Steel Nozzle Glass Insulator Fusing Automation Manual

Manufacturing Systems

ENGR 480

Final Report

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Directions

Instructions for loading

1. Clean all Nozzles and glass pieces
2. Wear clean gloves when handling clean parts
3. While the pneumatics are off, open clamps at Station 2 and push glass pieces up the shaft. Close pinchers so all pieces are above the highest clamp
4. Turn Pneumatics on by turning the E Stop button clockwise
5. Feed remaining nozzles into the top of station 1

Starting the Machine

The Machine will start with a full cycle as if it were running. Be sure to simulate the running environment before starting. Make sure there is a nozzle at station 2 and a nozzle/insulator pair at Station 3.

1. Turn on power strip
2. Turn PLC to run
2. Release E stop by turning clockwise
3. Index table twice, to make sure columns are centered
3. Flip on/off switch to on to start automation

Stopping the Machine

Emergency Stop

In case of emergency first hit the E Stop to disable pneumatics and turn off the power supply. Then flip the on/off switch to off to stop the PLC automation

Normal stop

1. Flip on/off switch
2. Push E-Stop button
3. Turn PLC to stop
4. Turn off Power Strip

Clearing Jams

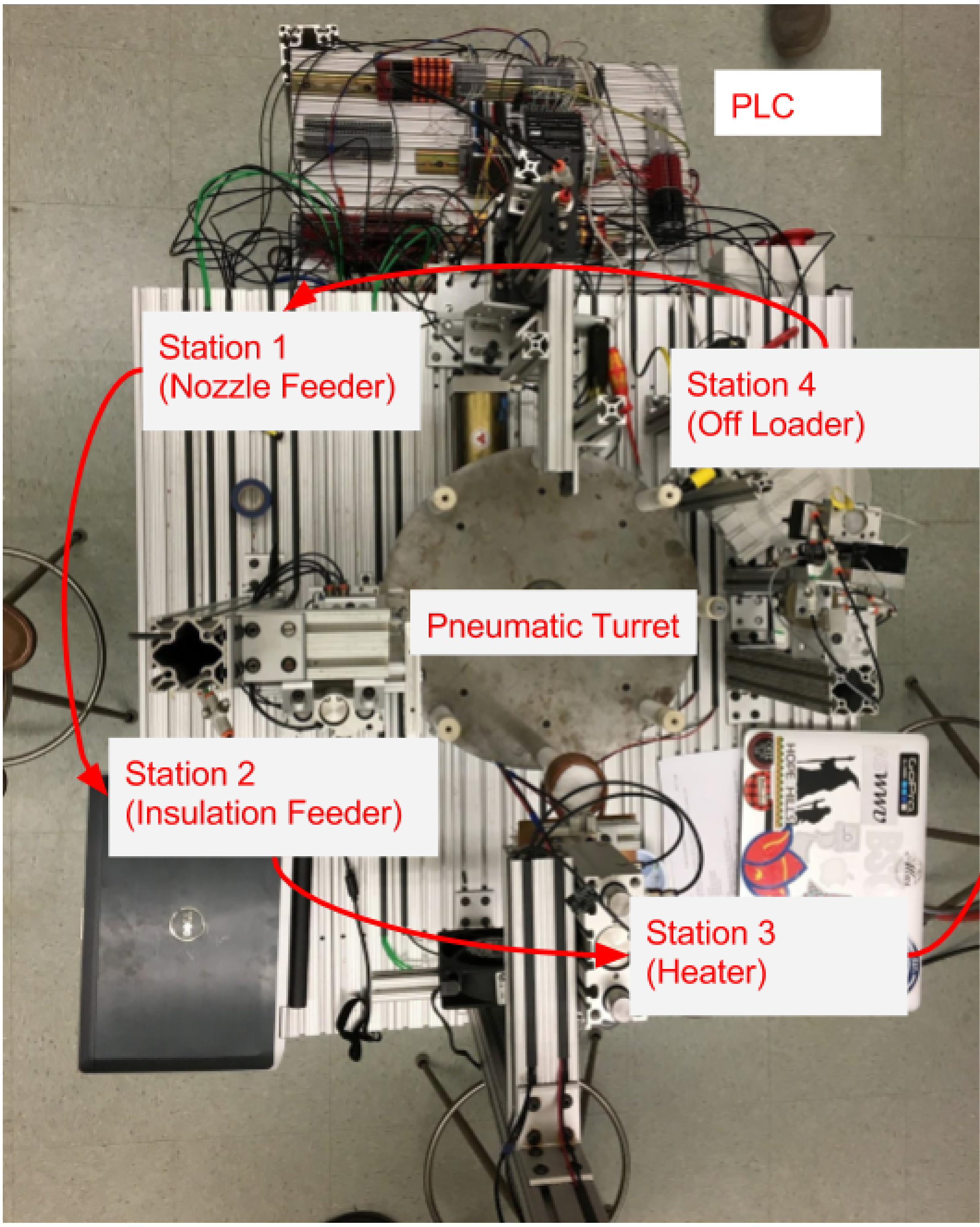
Jams may occur at stations 1, 2, and 4 if the nozzles, or insulators don't get handled properly. The pneumatics are quite strong, so if a jam occurs, begin by turning them off with the E Stop Button. When restarting, it is best to completely Power off the PLC, then repower it so it is safe to assume the PLC will start at the right state

1. Push big red E Stop button, then flip the on/off switch
2. Nozzles and towers may be extremely hot after Tower 3
3. Return the machine to state described in "Starting the Machine"
4. Follow start-up procedure

Table Outline

Diagrams

Top View of Table



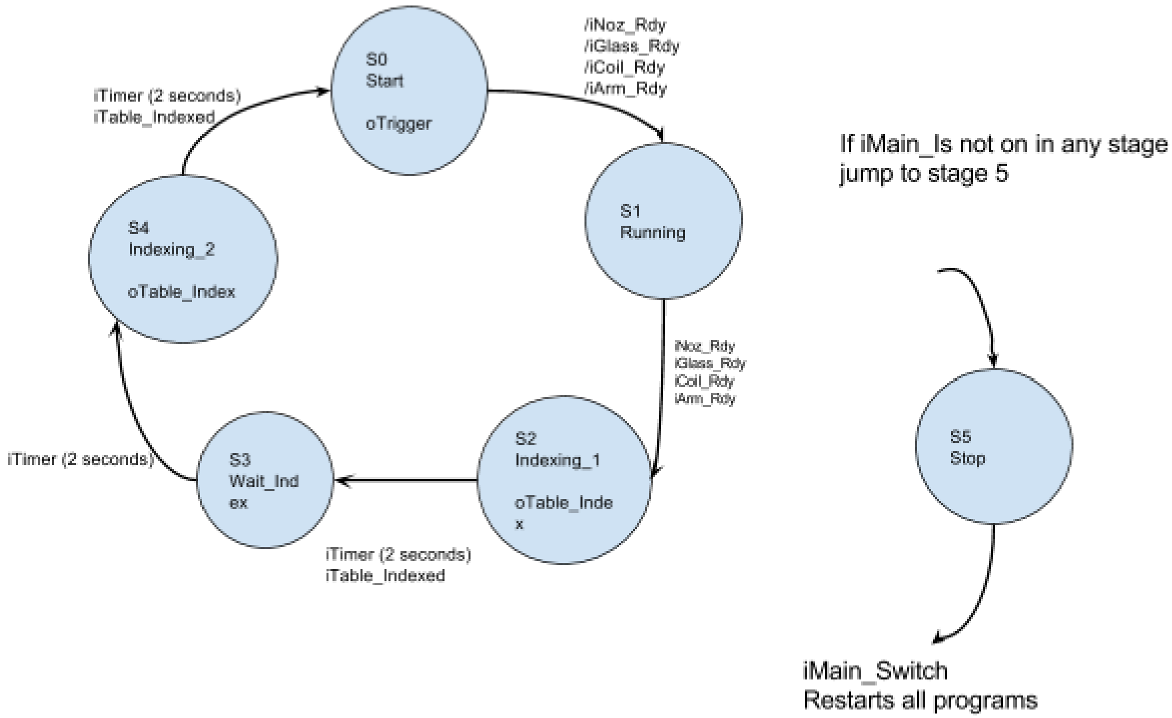
Operation description

This table assembles a 3D printer nozzle with a glass insulator. Assembly is accomplished through four stages of operation. A part holder mounted on a pneumatic turret rotates at the center of the table moving the assembly to a new station.

1) Station 1 - Nozzle Feeder
    a) The nozzle is placed in the part holder mounted to the pneumatic turret.
2) Station 2 - Insulation Feeder
    a) The glass insulator is dispensed and placed on top of the nozzle in the part holder.
3) Station 3 - Heater
    a) The assembled nozzle and insulator are moved under a induction heating coil which lowers over the part holder. The heating processes bonds the nozzle and insulator.
4) Station 4 - Off Loader
    a) A pneumatic pincer grabs and removes the bonded assembly then drops it into a collection container.

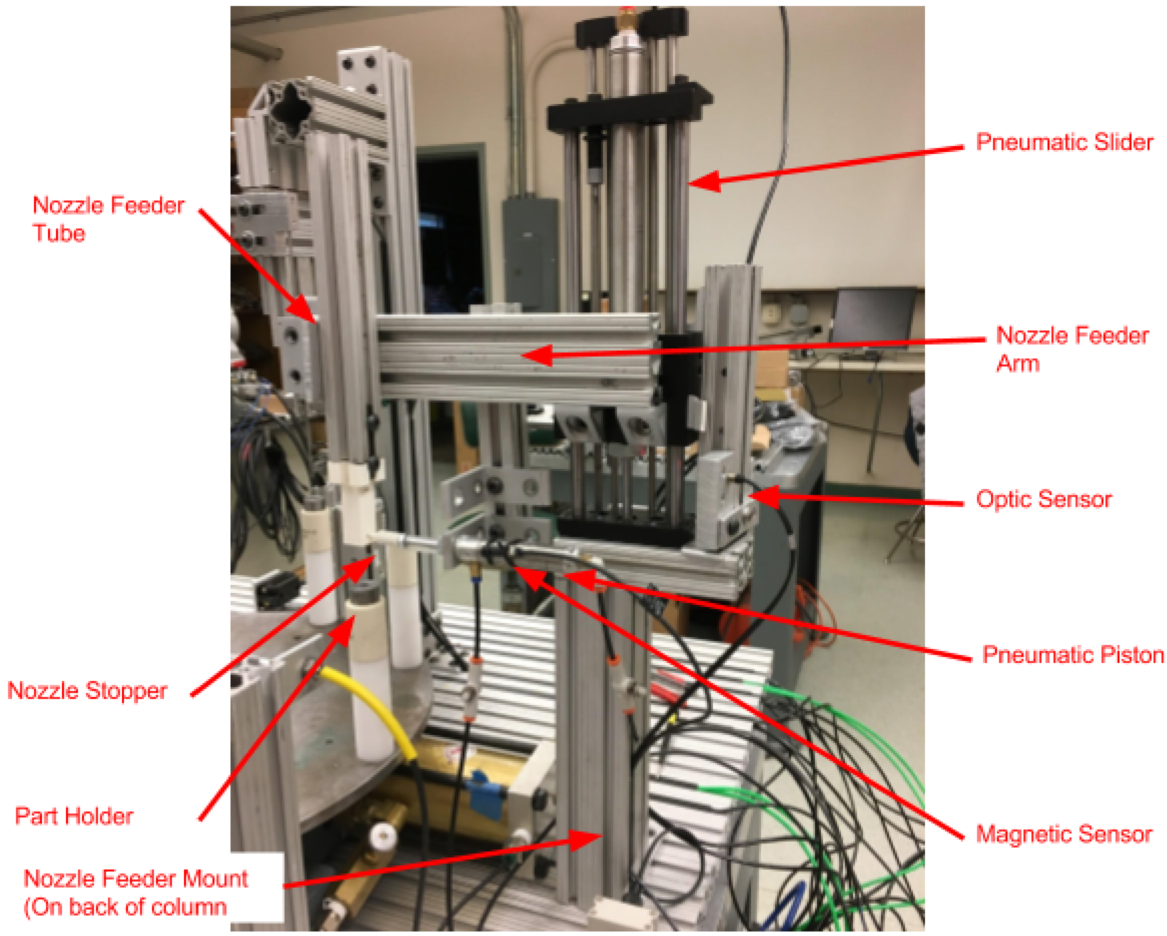
State Diagram

This state diagram is for the main program. This program trigger and controls individual programs that run each stations.



Station 1 (Nozzle Feeder)

Diagrams



Operation Description

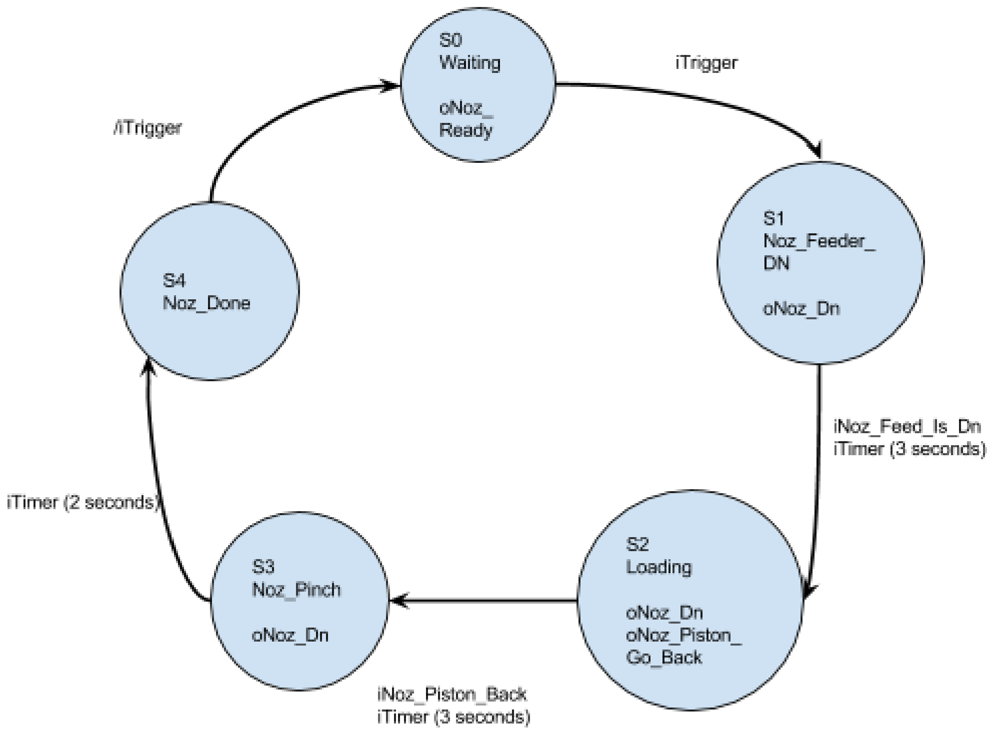
The function of Station 1, the nozzle feeder, is to place a nozzle into place on the pneumatic turret at the center of the table. It accomplishes this task with a four stage process starting from its waiting position. The waiting position of Station 1 has the nozzle feeder arm raised on the pneumatic slider and the pneumatic piston in the forward position.

1) Stage 1
   a) The nozzle feeder arm lowers.
      i) This brings the end of the nozzle feeder tube directly over top of part holder on the pneumatic turret.
2) Stage 2
   a) The pneumatic piston retracts.

   i) This allows nozzles stored in the nozzle feeder tube to move downward. The lowest nozzle in the tube falls into the part holder with higher nozzles stacked on top of it.

