remember to reference the transfer servo when you have the robot bypassed.) • On teach pendant… show how to reset faults and adjust robot speed • Reference the operations manual to be given to the students – copy from Flash drive, on the tablet, or on MSAMC.org. The students may not remember all of this information on the AMTEC simulator* and will require some supporting information to start. See **Attachment 1-3.** • Reference the manual on the Magnetic tablet. (MSAMC developed lab aid. Downloads for Tablet are available from HFC Dearborn. Tablet are magnetically affixed to the enclosures and contain AMTEC* Operation and Troubleshooting Manuals. Additionally the working drawings are available on the Tablet.)	Instructor Demonstrations

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Duration	Instructor Activities	Student Activities
	• Go over briefly the various screens on the HMI. Do not go through all the contents of the screens in detail. Navigation is the objective. The fault screen and Manual mode screen should be emphasized.	

3 Hrs.	**Introduction to Fluid Power - Lecture**
	
	For each device below, discussed name – symbol – function – gave an example in a circuit.
	Note: this is meant to be an introduction to the technology therefore only the basics are covered and no associated math. Therefore when discussing a double acting cylinder, no mention of cushions or F=P x A. (Minimum coverage if any) When discussing double-acting cylinders, the name - Double acting Cylinder – symbol – function = converts Fluid energy to linear motion - show cut-away, and then present an example in a circuit. The instructor may want to develop several symbols first and then go to a circuit. The students will discover cushions, F = P x A and etc. in the fluid power course. The following components should be covered:
	• Cylinders and Motors (fluid power) Single acting, double acting and rod-less (used on the AMTEC simulator*)
	• Directional control valves
	  ○ 2 and 3 positions
	  ○ 4 and 5 ported (Hydraulics and Pneumatics respectively)
	  ○ Solenoid controlled
	  ○ Closed center condition for 3 Position Valves
	  ○ Spring offset and centered valves
	  ○ Detents
	• Basic check valves (no Pilots)
	• Basic Flow control valves (fixed and variable)(no pressure or temperature compensations)
	• Meter-out flow control with bypass checks (only… no metered-in or other configuration)
	• Hydraulic power supply components [electric motor – Pump (a gear pump would suffice) – filter – gage - and tank]
		N/A

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Duration	Instructor Activities	Student Activities
	• Hydraulic pressure relief valve • Pneumatic power feed components – Regulator and filter only. Compressed air is always assumed to be available. (No lubricators) • Pneumatic mufflers (silencers) • Electrical solenoids as valve operators • Typical circuits, See **Attachment 1-5** Students need to memorize the symbols, names and function of each component. Many students have had success with creating flash cards on 3 x 5 cards. Students need to analyze basic circuit action. The students should be able to predict the cylinder action (extend or return) when any directional control valve is operated. Students should identify which flow control should be adjusted to affect a change in a cylinder's extension or retraction speed. The students should be able to visualize the operation of a hydraulic pressure relief valve, or a pneumatic regulator, from the circuit and the associated pilots. Students should be able to visualize a directional control valve shifting in a drawn circuit when a solenoid is energized and the resulting flow. Utilized numerous cutaways and training components from fluid power labs to illustrate the different configurations of fluid power components. Utilized the AMTEC* and SMC trainers for component identification To support the students in understanding the basic components, names, symbols and functions some online resources were used. See **Attachment 1-6.** Assign readings from attachment 6. Assign symbols to memorize as identified above. (Remember Name – Symbol – Function – Circuit action) Discuss PPE and safety associated with pneumatic components and circuits. The student will be quizzed on the Name, Symbol, Function, typical circuits. Develop a quiz to check for proficiency. Quite often, a grade of 80% is required to pass the quiz. Students achieving an 80% or higher earn the letter grade of A or B. Any student not achieving 80% or higher will have to	

Duration	Instructor Activities	Student Activities
	take the quiz again. The second time the quiz is a little harder. For example: • First pass - match the symbol to its name and function • Second pass – Match the name to the symbol and define function • Third pass –Given the function draw the symbol and name the device. Try not to penalize the student for learning late… Try to recognize the students who passed the test/quiz the first time – everyone should be able to pass the tests/quizzes with a C grade as long as they keep applying themselves. The lab grade is based on competencies and completion of the labs. We expect all students to complete the labs or they must come in on their own time to complete the labs.	
		Students will have to memorize the specified: Symbol, Name, Function and common circuits associated with Fluid Power Home Work
	Introduction to Electrical fundamentals and Relay Logic Introduce the concept of electricity 5 min or less… valence electrons – electron drift – current flow – voltage – AC and DC. (Wall outlet or batteries) Developed the concept of basic series and parallel circuits using household lighting examples. Introduce the concepts of opens and shorts. Introduce JIC electrical symbols from the list below. Support this introduction with classroom components showing what each looks like. Again remember: Name, Symbol, function and application in a simple circuit. Reference **Attachment 1-7** Components to be covered: • Disconnect • Fuses • Circuit breaker • Limit Switches • Pressure/vacuum Switches • Level switches	

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Duration	Instructor Activities	Student Activities
3 Hrs.	• Temperature switches • Single break and double break switches and single and double throw switches. • Momentary switches including mushroom head switches. (remember today's e-stops are maintained) • Relays and associated contacts • Panel lights • Basic Motor (single phase and three phase symbols) (don`t get into three phase discussion – recommendation: if anyone wants to know about 3 phase… do it after class) • Basic Timing relay (On-delay) • Note: there is not a symbol for magnetic switches found on the SMC cylinders they are indicated on the drawing as a proximity switch. The Proximity switches and optical pick-up symbols on the AMTEC trainer* is a switch embedded in a Diamond boarder. The name associated with the device helps define the device. When complete with this section the students should be able to understand a circuit like the one illustrated in **Attachment 1-8** To support the students in understanding the basic components, names, symbols and functions, some online resources (links) were used. See **Attachment 1-9** **When a number of students work with European equipment the IEC 617 symbols must also be covered. Simplified ANSI to IEC 617 can be found in Attachment 1-10.**	
		Students will have to memorize the specified Electrical Symbols, Names, Function and circuits. Homework
	Instructor Demonstration: The wiring and operation of a relay logic circuit can be demonstrated on available trainers at the institution. These demonstrations should reflect a momentary Push Button used as a start, Estop Push Button, sealing contacts and some kind of energizing output. Add panel lights if available.	

