

Filling Plant Process Simulation

1 Demo operation

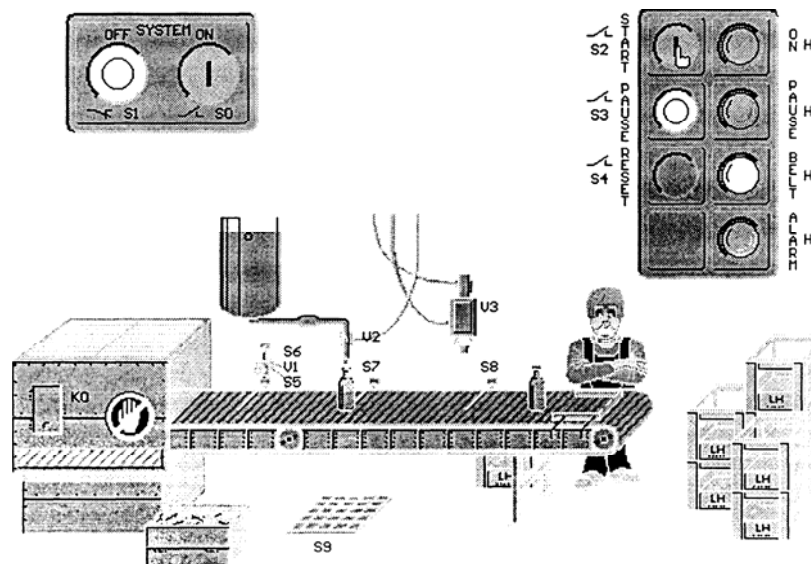
1.1 Putting the system into operation

Immediately after the program has been started, the process simulation appears on the screen.

The mouse cursor is visible as a hand. The main menus of the program can be selected from the menu bar at the upper edge of the screen. The process flow in the demo mode is automatic. The bottle filling system is controlled by the program itself. The DEMO mode shows a possible objective to be realised in terms of external control. In the next chapters, this automatic operation is analysed step-by-step through exercises and replaced by a real control system. None of the control elements are active during DEMO operation of the system. The process can only be observed.

Move the mouse cursor to the DEMO option key and briefly press the left mouse button.

The mouse cursor immediately starts moving and simulates the operational steps for starting the system. DEMO operation can be aborted by pressing any key or the left mouse button.



Display of the filling process simulation in the DEMO mode

1.2 Description of the bottle filling system

The system is activated via the ON switch SO. The green indicator light H4 signals that the system is active. At the same time, the yellow indicator light H5 signals that the system is in the paused state. The process is started with switch S2. The conveyor belt KO starts moving immediately. The bottles emerge from a shaft on the left and are evaluated by the optical sensors S5 and S6. S5 is a position indicator, while S6 indicates whether the bottle is intact or broken.

Intact bottles are transported to the optical position indicator S7. Here, they are filled with the beverage through the valve V2. The beverage dispenser never runs dry. During the filling period of approx. one second, the belt remains stationary. A crown cork is pressed on via valve V3 at the next processing station with the position indicator S8. The supply of crown corks is also endless. At the end of the conveyor belt, the assembly-line worker Joe packs the bottles into LH crates. Joe does not examine the condition of the bottles. He packs all the bottles which arrive. After twelve bottles, the belt is stopped with the pause switch S3. Joe now has time to prepare a new crate for packing. Production is continued with the start switch S2. The production process only remains smooth if no defective bottles infiltrate it.

Now activate the options menu (mouse click or [o] key) and switch over from *Defective bottles: never* to *Defective bottles: rarely* (mouse click or [d] key).

Close the options menu by clicking the *OK* key with the mouse cursor or by pressing the [w] key.

Start DEMO operation once again.

Broken bottles detected by optical sensors S5 and S6 are ejected by piston VI into a waste container.

In addition to broken bottles (visibly defective), some bottles have invisible defects. They have hairline cracks at the bottom, and are brought on to the conveyor belt at random if you select *Defective bottles: often* or *Defective bottles: specify* in the options menu.

Bottles with invisible defects are not recognised by optical sensors S5 and S6, and are filled just as intact bottles. The liquid leaks out of them and activates moisture detector S9. The belt stops at once, and the red alarm indicator light H7 comes on. Pressing switch S4 removes the moisture, after which production can be restarted with switch S2.