3) Stage 3
   a) The pneumatic piston extends.
      i) This traps the second lowest nozzle in the nozzle tube against the wall of the tube.
4) Stage 4
   a) The nozzle feeder arm raises.
      i) The nozzle in the part holder is left while other nozzles raised away from the path of the pneumatic turret.

Stage Diagram



Maintenance Instructions

Warning: Turn off all table power source before performing any maintenance.

Nozzle Tube Realignment

Due to the jarring action of the pneumatics slider the the nozzle tube and the part holder might become unaligned over time.

1) Make sure the nozzle feeder arm is in the down position and the pneumatics turret is in the indexed position.
   a) To insure the turret is in the indexed position the table will have to be turned on. After the turret is in position turn off all table power sources again.

2) Loosen the screws mounting the nozzle feeder assembly to the table.
    a) This allows for the movement of the nozzle feeder assembly back and forth as well as slight rotation.
3) Adjust the position of the nozzle tube directly above the part holder and tighten screws.
4) Drop nozzle through tube to ensure it falls into the part holder correctly. Repeat steps 2-3 until successful.
5) Run the table without the power supply to the heat on. Make sure the nozzle is dropping into the part holder reliably. Repeat steps 2-4 until successful.

Nozzle Tube Fatigue

The end of the nozzle tube is a 3D printed part that allows for the action of the nozzle stopper and accurate placement of the nozzle in the part holder. Due to the strength of the pneumatics and the properties of the plastic the connection of the plastic part with the aluminum extrusion above may fail. On fail 3D print a new part and mount in place of the old one. After the replacement nozzle tube realignment might be necessary.

Suggested Future Improvements

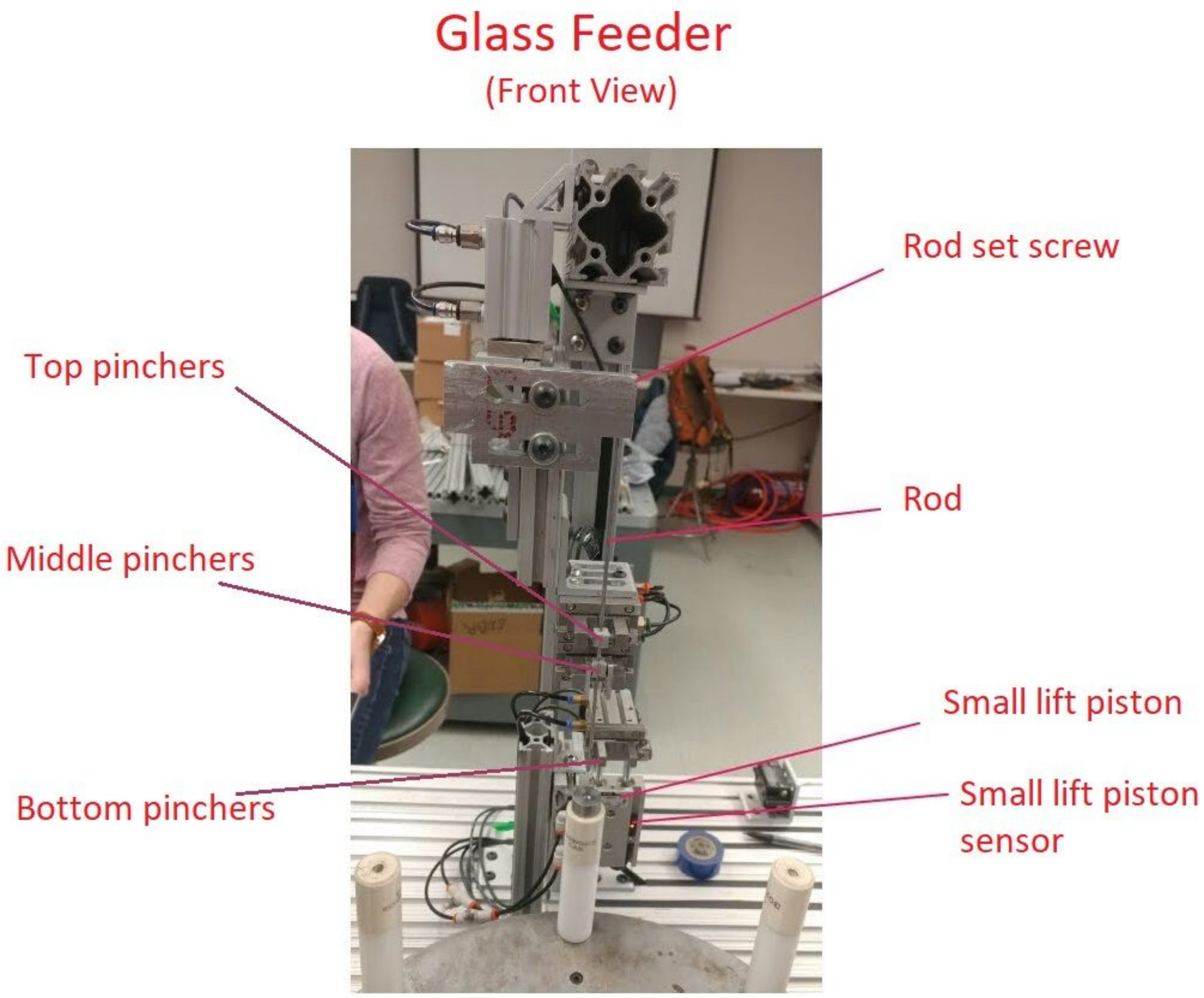
This system might be improved by a better nozzle tube and stopper geometry that is more precise. This will improve the overall reliability of the nozzle feeder.

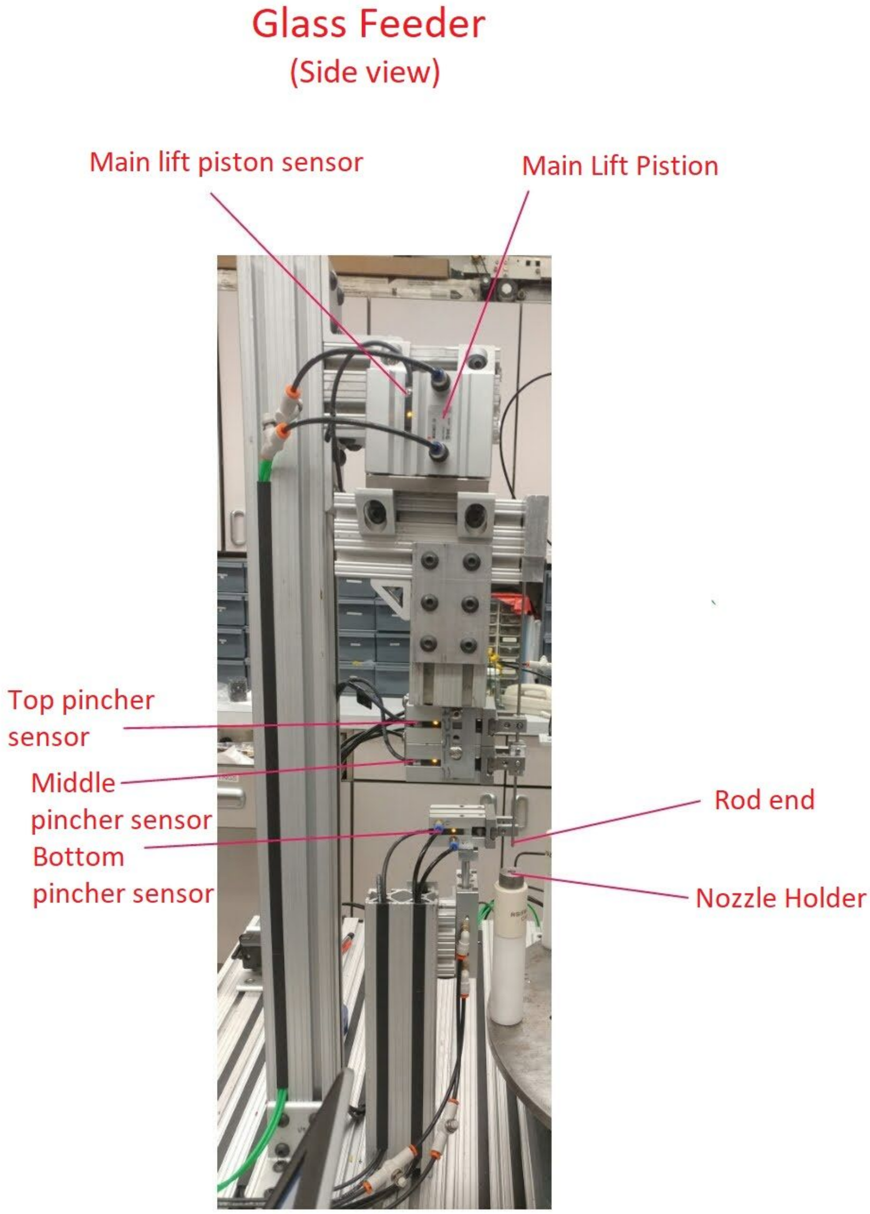
Performance Data

After proper alignment the nozzle feeder was successful approximately 80% of the time.

Station 2 (Insulator Feeder)

Diagrams





Operation description

The function of Station 2, the glass (insulation) feeder, is to place a glass tube into place on the nozzle on the pneumatic turret at the center of the table. It accomplishes this task with a seven stage process starting from its waiting position. The waiting position of Station 2 has the glass feeder arm raised on the top and middle pneumatic pinchers pinched as well as the bottom pincher up and away from the rod.

1) Stage 1
    a) The Glass feeder lowers.
        i) This brings the end of the rod directly in contact with the nozzle.
2) Stage 2

a) Top pincher opens
    i) This allows one glass to fall onto the middle pincher.

3) Stage 3
    a) Middle pincher opens
        i) This closes the top pincher and waits a second then opens the middle pincher allowing the one glass to fall onto the nozzle at the end of the rod.

4) Stage 4
    a) Bottom pincher opens
        i) This closes the middle pincher waits a second and opens the bottom pincher.

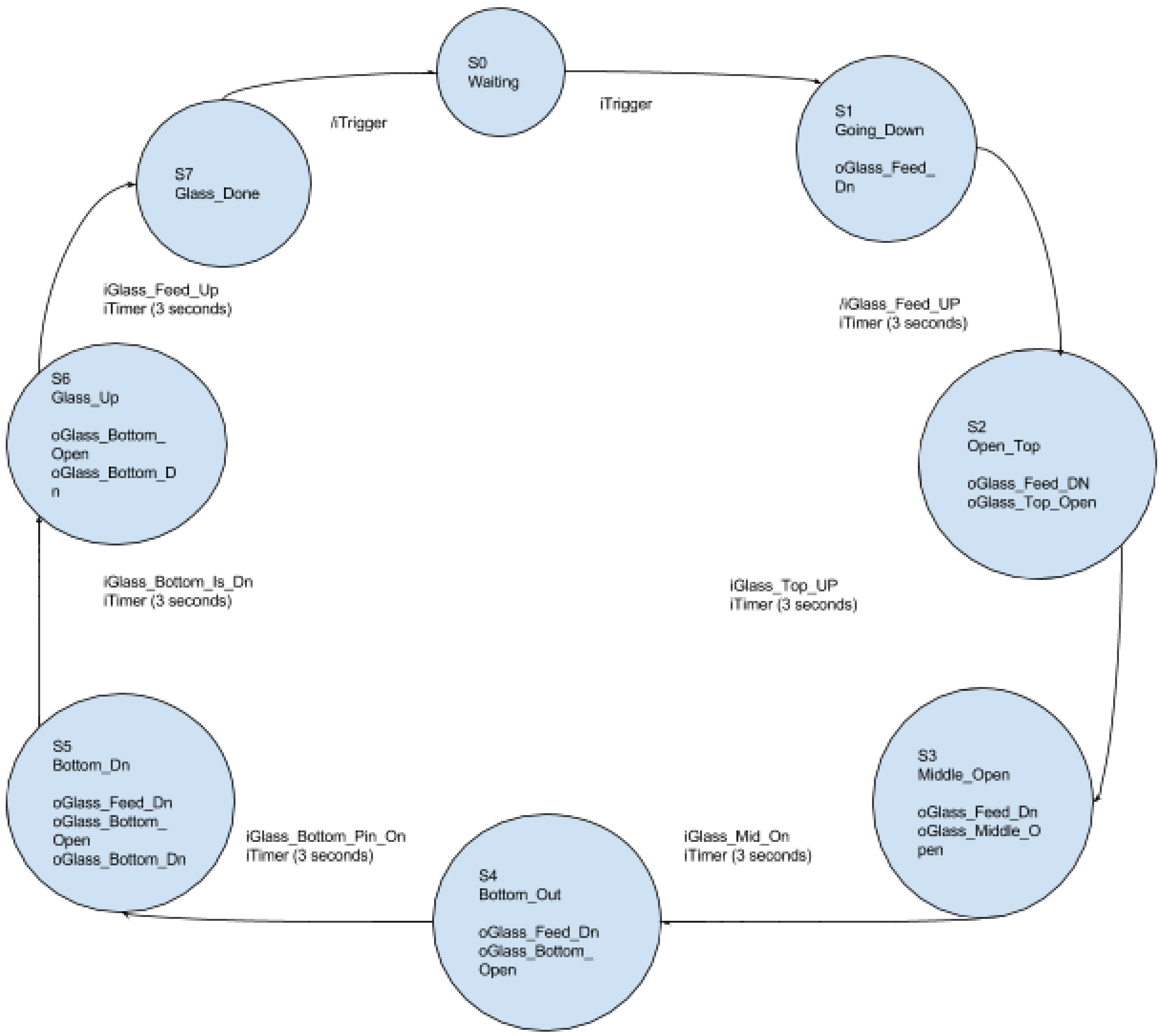
5) Stage 5
    a) Bottom pincher down
        i) This this pushes the lower pincher down to make sure the glass seats on the nozzle well.

8) Stage 6
    a) Glass feeder up
        i) This this raises the glass feeder.

7) Stage 7
    a) Bottom pincher return
        i) This raises the lower pincher as well as closes it.

0) Stage 0
    a) Wait
        i) This waits for the table to index to the correct position.

State Diagram



Maintenance Instructions

Warning: Turn off all table power source before performing any maintenance.

Slider Rod Realignment

Due to the jarring action of the pneumatics or loading and unloading the slider rod and the part holder might become unaligned over time.

1) Index the table with a nozzle in the holder for alignment. Then turn off pneumatics. Manual raise and lower the glass feeder as necessary.
    a) To insure the turret is in the indexed position the table will have to be turned on. After the turret is in position turn off all table power sources again.
2) Gently flex the rod in the direction it needs to go in little adjustments until it matches up with the nozzle in the holder.
3) If height needs adjusted slightly loosen the screws necessary and adjust with the main piston in full down.

4) Run the table without the power supply to the heat on. Make sure the glass is seating into the nozzle reliably. Repeat steps 1-4 until successful.

Pincher Foam Gripper Fatigue

The pinchers are equipped with grip foam. Should this foam fall off or get to old replace it with a new square of one sided foam as needed.