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Duration	Instructor Activities	Student Activities
30 min. to 1 hr.	Discuss PPE and safety associated with electrical components. Remember these students will not be inside of the AMTEC* enclosure with power on. Arc Flash equipment will not be needed for labs.	Instructor Demo
1 to 2 Hrs.	**Lab Opportunity** Have the students go on the trainers and power them up and run the stations in automatic and manual. They can start noting the sequence of operation and exercise the power up sequence that was demonstrated earlier. Typically, the AMTEC trainer* will support 3 students to a team for this exercise and the SMC trainer will support 2 students to a team per station. With the SCM trainer, always assign the students to a station that has an empty and unused station following. Students are assigned the first, third and possibly the fifth station. This will keep the station unencumbered by the following station when it is looking to release the carrier. HFC's normal class size was from 10 to 14 students. Remind the students to grab the carrier as it is released in the station that they are working on before it reached the next station. On the AMTEC simulator* the students may want to reference the operations manual issued on the flash drive or use the tablet's files to help them with the start-up of the machine or changing modes. Rotate the student through 2 SMC stations and the AMTEC simulator*. Eventually the students will have to generate sequence diagrams on several SMC stations and the AMTEC Simulator*. This will have to be entered on a sequence diagram master and submitted to the instructor. Instructor will have to track Team rotations on the SMC Stations and AMTEC Simulator*.	LAB: Students spend time familiarizing themselves with the operation of the Trainers on selected SMC stations and AMTEC Simulators*.
	Machine observations – Lecture What to look for when viewing an integrated system: Note: this is a multiple pass approach. Note: any reference to operator in the below is a reference to the physical device causing the action and not a person. • The first thing that should be noticed is the physical movement of the system. ○ Part transfers in.	

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Duration	Instructor Activities	Student Activities
1 to 2 Hrs.	○ Part gets positively located (clamps, shot pins, etc.)(May have several steps to the location of the part. Clamp 1 extends, clap 2 extends, etc.) ○ Some machining/welding/sealing/etc. process is initiated. (E.g. Advance drill, then return drill. Or initiate robot cycle.) ○ Process is complete and system releases part. (e.g. open Clamp 2, followed by open clamp 1) ○ Part transfers out of the system. ○ This identifies the steps in the sequence of the machine. *Note: there may be additional steps that are not apparent at first… We will get to these.* • The second thing that should be observed is the operator associated with each action. How did that clamp close? What drives that moving roller table? This leads the student to the fluid power or electrical component. For every step in the sequence, there typically is an operator. The operator normally has an intermediate control element associated with it. The cylinder is controlled by a directional control valve, which is operated by the PLC. A motor is controlled by a variable frequency drive, which is controlled by the PLC. These intermediate control components should be identified, as much as possible, by the students. The fluid power intermediate controls are the easiest to discern. • The third thing that should be observed is: *"How did the system know that the step in the sequence was complete? If a clamp closed, how did the system know that it did?* This leads the students into identifying the feedback devices that signaled the controls that the step was complete. Thus limit switches, proximity switches, vacuum switches, photo eyes, etc. are discovered. Note: on actual integrated systems there are feedback components for every action on a machine. However, on trainers and simulators, a dwell	N/A N/A

Duration	Instructor Activities	Student Activities
	timer may be used instead of a feedback device. The command to close a clamp can be followed by a “wait for 2 seconds and assume that the clamp was closed and then continue” action. This control scheme will not be found an actual manufacturing system. All operations have an associated feedback device; however, on the SMC trainers, there are several stations that use a dwell instead of feedback devices. This concept must be discussed in lecture. • Note: The sequence of the machine can be developed more fully. The first step is triggered by the cycle start; the completion of the first step is sensed by a feedback component - this signal is normally the trigger for the second step. The second step happens and there is a second feedback device signaling that that step is complete. This feedback device is the trigger for the next step. And so on. The controller will signal to a robot to initiate a cycle; the robot signals back that the robot cycle is complete. It is important to note that there may be more than one trigger for some steps; for example: not only does the cycle start push button need to be depressed but a part must be in place. There may be two triggers for that step. Example: To initiate a robot cycle on a machine you may have to have clamp 1 and clamp 2 closed. • Once the physical steps, the operators, and the feedback devices are known, the PLC interface should be identified. Using the electrical prints on the machine, Identify the PLC input or output associated with the operators (above) and the feedback devices. The students should be directed to follow this back to the I/O light on the interface module. It is important in troubleshooting to determine whether or not the PLC is attempting to turn on the output. If the PLC is attempting to turn on the output (Indicated by the light on the output module) and the output is not operating… then the problem probably lies between	

Duration	Instructor Activities	Student Activities
	the output module and the operator. If the output light is not on, then the PLC is not trying to turn on that output and we are most likely missing a trigger for that step. This leads us to the input module's lights looking for the trigger indications; thus we are most likely missing a trigger. The students must know which light on the I/O module is associated with that input or output that they are questioning. • Once completed with identifying the steps (physically observed), the operators (pneumatic, electrical, etc.) the intermediate control devices (e.g. directional control valves, etc.) and the feedback devices (which are most probably the triggers for the next step) we are ready to record our findings on the sequence diagram. • Before we record the findings, return to the machine and see which components have not been identified. The components on a machine have been added for a purpose. If we haven't evaluated all the components, then something has been missed. Example: there may be an inspection station (camera) that is examining if a stud or some small part is present. If not present the part is rejected. Under normal operation, these components are not seen to be operational and sit there idle; however, they are there for a reason. These idle components have to be evaluated. They will lead to the discovery of missing steps in the sequence. These steps might well be acting at the same time as the normal sequence and were missed. For example, as a clamp is retracting, a camera is evaluating the part and making a go – no go decision on whether to allow the part to continue or be rejected. This would then explain the presence of additional components to reject the part. Additionally, the station may be responsible for various component configurations. (Automotive example: two door or four door).	

