Q3)

A system having 3 loads is required to be controlled in the following manner:

- When a START pushbutton is pressed, load #1 is activated.
- After 3 minutes, load #2 which is a lamp starts flashing (0.5 sec. OFF and 1.0 sec. ON) and load #1 remains active. • After 2 minutes from starting to flash load #2, load #1 is switched OFF, load #2 is
- activated steadily and load #3 is switched ON. • After 1 minute from activation of load #3, both loads #2 and #3 are switched OFF
- and load #1 is activated again and the above process is repeated continuously. Pressing a STOP pushbutton at any moment switches OFF all the loads and the
- process can be restarted from the first step by pressing the START pushbutton.

Outputs:

3 Loads: Y1->Y3

It is required to develop a PLC program to control the above system.

Stop P.B.: X2

Analysis:

We start at an idle condition (wait state) and enter a state where #1 is

Inputs:

Start P.B.: X1

state where #2 also starts flashing and after another 2 minutes we enter a state where #2 is no longer flashing (steady) and 3 is as well on. Finally, after 1 minute we repeat the cycle. Stop can be pressed at any moment to take the system to the wait state.

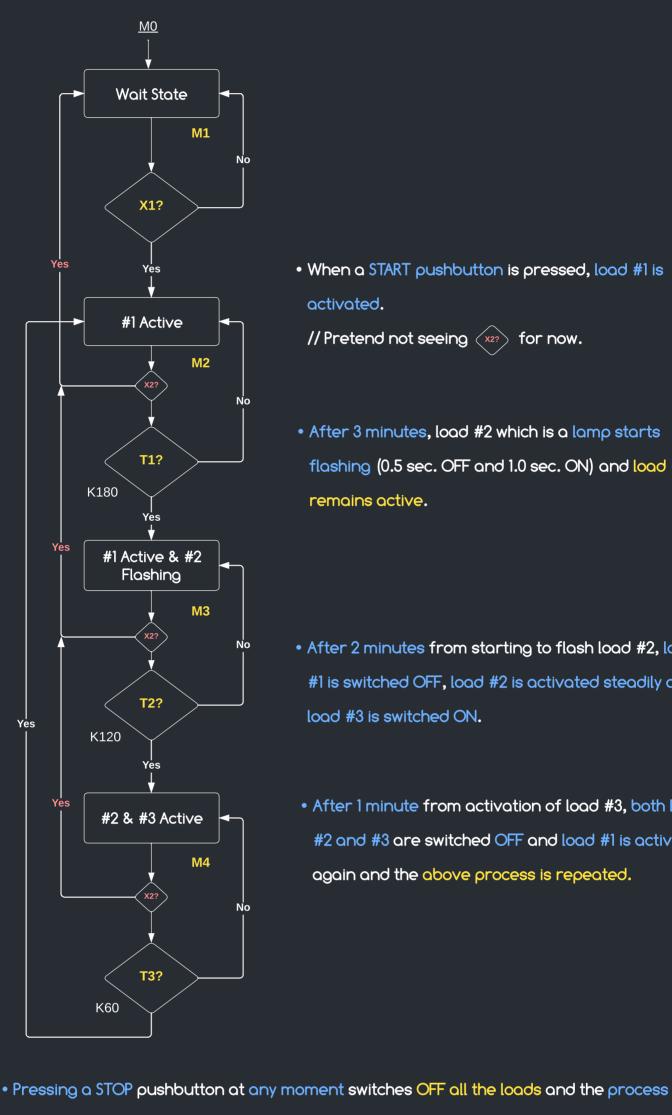
activated when START is pressed. After 3 minutes we enter another

Flow Chart:

activated.

remains active.

load #3 is switched ON.



Boolean Expressions:

<u>M0</u>

X1?

After 3 minutes, load #2 which is a lamp starts

• When a START pushbutton is pressed, load #1 is

flashing (0.5 sec. OFF and 1.0 sec. ON) and load #1

// Pretend not seeing (x27) for now.

- After 2 minutes from starting to flash load #2, load #1 is switched OFF, load #2 is activated steadily and
- #2 and #3 are switched OFF and load #1 is activated again and the above process is repeated.

