

***Fiberglass Panel Press  
Manufacturing Controls Project***

*By*

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### **Project Description**

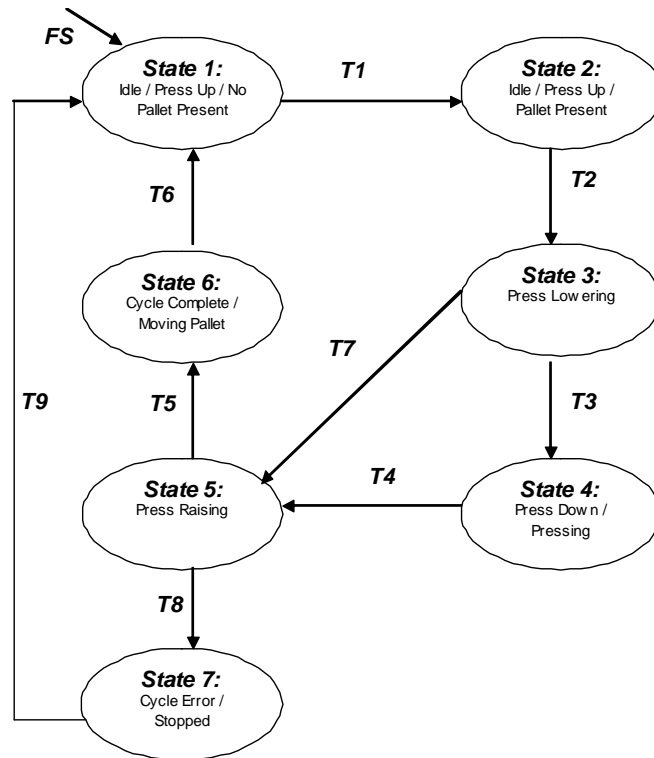
SoundTech Inc. was experiencing delaminating on one of their products due to lack of force applied after the adhesion process. The solution to this problem was to build a press onto the existing assembly line that will compress the parts with up to 900 pounds of pressure supplied by four 2" pneumatic cylinders. The force would be distributed over a 74" by 80" press surface. The press was constructed of 80/20 extruded aluminum and 5/8" oak board to add a tabletop and press head. Die foam was also adhered to the press head to evenly distribute the force to the parts without causing damage.

To insure a safe process, a Programmable Logic Controller (PLC) was used to control the operation of the press. A program was written to account for the many conditions that must be present before the press can safely operate including the safety of the assembly line. Due to the adhesive application process preceding the press, 4 pairs of sensors were used to detect the different configurations of material. If there is an inner panel present there must also be an outer panel present before the press can cycle. This is to eliminate the opportunity for a part to be adhered to the bottom of the press head. Other sensors, such as the location of the pallet and the press limit switches were added to insure the press would only cycle when the process is in correct safe order. Another important safety issue was address by communicating to the assembly line PLC to restrict the pallets from shuttling while the press was not in the up position.

### **PLC Program Design Process**

#### ***System State Diagram***

To begin the design process a system state diagram was developed to model each state of the press cycle and the transitions between states. The state diagram consisted of seven states and nine transitions between states. The graphical representation of the states and transition of the system, as shown in Figure 1, was used throughout the design and development process.



**Figure 1: System State Diagram**

**PLC Input, Output and Internal Memory**

Upon completion of the system state diagram the input, output and internal memory locations of the PLC were determined. Each of the three data types has a specific prefix to denote the type, X for input, Y for output and C for internal bit memory. A list of the input, output, and internal memory is shown in Table 1. There were 19 inputs, four outputs, and 21 internal memory locations assigned.