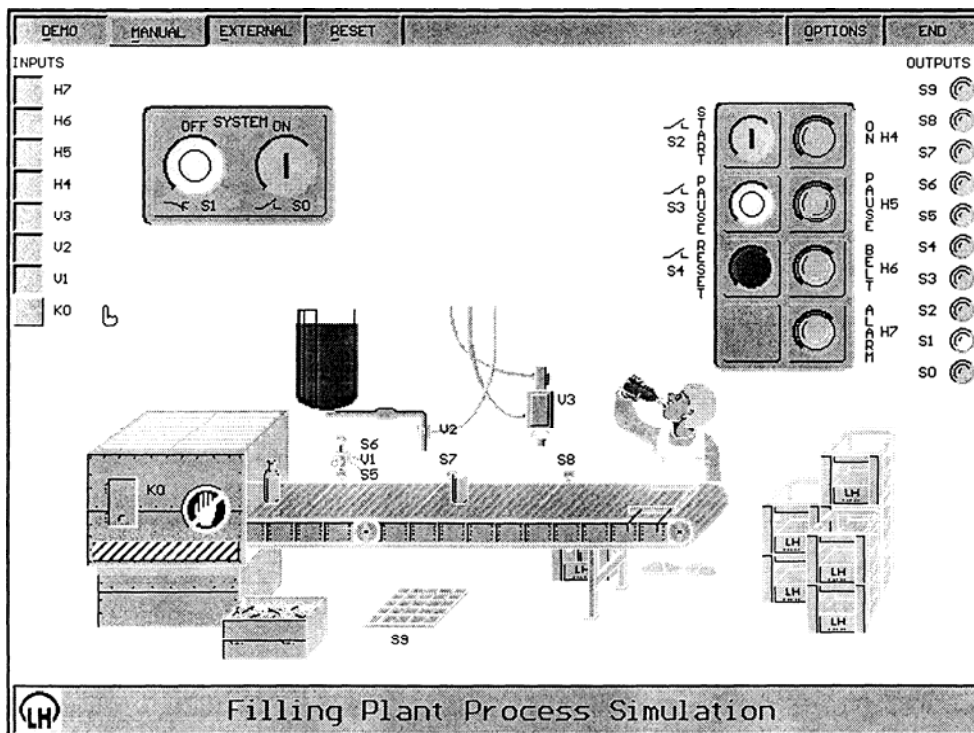
2 Manual control of the process simulation

2.1 Putting the system into operation

In the MANUAL operating mode, all functions of the process can be tested without the control unit being connected. By clicking the mouse, all actuators and control elements can be activated and their response observed. The status of the process sensors and control elements is indicated by LED's and simultaneously output to the PC adapter where it can actually be measured.

The main menus of the program are shown in the menu bar at the top edge of the screen. Move the mouse cursor to the option key OPTIONS and briefly click the left mouse button. Several available settings now appear in a window (also refer to Chapter 2.7). Check whether the parallel interface to which you have connected the PC adapter is displayed. If required, you can change the entry by clicking the mouse. Also check whether the options *Lettering on* and *Defective bottles: never* are active so that the same conditions can be assumed to exist in the following description.

Click on the MANUAL option key in the menu bar at the top. The process simulation is now in the manual operating mode.



MANUAL operating mode of the filling process simulation system

2.2 Testing the bottle filling system

The left edge of the screen displays 8 switches, while the right edge displays 10 LEDs. The bottle filling system has a total of 8 actuators or inputs. The motor contactor is designated K, the valves V and the indicator lights H. By clicking on a switch with the mouse, the corresponding actuator is operated. The switches can also be activated via the PC keyboard: press the [Shift] key together with the corresponding number, e.g. [0] for switch K0. In this case, the conveyor belt would immediately start moving.

The control elements of the system consist of switches S0 to S4. They, too, can be activated either by clicking the mouse or by pressing the corresponding number key on the PC keyboard. When operated from the keyboard though, they function as switches. Their status is indicated by the LED's at the right-hand edge of the screen. The off- switch S1 is a NC contact which supplies a 1-signal in the inactive state. The status of the system outputs can be measured directly at the corresponding outputs of the PC adapter. The numbers on the system outputs coincide with those on the PC-adapter sockets. The numbers on the switches at the left edge of the screen are also identical with the numbers on the PC-adapter inputs via which the system is controlled externally in the next chapter. Sensors S5 to S9 are further system outputs.