Duration	Instructor Activities	Student Activities
	Some of the components may not be needed for one of the configurations; therefore, before in order to consider being completed with the exercise, the students have identified all components on a station understand their function and associated position in the sequence of operation. If there is a physical person associated with the machine operation, ask questions of them. They probably know. • Note: The sequence of a machine is viewed from the start of a cycle in automatic. Any and all qualifiers necessary to place the machine into automatic mode are considered part of the set-up. These qualifies do not appear on the sequence diagram. Signals and qualifiers such as those that follow are not to be considered in the sequence diagrams. Set up qualifiers may include: o Enabling all electrical disconnects o Applying and sensing pneumatic power to the station o Resetting all safety gates o Resetting e-stop push buttons o Resetting emergency stop pull cords o Turning to machine on o Clearing start up faults o Selecting and enabling automatic mode • Dwell timers are used in many machines to give the machine time to stop vibrating after a mechanical actuation. (Limit switch bounce is eliminated if you wait for a half a second). These dwells should not be considered in the sequence of operations. (Dwell Timers lasting for 2 or more seconds should be considered a separate step in the sequence). The AMTEC trainer* uses these dwells and they should not be considered in the sequence diagram to follow; however, sometimes the machine hesitates deliberately for a second or longer. (to cool off a part or	

Duration	Instructor Activities	Student Activities
	allow the lubricant to remove shavings) These dwells should be considered. Hints to identifying the Sequence of operation: • From a pushbutton panel note that the order of the lights indicates the sequence of the machine. • From an HMI on the manual control screen. Note that the layout of the screen indicated the sequence order. (Left to Right, or Top Down) • Observation • From print package – sequence diagram or other documentation that contains the sequence information. • Talk to the Physical operator. (Person)	
30 min. to 1 Hr.	**Sequence Diagrams – Lecture** Sequence Diagrams are as a way of recording the sequence of the machine and capturing valuable information for troubleshooting. A master (Blank) diagram (Template) is included. **(Attachment 1-4) It is recommended that hard copies be made available for classroom discussions.** The instructor should go over the contents of the diagram: • Step in terms of the machine action • Time duration of each step • The output being actuated in terms of the output Cylinder/Directional Control Valve Solenoid/ and the PLC address – (Which will reflect the I/O indicator on the module). • The triggers that cause the action – Proximity, limit, etc., Devices, and PLC I/O address (associated I/O light) (This activity should not be attempted until after the PLC lecture.) • Remember the triggers that the student will identify from the machine operation are only guesses. The actual triggers can be identified through the PLC logic analysis. • Remember that the sequence chart starts with the Cycle Start Push Button (AMTEC*) or a carrier moving into position (SMC). Any set-up logic prior to that point	N/A

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	should be considered a set-up element and not recorded on the sequence diagram proper. • Discuss the importance of noting addresses on the sequence diagrams for future troubleshooting. (This identifies which I/O Module light to be analyzing) **Note**: the addresses (tags) cannot be identified from the electrical prints.(on either the SMC or the AMTEC simulators*) The sequence diagram is the critical tool in troubleshooting the machine without access to the logic via terminal.	N/A
2 Hrs.	**Lab Opportunity** Armed with a basic understanding of electrical components, Fluid power components, and sequence diagrams, the students can start developing the sequence charts on the assigned stations. The instructor should rotate the students through the different simulators and stations. Use the Sequence Diagram Master to capture the information. The student can record – the steps – the output operator – the intermediate control (Especially if fluid power) – and start identifying the triggers. *Remember that the students are guessing at the triggers. Only through an analysis of the logic can the actual triggers be identified with accuracy.* The PLC I/O light numbers should be avoided until after the PLC lecture. Reference **Attachment 1-4** Sequence Diagram Master Note the students will not finish this exercise in 2 Hrs. on the assigned stations. This will start backlogging the labs for the students.	LAB: Students develop Sequence Diagrams on AMTEC Simulator* and selected SMC Stations.
	Introduction to PLCs Introduce the PLCs as a replacement for relay logic. Advantages: • Flexible - can add storage bits (internal relays) through programming • Flexible – Don't have to change the wiring of a machine – change the program • Easier to troubleshoot • Supports Diagnostics • Less expensive • Etc.	

Duration	Instructor Activities	Student Activities
2 to 3 Hrs.	Disadvantage: • Requires a degree of Competency to utilize. Training is required. Instructor Demo: 10 minutes looking over a PLC trainer pointing out power supplies, processor, input and output modules and connections to real world devices. Remember, unlike Relay Logic circuits, each input and output is individually connected to the PLC I/O and the series and parallel circuits are connected in the processor's program. Each output is also individually controlled. **Instructor Note**: The sample drawings attached are used to explain basic PLC fundamentals are based on the PLC5. It is easier to understand the addressing on a PLC 5 than Control Logix or Siemen's S-7. Also a powerful simulator called "Logix Pro 500 made by "the Learning Pit"" is issued to the students and they will spend homework time learning the fundamentals of programming. This also lays the foundation for Control Logix studies that will follow. Remember, with the single PLC5 processor, it is internally cycling through – move inputs from the input module to memory – solve the logic – move the outputs from memory to the output module – then a little housekeeping. The PLC 5 sits in this loop under normal operation. During the following lecture, usually the following diagrams referred to in the discussion are drawn on a white board as bits are set and reset The movement of inputs to input Module to Input area of image table, output image table to output module to outputs, the solution of the ladder diagram using only memory (input area, output area and the binary area for storage bits) are shown on the white board. This takes a board larger than 8 Ft. to reflect all. **Input modules** Show Input diagram on overhead or drawn on the white board. See **Attachment 1-11 Basic PLC drawings. 5 Input Module.** Cover the following: The source power is applied to a series circuit of the input device and a solid state (electronic) module. When the discrete input PASSES POWER. The source voltage appears across the input module's inputs. The function of the input module is to convert this source power into some voltage level compatible with the	

Duration	Instructor Activities	Student Activities
	memory's circuits. Through the plc's action, at the start of the processor's cycle, the input information is stored in a reserved location in memory for that input module. Avoid discussing too much detail here. Optical isolation, logic levels and similar information is not important at this time. The concept that we emphasize is noting the outputs of the solid state circuits as being on or off. If the input (discrete device) passes power, the output of the solid state circuit will be On – High – 1 - True - + 5 volts. These all mean the same thing but are different ways of expressing what the circuit's output is doing. If the input does not pass power, the output of the electronic circuit is OFF – Low – 0 – False or 0 volts. The position of the associated input light is important. The input light is powered from the input (discrete) device and is electrically in parallel with the associated input circuit. Even if the solid state input circuit is malfunctioning the light will illuminate when the input device passes power. (Important troubleshooting point.) Even though the processor has faulted and is not moving the input information to memory, the input light will still work if the input device is passing power. Emphasize whether or not the input is passing power. Do not reference the XIC nomenclature found in programming. This makes the normally closed devices easier to work with. Go over the starting status of a machine and set up the binary bits with the students that will be moved to the input reserved memory location associated with that input card; thus: • The Estop which is normally closed, passes power to the input • The start PB – N/O does not pass power (assuming that no one pushes the button.) • The air on pressure switch should be made and passing power. • Assuming that the unit is returned, the unit returned Limit Switch will be passing power and the Unit Advanced Limit Switch will not be passing power. • A little diagram of a pneumatic cylinder and limit switches sensing the advanced and returned positions would be helpful on the white board. • The bit pattern on the input module drawing is – Top Down – 1 – 0 – 1 – 1 – 0 –	

