Mechatronics

PLC Applications
Level Process Control

Job Sheets - Courseware Sample

85253-F0

Safety and Common Symbols

The following safety and common symbols may be used in this manual and on the equipment:

Symbol	Description
⚠ **DANGER**	**DANGER** indicates a hazard with a high level of risk which, if not avoided, will result in death or serious injury.
⚠ **WARNING**	**WARNING** indicates a hazard with a medium level of risk which, if not avoided, could result in death or serious injury.
⚠ **CAUTION**	**CAUTION** indicates a hazard with a low level of risk which, if not avoided, could result in minor or moderate injury.
CAUTION	**CAUTION** used without the *Caution, risk of danger* sign ⚠, indicates a hazard with a potentially hazardous situation which, if not avoided, may result in property damage.
	Caution, risk of electric shock
	Caution, hot surface
	Caution, risk of danger. Consult the relevant user documentation.
	Caution, lifting hazard
	Caution, belt drive entanglement hazard
	Caution, chain drive entanglement hazard
	Caution, gear entanglement hazard
	Caution, hand crushing hazard
	Notice, non-ionizing radiation
	Consult the relevant user documentation.

Safety and Common Symbols

Symbol	Description
---	Direct current
∿	Alternating current
‾∿	Both direct and alternating current
3∿	Three-phase alternating current
⏚	Earth (ground) terminal
⏚	Protective conductor terminal
⏚	Frame or chassis terminal
▽	Equipotentiality
|	On (supply)
○	Off (supply)
▣	Equipment protected throughout by double insulation or reinforced insulation
⊓	In position of a bi-stable push control
⊔	Out position of a bi-stable push control

Table of Contents

Preface

The *Programmable Logic Controller, Basic Programming* student manual (P/N 88270) allowed the reader to become familiar with PLCs and ladder programming. This was accomplished with the help of the Programmable Logic Controller Training System (Model 3240).

The aim of the present series of PLC applications is to integrate the basic principles previously acquired by designing small-scale systems that can be found in the real world. Through practical examples, students will gain a strong knowledge of the PLC field of study.

Each manual of the PLC applications series concentrates on a specific example of PLC application that evolves along a path of increasing complexity. With each manual, new components are added to the PLC module to create different opportunities to learn.

We hope that your learning experience with the PLC Training System will be the first step of a successful career.

We invite readers of this manual to send us their tips, feedback, and suggestions for improving the book.

Please send these to did@de.festo.com.

The authors and Festo Didactic look forward to your comments.

About This Manual

Programmable Logic Controllers (PLC's) represent state-of-the-art microprocessor-based electronics that make up technologically advanced control systems with applications in virtually every segment of industry where automation is required.

The present manual includes five Job Sheets that introduce students to PLC control of the Level-Process Training System, Model 8075-6. Throughout the manual, students will learn how to program, connect, operate, and troubleshoot different configurations.

Prerequisite

Before performing the Job Sheets in this manual, it is recommended to review the *Programmable Logic Controller, Basic Programming* student manual (P/N 88270), which explains how to use the programming software and the most common PLC instructions. If any difficulty is encountered while performing the exercises, the programming software's user guide and help menu can assist students in problem solving.

Safety considerations

Safety symbols that may be used in this manual and on the equipment are listed in the Safety Symbols table at the beginning of the manual.

Safety procedures related to the tasks that you will be asked to perform are indicated in each exercise.

Control systems can be harmful when not used properly. Before performing any of the exercises in this manual, make sure that you respect the following general guidelines:

- Put your safety glasses on.

- Avoid wearing any loose clothing (e.g., tie, long sleeves, jewelry).

- Have your hair tied out of the way if it is long.

- Clean your work area if necessary.

- Be careful not to spill water on the PLC and the system electrical components.

Remember that you should never perform an exercise if you have any reason to think that a manipulation could be dangerous to you or your teammates.

Systems of units

Units are expressed using the International System of Units (SI) followed by units expressed in the U.S. customary system of units (between parentheses).

About This Manual

Appendices

Appendix A: *List of Equipment Required*, gives the list of equipment needed to perform the exercises.

Appendix B: *Ladder Program Design*, presents two different methods that can be employed to program a PLC ladder program.

Appendix C: *Boolean Algebra and Digital Logic*, shows the logical relationships that can be employed with normally-open (NO) and normally-closed (NC) contacts.

Appendix D: *Troubleshooting Procedures*, is a set of guidelines permitting students to locate and correct PLC system failures.

Appendix E: *Glossary of Terms*, defines technical words and expressions contained in this manual.

Appendix F: *Ladder Diagram Graphic Symbols*, depicts the main symbols used in ladder diagrams.

To the Instructor

You will find in this Instructor Guide all the elements included in the Student Manual together with the answers to all questions, results of measurements, graphs, explanations, suggestions, and, in some cases, instructions to help you guide the students through their learning process. All the information that applies to you is placed between markers and appears in red.

Accuracy of measurements

The numerical results of the hands-on exercises may differ from one student to another. For this reason, the results and answers given in this manual should be considered as a guide. Students who correctly performed the exercises should expect to demonstrate the principles involved and make observations and measurements similar to those given as answers.

The instructor should be familiar with PLCs to recognize erroneous results. It is advised that a complete run-through of each job sheet be included in the instructor's preparation for class. Each Job Sheet has several performance objectives. The instructor should ensure that each student understands them.

Sample
Extracted from
the Job Sheets Student
and the Job Sheets Instructor

Batch Process

Batch processes

A batch process is a production method used to obtain a desired product by batches and not in a continuous manner. This method is popular in the food and chemical industries where specific conditions (temperature, pressure, and/or ingredients relative quantities) must be obtained to ensure proper transformation. PLCs are particularly useful in monitoring and controlling these conditions. Figure 13 shows how a batch of dough is prepared in a bakery.

Figure 13. Example of batch process.