The sensors supply a 1-signal if activated from within the system. For example, the optical position sensor S5 supplies a 1-signal when a bottle crosses the light beam.

To acquaint ourselves with the MANUAL operating mode and, thus, with the system as such, let us now fill and cork a bottle manually.

Click on switch K0 with the left mouse button, whereupon the conveyor belt starts moving. Try to stop the belt when a bottle is situated below filling valve V2, i.e. when position sensor S7 supplies a 1-signal.

As this manual task is almost impossible to accomplish, the MANUAL operating mode allows jog control of the conveyor belt. Whenever you click on switch K0 with the right mouse button, the belt moves one step rightward. If the PC keyboard is used, this operation is performed with the [Space] key.

The bottle is filled by activating valve V2. Incidentally, the dispenser never runs empty.

Determine the filling time for one bottle by trial. When liquid drips off the conveyor belt, moisture sensor S9 supplies a 1-signal. By pressing the enable switch S4, the system is cleaned and S9 reset.

Transport the filled bottle to the corking station at position sensor S8 and press a crown-cork on to the bottle by activating valve V3. Assembly-line operator Joe packs all arriving bottles into the LH crate.

The crate is emptied by pressing the start key S2.

If you also want to introduce defective bottles into this process, simply branch to the Options menu and change the entry for defective bottles there.

Defective bottles are discarded by operating the eject-piston VI. They fall into a crate which never becomes full. Intact bottles are recognized when optical sensors S5 and S6 supply a 1 signal simultaneously. In the case of defective bottles, only S5 supplies a 1-Signal.

Now test the entire system simply by playing around with it. Also use the lettering for the system components as an aid. A copy sheet of the allocation list with enough room for remarks can be found on the next page.

By clicking on the RESET option key in the line at the top of the screen, the system can be returned to a defined initial state at any time.

Exercise 1

When controlling systems, a basic distinction is made between sequential control and logic control.

In sequential control, the process can be divided into various discrete steps which are performed more or less consecutively.

In logic control, no particular sequence of recurring events exists. Which of these two types of control would be suitable for this bottle filling system, and why? State further possible applications for both types of control.

Exercise 2

Operate the red OFF key S 1 and observe the corresponding output. Is it a NC or NO contact? Why? Fill out the corresponding column for all system outputs in the allocation list on the next page.

Exercise 3

The control elements are designed as buttons, supplying a 1-signal only during the period of operation. Which logic modules can nevertheless be used to reliably register these brief, irregular events?

Allocation list for inputs and outputs

Input	Active on	Control	Description	Remarks
K0	1		Conveyor belt	
VI	1		Ejection valve for bottles	
V2	1		Filling valve	
V3	1		Corking valve	
H4	1		Indicator light ON	
H5	1		Indicator light PAUSE	
H6	1		Indicator light BELT	
H7	1		Indicator light ALARM	

Output	Contact NO/NC	Control	Description	Remarks
SO	NO		ON button	
S1			OFF button	
S2			START button	
S3			PAUSE button	
S4			ENABLE button	
S5			Ejection position sensor	
S6			Intact bottle sensor	
S7			Filling position sensor	
S8			Corking position sensor	
S9			Moisture sensor	

Flag/Timer	Active on	Control	Description	Remarks
M10	1		System started	
M11	1		S7 sensor in cycle -1	
M12	1		Positive edge to S7	
M13	1		S8 sensor in cycle -1	
M14	1		Positive edge to S8	
M15	1		Alarm state	
M16	1		Defective bottle	
M17	/		Flashing frequency IHz	
T1	/		Filling time for V2	
T2	/		Corking time for V3	

NO = Normally Open, supplying a 1-signal on operation

NC = Normally Closed, supplying a 0-signal on operation

3 External control of the process simulation

3.1 Putting the system into operation

In the EXTERNAL operating mode, the bottle filling system is connected to a real control unit via the PC adapter.