**Table 1: Input, Output and Internal Memory List**

Inputs		Outputs		Internal Memory	
X0	Control Relay	Y0	Brake Output	C1	T1- Transition from state 1 to state 2
X1	Cycle Reset	Y1	Error Light	C2	T2- Transition from state 2 to state 3
X2	Brake Input	Y2	Timer Start	C3	T3- Transition from state 3 to state 4
X3	T1 - External Timer Done	Y3	SC1- Cylinder 1 Solenoid Valve	C4	T4- Transition from state 4 to state 5
X4	A1 - 1 Inner Panel			C5	T5- Transition from state 5 to state 6
X5	A2 - 1 Outer Panel			C6	T6- Transition from state 6 to state 1
X6	B1 - 2 Inner Panel			C7	T7- Transition from state 3 to state 5
X7	B2 - 2 Outer Panel			C10	T8- Transition from state 4 to state 5
X10	C1 - 3 Inner Panel			C11	T9- Transition from state 5 to state 7
X11	C2 - 3 Outer Panel			C12	T10- Transition from state 7 to state 3
X12	D1 - 4 Inner Panel			C13	S1- State 1 Idle/Press Up/No Pallet Present
X13	D2 - 4 Outer Panel			C14	S2- State 2 Idle/Press Up/ Pallet Present
X14	P1 - Pallet Sensor 1			C15	S3- State 3 Press Lowering
X15	P2 - Pallet Sensor 2			C16	S4- State 4 Press Down, Pressing
X16	LS1 - Press Up Limit Switch			C17	S5- State 5 Press Raising
X17	LS2 - Guarding Switch 1			C20	S6- State 6 Cycle Complete/Moving Pallet
X20	LS3 - Guarding Switch 2			C21	S7- State 7 Cycle Stopped or Failed/Press Raising
X21	LS4 - Press Down Limit Switch			C22	Ok to Press- Correct pannel cofiguration
X22	SW1 - Press E-Stop			C23	Active- Press is active
				C24	Pallet Present
				C25	Cycle Error

### ***System State/Transition Equations***

The system state/transition equations were written from the developed system state diagram using Boolean logic. Equations were first written to define the transitions and then the equations defining the states of the system. The PLC bit memory locations were used to write the state/transition equations to simplify the process. The state/transition equations are shown in Figure 2.

$$\begin{aligned} T1 &= S1 \cdot C22 \cdot C23 \cdot C24 \\ T2 &= S2 \cdot X2 \cdot C23 \\ T3 &= S3 \cdot X21 \cdot C23 \\ T4 &= S4 \cdot (X3 \cdot C23) + \overline{C23} \\ T5 &= S5 \cdot X16 \cdot C23 \cdot \overline{C25} \\ T6 &= S6 \cdot \overline{C24} \cdot C23 \\ T7 &= S3 \cdot \overline{C23} + T0 \\ T8 &= S5 \cdot C25 \cdot X16 \\ T9 &= S7 \cdot C21 \cdot X1 \\ S1 &= S1 + T6 + FS + T9 \cdot \overline{T1} \\ S2 &= S2 + T1 \cdot \overline{T2} \\ S3 &= S3 + T2 + T9 \cdot \overline{T3} \cdot \overline{T7} \\ S4 &= S4 + T3 \cdot \overline{T4} \\ S5 &= S5 + T4 + T7 \cdot \overline{T5} \cdot \overline{T8} \\ S6 &= S6 + T5 \cdot \overline{T6} \\ S7 &= S7 + T8 \cdot \overline{T9} \end{aligned}$$

***Figure 2: System State/Transition Equations***

### ***Transition Descriptions***

T1: Transition one occurs when the system is idle with no pallet present, state 1, each of the pallet sensors detect the pallet, the correct panel configuration is present, and the press is in the active state.

T2: Transition two occurs when the system is idle with a pallet present, state 2, the brake input from the conveyor is true, and the press is in the active state.

T3: Transition three occurs when the press is lowering, state 3, and the bottom limit switch is active, while the press is in the active state.

T4: Transition four occurs when the press is in down and pressing, state 4, the external press timer input is active, and the press is in the active state or if the press active bit turns off.

T5: Transition five occurs when the press is raising, state 5, the press up limit switch is turns on, the press is in the active state and the cycle error bit is not on.

T6: Transition six occurs when the cycle is complete, state 6, the pallet leaves the station, tuning off the pallet sensors, and the press is in the active state.

T7: Transition seven occurs when the when the press is lowering, state 3, the press active bit turns off or the three second lowering timer done bit is on.

T8: Transition eight occurs when the press is raising, state 5, the cycle error bit is turned on and the press up limit switch is set.

T9: Transition nine occurs when the press is in the cycle stopped state, state 7, and the reset button is pressed.

### ***State Descriptions***

S1: State one is when the press is idle in the up position and no pallet is present. No outputs are active in this state.

S2: State two is when the press is idle in the up position and a pallet is present. The brake output is latched on in this state, which tells the conveyor PLC to apply the brake at the press station.

S3: State three is when the press is lowering from the up position. The pneumatic solenoid output is turned on in this state and a press lowering timer is started.

S4: State four is when the press is pressing/holding in the down position. The pneumatic solenoid output is turned on in this state.