PLC program initialization

To avoid unexpected outcomes, it is good practice to start a program by setting data files to precise values. This is particularly important with sensitive files such as outputs or control bits.

A way to realize this in practice is to use a condition that is only true during the first processor **scan**. With Micrologix Controllers from Allen-Bradley, S:1/15 is a reserved status bit that is only actuated during the first pass. As an example,

Figure 14 shows how all outputs of slot 0 can be reset at the beginning of the program.

*The instruction CLR (**clear**) sets all the bits in a word to zero.*

First Pass
S:1

CLR
Clear
Dest   O:0.0
                  0

END
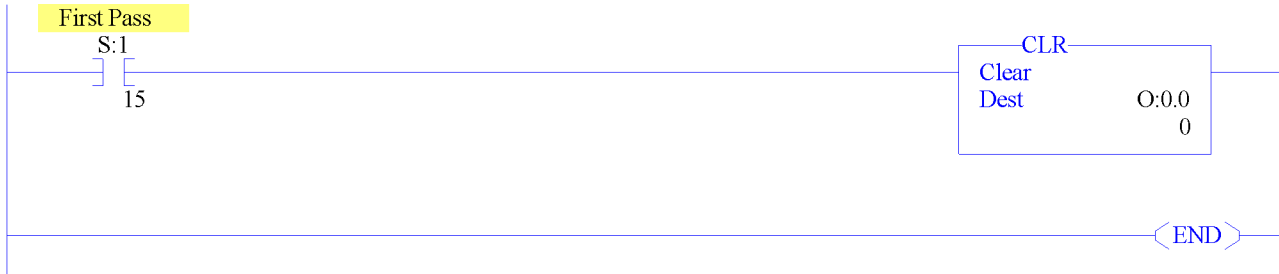
Figure 14. Outputs reset upon initial scan.

Timer On (TON) instruction

With Micrologix Controllers from Allen-Bradley, the TON instruction starts to count time base intervals when the **rung** in which it is contained goes from false to true. As long as the rung remains true, the TON instruction increases its **accumulated value** until it reaches the **preset** value. If the rung becomes false, the accumulated value is reset to zero regardless of whether or not the preset value has been reached.

Figure 15 shows the data file of a timer instruction. The timer status bits that you can use to control relay-type (XIO and XIC) instructions in your program are (timer T4:0 given as an example):

- **Done bit (T4:0/DN)**: Set to logic state 1 when the accumulated value becomes equal to the preset value, and reset to logic state 0 when the rung becomes false.

- **Timer timing bit (T4:0/TT)**: Set to logic state 1 when the TON rung is true and the accumulated value is less than the preset value.

- **Timer enable bit (T4:0/EN)**: Set to logic state value 1 when the TON rung is true.

The timer status words that you can use in your program's comparison instructions are (timer T4:0 given as an example):

- **Preset value word (T4:0.PRE)**: Final value the accumulated value must reach to stop timing and set the done bit.

- **Accumulated value word (T4:0.ACC)**: Value accumulated since the timer was last reset to zero.
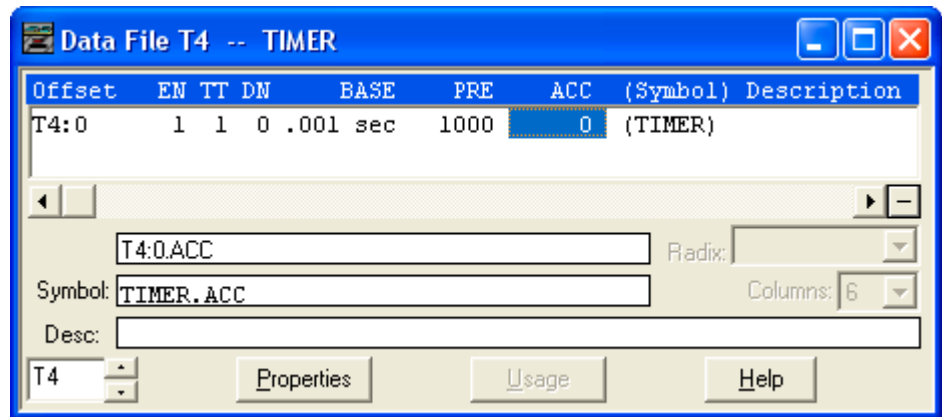
Figure 15. Timer instruction file.

Alarms

A good PLC program must be able to cope with all the possible states that the system can be found in. This includes all the faulty conditions resulting from a physical failure. For example, the high-level float switch of the Level-Process Training System may stop working, causing water to spill from over the top of the cylinder. If this situation occurs, the program should inform the operator, through an alarm routine, that an unusual situation is happening. In this particular case, a second float switch may be installed higher on the cylinder to set the alarm and avoid damage if it ever gets triggered.

Alarms are particularly important when the system is not under direct operator supervision. Serious alarms may require shutting down the whole process automatically. Safety here is the main issue.

Be careful when performing maintenance work on any system where sources of energy (electrical, mechanical, pneumatic, hydraulic, etc.) can cause you harm. More sophisticated systems in the industry may require specific procedures, including lockout and/or tagout, as shown in Figure 16.

Figure 16. Lockout / Tagout procedure.

Height-adjustable float switch

The height-adjustable float switch can be converted from NO to NC operation, as shown in Figure 17. In this Job Sheet, we will assume that the switch is NO and marking the normal water height desired for heating.
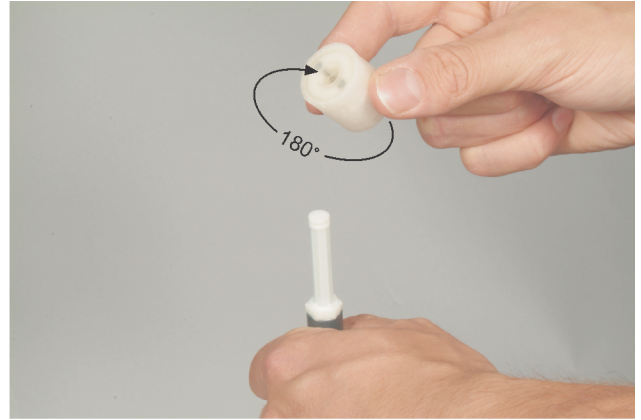
Figure 17. Changing float switch from NO to NC.