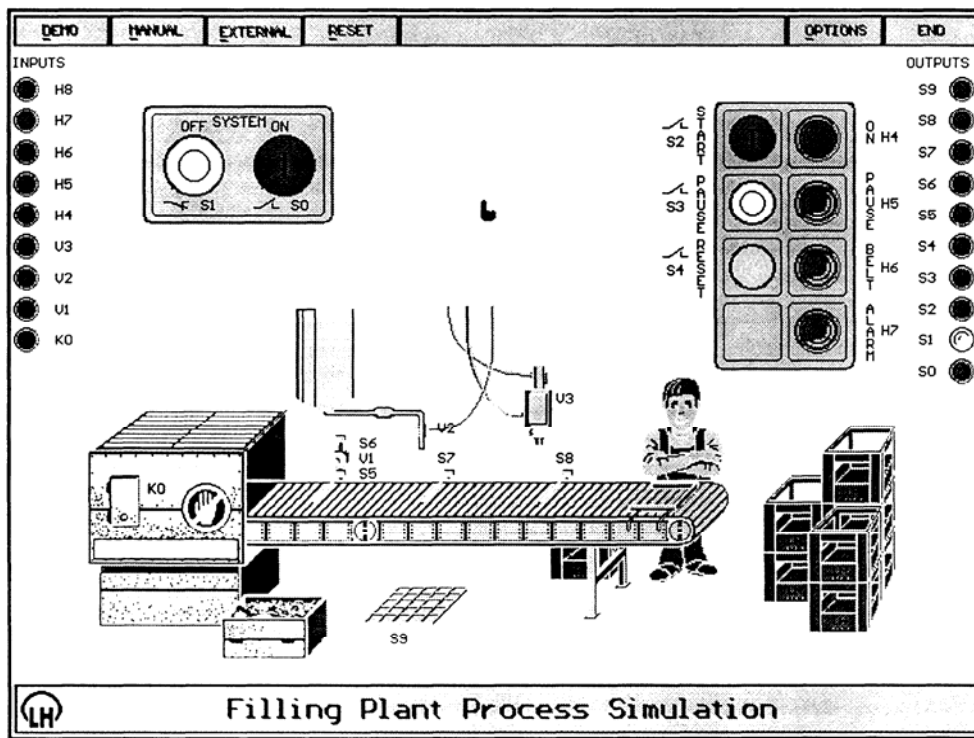
Move the mouse cursor to the option key OPTIONS and briefly click the left mouse button.

Check whether the parallel interface connected to your PC adapter is indicated. Also check whether *Defective bottles: never*, *Lettering* and *Status display* are active. If necessary, you can change the settings by clicking the mouse.

Clicking on the EXTERNAL option key in the upper menu bar activates the EXTERNAL operating mode for the process simulation. The screen configuration is similar to that in the MANUAL operating mode. The states of the PC adapter inputs and, thus, the indicator lights and contactors of the bottle filling system are now displayed by LED's on the left edge of the screen.

A 1-signal at a PC adapter input activates the corresponding LED and the related function of the bottle filling system.

The states of the bottle filling system's outputs (buttons, sensors) are also indicated by LED's on the right edge of the screen. They can be measured in real terms at the PC adapter outputs.



Screen display of the EXTERNAL operating mode

3.2 Connecting the control unit

If a PLC unit is to perform control, it can be connected to the PC adapter. The PLC inputs and outputs are freely selectable. The PC adapter outputs are connected with the PLC digital inputs, while the PLC digital outputs are connected with the PC adapter inputs. The allocation of the inputs and outputs should then be entered in the allocation table from Exercise 2. Simply enter the designations of the PLC inputs and outputs in the column titled "Control".

We will always refer to the inputs and outputs of the bottle filling system in the following. The allocation list will be absolutely necessary for programming the PLC later on.

Remember to connect the 0V rail of the PC adapter with the signal ground of the PLC.

If the PLC is programmed with the same PC used for running the process simulation, proceed in the following sequence:

1. Connect the PC adapter with the PLC
2. Develop a control program and transfer it to the PLC
3. Call up the process simulation and branch to the EXTERNAL operating mode
4. Start (switch on) the PLC

If a discrete control is to be used for controlling the system, the wiring for it cannot be realized yet because the control logic must first be developed.

The DEMO operating mode from Chapter 3 shows the actual control function for the bottle filling system. We were able to observe this process at leisure. The control sequence must next be interpreted step-by-step in Chapter 6, based on the verbal description of the process.