Duration	Instructor Activities	Student Activities
	• Change a couple of switches and show the bit pattern change, always stressing whether or not the input is passing power or not. **Reference Attachment 1-11** **The PLC moves the input card's data to Memory. See Attachment 1-12.** • Do not get into addressing at this point. Just refer to the memory location as a reserved location • Somehow the PLC moves the bit information into the input image table. Reflect movement on board **The PLC will move the Output Image table bits to the associated output card**. See **Attachment 1-11 and Attachment 1-12** • The PLC moves the output Image table bits to the associated output card. These bits, if on, turn on the output module. This applies power to the load. In this case it is a relay, which, in turn, energizes a solenoid controlling a directional control valve. Or a panel lamp • Note the position of the output indicator on the output module. • The output indicator is in parallel with the load. • If the indicator is on, the PLC is trying to turn on the load. • Remember, on most output cards there is always some kind of blown fuse indicator. • The position of the indicator is correct for most but not all output cards. Assume that this is always the case for this discussion. In reality, some output modules using dry contact outputs have the indicator up stream. The student will learn about these differences in their PLC course that will follow. **The PLC sequence of operation.** Emphasize the PLC operation… Move Inputs to Input area of memory… Solve the ladder Diagram referencing memory only…	

Duration	Instructor Activities	Student Activities
	Then move the output area of memory to the associated output module. Do not mention other PLC functions between the sending outputs out and the next input operation. This is a subject for a latter class. **The Ladder Diagram**. **See Attachment 1-13** Go over the ladder logic and explain in words what the circuit is intended to perform. Points that should be noted: • The use of the "Examine On" instruction associated with the normally closed E-Stop PB • Storage bits (internal relays) in the Binary area of memory • Branches • The concept of cycle complete • Most importantly emphasize the logic scan. Starts at rung zero - Left to right – top down – one instruction at a time. (Note: use the terms Examine to see if that bit in memory is on – not XIC, examine to see if that bit is off in memory – not XIO, Set this bit in memory if the rung is true, Not OTE – this also means – reset this bit in memory if the rung is not true. • Note the common use of checking for the unit being returned and not advanced in rung 2. This may seem a little redundant, but a common practice and a safer design. • Note that in rung 0, the On CR storage bit is turned on (set) if the rung is true. Rung 1 Checks the same bit in memory to see if it is on. The machine only does what you tell it to do. Some students will have an issue with this. • Note that the sealing contacts around the start PB are not true until the second logic scan of the processor. • Never look back in a program and see what the current action could impact… the processor doesn't. Remember: Top down – one rung at a time – left to right – is the processor scan for Allen Bradley PLCs.	

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INSTRUCTOR DAY BY DAY

Duration	Instructor Activities	Student Activities
	All the pieces together. Show all diagrams on the board at once. Attachments **11, 12 and 13.** From a reset condition (Estop not depressed, Air on, No start PB yet, unit is returned, unit is not advanced) follow the total processor sequence through. • Inputs to input module – noting whether it passes power or not • Input modules generate a logic 1 (True – Hi- +5 v. – or a logic 1) based on whether the input device passed power or not • PLC moves the input module's bits to memory (mark the bits on the board) • Solve the ladder diagram using memory only • PLC moves the Output memory bits to the output card (at reset 0 – 0 – 0 – is moved to the output card) • The output card switches on if the bit is HI and applies power to load • Operation of the machine • Remember the PLC is continuously doing its sequence. Therefore this happened thousands or millions of times before the start PB is pushed Repeat the sequence. This time the Start PB is depressed. • It turns on the ON CR bit • Turns on the unit on Panel Light bit • It generated the Advance command (sets the Bit) • And so on Going through the sequence is time consuming and requires concentration, but most students will leave the class understanding the basic control of a machine by a PLC. **Instructor Note**: a much shorter program with less I/O can be used to convey the above points on a PLC control. Also the logic can be issued to the student and avoid some of the board work. Hopefully, the students now have a basic understanding of how a PLC controls a basic machine. Now a self-paced tutorial and simulator will provide them with more programming experience. This simulator is based on a PLC 5 type of family, but works well	

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Duration	Instructor Activities	Student Activities
	here. Later the students will study the Modern Rockwell or Siemens Processors.	
	The LogixPro software. **Issue the LogixPro Software to the students and have them install. When launching the software from the icon, the disk must be installed and the timer at the top left of the screen should never get to 0 and ask if they want to use the free trial. If this happens, uninstall the software and re-install.** It is suggested that the following functions be reviewed on the LogixPro software: • Start by selecting the I/O simulator from the Simulations menu • Demo the left clicking of a switch and watch the input module light • Right clicking on the input device changes the device type … start with all SPST switches • Go to the user instruction at the top of the logic window and select – new rung • Enter a rung with one Examine on and one OTE instruction - do not address • Click and drag the input light to the address location above the XIC. The address is assigned first light is I:1/0 (Remember: Examine On) • Click and drag the first output light and place it in the address location for the OTE instruction • Toggle the Instruction menu with the little arrow above the instruction's menu • Click on the download button and select run • Demo the program functioning **and the screen highlighting when the instruction is qualified. This is important** • The instructor might want to repeat this operation with an XIO instruction. (Examine Off) Going back into	Instructor Demos the LogixPro software using an overhead. No student activities.

Duration	Instructor Activities	Student Activities
	programming mode prior to toggling the Mode/Instruction functions • Note the scan rate which is available to the right of the Program/Step and Run screen. This will be helpful in some of the simulations slow down the graphics • Demo how to save a program (Which the students can do to save a program for later work) • Briefly (only for a 30 sec.) Look at the other simulations that this software provided -Select the Help menu and select student exercises • We have entered the tutorial/Lab section of the software • Have the students run through these items and turn their completed labs to the instructor • Usually the student are asked to complete and turn in (email their programs) to the instructor • Normally the students complete the exercises through the traffic light exercise • On the traffic light exercise – the students are asked to complete it first with multiple timers - Then one timer and multiple counters – then one timer, one counter, and comparison instructions (e.g. EQU GRT, GEQ, etc.) • The software is fun to use and challenges the students • Emphasize the basic function and process of the PLC After spending a week or two writing programs on LogixPro (Homework Assignments) the student usually have an idea of how a PLC controls the machine. Some individual instructor support will be required by some students to complete the assignments. **Instructor Note:** If only one integrated system is available in the lab such as the AMTEC Simulator*… these programming assignments occupy the students while 2 or 3 students are working on the simulator.	