Batch Process

OBJECTIVE

Implement a ladder program permitting batch process.

PROCEDURE

<div align="center">

⚠ **CAUTION**

</div>

⚠ Make sure you are wearing appropriate protective equipment when performing the jobs. You should never perform a job if you have any reason to think that a manipulation could be dangerous for you or your teammates.

Also, be careful not to spill water on the system electrical components.

1. Connect the Level-Process Training System according to Figure 18. This arrangement will be used in both parts of the procedure section (without and with the alarm).

> *Some items connected will only be used in the second part of the procedure section.*
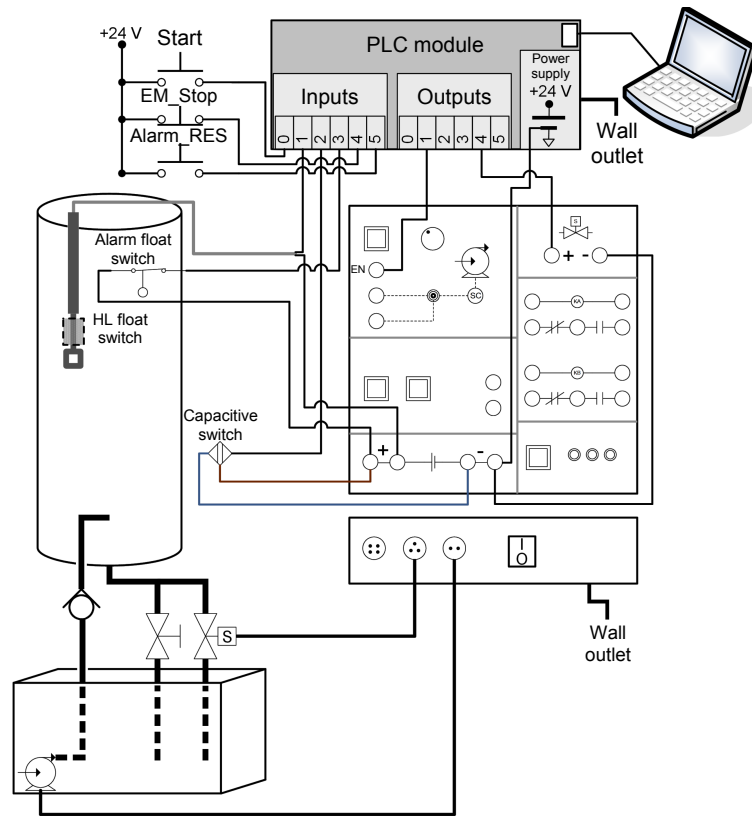
Figure 18. Job Sheet 3 configuration.

Table 5. Job Sheet 3 PLC I/O connections.

PLC address	PLC port	Connected to
I:0/0 (START_PB)	Input 0	Start Pushbutton
I:0/1 (HIGH_FS)	Input 1	High-Level Float Switch (Adjustable)
I:0/2 (LOW_CS)	Input 2	Low-Level Capacitive Switch
I:0/3 (ALARM_FS)	Input 3	Alarm Float Switch
I:0/4 (EM_STOP)	Input 4	Emergency Stop Pushbutton
I:0/5 (ALARM_RES)	Input 5	Reset Pushbutton
O:0/0 (IDLING)	Output 0	Nothing (LED indicates IDLE mode)
O:0/1 (PUMP)	Output 1	Pump EN terminal
O:0/2 (HEATER)	Output 2	Nothing (LED indicates heating process)
O:0/3 (MIXER)	Output 3	Nothing (LED indicates mixing process)
O:0/4 (VALVE)	Output 4	Solenoid Valve + Terminal
O:0/5 (ALARM_LED)	Output 5	Nothing (LED indicates FAULT mode)

2. The ladder program that you are about to write will control a batch process in which a liquid enters a tank until a given level is reached. The liquid is then heated and mixed for a predetermined time period (30 seconds) after which it is evacuated.

The system will work in four different states, as shown in Figure 19.
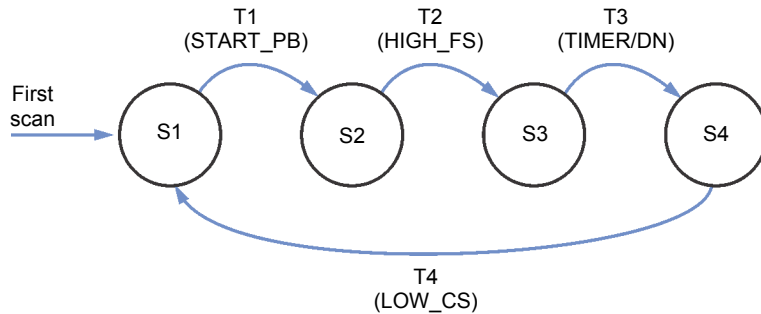
Figure 19. State diagram of Job Sheet 3 (without the alarm).

- **State 1 (IDLE)**: Begins when the program is started (upon first scan) or after a cycle is completed (when the liquid level is low). Ends when the START pushbutton is pressed.

- **State 2 (FILL)**: Begins when the START pushbutton is pressed in IDLE state. Ends when HIGH_FS is triggered.

- **State 3 (HEAT)**: Begins when HIGH_FS is triggered in FILL state. Ends when the timer is done (after 30 seconds).

- **State 4 (EMPTY)**: Begins when the timer is done in HEAT state. Ends when the capacitive switch stops detecting water.

Table 6 shows the different outputs that are triggered in each state.

Table 6. Actuated output per state.