4 Developing the control program

Control circuit elements:

Chapter	4.1 Switching on the system
	4.2 Starting the system
	4.3 Filling bottles
	4.4 Corking bottles
	4.5 Conveyor belt
	4.6 Ejecting defective bottles
	4.7 Alarm state
	4.8 Monitoring defective bottles
	4.9 Additional remarks

4.1 Switching on the system

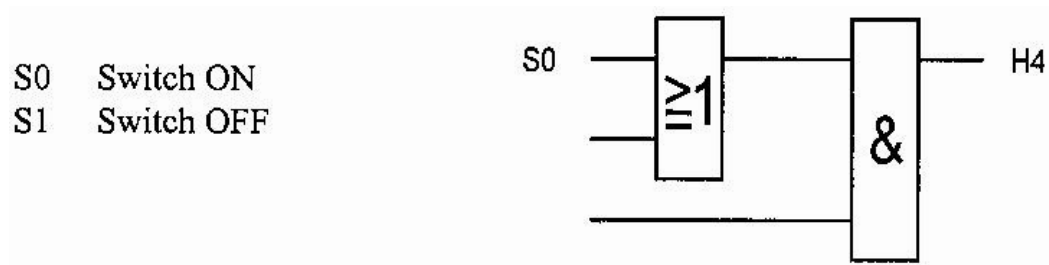
The system is switched on via NO contact S0 and switched off via NC contact S1. Switching off carries priority. The on-state of the system is signalled by the green indicator light H4.

For storing the on-state, H4 is controlled with self-locking. Naturally, an RS storage element can be used as an alternative.

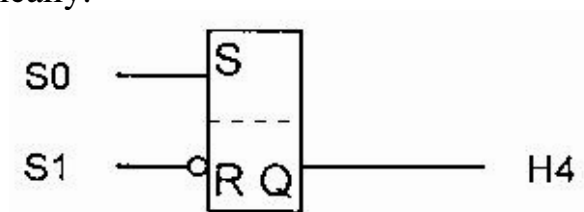
Exercise 4

Complete the following flowchart for indicator light H4 system ON

Network 1: H4 indicator light ON (system on)



An RS storage element can be used alternatively for storing the on-state. Both circuits respond identically.



4.2 Starting the system

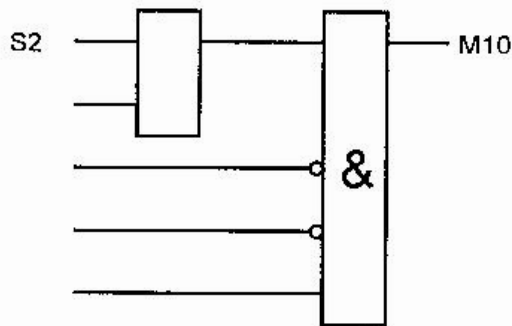
The system is started via NC contact S2. The *started* state is stored with flag M10. If the S3 PAUSE or S1 system OFF switch is operated, or the system is in the alarm state M15, the control resets the start state.

Exercise 5

Complete the following flowchart.

Network 2: M10 system started

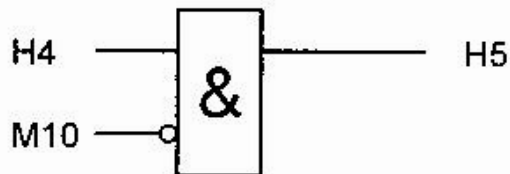
S2 Switch START
S3 Switch PAUSE
H4 Indicator light system ON
M10 System started
M15 Alarm state



If the system is on (H4) without having been started (M10), indicator light PAUSE H5 should be actuated.

Network 3: H5 indicator light PAUSE

H4 Indicator light system ON
M10 System started

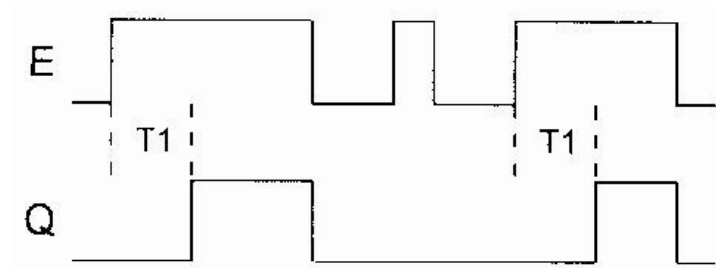


6.3 Filling bottles

When a bottle activates optical sensor S7, conveyor belt KO is stopped and the bottle is filled with V2. There is no sensor to indicate whether the bottle is full. The filling time T1 is initially set to one second and, if necessary, corrected later during start-up. Signal S7 is static and still present once the bottle has been filled. Consequently, S7 cannot be used directly to start the filling time T1. In our further considerations, we will assume that we are dealing with a turn-on delayed timer having the following response:

The timer's set period commences on a change from 0 to 1 at its input E. If the input is reset during the running period, the timer is reset too. After the set period

has ended, the output Q of the turn-on delayed timer supplies a 1-signal. The timer period has been set differently for each control and must be determined from its handbook.



Timer T1 is started and valve V2 opened on the positive edge of the sensor signal S7. After T1 has expired, V2 is closed again and the conveyor belt KO can start moving again.

Positive edge of S7

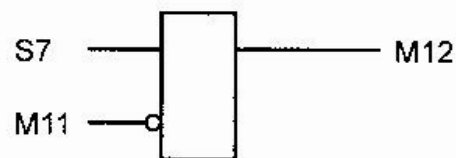
How is a positive edge evaluated with the help of a PLC? By using the PLC characteristic of processing programs in cycles. A positive edge is present if sensor S7 supplies a 1-signal after having supplied a 0-signal in the previous cycle. We will reserve flag M1 2 for storing the positive edge of S7, and flag M1 1 for storing the state of S7. For edge evaluation, the following network sequence must be maintained during programming.

Exercise 6

Complete the following networks for controlling the filling valve V2

Network 4: M12 positive edge at S7

S7 Filling position sensor
M11 Sensor S7 in cycle -1



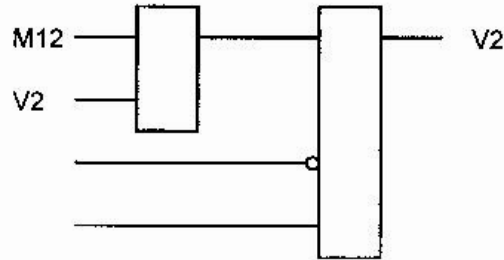
Network 5: M11 sensor S7 in cycle -1

S7 Filling position sensor



Network 6: V2 filling valve

M12 Positive edge at S7
V2 Filling valve
T1 Filling time for V2
H4 Indicator light ON



Network 7: T1 filling time for V2

V2 Filling valve



4.4 Corking bottles

When a bottle activates optical sensor S8, conveyor belt KO stops and a cork is pressed on by activating valve V3. Valve V3 is to remain active for a corking period T2 of 0.5 seconds before conveyor belt KO starts moving again. The signal S8 is static, so it cannot be used directly to start the corking time T2. In our further considerations, we will assume that we are dealing with a turn-on delayed timer, as in the case of filling time T1.

Timer T2 is started and valve V3 opened on the positive edge of the sensor signal S8. After T2 has expired, valve V3 is closed and conveyor belt KO can start moving again.

Positive edge of S8

As in Chapter 6.3, we need two flags to determine the positive edge of S8. We will reserve flag M1 4 to store the positive edge at S8 and flag M1 3 to store the state of S8. For edge evaluation, the following network sequence must be maintained during programming.

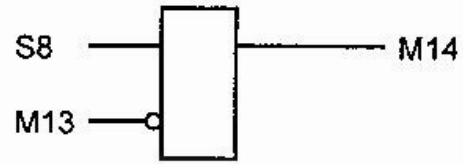
M1 4 can also be used later for counting bottles.

Exercise 7

Complete the following networks for controlling the corking valve V3.