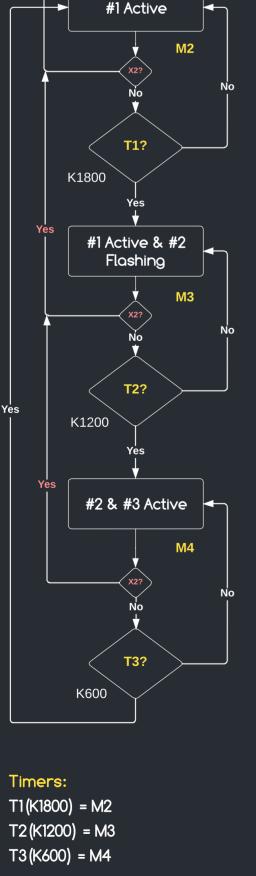
After 1 minute from activation of load #3, both loads

M = <u>Start-up</u> + EntryPaths + Self-hold . <u>Exits</u> M1 = M0 + (M2 + M3 + M4).X2 + M1.M2**Wait State M1**

can be restarted from the first step by pressing the START pushbutton = We need the

after each state to be able to go back to wait state if stop is pressed.

Recall,



M3 = M2.X2.T1 + M3.M4.M1

M2 = M1.X1 + M4.X2.T3 + M2.M3.M1

M0 = M0 + M1 (Start-up Marker)

M4 = M3.X2.T2 + M4.M1.M2

Outputs: Recall that given an active input X1 (in our context a state M) to make the

would be: TO(k LOW) = X1.T1T1(k HIGH) = M1 = TO

Thus, to flash the second load we need two extra timers and an extra

output flash low for "LOW" deciseconds and high for "HIGH" deciseconds then we need two timers TO and T1 then a flashing marker M1 output

marker that captures the flashing logic:

T4(k5) = M3.T5

T5(k10) = M5 = T4// Now M5 will flash as long as M3 is ON.

Now since #1 is active if we're either in the first or second states:

Y1 = M1 + M2

states: Y2 = M5 + M4

and since #2 is active if we're either in the second (flashing) or third

// M5 captures that we're in the 2nd state (M3) and causes Y2 to flash. // We also can't be in both M4 and M5. and since #3 is only active in the last state:

Y3 = M4

Q4)

It is required to develop a PLC program to control a system having 3 loads, in the following manner:

- When a START pushbutton is pressed, load #1 is activated. While load #1 is active, pressing a pushbutton PB1 deactivates load #1 and activates load #2.
- While load #2 is active, pressing a pushbutton PB2 deactivates load #2 and activates load #3.
- While load #3 is active, pressing a STOP pushbutton deactivates load #3 and the system is stopped. It can be restarted by pressing the START pushbutton. • During activation of any load, pressing a PAUSE pushbutton deactivates this load and
- turns ON a YELLOW lamp. This load can be reactivated and the YELLOW lamp is switched OFF by pressing a RESUME pushbutton. Pressing any pushbutton other than the RESUME pushbutton while a load is paused should have no effect.

Start P.B.: X1

Inputs:

Pushbutton PB1: X2 Pushbutton PB2: X3

Stop P.B. : X4

Pause P.B.: X5 Resume P.B.: X6

Flow Chart:

3 Loads: Y1->Y3

Outputs:

Yellow Lamp: Y4

<u>M0</u> **Wait State M1** X1? Yes Load #1 Active M2 **X2?** Yes Load #2 Active Yes **M3** X3? Load #3 Active M4 X4?

• While load #1 is active, pressing a pushbutton PB1

deactivates load #1 and activates load #2

activated.

When a START pushbutton is pressed, load #1 is

• While load #2 is active, pressing a pushbutton PB2 deactivates load #2 and activates load #3.

• While load #3 is active, pressing a STOP pushbutton

deactivates load #3 and the system is stopped.

OFF by pressing a RESUME pushbutton. Pressing any pushbutton other than the RESUME

An example on load #1:

Active

Looks like we missed this part:

pushbutton while a load is paused should have no effect." In any of the three states, we should check first if pause is pressed. If it is then we should switch to a "yellow lamp" state, pressing resume does the opposite (it's a cycle).