Suggested Future Improvements

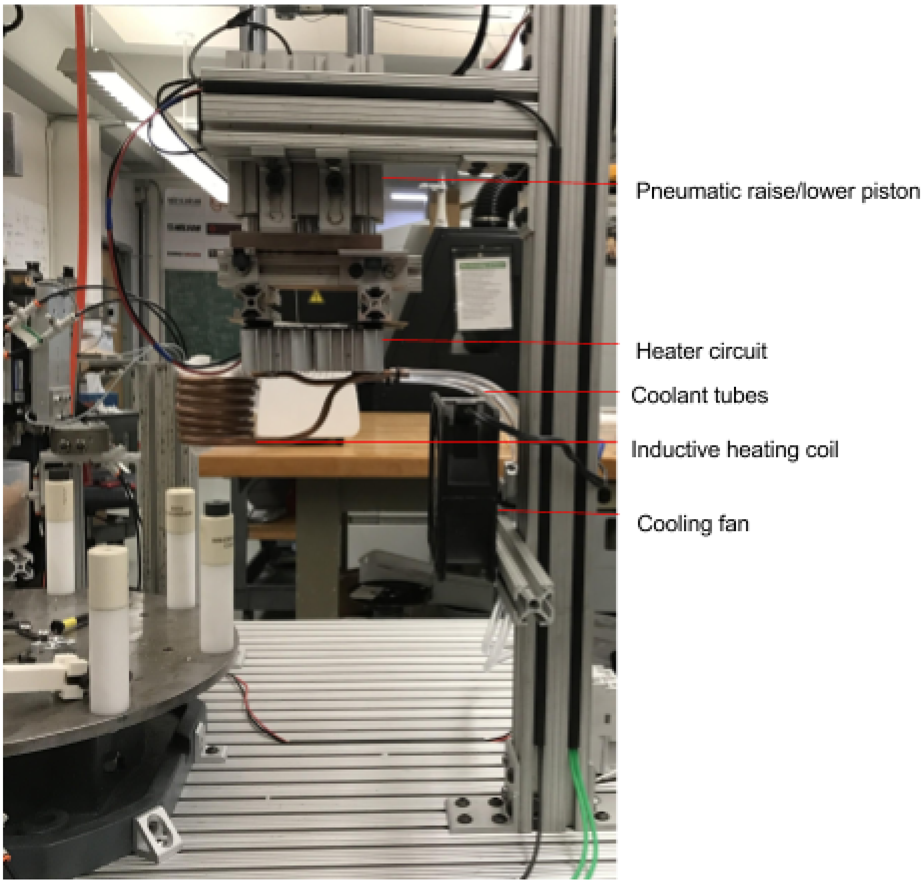
Have the glass be precision glass so that it fits the nozzles better. Replace the foam pads with soft molded rubber.

Performance Data

Successful in 9.5 out of 10 placements of the glass tube to the nozzle.
Can keep up with the heater just fine.

Station 3 (Heater)

Diagrams



Operation description

The heater function is the task that this whole device is made to automate. As current goes through the heater coil, it creates heat in any magnetic object inside the field. The heating coil lowers on top of an assembled part, and heats the steel nozzle to a temperature above the melting point of glass. The glass is only heated where it contacts the nozzle, so it forms a seal. The coil is set to heat for 4 minutes. Water coolant helps to keep the copper coil cool, while the fan helps to keep the circuit cool. The pneumatic piston liftin allows the table to rotate a new part in after completing a heating segment. It is a four stage system.

Stage 1

b) The inductive heater coil arm lowers.
   i) This brings the part holder right in the center of the inductive heater coil.

Stage 2

c) The inductive coil and cooling system comes on for 4 minutes.
   i) This allows nozzles and glass pieces to heat up and bond

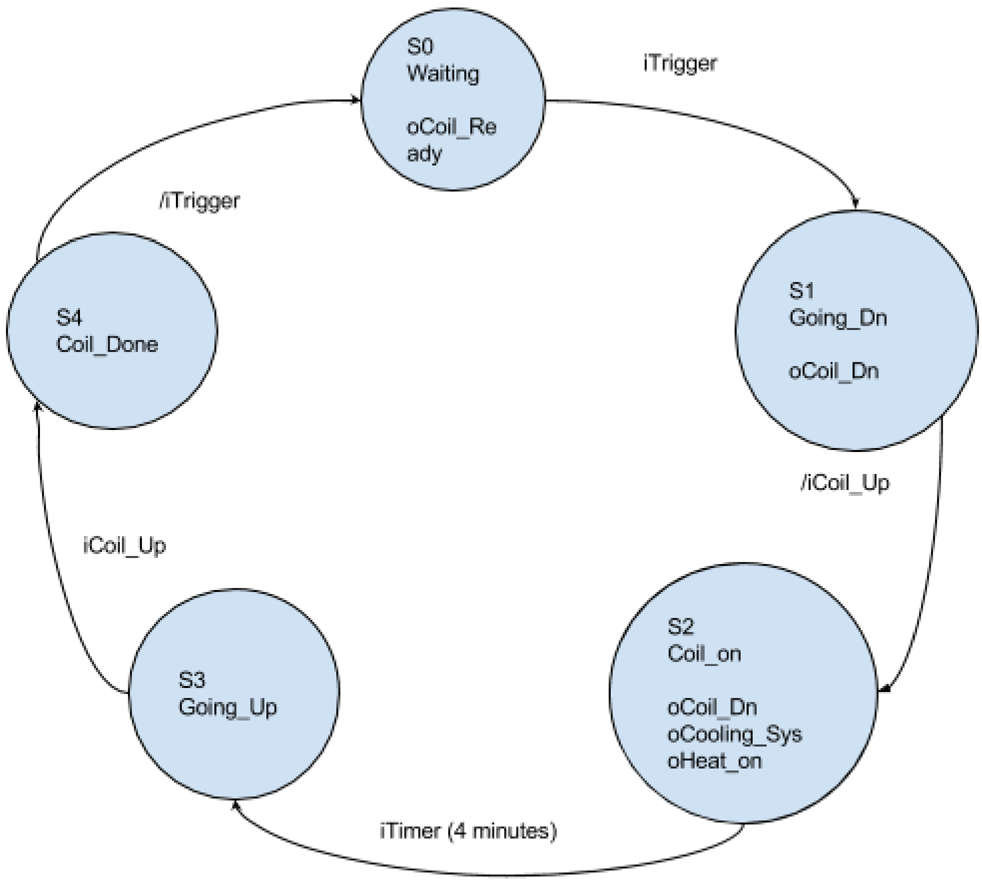
Stage 3

d) The heater arm goes back up to home position
   i) This shuts off the heater coil and the cooling system

Stage 4

e) The heater coil cycle is done
   i) This intermediate stage makes sure that the trigger has gone off.

State Diagram



Maintenance Instructions

Check to be sure there are no coolant leaks in the tubes or coil.

Suggested Future Improvements

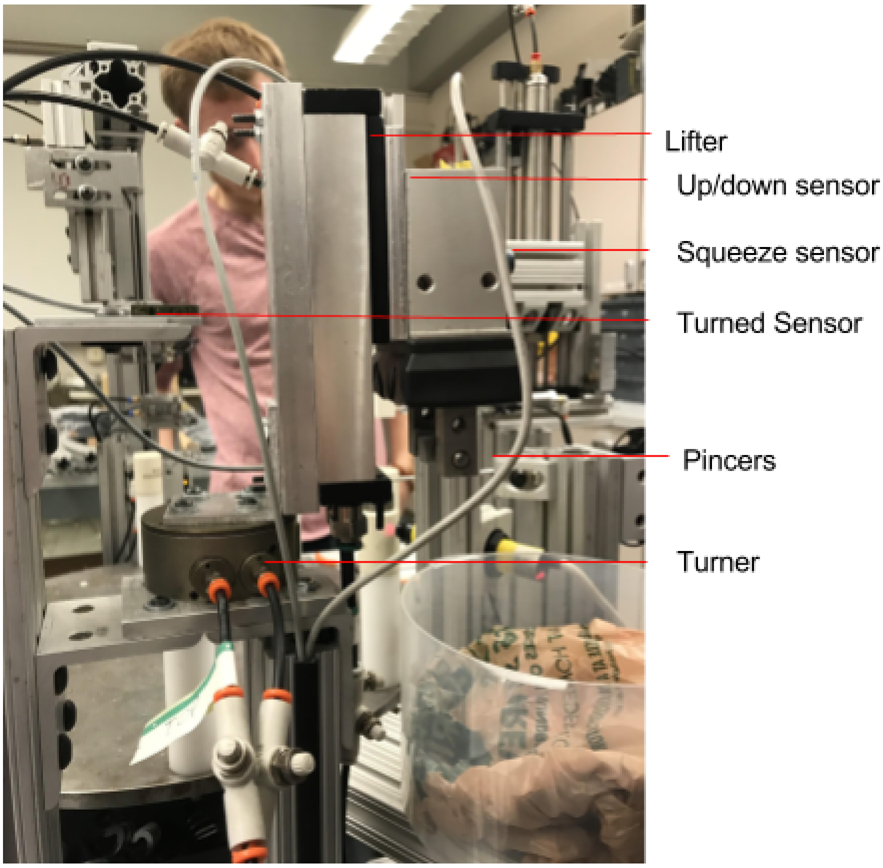
The timing for ideal melting periods can use optimization, but that requires many disposable insulators and nozzles.

Performance Data

The heater works successfully every time, Four minute baking time with insulation is enough to form a proper glass steel bond.

Station 4 (Offloader)

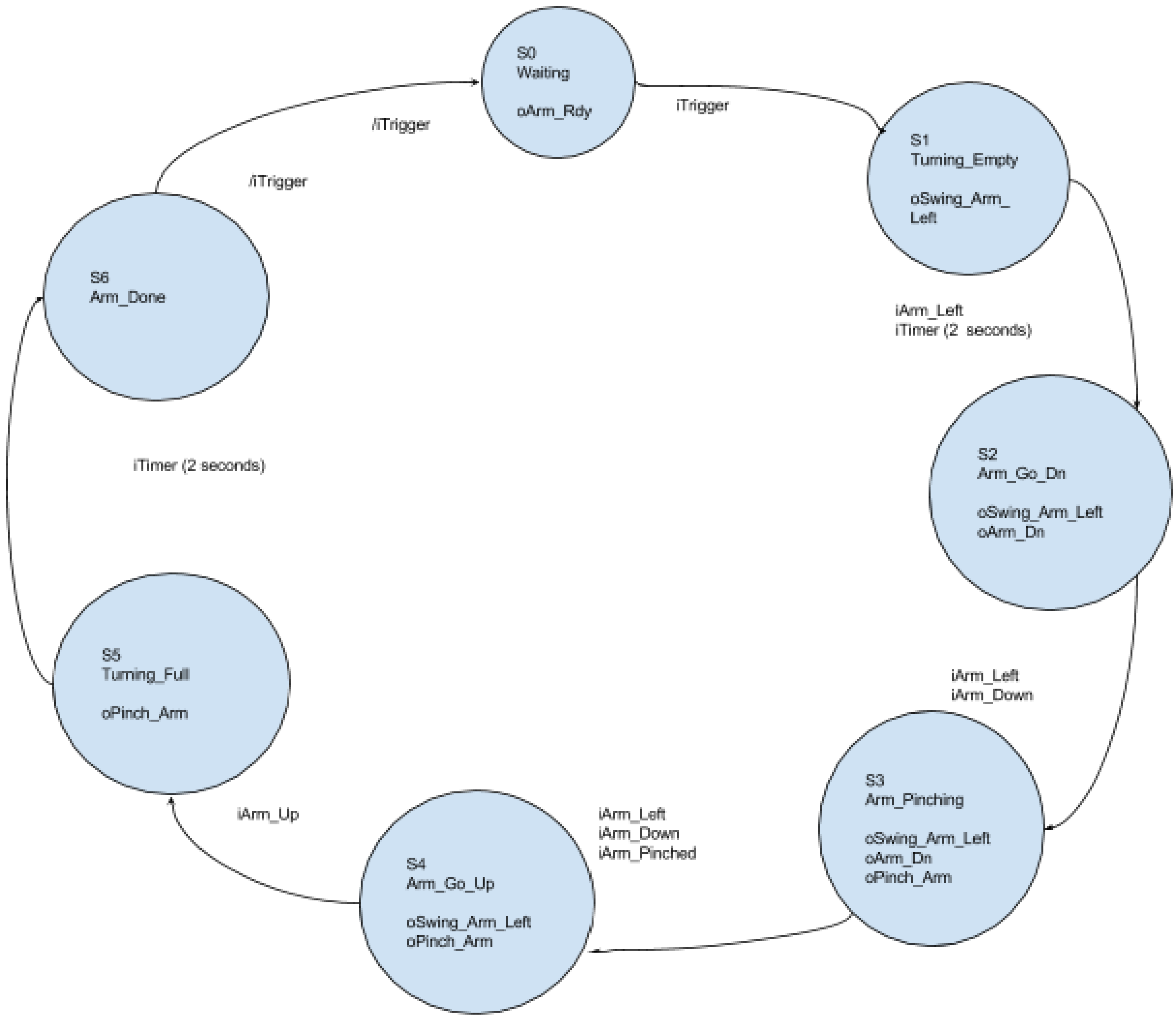
Diagrams



Operation description

At this station the fused nozzle will be taken from the turret so a new piece may begin to be assembled. The turner will rotate the entire assembly to face over the turret. The lifter will drop, and the pincers will squeeze to grab the completed nozzle. The Assembly lifts, rotates and then releases the nozzle into a collector.

State Diagram



Maintenance Instructions

May need new styrofoam pads periodically.

Suggested Future Improvements

This station functions as designed and is not a bottleneck in the process.

Performance Data

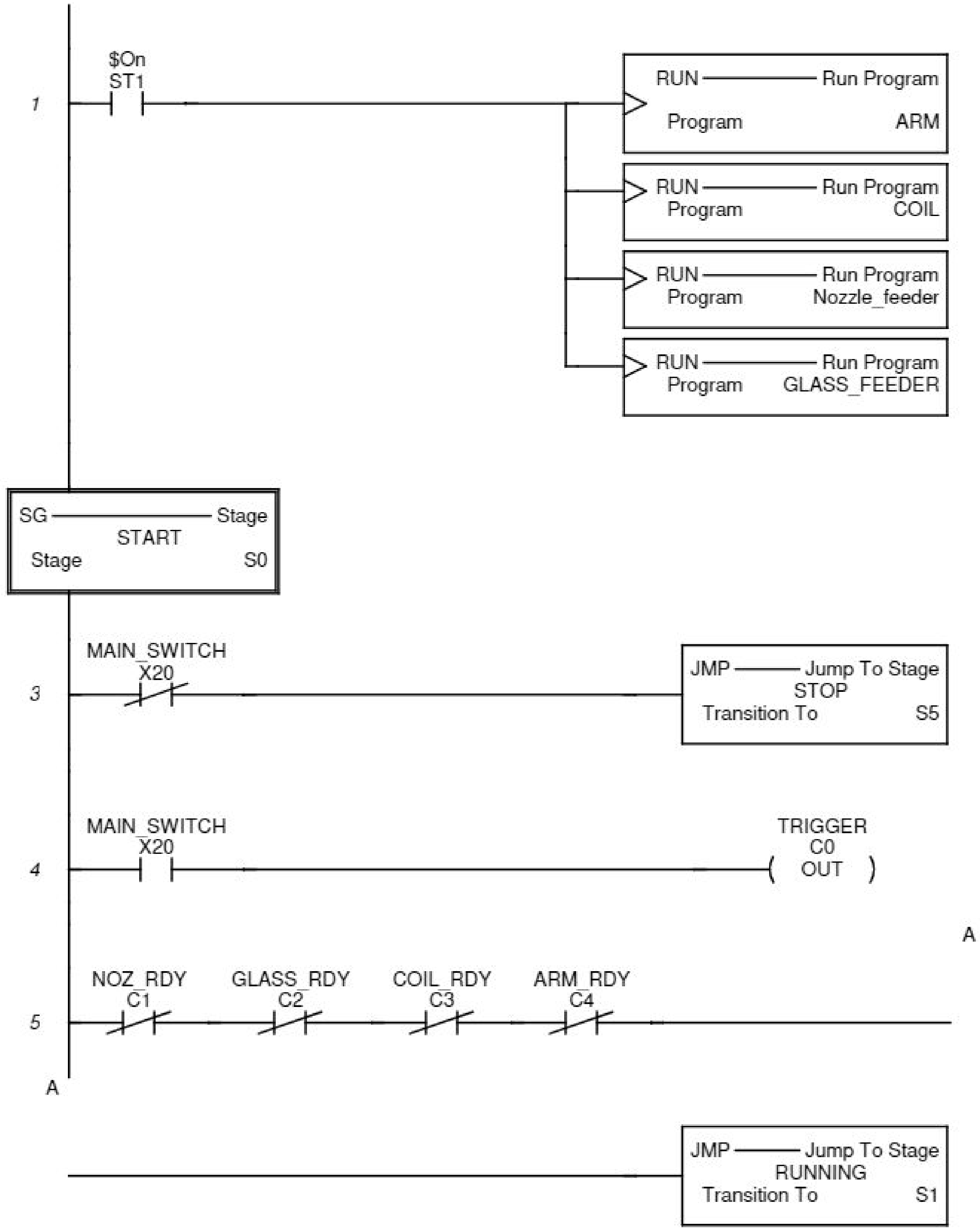
No imperfections have been observed.