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Duration	Instructor Activities	Student Activities
2 Hrs.	Lab opportunity	Students continue developing the sequence diagrams assigned. When waiting for an open trainer the students are working on the LogixPro assignments
15 to 30 Min.	**I/O addressing Lecture** This is an introductory course and addressing is not meant to be lectured on. But what is critical for troubleshooting is to be able to identify which I/O light on the I/O modules is connected to which input or output. The electrical prints of the lab simulators should be reviewed with the class to enable them to identify the I/O light associated with the inputs and outputs used. Hard copies are best for the classroom. Reproduce copies related to the lab equipment being used. Note: if using a SMC simulator, IEC 617 symbology is used and a cross reference handout was used. **See Attachment 1-10.** On the AMTEC trainer* prints, work from the I/O device to the I/O module and note that Input 1 is related to Light 1 on the input module… do not try to associate this with the tag at this time. Likewise, output 1 relates to light 1 on the output module. **Attachment 1-14 – AMTEC* Prints**.	N/A
2 Hrs.	Lab Opportunity	Students continue developing the sequence diagrams assigned. When waiting for an open trainer the students are working on the LogixPro assignments
	Introduction to Troubleshooting - Lecture Develop Troubleshooting Methodology on the white board. *Note this will be redeveloped and expanded on, several times.* Develop this methodology with the logic first and then later it will be done without the logic. This will give importance to the sequence charts.	

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Duration	Instructor Activities	Student Activities
1 Hr.	**(Rough methodology found in Attachment 1-15)** **Go through each step of the troubleshooting sequence "with the logic".** **Note:** This methodology is for a sequencing machine. This methodology does not apply to process control equipment or the troubleshooting of electronics. **In this Attachment (1-15) there is also a manual for troubleshooting that reflects this methodology. It is called "Troubleshooting level one for instructors". To run this supplement, open up the folder and click on the index file. Under the troubleshooting tab, select troubleshooting steps from the pull down menu.** **Remember** that Sequence Diagrams used to be included in the working prints. Now, quite often, troubleshooters have to refer to the user's manual on the equipment. Always emphasize the importance of working backward from the output that they are waiting for. Reference the troubleshooting chart, but develop on the white board. Do not issue the flow chart. Remember: Troubleshooting has different levels: • A machine that was just working (The logic is good and the wiring and piping are correct). Note: a wire may have broken, but it was wired properly for the machine to function in the first place.) • A Machine that wouldn't start in the morning (This condition causes examination of disconnects, estops, safety gates, interlocks, etc.) • A machine where the problem crosses shifts (Now there may be more than one fault and any replaced components may not have been installed correctly or configured correctly). Therefore flow controls, remote disconnects and manual shut-off valves may have been operated to facilitate installation of a device. Additionally, pressure switches, optical pick-ups and etc. may not be configured properly.	N/A

Duration	Instructor Activities	Student Activities
	• Commissioning of a new machine (In this exercise, everything has to be considered. (Logic, wiring, piping/tubing, configuration of components, etc.) (This course does not cover the last level.) Q&A **Note:** Prior to changing an input module or output module a meter check should be made on the module. **Note:** Depending on the flow of the material and the time allowed, It has been found beneficial to review the troubleshooting logic at the beginning of several classes. This was developed on the white board and the students were asked to develop from memory with the instructor. (Memory imprinting) Expand to include PS lights – Proximity lights - how to check proximity and limit switches - etc. This is all white board work or demonstrations on the trainers. The instructor should quiz the class for each step. These activities are normally done when verifying the operator's complaint. (Step 2 in the troubleshooting methodology)	
	Simulator Show and Tell: On all available simulators, the instructor can identify the Power Supplies and lights, communication modules indicators, Processor indicators, Proximity & Photo detectors (and demonstrate how to check in the field), etc. **Lecture: Troubleshooting step 2** If the sequence of a machine is known, a thorough examination can identify many faulty components. This relates to step 2 in the troubleshooting methodology. While verifying the operator's description of the problem. Example. Clamp one closed. Its closure is the trigger for the next step. The next step is clamp 2 should close. When examining the machine look for:	Instructor Demonstration

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Duration	Instructor Activities	Student Activities
	• Insure that Clamp 1 did close completely • Look to insure that the feedback device associated with clamp 1's closure seems to be working (Proximity light is on or limit switch appears to be activated). This is important since the sensor for the "previous step is complete", is quite often the trigger for the next step. • Is the part seated correctly in the fixture • Etc. Knowing the sequence of a machine and the outputs that are associated with each step and the inputs triggering each step, is fundamental to troubleshooting.	
2 Hrs.	Lab Opportunity	Students continue developing the sequence diagrams assigned. Now with the I/O addresses or lights identified on the sequence diagram. When waiting for an open trainer the students are working on the LogixPro assignments
N/A	**Instructor Note**: In classes where computers have been issued and Microsoft office provided, the students are asked ask to generate excel spreadsheets for the 3 sequence diagrams and email to the instructor. (or otherwise submit an electronic copy)	N/A
15 Min. to 30 Min.	**Written - Troubleshooting Set-up – With the logic** **Warning: the students must have completed the LogixPro assignments up to the Timers prior to continuing with this troubleshooting.** Have the students develop a sequence diagram from the templates associated with troubleshooting version 1. **See Attachment 1-16**. For templates and direction.	Students develop sequence chart from template information

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Duration	Instructor Activities	Student Activities
15 Min to 30 Min.	**Instructor review** (of the Developed sequence diagrams) On the board, review the sequenced diagrams that was just developed to ensure that all the students have an accurate diagram. Remember that the dwell is a separate step in the diagram. Answer diagram in **Attachment 1-16** Discuss: • Pushbuttons and panel lamps • Panel Indicators • Questions about the logic - note that a cycle complete is used in this logic and the students have not experienced this before • Note the use of internal storage bits, for command signals and cycle complete. Note the bit numbers are identified in the exercises to follow. They are missing on the templates. The names will work for this exercise. • Point out Communication fault indicators – overview only. They are typically red when faulted. • Blown fuse indicators • Physical layout of the Hydraulics and switches	In Lab Students correct any errors in their sequence diagrams.
	Troubleshooting – Written exercises. Referring to the sequence diagram just developed, Issue first (#2) Troubleshooting exercise with logic. Give the students the operator's description of the fault. (This is noted on the bottom of the circuit page.) Have them apply the methodology discussed to isolate the fault. Answer sheet is attached. Reference **Attachment 1-17.** Have the students mark the answer on the bottom of the sheet and not share their answers. The instructor circulates through the room and confirms the answer Using the Overhead displaying troubleshooting exercise 2, discuss the proper application of the methodology that would have led to the answer. Q&A Issue exercises 3 through 8 **one at a time** and repeat above. **Instructor Hint:** Have hard copies available to support this activity. This works better than files on a computer screen.	Students are solving the written troubleshooting exercises.