Network 8: M14 positive edge at S8

S8 Corking position sensor
M13 Sensor S8 in cycle -1



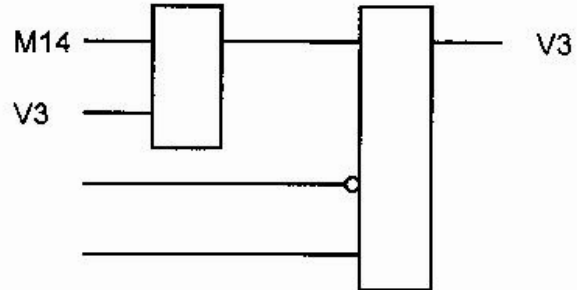
Network 9: M13 sensor S8 in cycle -1

S8 Corking position sensor



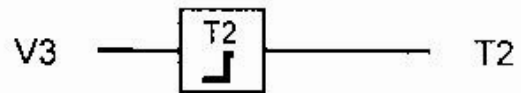
Network 10: V3 corking valve

M14 Positive edge at S8
V3 Corking valve
H4 Indicator light ON
T2 Corking time for V3



Network 11: T2 corking time for V3

V3 Corking valve

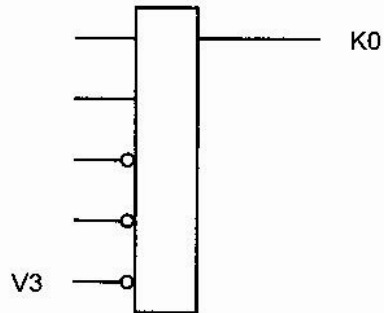


4.5 Conveyor belt

Conveyor belt KO starts moving if the system is switched on (H4) and started (M10), and none of the valves V1 to V3 is actuated. The indicator light H6 BELT is switched on additionally:

Network 12: KO conveyor belt

H4 Indicator light system ON
V1 Ejection valve
V2 Filling valve
V3 Corking valve
M10 System started



Network 13: H6 indicator light BELT

KO Conveyor belt



The control program can already be run at this stage. You can now enter networks 1-13 into your PLC and try out the program (also see Chapter 5). The filling time T1 might need to be corrected.

4.6 Ejecting defective bottles

Once you have got your system to operate satisfactorily, branch to the options menu and change the entry *Defective bottles: never* to *Defective bottles: rarely*.

Now a random generator also causes broken bottles to arrive on the belt. They are filled at the filling station just like intact bottles. The liquid runs out though, causing moisture sensor S9 to respond. The moisture is removed by operating the enable-switch S4.

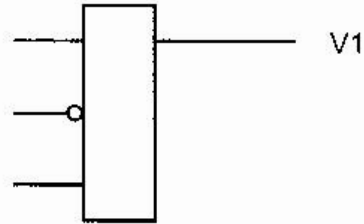
To solve this problem, the broken bottles must be discarded at the ejection station. When a bottle is positioned before the ejection piston VI, sensor S5 supplies a 1-signal. If the bottle is intact, sensor S6 simultaneously supplies a 1-signal. The ejection condition can now easily be derived from this.

Exercise 8

Complete the following flowchart

Network 14: VI bottle ejection valve

H4 Indicator light system ON
S5 Ejection position sensor
S6 Intact bottle sensor



4.7 Alarm state

If you now extend your PLC program with network 14 and start up the system again, the defective bottles are discarded, while the intact bottles are filled and corked properly.

Branch once again to the options menu and activate *Defective bottles: often*.

After the system is started in the EXTERNAL mode, bottles with invisible defects now also arrive randomly on the belt. They are cracked at the bottom, and recognized by S 6 as intact bottles instead of being discarded. They leak fluid at the filling station, causing moisture sensor S9 to supply a 1-signal.

In this case, the system should assume an alarm state, with the alarm indicator light H7 flashing. The alarm state MI 5 is self-locking, and reset only when switch S4 is operated or the system is switched off (H4).

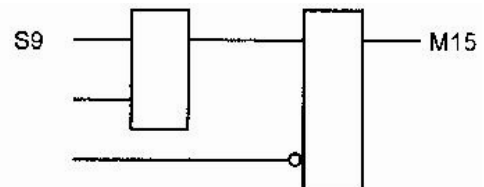
We already allocated flag MI 5 to the alarm state in network 2, where it switches the system into the PAUSE state (H5).