State	Actuated output(s)
IDLE (1)	IDLING (O:0/0)
FILL (2)	PUMP (O:0/1)
HEAT (3)	HEATER (O:0/2)
	MIXER (O:0/3)
EMPTY (4)	VALVE (O:0/4)

The ladder program should only use the RSLogix instructions part of the following list:

CLR - XIC - XIO - OTE - TON

3. Start RSLogix Micro and write a ladder program satisfying all the previous conditions. Refer to Appendix B if necessary.

4. Switch on the Level-Process Interface and the PLC.

5. Download your ladder program to the PLC.

Test and comment your ladder program. Correct the program if it does not behave as expected.

6. Demonstrate the operation of the Level-Process Training System to your instructor.

```
                              JS3_WITHOUT_ALARM.RSS
                    LAD 2 -  --- Total Rungs in File = 15
```


Batch process ladder program (no alarm, part 1).

Batch process ladder program (no alarm, part 2).

Batch process ladder program (no alarm, part 3).

7. Save and print your ladder.

Alarm Implementation

8. Modify the program of the first part of the procedures by creating a fifth state called FAULT. The new program will work according to Figure 20 state diagram. The system will be in State 5 (FAULT) when the alarm float switch is triggered or when the emergency stop pushbutton is pressed. This state actuates PLC output 5 (I:0/5) for indicating purpose. The system returns to State 1 (Idle) when the reset pushbutton is pressed.

Figure 20. State diagram of Job Sheet 3 (with the alarm).

9. Download your ladder program to the PLC. Test and comment your ladder program. Correct the program if it does not behave as expected.

10. Demonstrate the operation of the Level-Process Training System to your instructor.

JS3_ALARM.RSS

LAD 2 - --- Total Rungs in File = 19
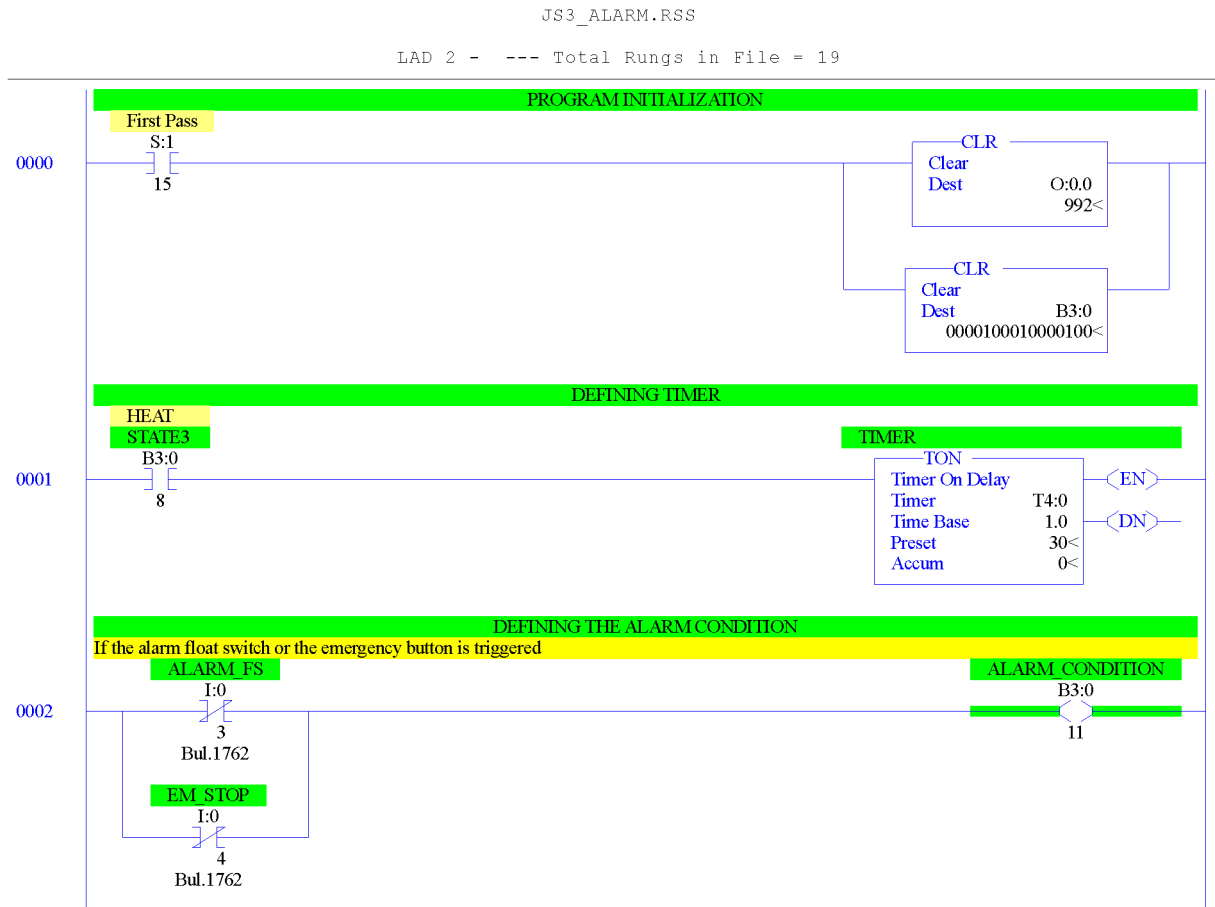
Batch process ladder program (with alarm, part 1).
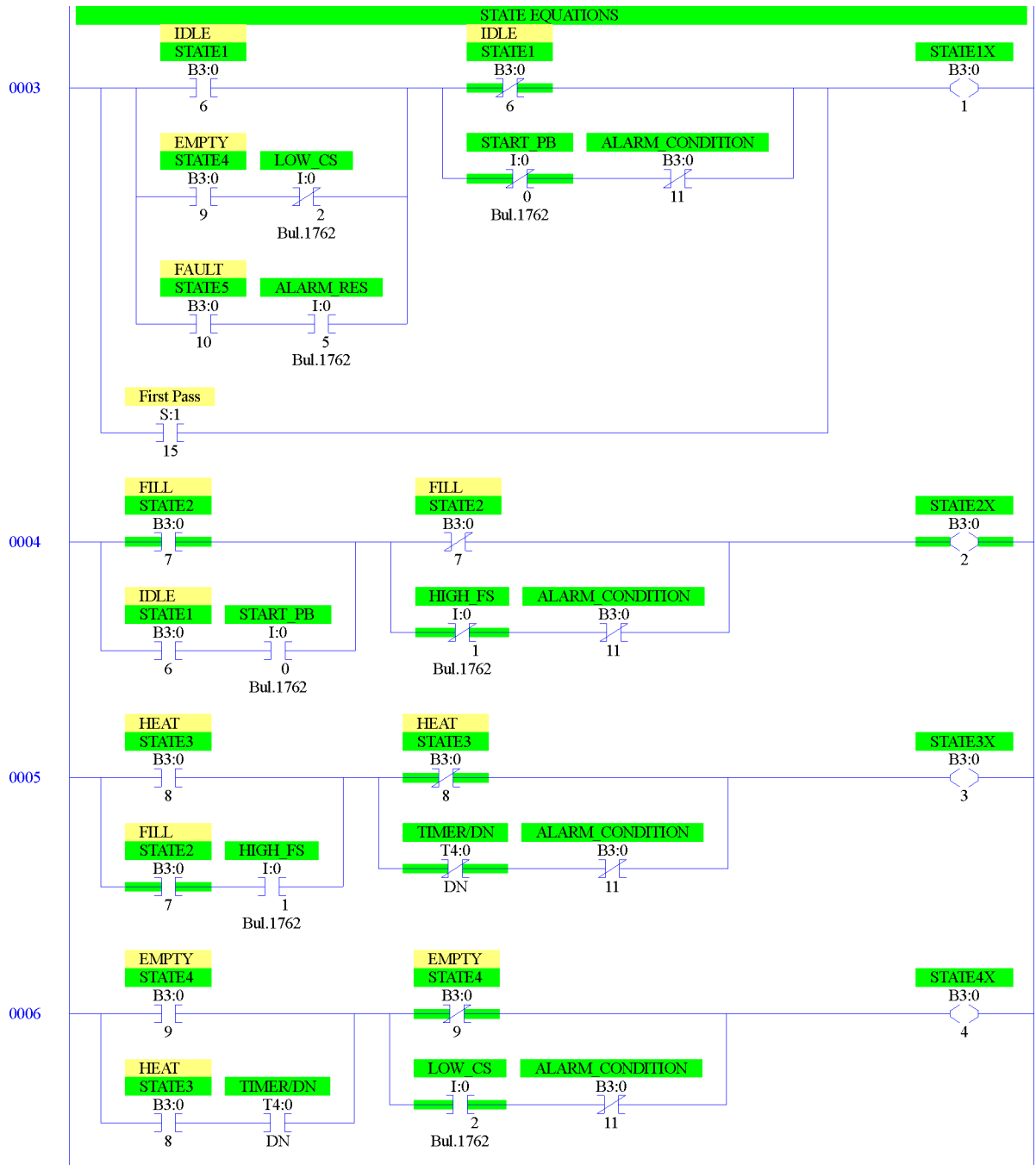
Batch process ladder program (with alarm, part 2).