S5: State five is when the press is rising from the down position. The pneumatic solenoid output is turned off in this state.

S6: State six is when the press is in the up position with a completed pallet present. The brake output to the conveyor PLC is turned off in this state.

S7: State seven is when the press is in the cycle error state. The press error light is turned on in this state.

### ***PLC Program***

Using the state/transition equations the PLC program was written in Direct Soft ladder logic for the Direct Logic PLC. The logic for the press active bit was written first since

the program operation is dependent upon this active bit. The press is active only when the system emergency stop circuit is closed, both the press guarding switches are on and the press emergency stop is not pressed. The panel configuration bit was then defined so the correct panel configuration was present on the pallet. Either both fiberglass panels must be present or neither panel at each of the four locations. The transition and state equations were then written the written in ladder logic program. To complete the program the ladder logic to activate the outputs was written. The completed PLC program is shown in the Appendix.

## **Electrical and Panel Design**

### ***Components***

In the design of the electrical panel and system it was first necessary to identify all of the system components. A bill of material was created for identifying and tracking the components for the electrical system. The major electrical components consisted of the PLC, 24 volt power supply, relays, external timer, optical sensors, inductive sensors, limit switches, terminal and fuse blocks, push buttons, indicator light and electrical panel cabinet.

### ***Design Considerations***

The design of the electrical system was based upon the requirements of the Direct Logic PLC. The PLC is powered using 120 volts AC, with 24 volts DC powering both the inputs and outputs. The input channels are sinking inputs, where current from the 24 VDC supply flows through the PNP sensor or switch and into the PLC input. The inputs are grouped in to a bank of four with a common input connected to the DC common. The output were also grouped in to a bank of four, but had a common 24 VDC supply.

Two 120 VAC relays were used in the electrical design, one for the emergency-stop circuit and one for the brake input signal. The existing conveyor system emergency stop circuit was implemented in to the electrical/control system. A mushroom emergency stop button was already located directly next to the placement of the press. This e-stop circuit was connected to a control relay in the control panel, which turns the outputs of the PLC off when the circuit is broken. A second relay was used for the brake signal from the conveyor PLC. The brake signal is 120V, which controlled a relay for a 24V input signal to the PLC.

The electrical schematics and an image of the completed control panel are found in the appendix.