Exercise 9

Complete the following flowchart

Network 15: MI 5 alarm state

M15 Alarm state
S4 ENABLE switch
S9 Moisture sensor

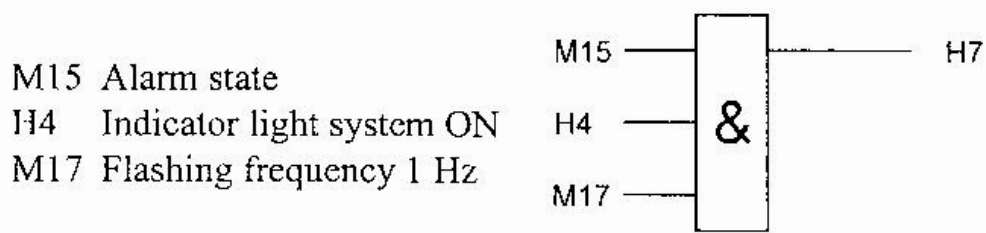


The ALARM indicator light can now be controlled directly via M15. However, many controls possess flashing flags which, if combined with alarm state 15 by means of an AND-element, easily provide a flashing indicator light H7.

If the control does not possess flashing flags, they can be user-programmed with the help of timers.

Refer to your PLC manual for assistance here.

Network 16: H7 indicator light ALARM

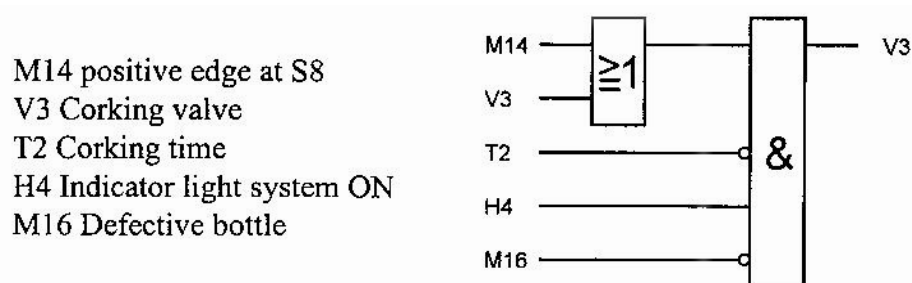


4.8 Monitoring defective bottles

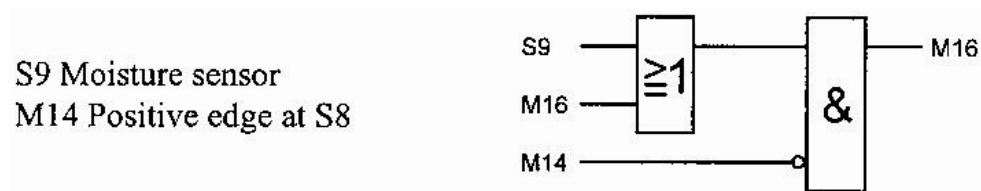
After the integration of network 16 into the PLC program, a defective bottle leaking fluid triggers the alarm state M15. When enable-switch S4 is operated, the alarm is reset, and the system can be restarted with S2. However, the belt is still carrying the defective bottle, which is destined for corking. To prevent this, the defective bottle must be monitored between the filling and corking stations.

A flag (M1 6) is set on the detection of moisture (S9). In this case, a defective bottle is located on the belt before the corking station. The flag M1 6 is now integrated into network 10 to prevent the bottle from being corked. Afterwards, it can be reset with the positive edge at S8, i.e. flag M14.

Modified network 10: V3 corking valve



Network 17: M16 defective bottle



4.9 Additional remarks

Of course, the filled and corked bottles can also be counted.

One possibility would be to count twelve bottles (the equivalent of one crate) and then automatically switch the system into the PAUSE state. Assembly-line worker Joe would then have enough time to remove the full crate and restart the system with S2.

You might have noticed that input H8 of the process simulation has not been documented yet.

Connect a 1-signal with input 8 of the PC adapter and, thus, with H8 of the process simulation (24 V connecting lead). Start your system, including the control unit. Now disconnect the lead from input 3 of the PC adapter (V3 corking valve) and observe the result.

Now the system does not receive any corking signal from the external control, so that correctly filled bottles are not corked. Joe makes use of this opportunity to take a small refreshment.

Would you like to integrate this animation into your control program? It is started whenever input 8 of the PC adapter is supplied with a 1-signal and a correctly filled bottle is not corked. In the MANUAL operating mode you have to spend Joe a filled but not corked bottle. To view the animation in the DEMO mode, briefly press the [Shift] and [a] key combination.

If you simply program the system so that every tenth bottle is not corked, Joe immediately starts receiving regular refreshments. Have fun!