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Duration	Instructor Activities	Student Activities
1.5 Hrs.	Reinforce the troubleshooting methodology each time a troubleshooting exercise is discussed. 1) Talk to operator - see bottom of circuit page for operators description 2) Verify the operator's description – look at bottom of the circuit for the physical position of the cylinder and ensure that it has extended and is making the limit switch 3) Check for Diagnostics… (Not applicable here). 4) Determine what output you are waiting for 5) Find the output in the logic – is it highlighted – no why not – work backward in the program 6) Timer never started – leads back to the Full Depth Limit Switch 7) Look at the input module light associated with that input 8) The light is not on – which leads you to the conclusion that the issue is a real world problem associated with that limit switch Repeat this sequence with the first couple (if not all) of the exercises to force the students to embrace the methodology. **DO ONE AT A TIME WITH THE CLASS** Remember any time that the Memory (highlighting in the logic) does not agree with the I/O light, suspect the module. In reality, a body shop of an automotive OEM may only experience a bad input module once per year, but it will shut them down for a while only because it happens so rarely. They will lose several output modules over a year. Usually there is a mini lecture associated with each exercise. For example: • Exercise 2 – Full Depth Limit Switch- discuss how limit switch arms become loose, or if proximity switches are used – discuss how they can become physically loose. Remind the students how to check Proximity switches and optical pick-ups on a machine. Remember, if no input lights are present on the input module, suspect the Power Supply. • Exercise 3 – Adaptor card or blown output module – The students must be aware of fault lights wherever they appear. Processor faults, communication cards, VFDs and etc. They must pick up on all red lights.	

Duration	Instructor Activities	Student Activities
	• Exercise 4 -- Output Card Fuse – Again the students must be aware of all lights. If they replace/reset the fuse and it blows again, they now must face a shorted component connected to that output. • Exercise 5 -- E-Stop PB or open Wire associated with the E-Stop PB. The Pushbuttons will confuse a student. For example, the cycle start PB will only pass power while being depressed. The terminal is often a distance from the PB and therefore it becomes a two man job for troubleshooting. An E-stop signal should be maintained. • Exercise 6 -- Bad Input Module. Remember to meter out the input to ensure that it is not getting power, prior to changing the module. Remember any time that Memory (highlighting in the logic) does not agree with the I/O light, suspect the module. This may get a little confusing for the students when dealing with a XIC logic element. • Exercise 7 --Bad Output solenoid, or Stuck Dir. Valve. Or mechanical jam or etc. The students should be becoming proficient by this time. • Exercise 8 -- Return Limit switch Stuck or Shorted or shorted cable. This is where it should be noted that the panel lights indicated this problem and this problem should have been detected in step 3 – Check for diagnostics. Note: On an actual machine, the selector switch for AUTO/Manual should always be inspected for being in Auto. If someone has taken it to manual, they have pushed some buttons which might have taken the machine out of sequence.	
N/A	**See Attachment 1-19** for the version 2 troubleshooting exercises with the logic	N/A
N/A	**See Attachment 1-20** for the version 2 troubleshooting exercises without the logic.	N/A
N/A	**Instructor Note**: Rotation 1 gets the students familiar with the trainers, power up, manual operation, and HMI screens. Rotation 2 has the students start to capture the Sequence Diagram. This is without the I/O addresses.	N/A

Duration	Instructor Activities	Student Activities
	Rotation 3 has the students referencing the prints while identifying the I/O lights associated with each I/O point in the sequence diagram **See Attachment 1-21** for the SMC Prints.	
	Lecture - Troubleshooting Methodology when the logic is not available The instructor can Reference the MSAMC Support materials (Troubleshooting for instructors level 1) in **Attachment 1-15** to support this lecture or develop on the white board. **In this Attachment (1-15) there is also a manual for troubleshooting that reflects this methodology. It is called "Troubleshooting level on for instructors". To run this supplement, open up the folder and click on the index file. Under the troubleshooting tab, select troubleshooting steps from the pull down menu.** These exercises are critical to this course. Since the students have not studied PLC programming with control Logix, they cannot use the PLC logic to help in troubleshooting. The methodology applied to troubleshooting without the logic is essential for the lab exercises that will follow at the end of this course. It is important to do the exercises with the logic first, then move into the troubleshooting without the logic. To enable this methodology, it is assumed that the students have an accurate Sequence Diagram. The instructor should discuss the methodology (Troubleshooting without the logic) in class using the Integrated Manufacturing Systems Troubleshooting Level One for Instructors materials in **Attachment 1-15.** **Instructor's Note:** Without the ability to see the highlighting on the PLC logic, the status of memory is unknown. It can be determined whether or not the PLC is trying to turn on an output (output light on the output module) and it can be determined whether an input trigger is passing power (Input light on the Input Module). Logically it would follow, if the output is not on and the triggers are present, there is something wrong with the PLC processor, Input, or Output modules. The processor fault light will	

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INSTRUCTOR DAY BY DAY

Duration	Instructor Activities	Student Activities
1 to 2 Hrs.	identify whether there are any issues with the processor. Once the processor is ruled out, the fault is most probably with an input or output module. Meter check these modules first. Check the output voltage from the output module to ensure that the output light is not faulty. While on the output module also check for the power connections on the modules. On today's machines, the motion causing output power is switched off when an E-Stop, Light Curtain violation or Safety Gate switch is activated. The input modules and devices, processor, and communications modules will have power applied, even under an E-Stop condition. While observing the output module (Checking to see if the PLC is trying to turn on the output) note if any other outputs are on. If another output is on, then the motion causing output power is probably on. A meter check of the output power connections on the output module would also verify that output power is on. This meter check would have to be supported by some classroom discussion if the instructor wanted to pursue this option. This will be discussed in detail in the PLC courses that will follow later in the program. Should an E-Stop or Safety Gate violation cause motion causing output power to be turned off, there should have been other indications earlier in the troubleshooting. Any Power ON indicators should have been off and typically a diagnostic message would have appeared should an E-stop have been depressed. Discuss the methodology with the class. Re-issue exercise 2 without the logic and have students reference the previously developed Sequence Diagram. Reference **Attachment 1-18.** Completed troubleshooting exercise 2 through 8 without logic. Again this should be completed one at a time with discussion each time of how they should have applied the methodology to solve problem. Remember to warn students to watch for fault lights. The methodology presented here will identify the common faults on today's sequencing systems. There remains 5 to 10% of the faults that cannot be identified with this process and require access to the PLC's logic. Missing Interlocks, for example, between stations is difficult to identify with this methodology.	Students are solving the written troubleshooting exercises "When the PLC logic is not available".