### **Project Results**

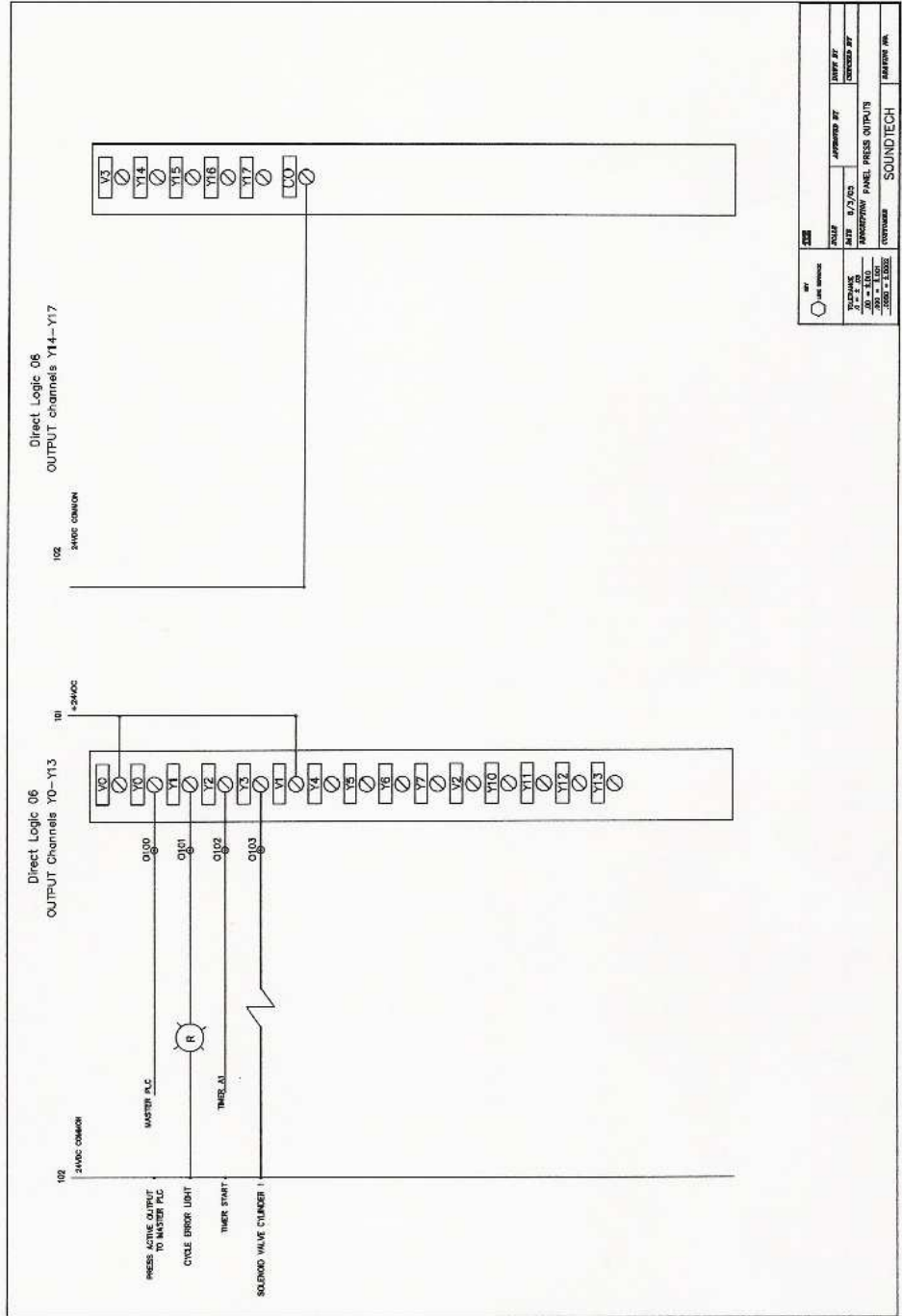
The press was constructed onto the existing assembly line and the pneumatics and electrical components were connected in accordance to schematics. The electrical panel was powered and the sensors were tuned into the appropriate ranges. The program was downloaded onto the PLC and the machine was run. The press operated successfully on the first try since program and mechanical testing had been performed prior to the machine being assembled onto the existing assembly line. The press should be cleared for full production by 8/12/2005 after the final safety inspections have been performed.