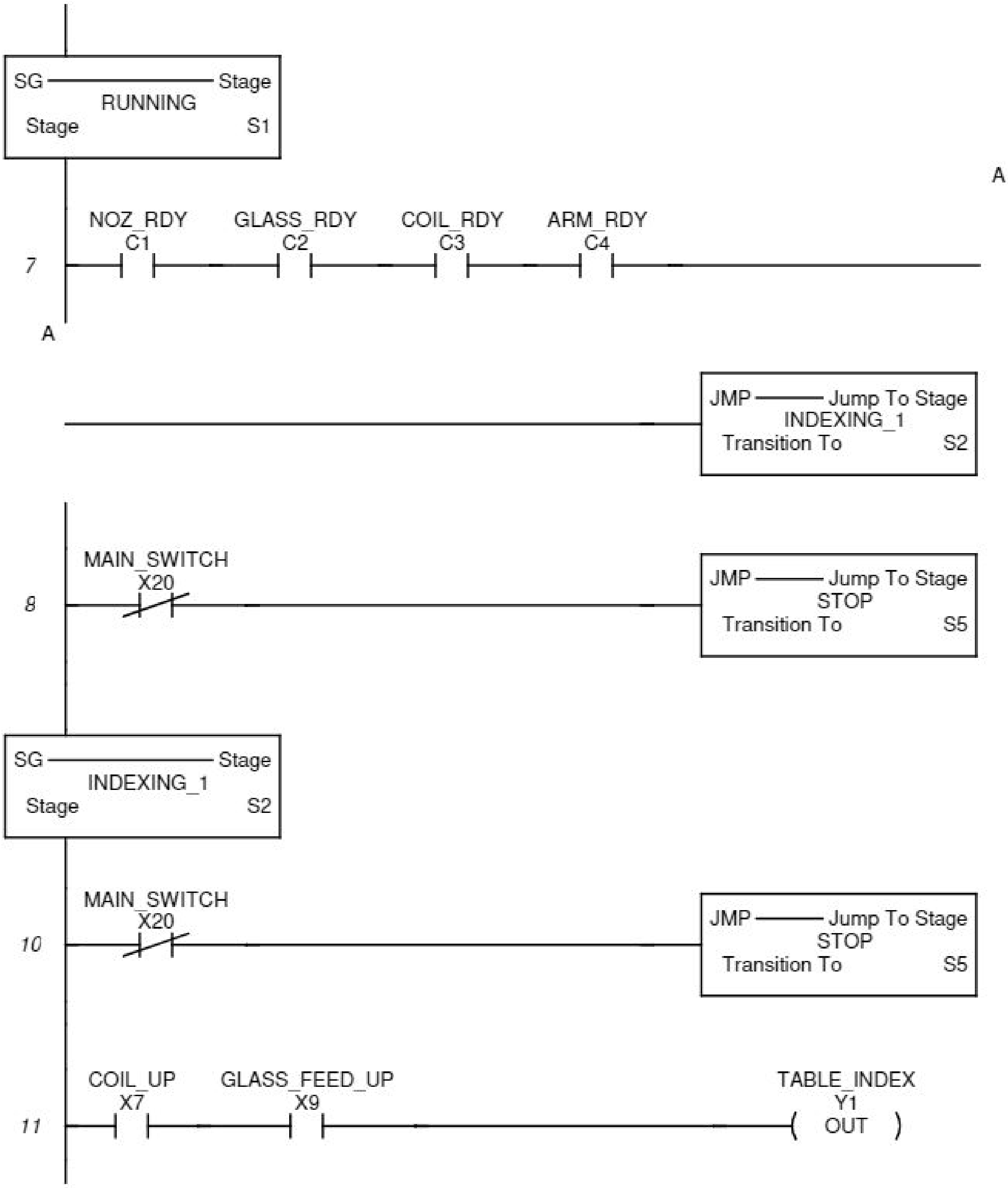
Wiring Diagram

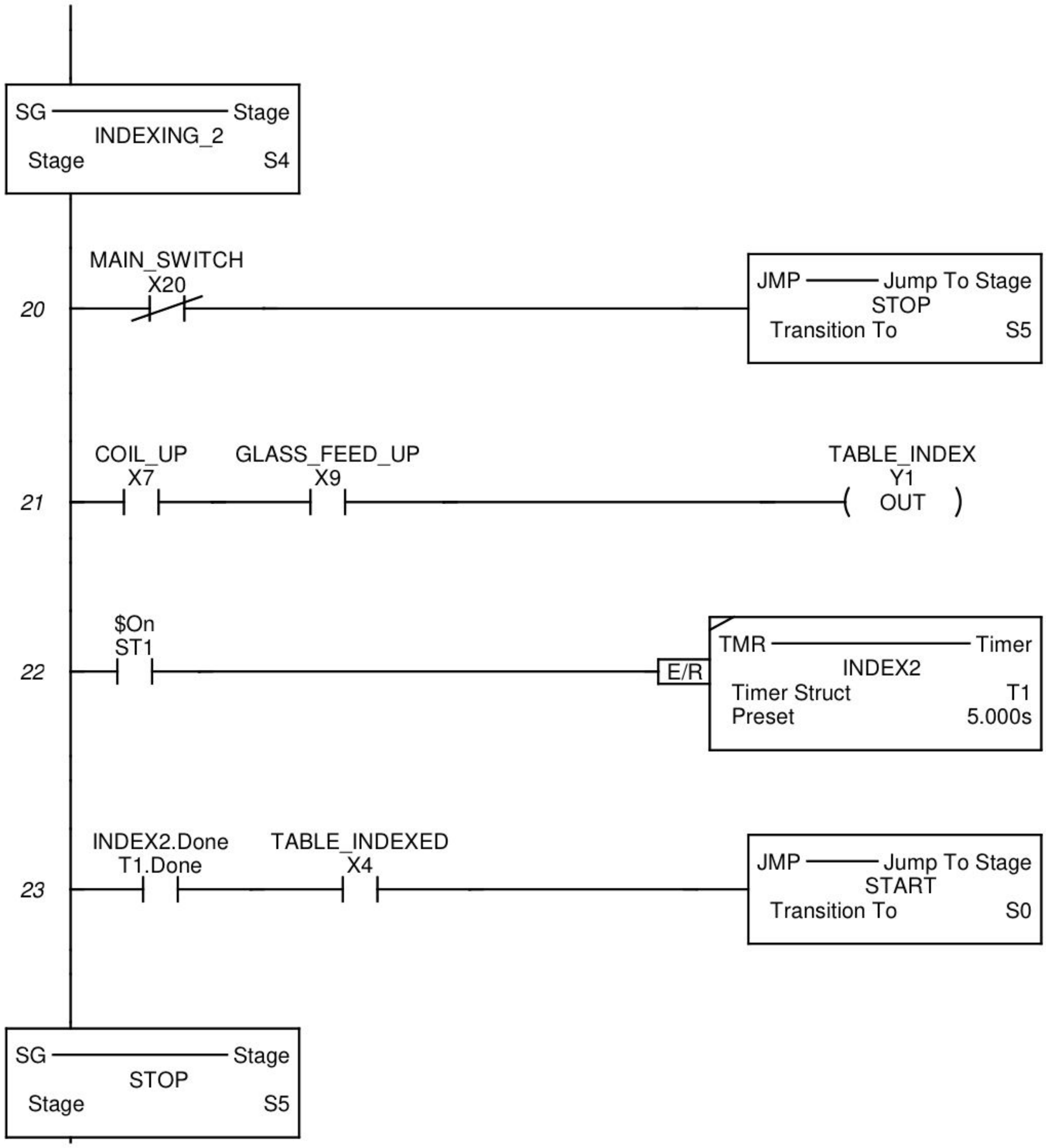
Inputs		Outputs	
Pick up arm turn sensor (prox)	X0	Y0	Glass feeder middle pincher open
Pick up arm up position sensor (prox)	X1	Y1	Turn table index
Pick up arm pinch sensor (magnetic)	X2	Y2	Pick up arm turn left
Pick up arm down position sensor (prox)	X3	Y3	Pick up arm pincher close
Turn table index sensor (optical)	X4	Y4	Glass feeder top pincher open
Pick up arm failure sensor (optical)	X5	Y5	Glass feeder bottom pincher go down
Nozzle feeder piston off sensor (magnetic)	X6	Y6	Pick up arm go down
Heater coil arm up sensor (magnetic)	X7	Y7	Heater coil arm go down
Glass feeder middle pincher on sensor (magnetic)	X8	Y8	Nozzle feeder arm go down
Glass feeder arm up sensor (magnetic)	X9	Y9	Nozzle feeder piston off
Glass feeder top pincher on sensor (magnetic)	X16	Y10	Glass feeder bottom pincher open
Glass feeder bottom pincher down sensor (magnetic)	X17	Y11	Glass feeder arm go down
Glass feeder bottom pincher on sensor (magnetic)	X18	Y12	Heater/cooling system on (relay)
Nozzle feeder arm down sensor (optical)	X19	--	
Main on/off switch (mechanical flip type)	X20	--	