Batch process ladder program (with alarm, part 3).

```
                                    UPDATING OUTPUTS
         IDLE
         STATE1                                                      IDLING
         B3:0                                                        O:0
0013     ┤ ├                                                         < >
          6                                                           0
                                                                    Bul.1762

         FILL
         STATE2                                                      PUMP
         B3:0                                                        O:0
0014     ┤ ├                                                         < >
          7                                                           1
                                                                    Bul.1762

         HEAT
         STATE3                                                      HEATER
         B3:0                                                        O:0
0015     ┤ ├                                                         < >
          8                                                           2
                                                                    Bul.1762

                                                                    MIXER
                                                                    O:0
                                                                    < >
                                                                     3
                                                                    Bul.1762

         EMPTY
         STATE4                                                      VALVE
         B3:0                                                        O:0
0016     ┤ ├                                                         < >
          9                                                           4
                                                                    Bul.1762

         FAULT
         STATE5                                                      FAULT_LED
         B3:0                                                        O:0
0017     ┤ ├                                                         < >
          10                                                          5
                                                                    Bul.1762

0018                                                                < END >
```
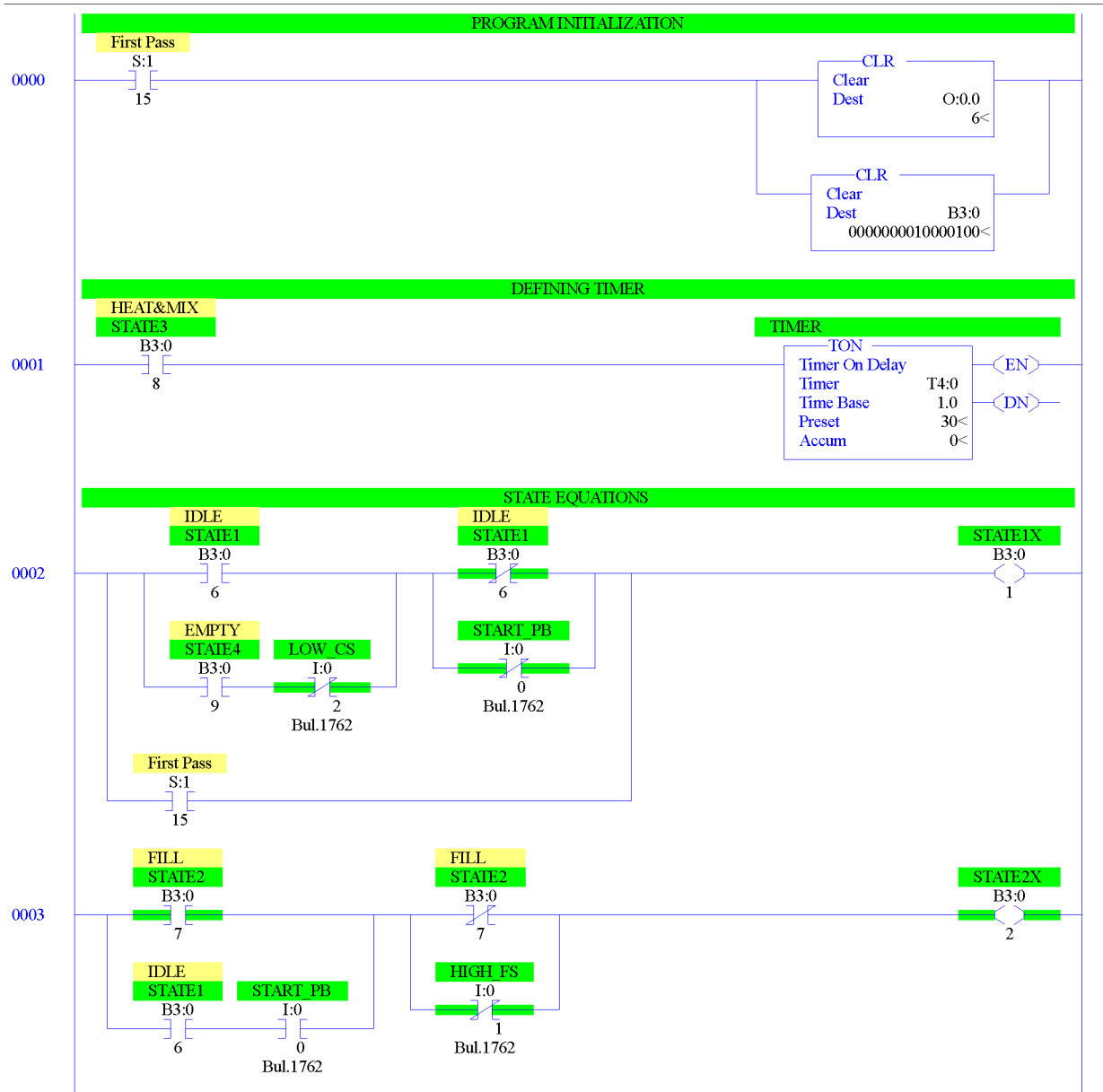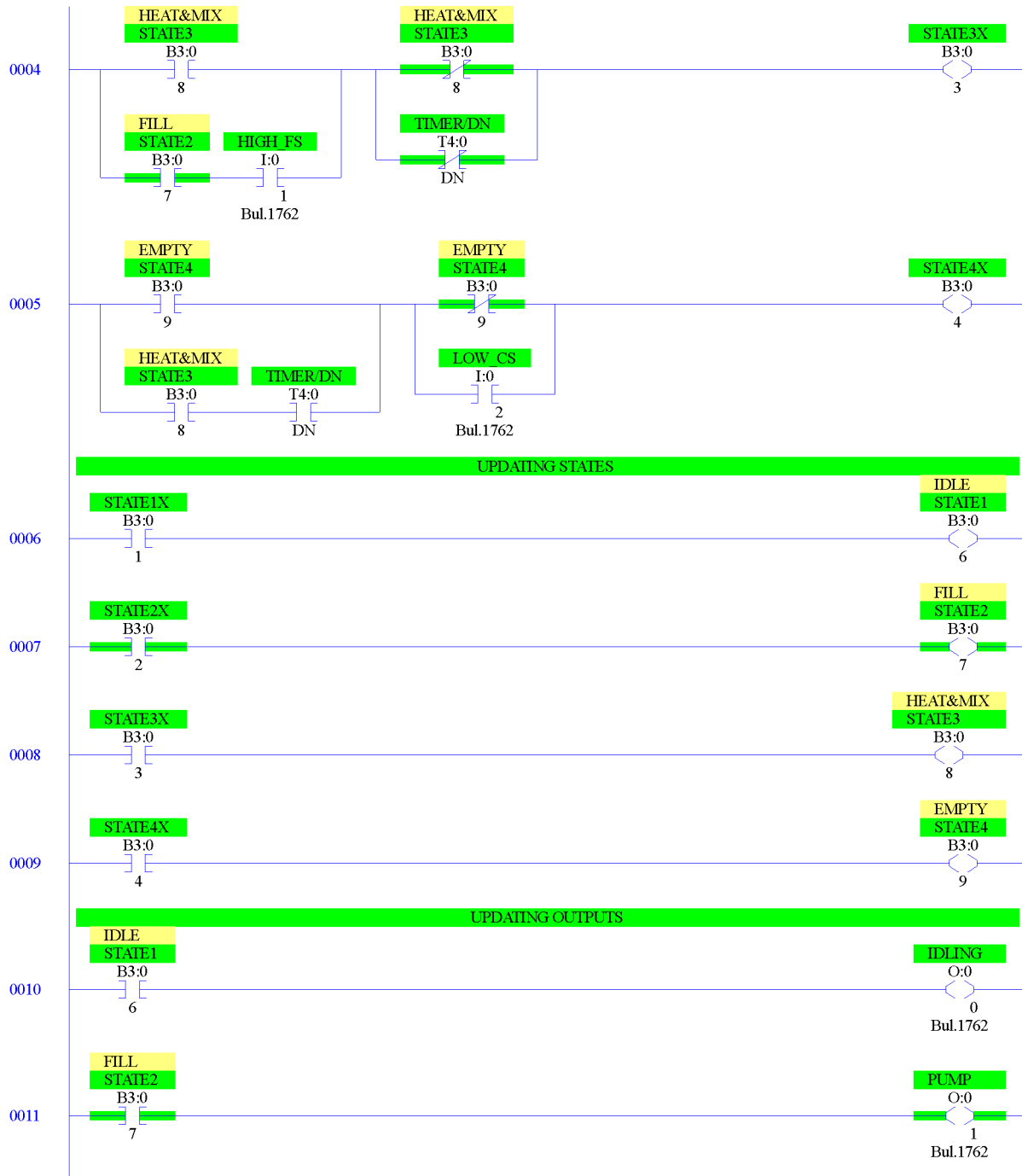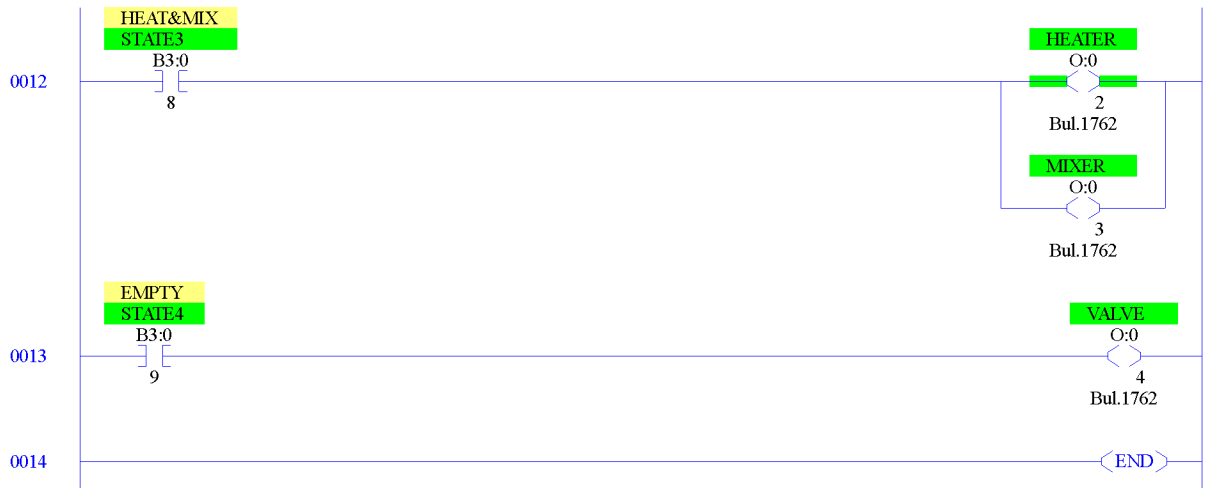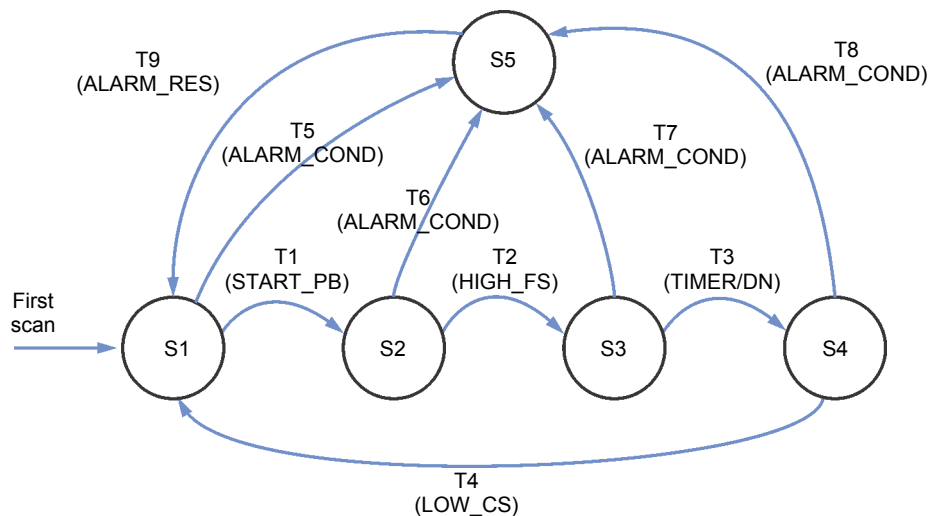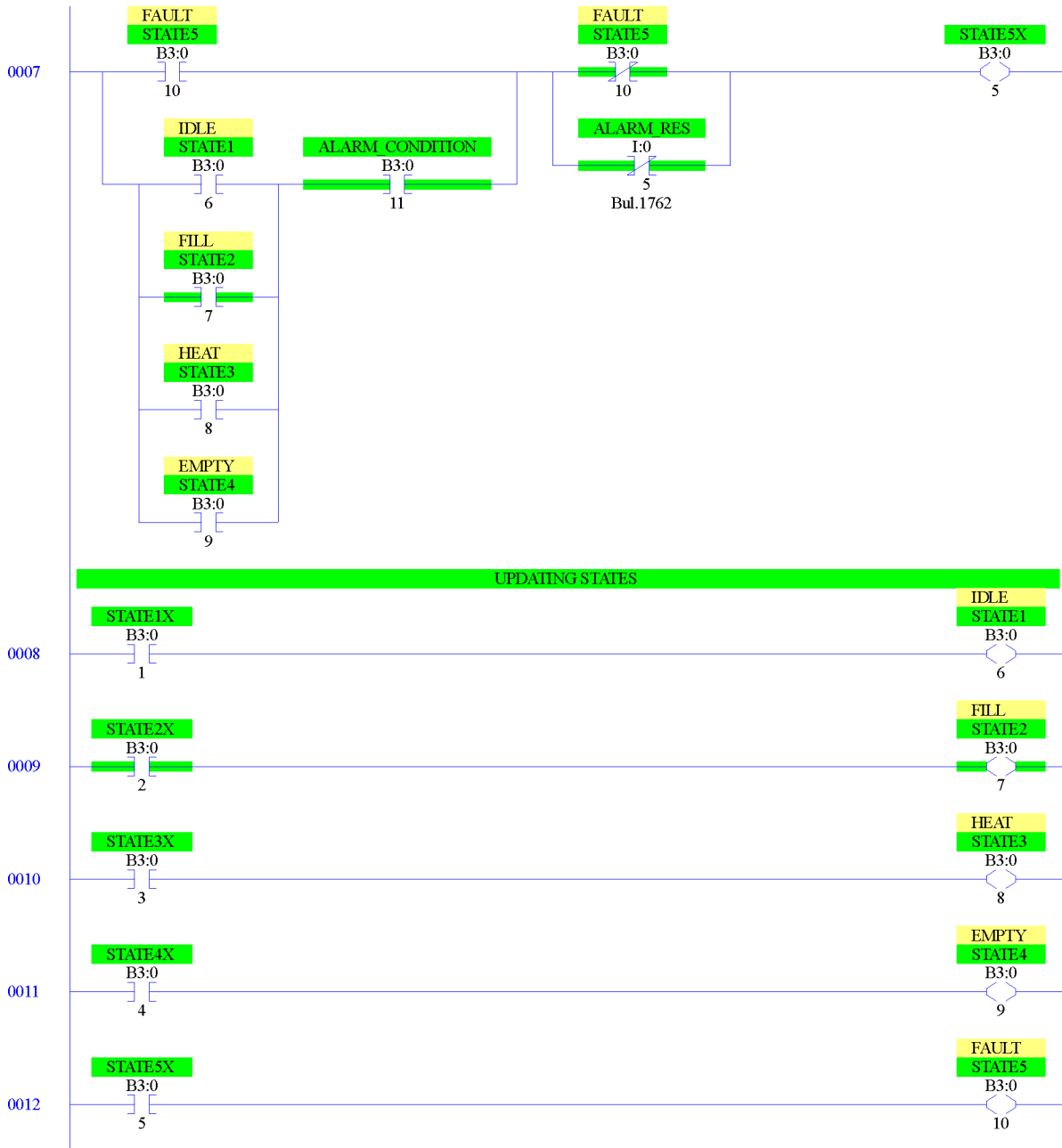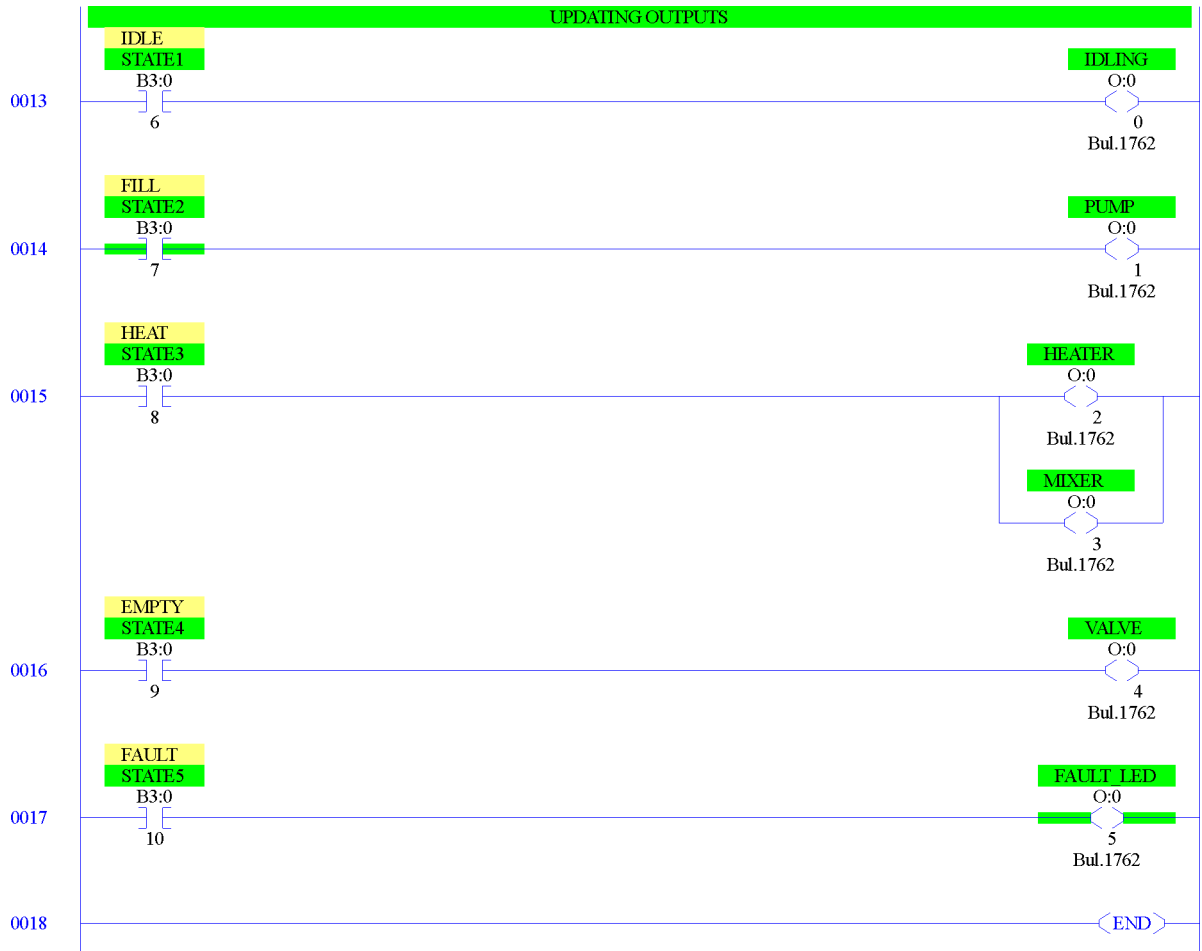
Batch process ladder program (with alarm, part 4).

11. Save and print your ladder.

12. Close RSLogix Micro and turn off the PLC.

Name: _____   Date: _____

Instructor's approval: _____