## Appendix

1. Wiring Diagram
2. PLC Ladder Logic Program
3. Control Panel Image

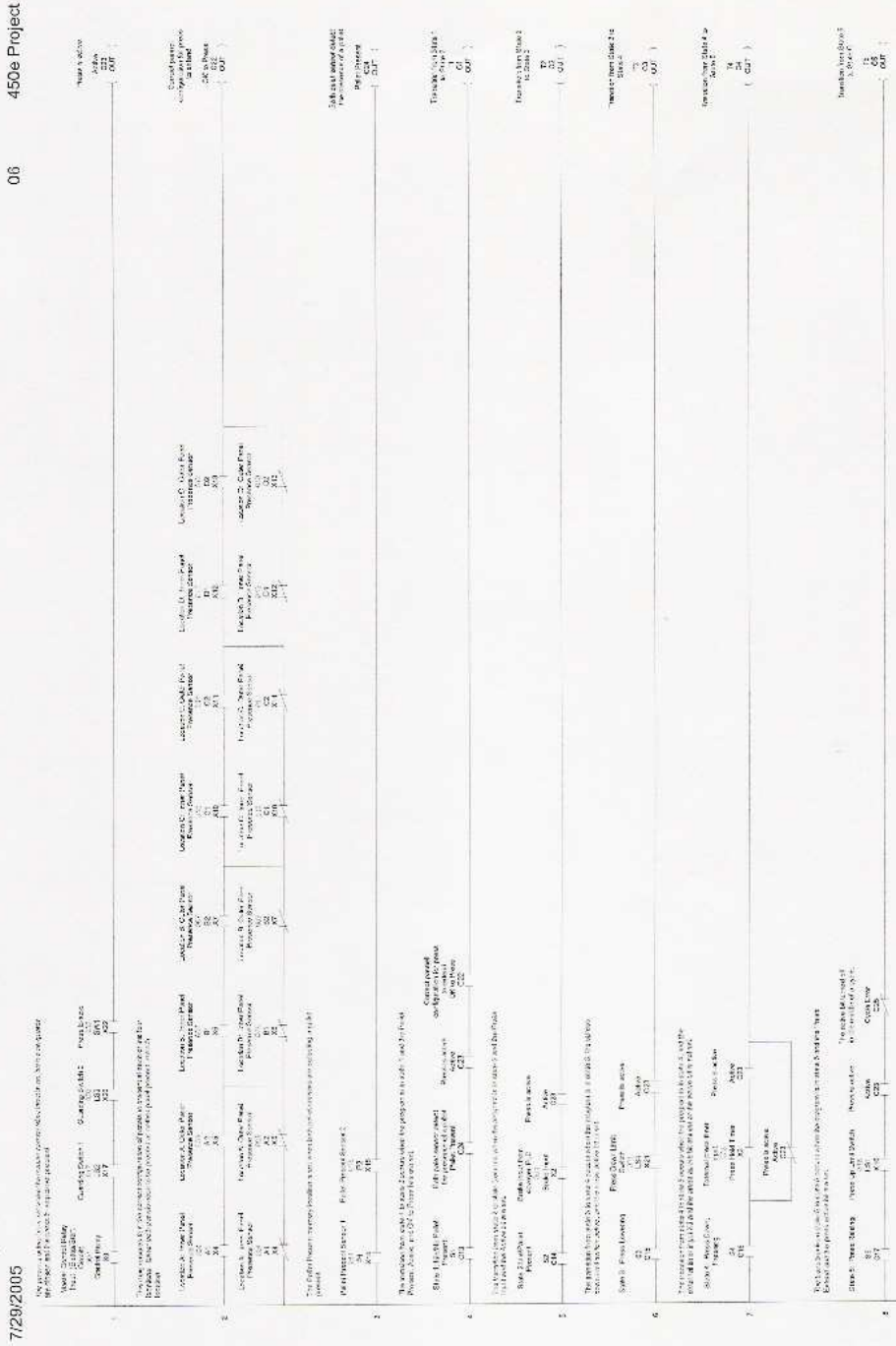






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# Ladder Logic Program