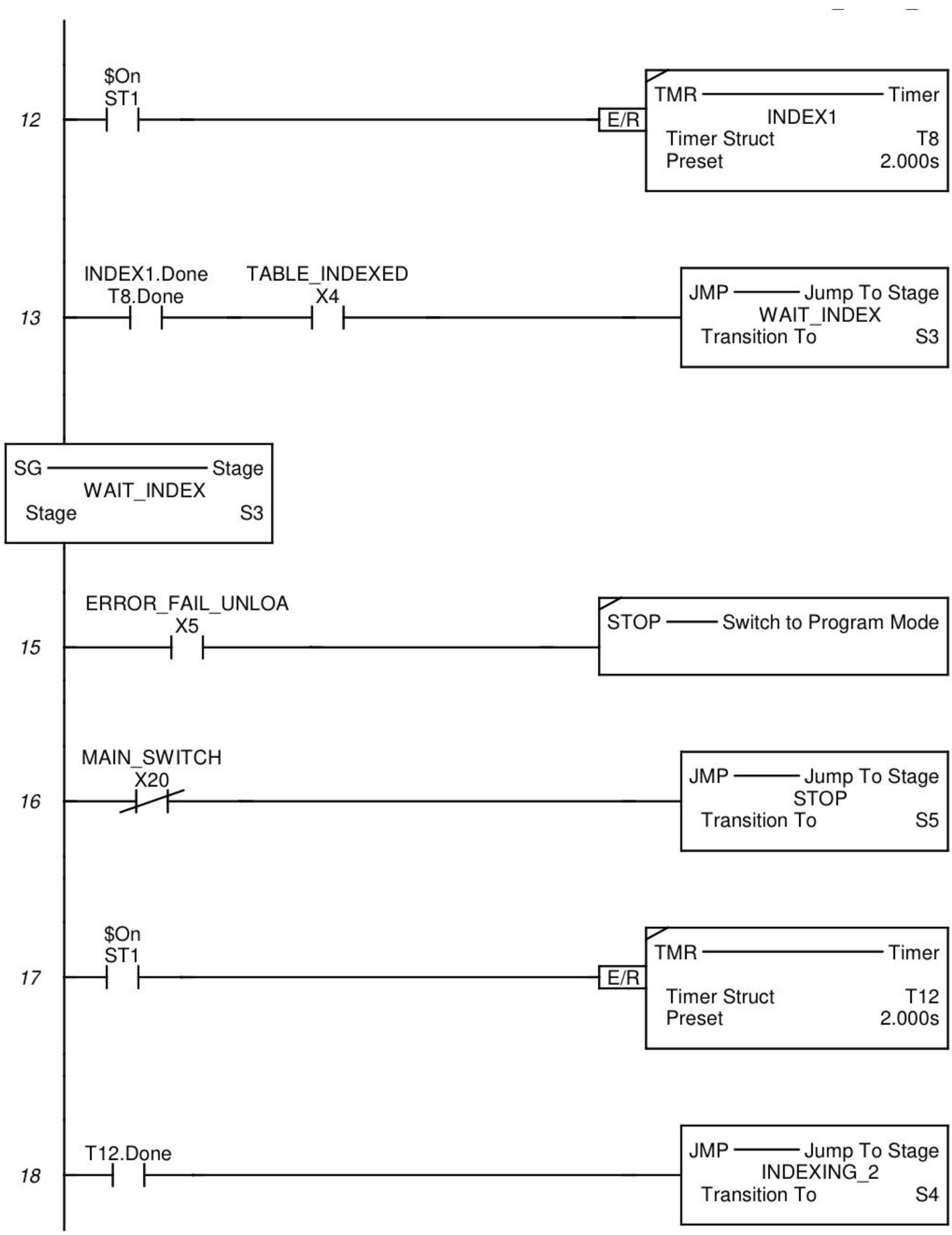
PLC Ladder Logic

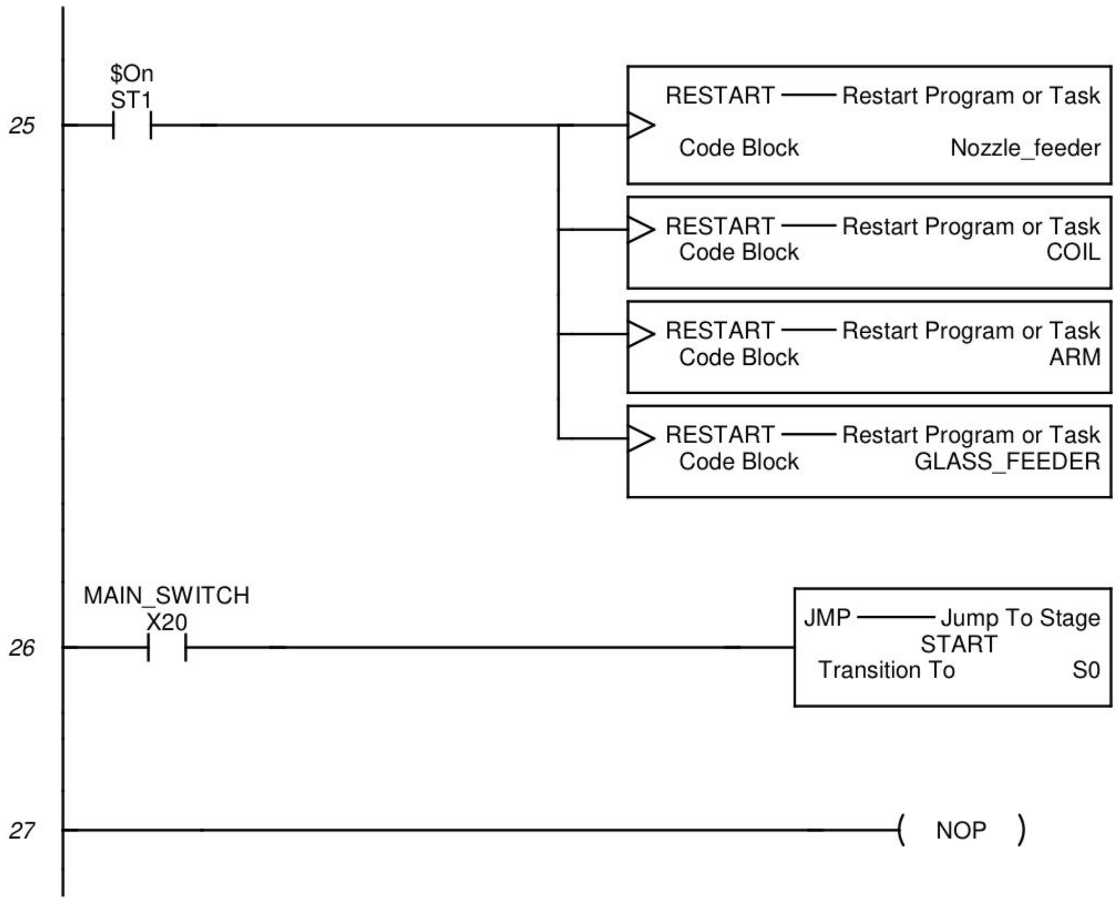
Main



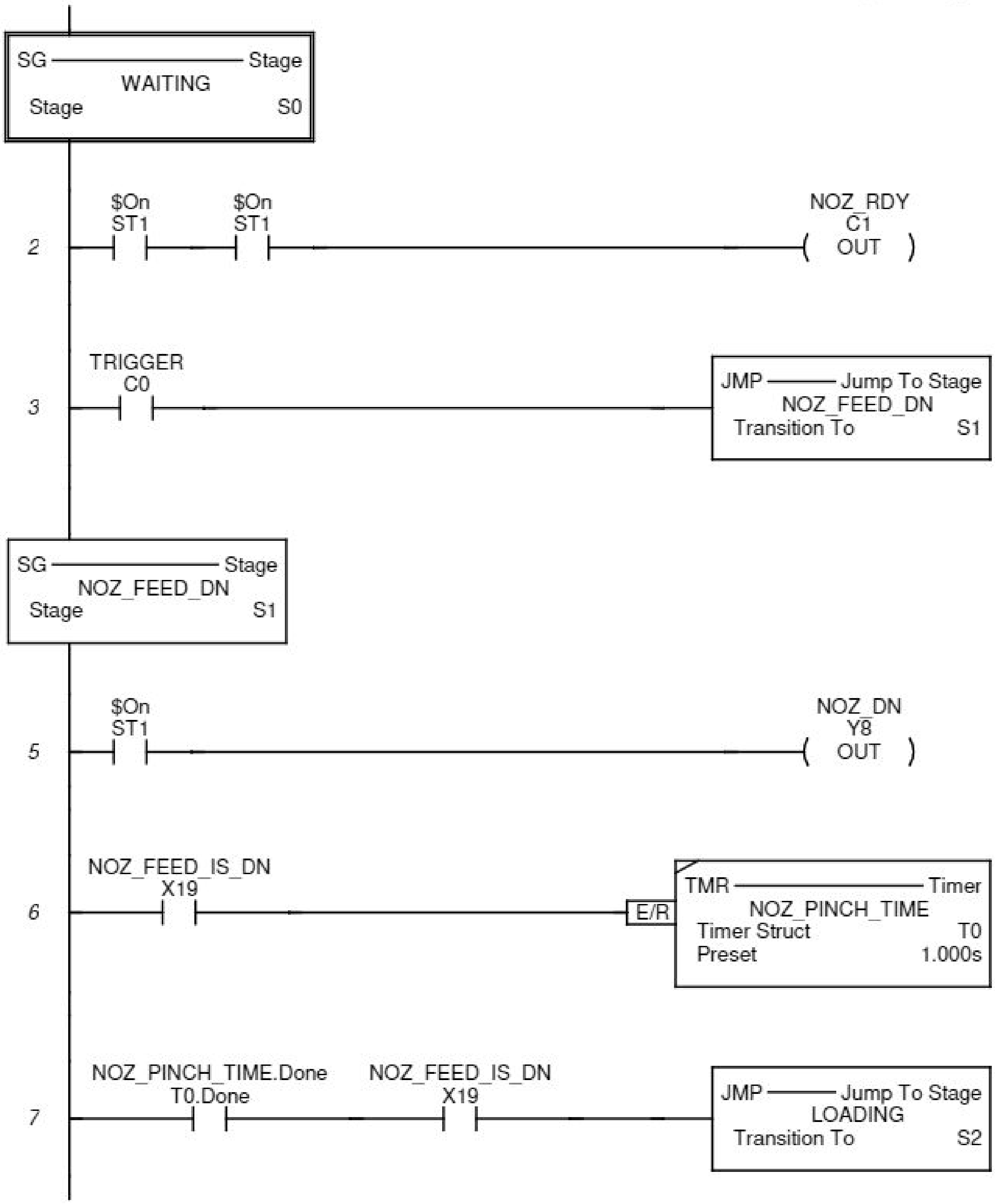

SG Stage
RUNNING
Stage S1
A
NOZ_RDY C1
GLASS_RDY C2
COIL_RDY C3
ARM_RDY C4
7
A
JMP Jump To Stage
INDEXING_1
Transition To S2
MAIN_SWITCH X20
8
JMP Jump To Stage
STOP
Transition To S5
SG Stage
INDEXING_1
Stage S2
MAIN_SWITCH X20
10
JMP Jump To Stage
STOP
Transition To S5
COIL_UP X7
GLASS_FEED_UP X9
11
TABLE_INDEX Y1
OUT

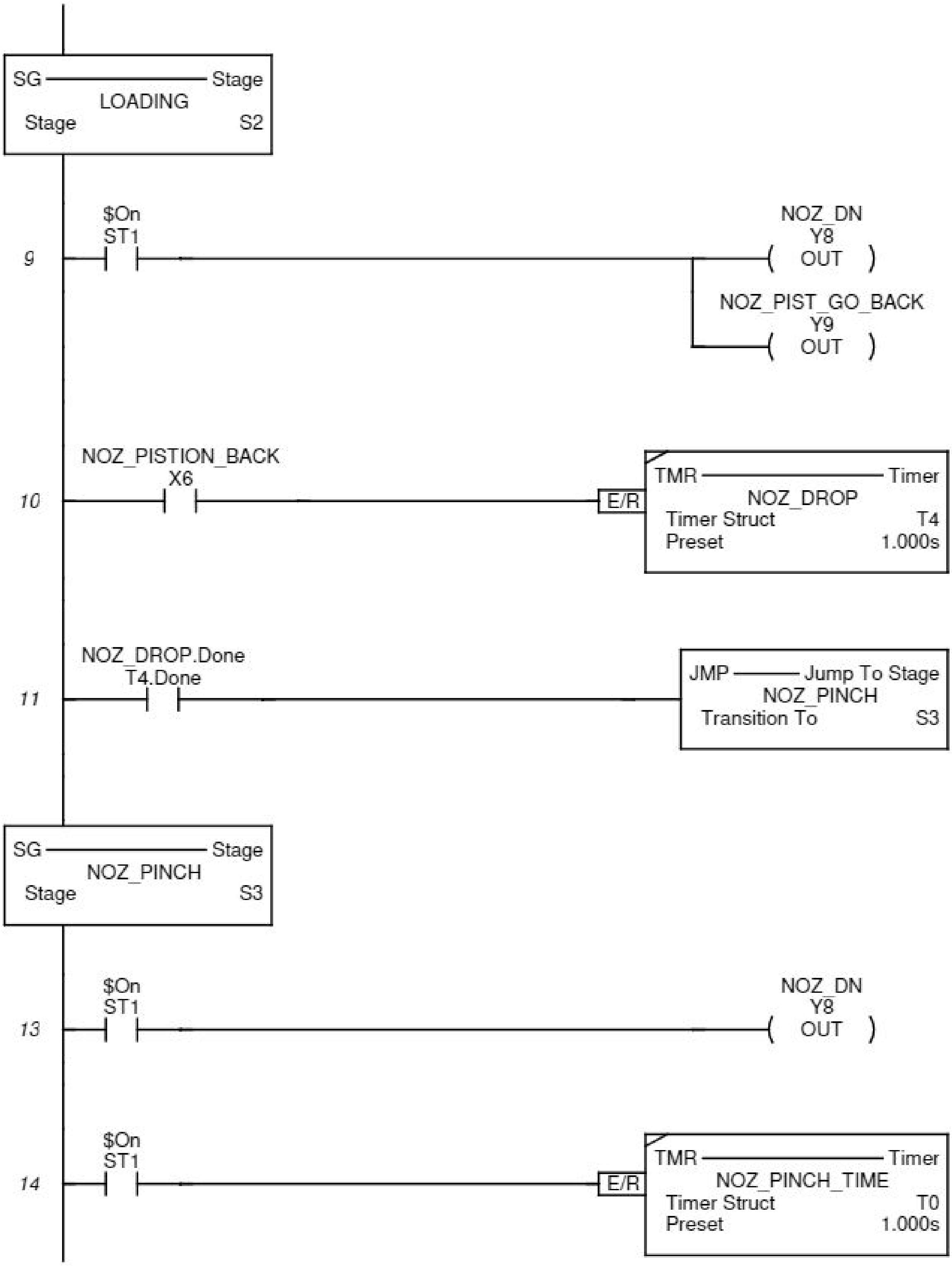

SG Stage
INDEXING_2
Stage S4
20
MAIN_SWITCH
X20
JMP Jump To Stage
STOP
Transition To S5
21
COIL_UP
X7
GLASS_FEED_UP
X9
TABLE_INDEX
Y1
OUT
22
$On
ST1
E/R
TMR Timer
INDEX2
Timer Struct T1
Preset 5.000s
23
INDEX2.Done
T1.Done
TABLE_INDEXED
X4
JMP Jump To Stage
START
Transition To S0
SG Stage
STOP
Stage S5

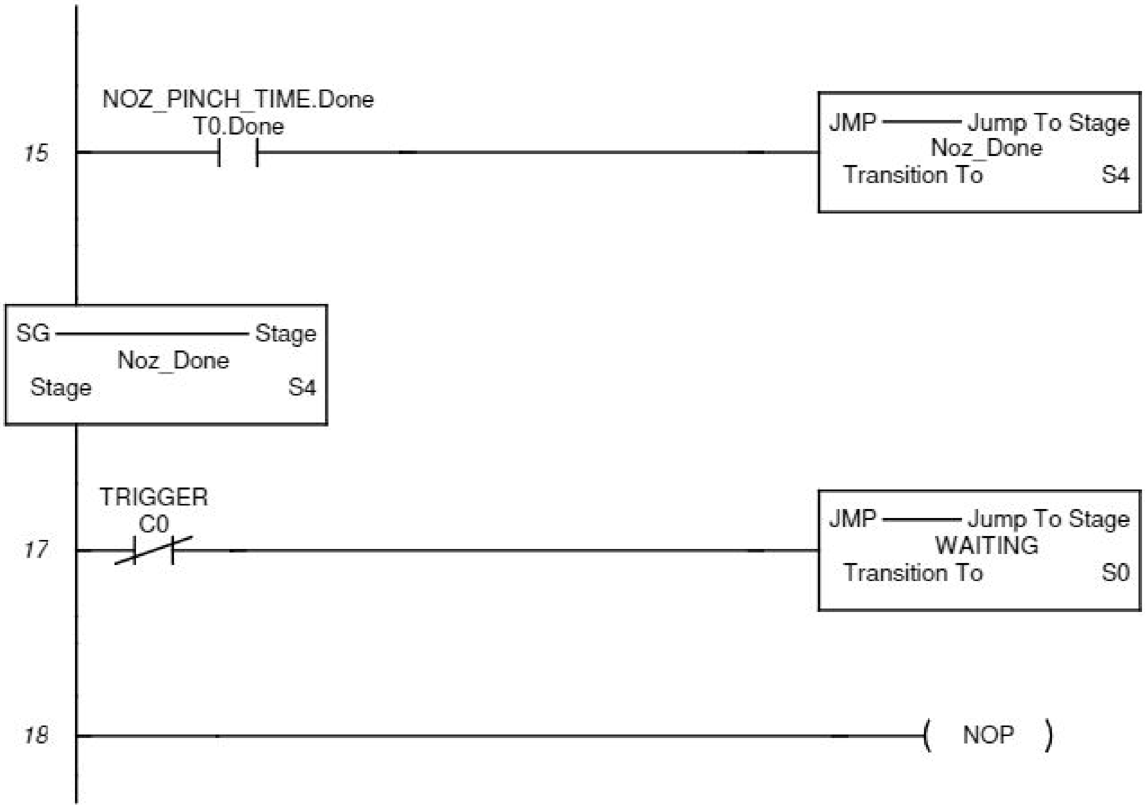

12
$On
ST1
E/R
TMR Timer
INDEX1
Timer Struct T8
Preset 2.000s
13
INDEX1.Done
T8.Done
TABLE_INDEXED
X4
JMP Jump To Stage
WAIT_INDEX
Transition To S3
SG Stage
WAIT_INDEX
Stage S3
15
ERROR_FAIL_UNLOA
X5
STOP Switch to Program Mode
16
MAIN_SWITCH
X20
JMP Jump To Stage
STOP
Transition To S5
17
$On
ST1
E/R
TMR Timer
Timer Struct T12
Preset 2.000s
18
T12.Done
JMP Jump To Stage
INDEXING_2
Transition To S4


$On
ST1
25
RESTART Restart Program or Task
Code Block Nozzle_feeder
RESTART Restart Program or Task
Code Block COIL
RESTART Restart Program or Task
Code Block ARM
RESTART Restart Program or Task
Code Block GLASS_FEEDER
MAIN_SWITCH
X20
26
JMP Jump To Stage
START
Transition To S0
27
NOP