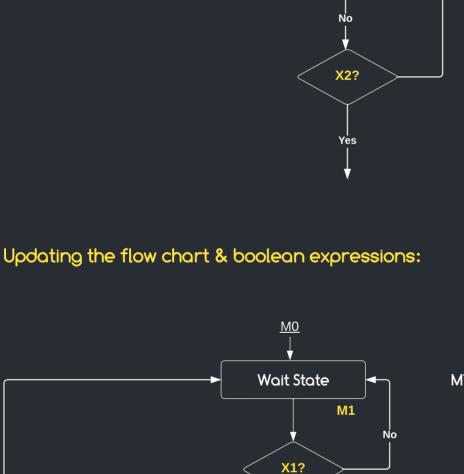
• "During activation of any load, pressing a PAUSE pushbutton deactivates this load and

turns ON a YELLOW lamp. This load can be reactivated and the YELLOW lamp is switched

No X6? Load #1 Active Note: checking for "pause" is M2 what matters. Here we gave that precedence over the Yellow Lamp

X5?

No



in the text and both are okay.) M1 = M0 + M4.X5.X4 + M1.M2

button press that takes us to

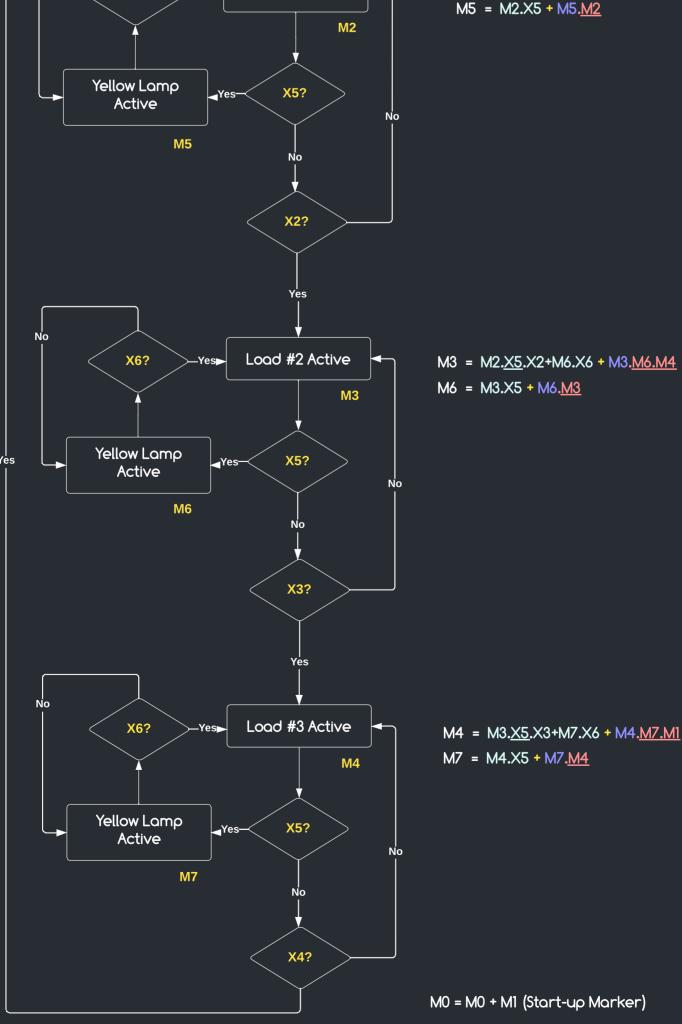
the other state but we could

opposite (neither is enforced

have as well done the

Νo M2 = M1.X1+M5.X6 + M2.M3.M5Load #1 Active X6?

Yes



Y2 = M3Y3 = M4Y4 = M5 + M6 + M7

Y1 = M2

Outputs:

// Yellow Lamp.

Q6)

It is required to develop a PLC program to control a system with 3 loads in the following manner:

- When a START pushbutton is pressed, load #1 is activated.
- After 1 minute from activation of load #1, pressing a pushbutton PB1, at any time, deactivates load #1 and activates load #2. If PB1 is not pressed until a period of 3 minutes passed from the moment of pressing the START pushbutton, then load #1 should be switched OFF and load #2 should be switched ON.
- After 1 minute from activation of load #2, pressing a pushbutton PB2, at any time, deactivates load #2 and activates load #3. If PB2 is not pressed until a period of 5 minutes passed from the moment of pressing the START pushbutton, then load #2 should be switched OFF and load #3 should be switched ON.