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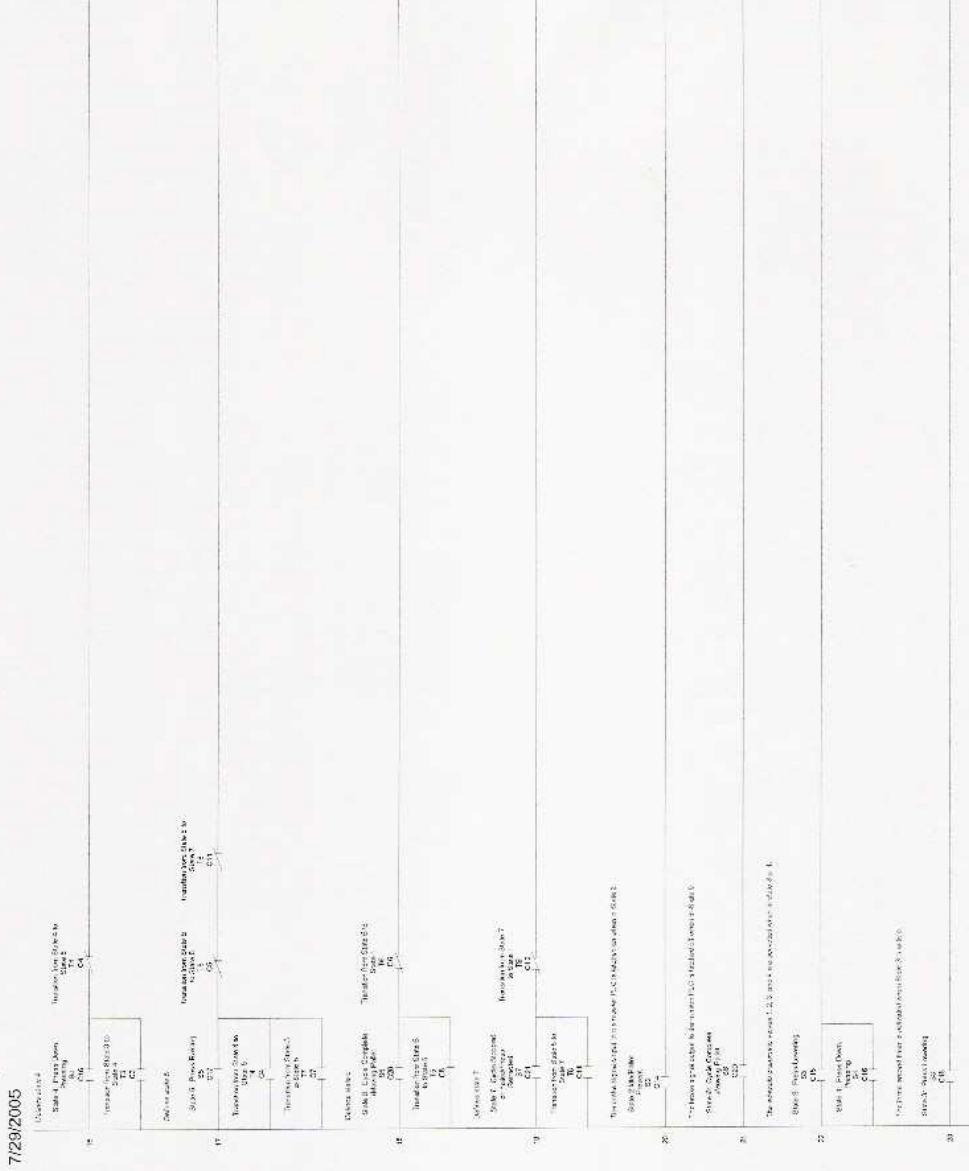
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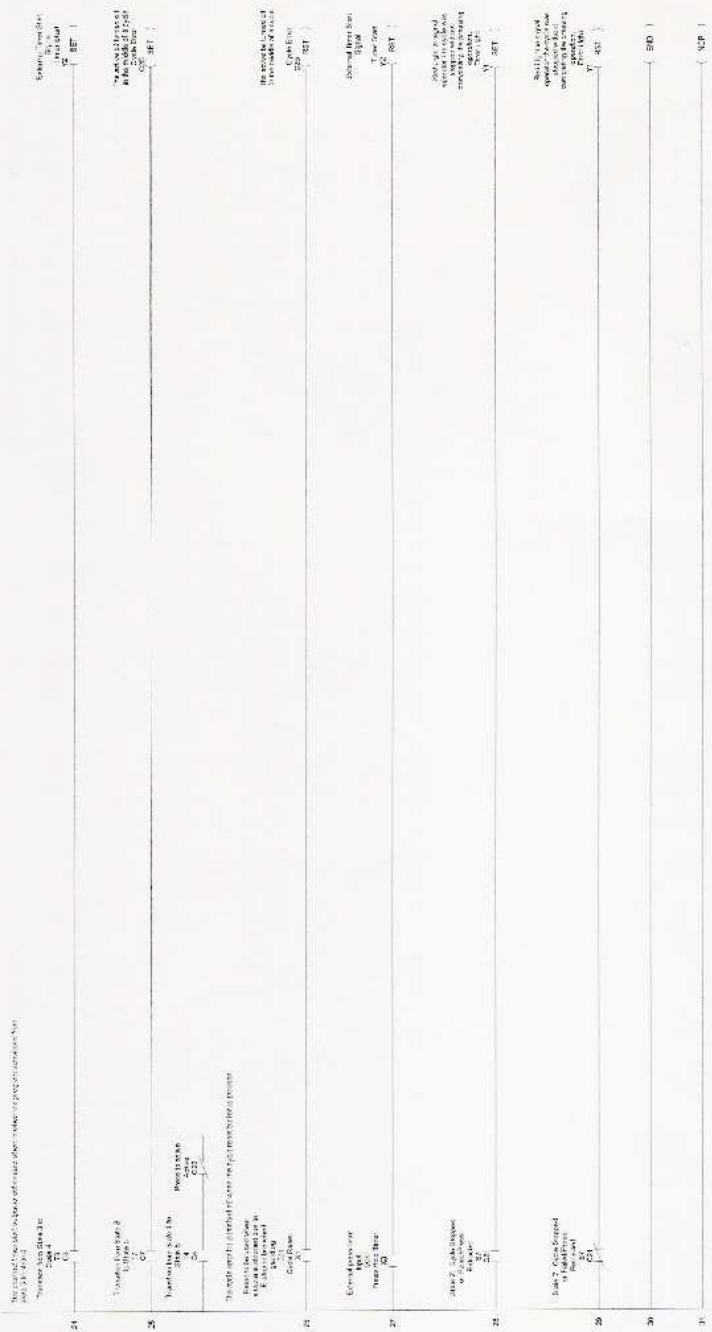
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*Control Panel*