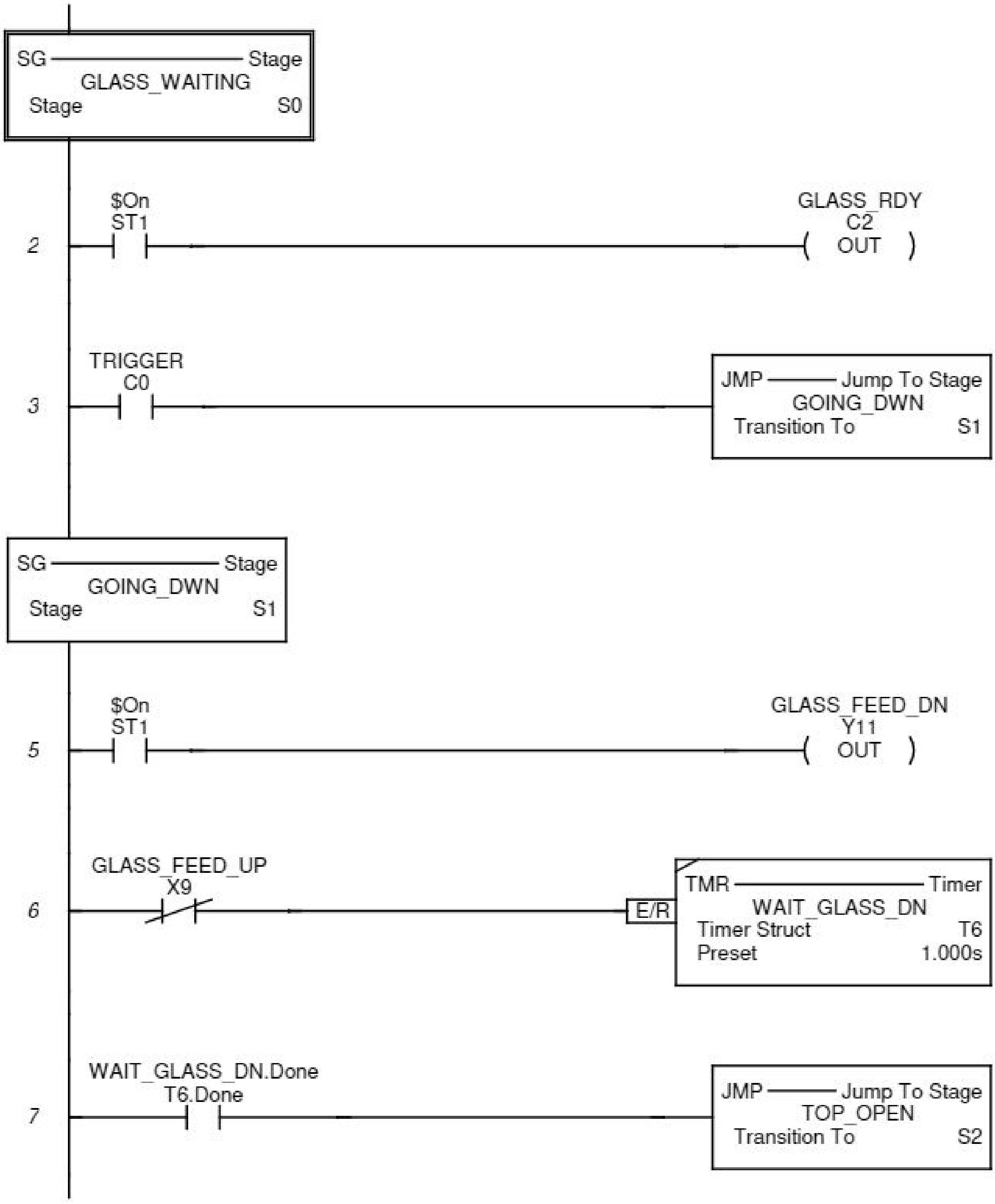
Nozzle Feeder

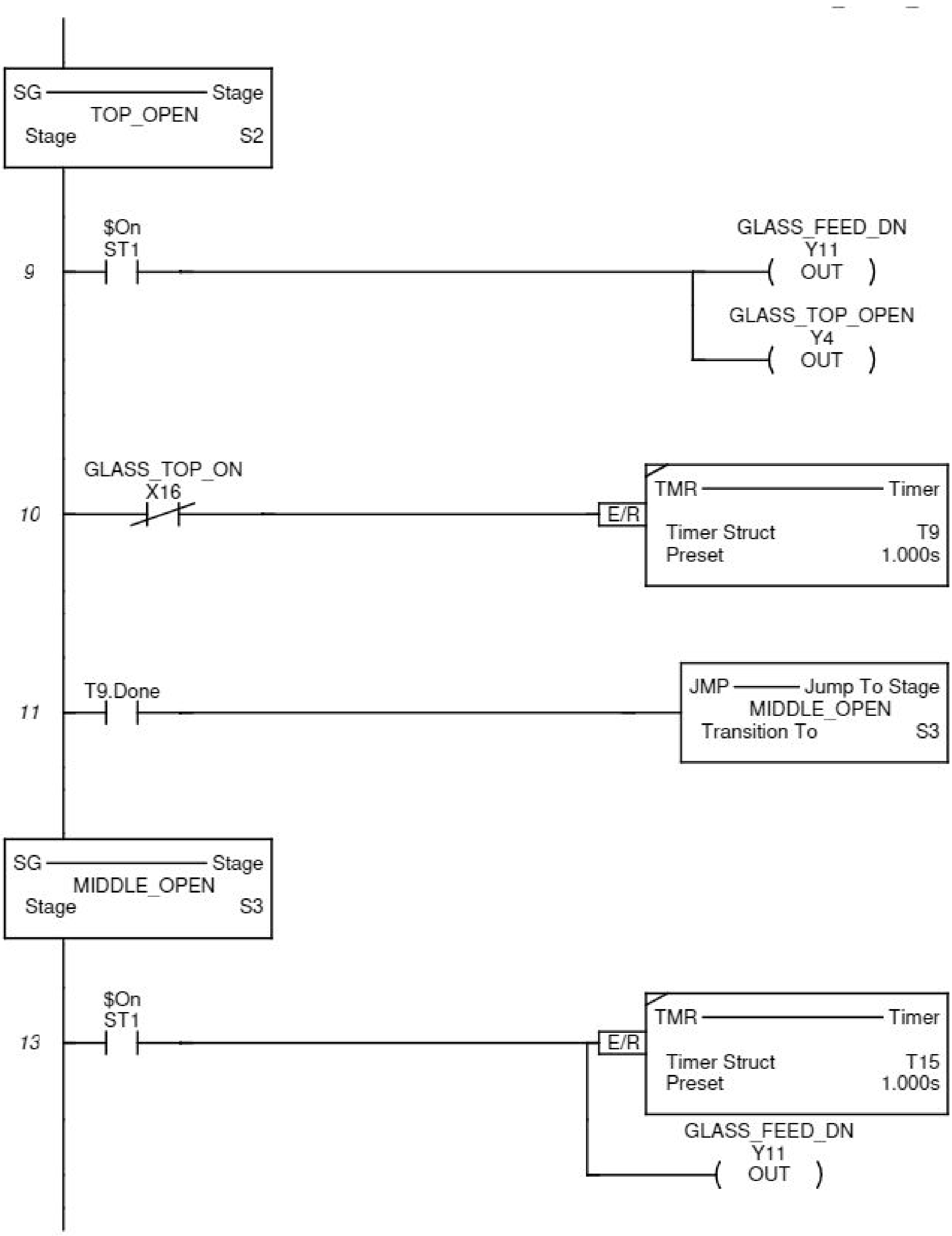


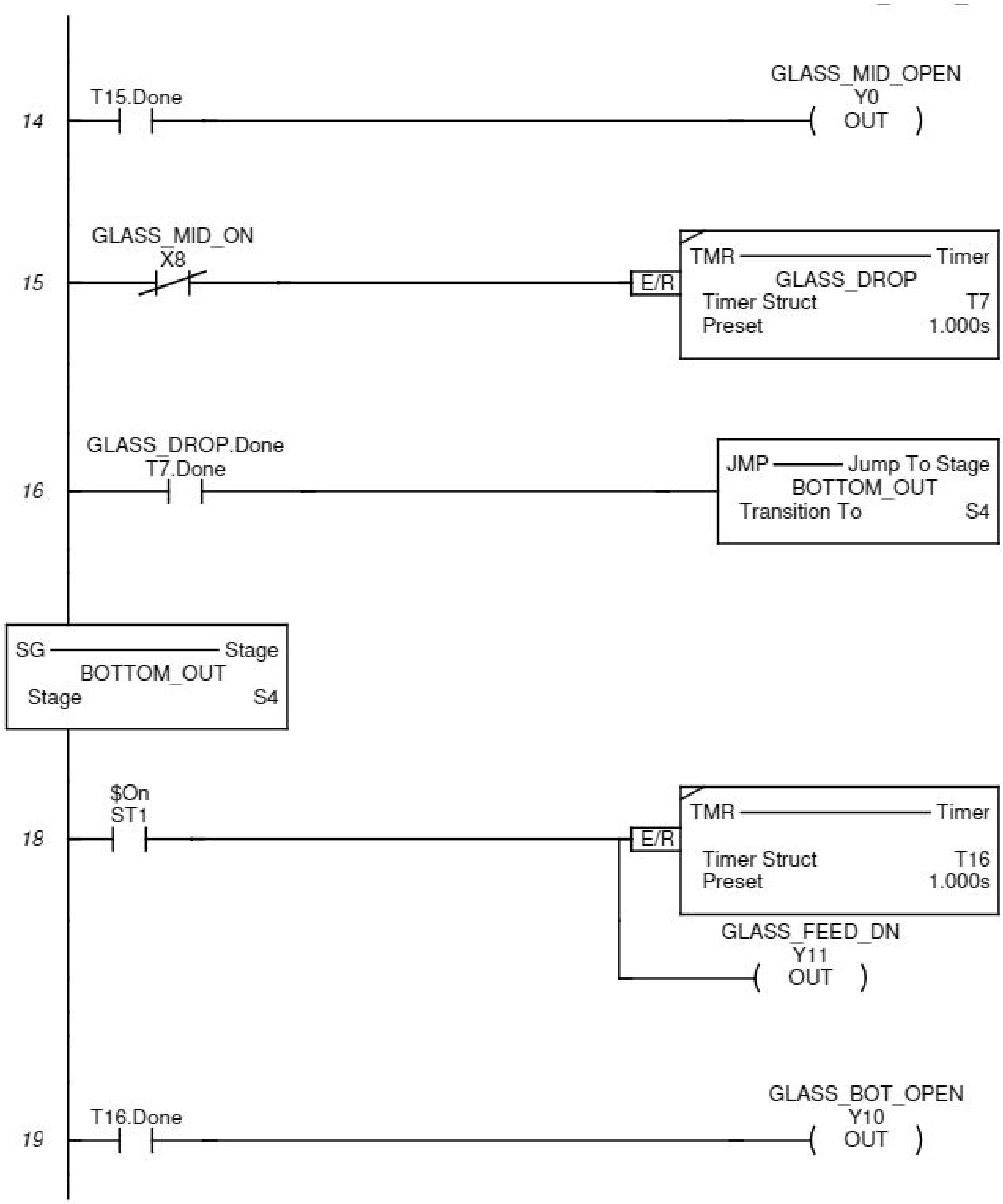

SG Stage
LOADING
Stage S2
9
$On
ST1
NOZ_DN
Y8
OUT
NOZ_PIST_GO_BACK
Y9
OUT
10
NOZ_PISTION_BACK
X6
E/R
TMR Timer
NOZ_DROP
Timer Struct T4
Preset 1.000s
11
NOZ_DROP.Done
T4.Done
JMP Jump To Stage
NOZ_PINCH
Transition To S3
SG Stage
NOZ_PINCH
Stage S3
13
$On
ST1
NOZ_DN
Y8
OUT
14
$On
ST1
E/R
TMR Timer
NOZ_PINCH_TIME
Timer Struct T0
Preset 1.000s

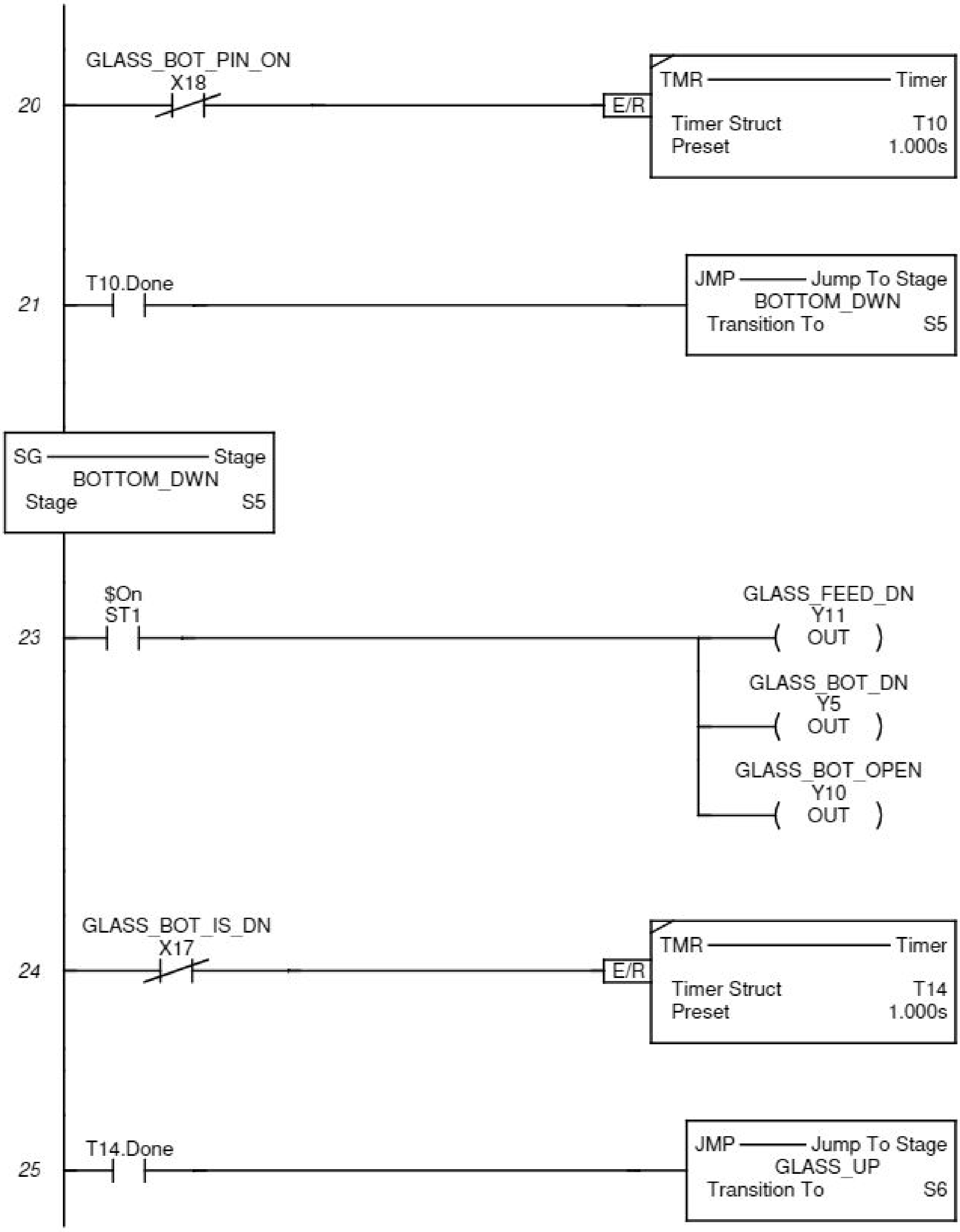

NOZ_PINCH_TIME.Done
T0.Done
15
JMP Jump To Stage
Noz_Done
Transition To S4
SG Stage
Noz_Done
Stage S4
TRIGGER
C0
17
JMP Jump To Stage
WAITING
Transition To S0
18
NOP