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INSTRUCTOR DAY BY DAY

Duration	Instructor Activities	Student Activities
	A well-developed sequence chart is invaluable to the troubleshooting exercises.	
N/A	**Instructor Note:** On the beginning of each day: Redevelop the Troubleshooting Methodology. This is done on white board with the students providing the information. Remember to expand the methodology to include a check for manual, how to get the machine back in sequence, use of Diagnostics, and use of the meter (If applicable). This implies checking the meter connections, proper range and scale, and the proper deployment of the measurements. Concentrate on the methodology that does not require access to the PLC's logic. This is the methodology that the students will be using in this course. Classroom experience in this program has shown it to be beneficial to cover the "With the Logic" approach first and then develop the "Without the Logic" methodology.	N/A
N/A	**Instructor Hints:** • Can't troubleshoot a complicated system that is out of sequence • If a system is out of sequence - remove all parts - return all operators to set-up condition - reset key signals (examples Cycle Complete, Clear to Transfer, etc.) • On the AMTEC trainer* - remove all parts - robot to home - Cycle power on system (due to the students not understanding some of the key Ethernet signals yet) • OR on the AMTEC Simulator* - run the part through in manual until the sequence is completed • Run the system in automatic and when it fails in sequence, start troubleshooting • It should be noted that when checking for the Diagnostics (Step 3) also look at the auto/manual selector switch. If not in auto, be suspicious that someone might have manually operated the system and have gotten it out of sequence	N/A
	Machine set-up	

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Duration	Instructor Activities	Student Activities
1 Hr.	**Lecture/Demonstration** On the bottom of the sequence chart, it would prove beneficial to the student to capture the elements necessary for the machine set-up. For example: **On the AMTEC Simulator*** • All 3 E-Stops must be returned to their operating position • All Safety Gates must be closed (5) • The light screen must be clear • 5 Disconnects must be on • System Air must be applied • Pull Cord must be reset • Power on PB must be depressed and illuminated • All faults cleared • Auto mode selected • Continuous ON PB must be depressed and illuminated Additionally, the following points should have been discussed (or demonstrated) in the class: • How to go into the robot teach mode and return the robot to home (Data – Type – position registers – highlight position 1, home – Shift & move to), This implies covering the pendant teach switch, the controller teach switch, and the Deadman switches on the teach pendant. Should the system be faulted in the middle of a robot cycle, this will be necessary. • Cycle power on the system to get the PLC and Robot back into sequence when the robot is at home. (There is a more efficient way to achieving an "in sequence" condition, but it is beyond this course.) • How to adjust the robot speed • How to clear a robot fault from the teach pendant (Shift & Reset) **Additional Labs** can be required by the instructor for the student to evaluate the additional HMI screens.	Instructor Demonstration

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Duration	Instructor Activities	Student Activities
	The students should be able to power up the simulator, clear all faults, place the system into Automatic mode and adjust the robot speed. This will enable the machine for a "Cycle Start" (Finger switch next to the load position). The HMI screens contain additional information. Have the students reference the Operations Manual for the AMTEC Simulator* to help clarify. See **Attachment 1-3.** **On the SMC** • All actuators must be in their rest position • Power must be applied • Station 1 Air must be on (cycle start station one in auto or initiate the first step in manual). This includes a manual shut off valve. • Station air must be on at the station the students are working on.(Manual shut off valve) • Clear any faults with the Fault Reset PB • Depress the reset PB and hold for more than 3 seconds • Remember the Cycle Start for the SMC station is the limit switch that is made when the carrier is present **On Both trainers:** The students must be able to power up the trainers, place the trainers into automatic and manual modes, and operate the stations in auto or manual modes.	
	The students are now ready for the start of troubleshooting. **Level one faults** assume that the machine has just been running and something has JUST failed. Sample faults include: **On The AMTEC Simulator*** • Physically move up the Proximity switch at the unload station. It can be moved up by hand without loosening any set screw. Symptom: Unload Stop will not extend. Machine stops in the sequence. The students should be	

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Duration	Instructor Activities	Student Activities
As Time Allows	able to isolate this fault to the proximity switch positioning. • Physically move the reflector associated with the Puck-in-Place on the load conveyor. This will cause the machine to go into an E-Stop condition. This fault will probably reflect a student error in their sequence diagram. The sharper students will have two triggers for cycle start: the finger switch and the part-in place optical pick up. The reality is that only the finger switch is the trigger. Once the load conveyor starts to move, the processor checks for part-in-place optical signal. When it doesn't see any, it faults the machine. The instructor may have to loosen the set screws to facilitate this move of the mirror. The students should be able to isolate the fault to the mirror. • Change the orientation of the pucks in the side stack near the unload chute. This will cause the students to load the part improperly. When the part moves into the unload zone, it won't be detected by the proximity switch. The Unload stop will not advance and the machine will stop in sequence. • Physically move the reflective mirror sensing a puck in the unload chute area. This will probably be missed by students in their sequence diagram. This light beam has to remain unbroken in order to extend the Unload Stop and extend the Pusher. The students should be able to isolate the fault to the misaligned reflector. • RFB 10 – Radio Frequency Box, fault remote – Unload pusher advance solenoid – open circuit. This fault disconnects power to the Unload Pusher Advance Solenoid. With a meter the students can actually isolate this fault. Without a meter and good print reading capabilities, the students will only be able to identify that there is an open somewhere in this circuit. The PLC is trying to turn on the output (Output light is on) but the solenoid is not energized. This action simulates a broken wire or an open solenoid. Manual operation of	Students are troubleshooting faults on the Machine. Sometimes they can actually repair the fault and return the system to full operation. Sometimes they can only identify the fault and report it to the instructor. (Example: There is an open circuit between this input and the input module.) Students are troubleshooting faults on the Machine.