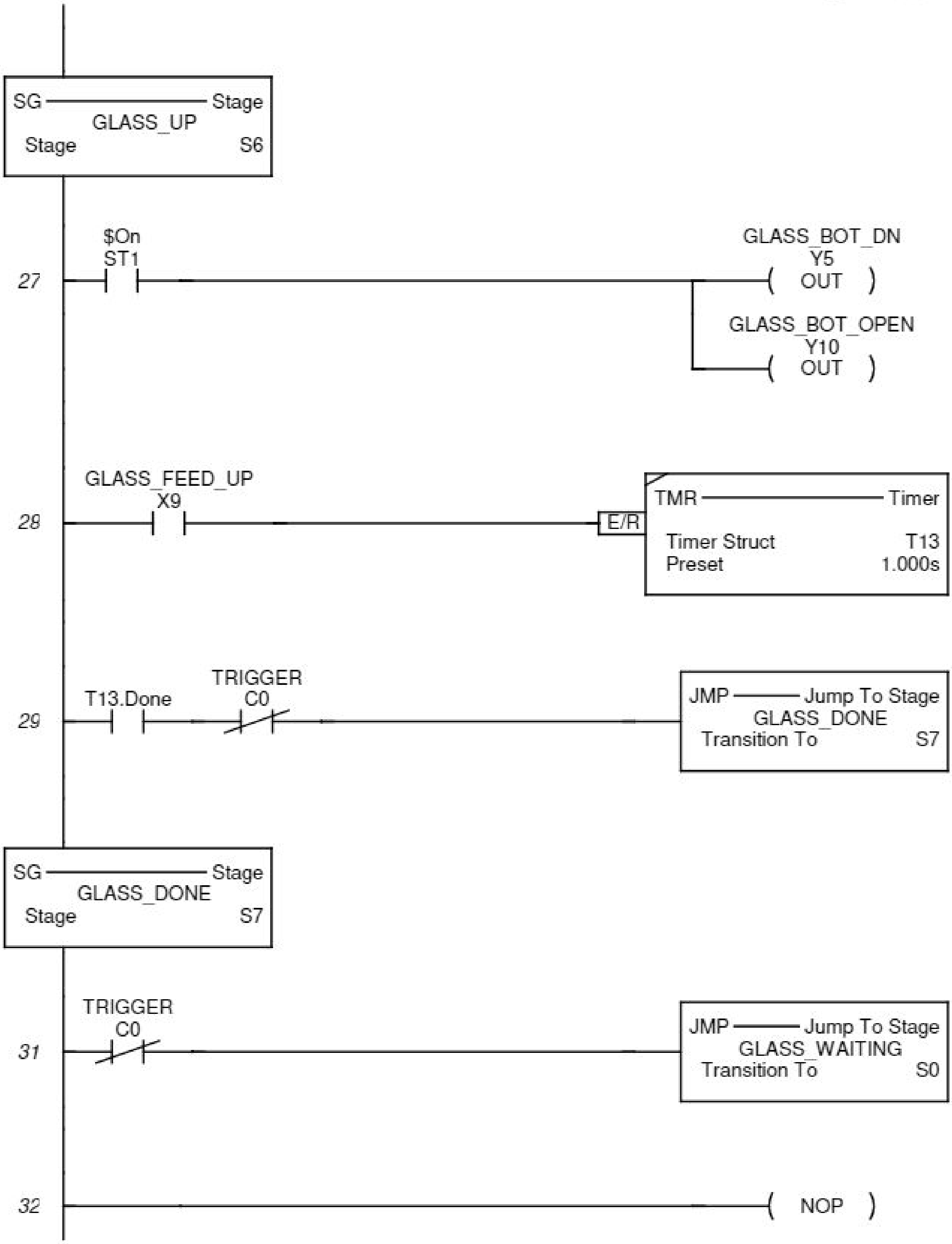
Insulation Feeder



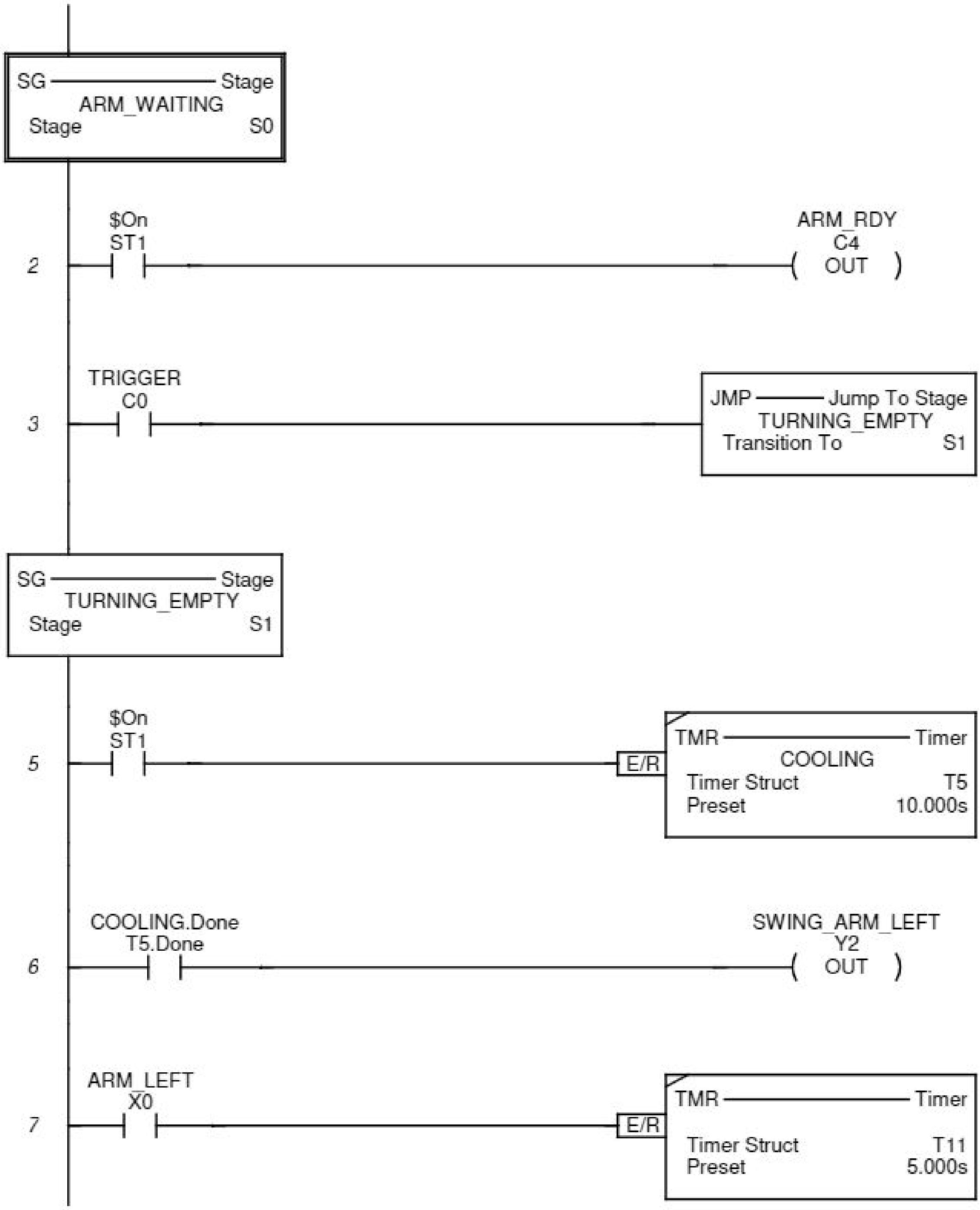

SG Stage
TOP_OPEN
Stage S2
$On
ST1
9
GLASS_FEED_DN
Y11
OUT
GLASS_TOP_OPEN
Y4
OUT
GLASS_TOP_ON
X16
10
E/R
TMR Timer
Timer Struct T9
Preset 1.000s
T9.Done
11
JMP Jump To Stage
MIDDLE_OPEN
Transition To S3
SG Stage
MIDDLE_OPEN
Stage S3
$On
ST1
13
E/R
TMR Timer
Timer Struct T15
Preset 1.000s
GLASS_FEED_DN
Y11
OUT

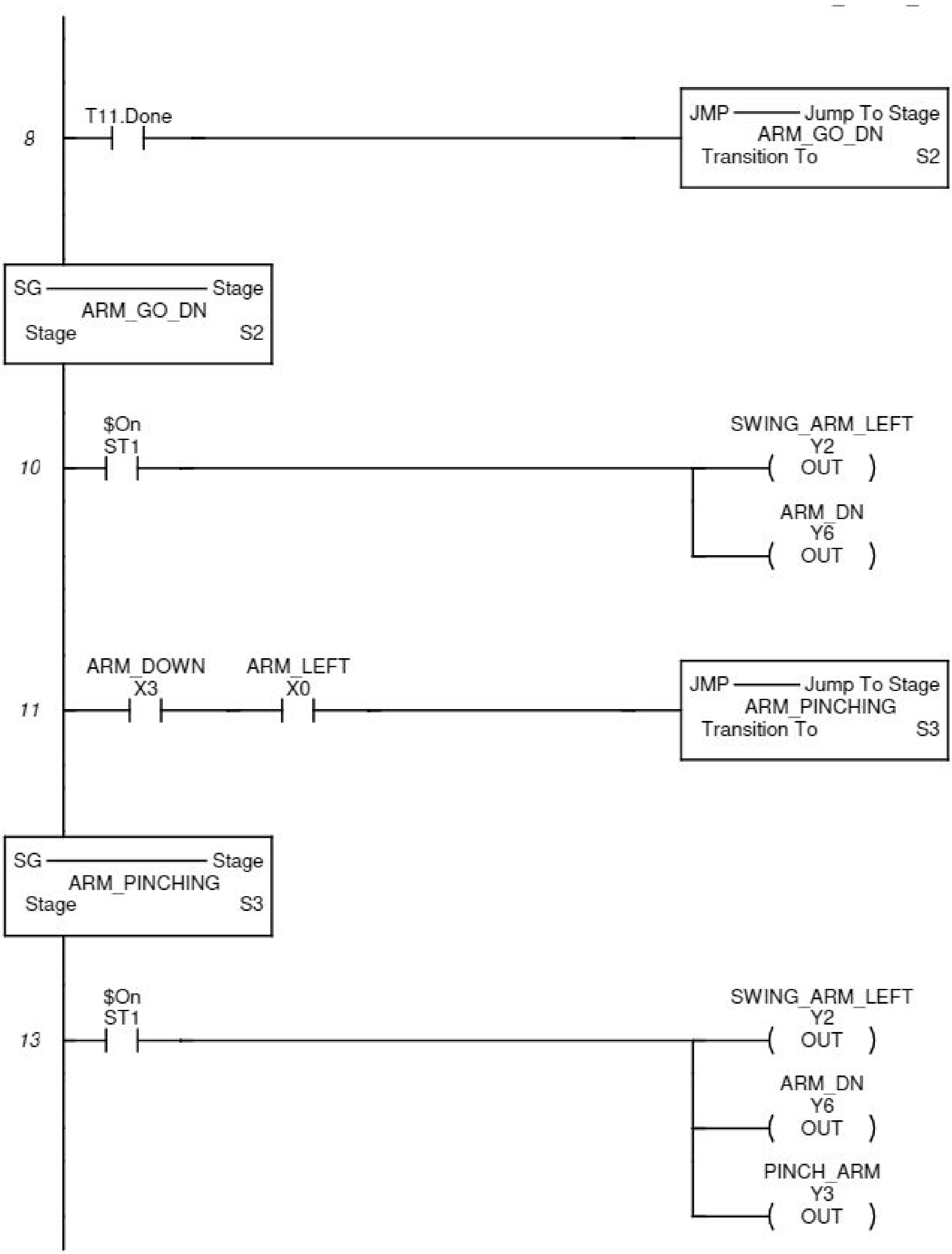

14
T15.Done
GLASS_MID_OPEN
Y0
OUT
15
GLASS_MID_ON
X8
E/R
TMR Timer
GLASS_DROP
Timer Struct T7
Preset 1.000s
16
GLASS_DROP.Done
T7.Done
JMP Jump To Stage
BOTTOM_OUT
Transition To S4
SG Stage
BOTTOM_OUT
Stage S4
18
$On
ST1
E/R
TMR Timer
Timer Struct T16
Preset 1.000s
GLASS_FEED_DN
Y11
OUT
19
T16.Done
GLASS_BOT_OPEN
Y10
OUT

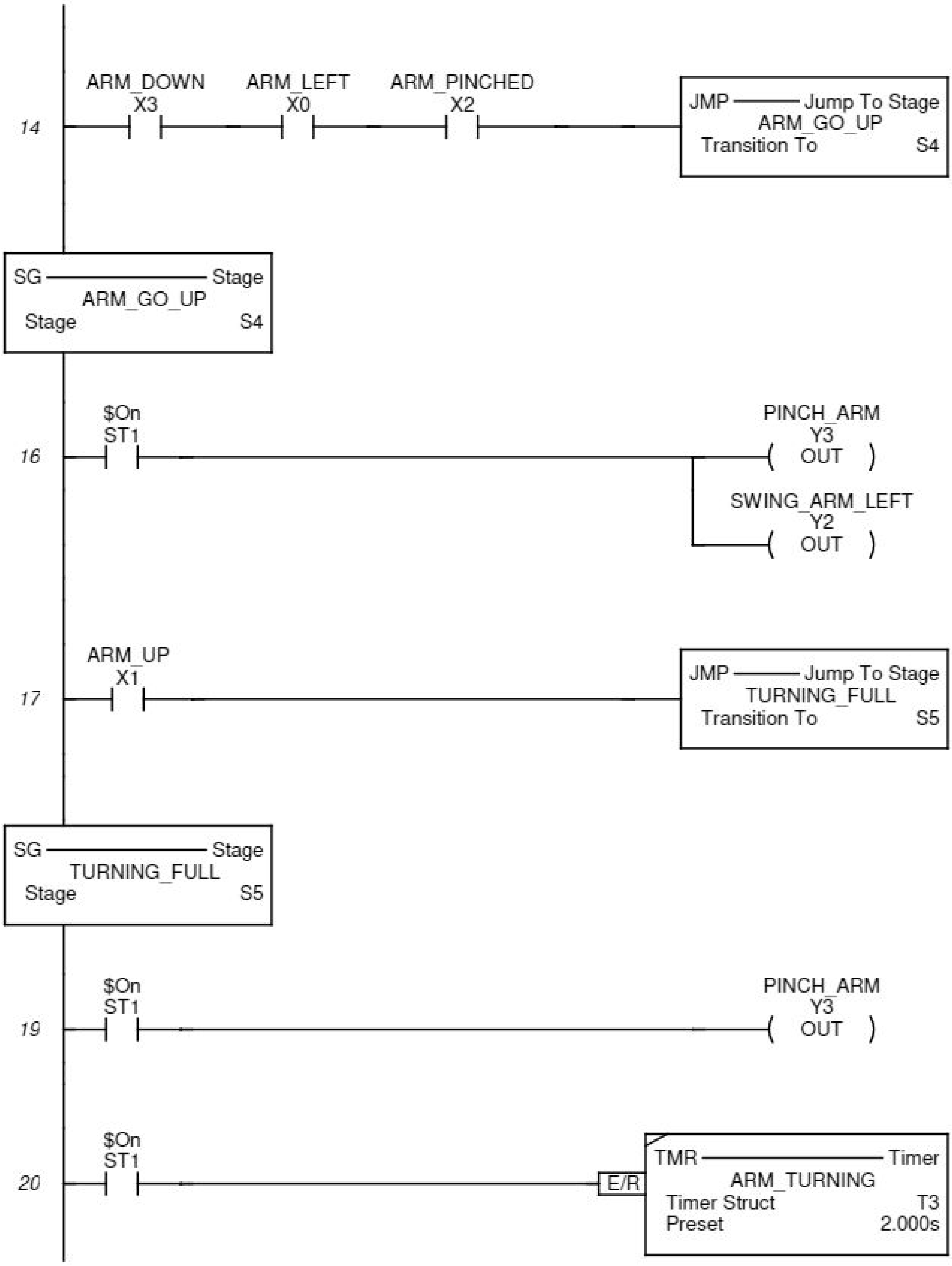

20
GLASS_BOT_PIN_ON
X18
E/R
TMR Timer
Timer Struct T10
Preset 1.000s
21
T10.Done
JMP Jump To Stage
BOTTOM_DWN
Transition To S5
SG Stage
BOTTOM_DWN
Stage S5
23
$On
ST1
GLASS_FEED_DN
Y11
OUT
GLASS_BOT_DN
Y5
OUT
GLASS_BOT_OPEN
Y10
OUT
24
GLASS_BOT_IS_DN
X17
E/R
TMR Timer
Timer Struct T14
Preset 1.000s
25
T14.Done
JMP Jump To Stage
GLASS_UP
Transition To S6