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Duration	Instructor Activities	Student Activities
As Time Allows	the directional control valve will demonstrate that the pneumatic circuit is functioning. • RFB 11. This fault breaks the circuit on the magnetic switch telling the processor that the pneumatic pusher is returned. This loss of signal inhibits the operation of the machine. Examining the input lights on the unload junction box input module would identify that this signal has been lost and it is a real world (not related to the PLC) problem. • RFB 12. This fault opens the circuit in the unload pusher stop advance solenoid. Again the students should be able to isolate this fault to an open in this circuit. The PLC's associated output light in the Unload Conveyor Junction Box will be on. The students will rely on the sequence diagram at the beginning of the troubleshooting exercises. They will then be less reliant as they start to memorize the sequence, outputs and triggers. They will struggle when a fault appears that reflects an error in the sequence that they have recorded. For example, the students usually miss the high level optical pick-up on the chute area. This device tell the processor that the output is clear to unload. When the signal is lost, the pusher stop will not advance and the machine stops. The students usually miss this trigger. This will cause them problems that will force them to correct their sequence diagram and understanding. Additional AMTEC* Level 1 Faults can be identified by viewing **Attachment 1-22**. Refer to the color coding to identify the level of the fault. It should be noted that some of the faults listed in this spreadsheet cannot be used for this course. For example, the students have not studied PLCs yet, therefore faults that require reloading the PLC software are not possible. These advanced faults will be used in the level 2 course. **SMC Level 1 Faults.** • Station 1 – Load a Body sideways in the feeder. This will jam the feed mechanism, yet it will still be sensed by the Body present Proximity switch. Physical examination should identify this fault.	Students are troubleshooting faults on the Machine.

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INSTRUCTOR DAY BY DAY

Duration	Instructor Activities	Student Activities
As Time Allows As Time Allows	• Any Station – Lower the carrier sensing limit switch. You will need to have metric wrenches for the set screws. One will have to be removed. The loss of this input should be confirmed on the input light (input module) associated with that switch. Remember that in automatic, this is the cycle start trigger. • Cover Station. – Load the cover sideways in the feeder (Vertical). This will prevent the cover from being moved into the transfer area. A limit switch is used to sense that the part is in place in the transfer area. The loss of the signal to the input module should identify this fault. • Bearing station. Remove one set screw to the limit switch that senses that the bearing has been moved out of the feeder. Move the switch so that it cannot sense the bearing. Again, the loss of an input to the input card will help identify this fault for the students. • Refer to **Attachment 1-23** for additional SMC Level One Faults and comments on their functionality. The levels are called categories in this attachment. The switches on the side of the trainer are used to initiate these faults.	Students are troubleshooting faults on the Machine.
	Level two faults. These faults reflect what might be discovered with the start-up of a machine at the beginning of a shift. Sample faults would include: **AMTEC* Faults:** • Air is turned off at the feed to the simulator or further up stream • One of the Disconnects on the back of the trainer is turned off • A Safety Gate is open – One of the vertical gates can be opened ¼ inch and use the spring loaded latch to hold it in place. • Robot controller is turned off • Robot teach pendant switch is in the teach (ON) position	

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Duration	Instructor Activities	Student Activities
As Time Allows	• Any E-stop can be depressed • Pull Cord has been activated **SMC Faults:** • Power is off at the station • Air on the body station is off, thus shutting off air to all stations • Air is turned off at the station (Manual Valve) • The actuators are not at their rest position at a station when starting the sequence **Instructor Note:** Level two faults are usually introduced to the students after a couple of successes at the level one faults. These level 2 faults are then applied in association with another fault; therefore the students must achieve a power up condition prior to trouble shooting the remaining fault.	Students are troubleshooting faults on the Machine.
As Time Allows	**Level three faults** Level Three faults are faults that cross shifts and the system is not brought back into operation. There might remain the original fault plus faults that are introduced by the attempted repair. AMTEC* Level 3 Faults • Problem: the robot vacuum generator was replaced last night. The night shift did not have time to return the system to operation. Induced fault: Shut off the robot vacuum air on the bottom of the pneumatic valve assembly. This manual valve is not normally switched and the students probably have not noticed it before. It will cause the robot to stall-mid program when they try to run the system. Be sure to shut off all disconnects prior to allowing the students on the system. • Problem: While the robot is running its program, shut off pneumatic supply at the lock-out valve. This will cause 2 problems. The first problem is the vacuum generator will remain on with no puck in place (it will probably fall off within 5 - 10 seconds). This might cause the system air pressure to drop so low that the system will fault out due to low air pressure. On the	Students are troubleshooting faults on the Machine.

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INSTRUCTOR DAY BY DAY

Duration	Instructor Activities	Student Activities
As Time Allows	teach pendant, select robot I/O and toggle inputs 1 or 2 to shut off the vacuum generator. **(This function needs to be demonstrated to the class during one of the instructor demonstrations.)** Now the robot and Plc are out of sequence. The robot will have to be taught home and system power cycled to re-sequence the machine. This is a tough problem. **SMC Level Three faults.** • Magnetic switch of body feeding cylinder (f1) OPEN - switch 3 on the Troubleshooting Box. In addition close off the flow control on the associated cylinder for extension. Problem: Station one failed last night and they couldn't get it working. The student will have to discover the closed flow control and after adjusting it, the station will still not work due to the magnetic switch. **Instructor Note:** The instructor will have to bug the trainers and rotate the students through the faulted stations. Keep track of the faults and the students completing the troubleshooting. Modify the rubric to reflect the faults that have been fixed by the students. **NOTE**: it is critical that a good tracking sheet be developed. Students will be rotating through the faulted systems and the instructor will have to keep track of the students and the faults. See the rubric. **See Attachment 1-2.**	Students are troubleshooting faults on the Machine.
N/A	**Instructor Note:** Add additional faults from the fault lists. Make sure that the fault is checked out prior to assigning to the students. As can be seen from the SMC fault list comments, not all of the faults work as described. Many of the AMTEC* faults are beyond the scope of this course and will be covered in the troubleshooting course following the completion of all other courseware. **Instructor Note:** On the AMTEC Simulator*, the instructor must copy the files of the robot and the image of the robot on separate	N/A

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INSTRUCTOR DAY BY DAY

Duration	Instructor Activities	Student Activities
	flash drives. Students may inadvertently modify the programs or configuration. This would allow the instructor to recover the operation. The Instructor should also have a copy of the PLC program on a flash drive, as a back-up. Even though the content of this course does not cover the PLC or the robot programming, it will benefit the instructor to study these programs prior to the class. Remember that the triggers that the students record on the trainers are guesses. It is only through an analysis of the PLC programs that they can be identified with certainty.	
As Time Allows	Continue with troubleshooting	Students Continue with Troubleshooting
	Instructor's Note: Remember to up-date the rubric to match the student's progress.	

* AMTEC, NSF ATE DUE-0903193

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INSTRUCTOR DAY BY DAY