SG Stage
GLASS_UP
Stage S6
27
$On
ST1
GLASS_BOT_DN
Y5
OUT
GLASS_BOT_OPEN
Y10
OUT
28
GLASS_FEED_UP
X9
E/R
TMR Timer
Timer Struct T13
Preset 1.000s
29
T13.Done
TRIGGER
C0
JMP Jump To Stage
GLASS_DONE
Transition To S7
SG Stage
GLASS_DONE
Stage S7
31
TRIGGER
C0
JMP Jump To Stage
GLASS_WAITING
Transition To S0
32
NOP

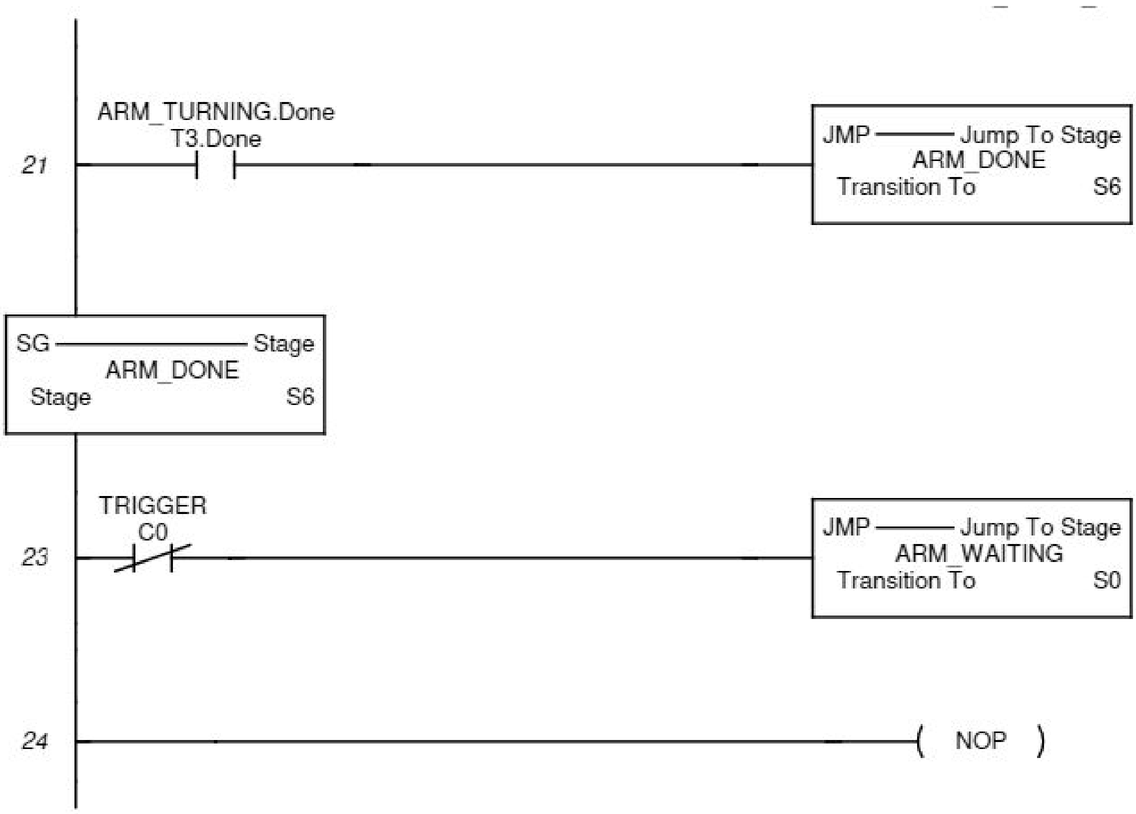
Offloader


SG Stage
ARM_WAITING
Stage S0
2
$On
ST1
ARM_RDY
C4
OUT
3
TRIGGER
C0
JMP Jump To Stage
TURNING_EMPTY
Transition To S1
SG Stage
TURNING_EMPTY
Stage S1
5
$On
ST1
E/R
TMR Timer
COOLING
Timer Struct T5
Preset 10.000s
6
COOLING.Done
T5.Done
SWING_ARM_LEFT
Y2
OUT
7
ARM_LEFT
X0
E/R
TMR Timer
Timer Struct T11
Preset 5.000s

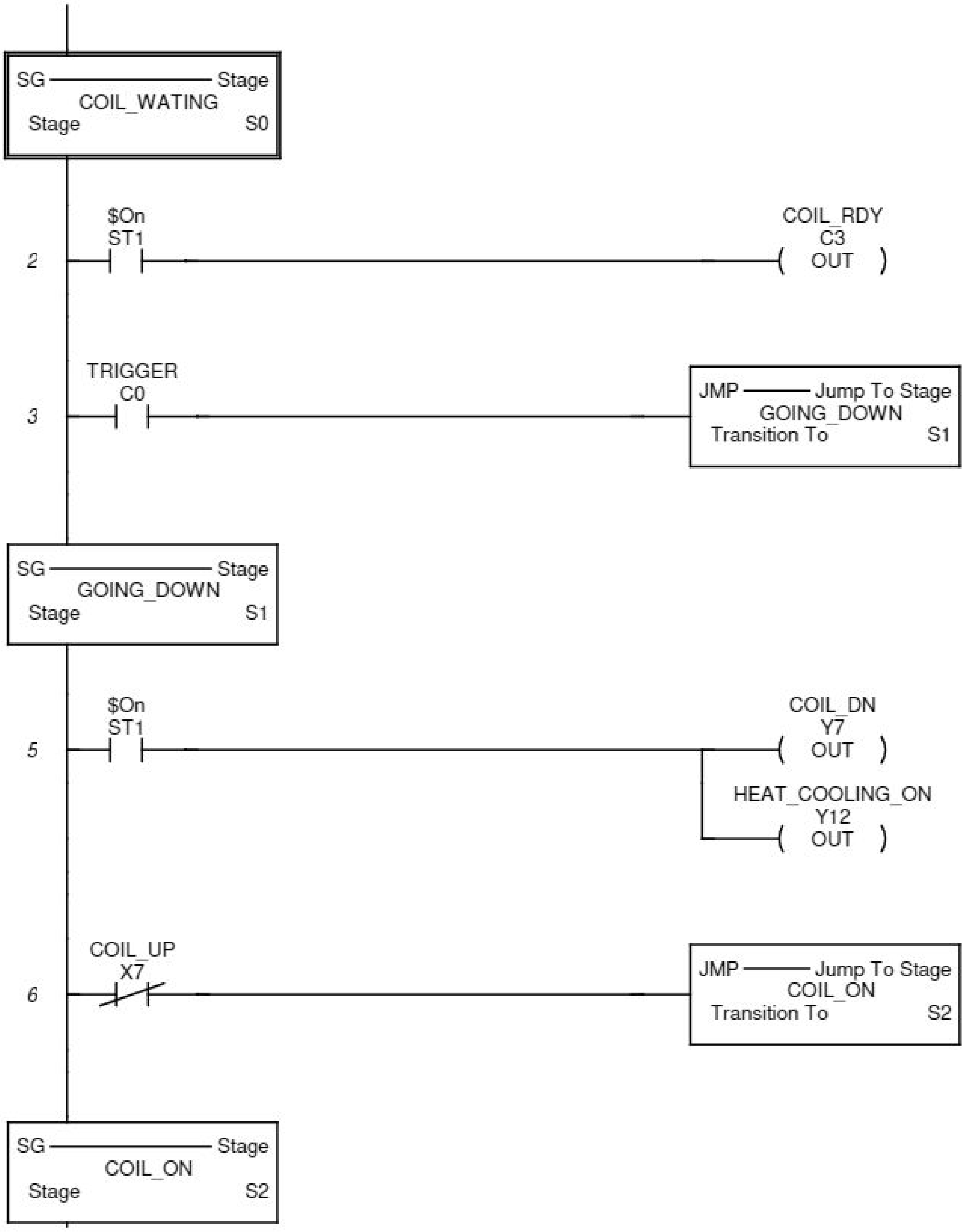

8
T11.Done
JMP Jump To Stage
ARM_GO_DN
Transition To S2
SG Stage
ARM_GO_DN
Stage S2
10
$On
ST1
SWING_ARM_LEFT
Y2
OUT
ARM_DN
Y6
OUT
11
ARM_DOWN
X3
ARM_LEFT
X0
JMP Jump To Stage
ARM_PINCHING
Transition To S3
SG Stage
ARM_PINCHING
Stage S3
13
$On
ST1
SWING_ARM_LEFT
Y2
OUT
ARM_DN
Y6
OUT
PINCH_ARM
Y3
OUT

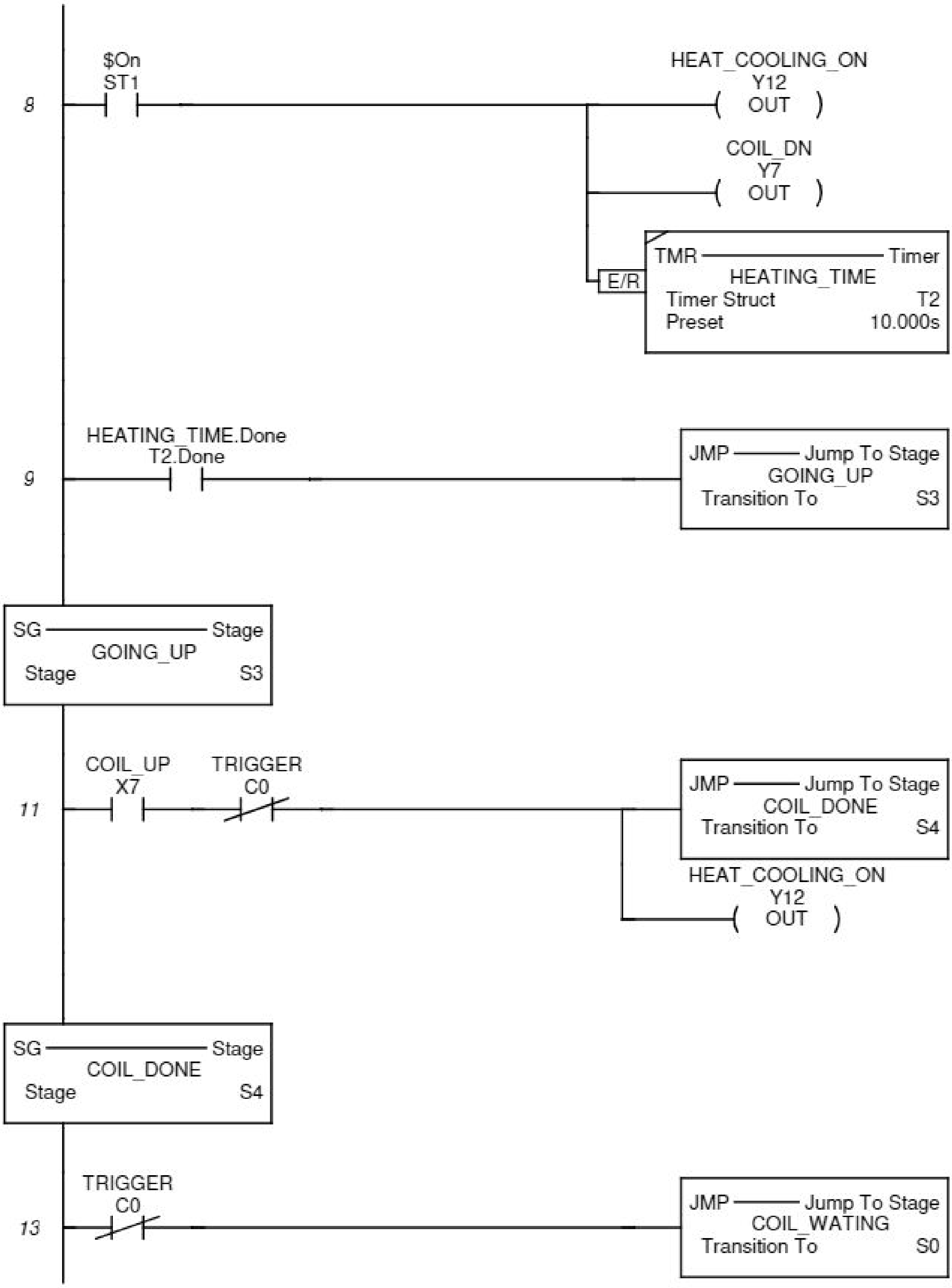


14
ARM_DOWN X3
ARM_LEFT X0
ARM_PINCHED X2
JMP Jump To Stage ARM_GO_UP Transition To S4
SG Stage ARM_GO_UP Stage S4
16
$On ST1
PINCH_ARM Y3 OUT
SWING_ARM_LEFT Y2 OUT
17
ARM_UP X1
JMP Jump To Stage TURNING_FULL Transition To S5
SG Stage TURNING_FULL Stage S5
19
$On ST1
PINCH_ARM Y3 OUT
20
$On ST1
E/R
TMR Timer ARM_TURNING Timer Struct T3 Preset 2.000s

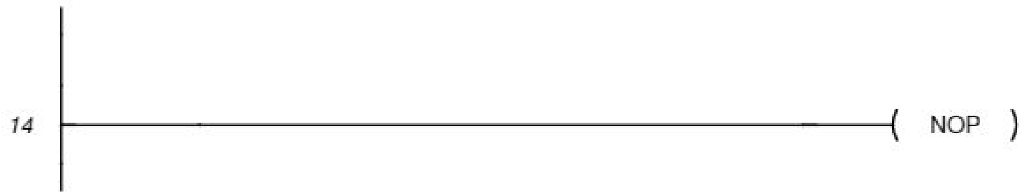

ARM_TURNING.Done
T3.Done
21
JMP Jump To Stage
ARM_DONE
Transition To S6
SG Stage
ARM_DONE
Stage S6
TRIGGER
C0
23
JMP Jump To Stage
ARM_WAITING
Transition To S0
24
NOP

Heating Coil





8
$On
ST1
HEAT_COOLING_ON
Y12
OUT
COIL_DN
Y7
OUT
E/R
TMR Timer
HEATING_TIME
Timer Struct T2
Preset 10.000s
9
HEATING_TIME.Done
T2.Done
JMP Jump To Stage
GOING_UP
Transition To S3
SG Stage
GOING_UP
Stage S3
11
COIL_UP
X7
TRIGGER
C0
JMP Jump To Stage
COIL_DONE
Transition To S4
HEAT_COOLING_ON
Y12
OUT
SG Stage
COIL_DONE
Stage S4
13
TRIGGER
C0
JMP Jump To Stage
COIL_WATING
Transition To S0


14
NOP