• After 1 minute from activation of load #3, pressing a STOP pushbutton, at any time,

deactivates load #3 and the system is stopped. It can be restarted by pressing the START pushbutton. If the STOP pushbutton is not pressed until a period of 8 minutes passed from the moment of pressing the START pushbutton, then load #3 should be switched OFF and the system is stopped. It can be restarted by pressing the SATRT pushbutton.

Start P.B.: X1

Inputs:

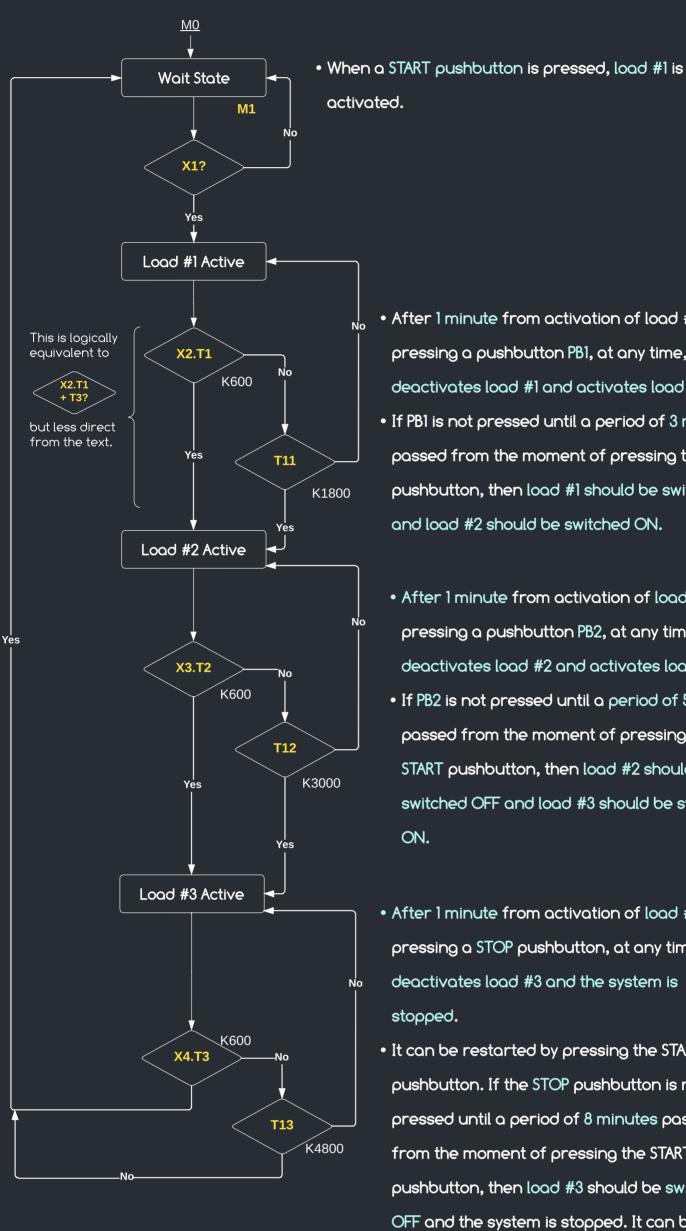
Pushbutton PB1: X2

Pushbutton PB2: X3 Stop P.B. : X4

Flow Chart:

Outputs:

3 Loads: Y1->Y3



• If PB1 is not pressed until a period of 3 minutes passed from the moment of pressing the START pushbutton, then load #1 should be switched OFF

and load #2 should be switched ON.

After 1 minute from activation of load #1,

pressing a pushbutton PB1, at any time,

deactivates load #1 and activates load #2.

pressing a pushbutton PB2, at any time, deactivates load #2 and activates load #3. • If PB2 is not pressed until a period of 5 minutes passed from the moment of pressing the

• After 1 minute from activation of load #2,

START pushbutton, then load #2 should be switched OFF and load #3 should be switched ON. After 1 minute from activation of load #3,

pressing a STOP pushbutton, at any time,

deactivates load #3 and the system is

It can be restarted by pressing the START

pushbutton. If the STOP pushbutton is not

stopped.

pressed until a period of 8 minutes passed from the moment of pressing the START pushbutton, then load #3 should be switched OFF and the system is stopped. It can be restarted by pressing the SATRT pushbutton.

M1 = M0 + M4.(X4.T3+T13) + M1.M2

MO = MO + M1

Note we'd naturally write:

X1?

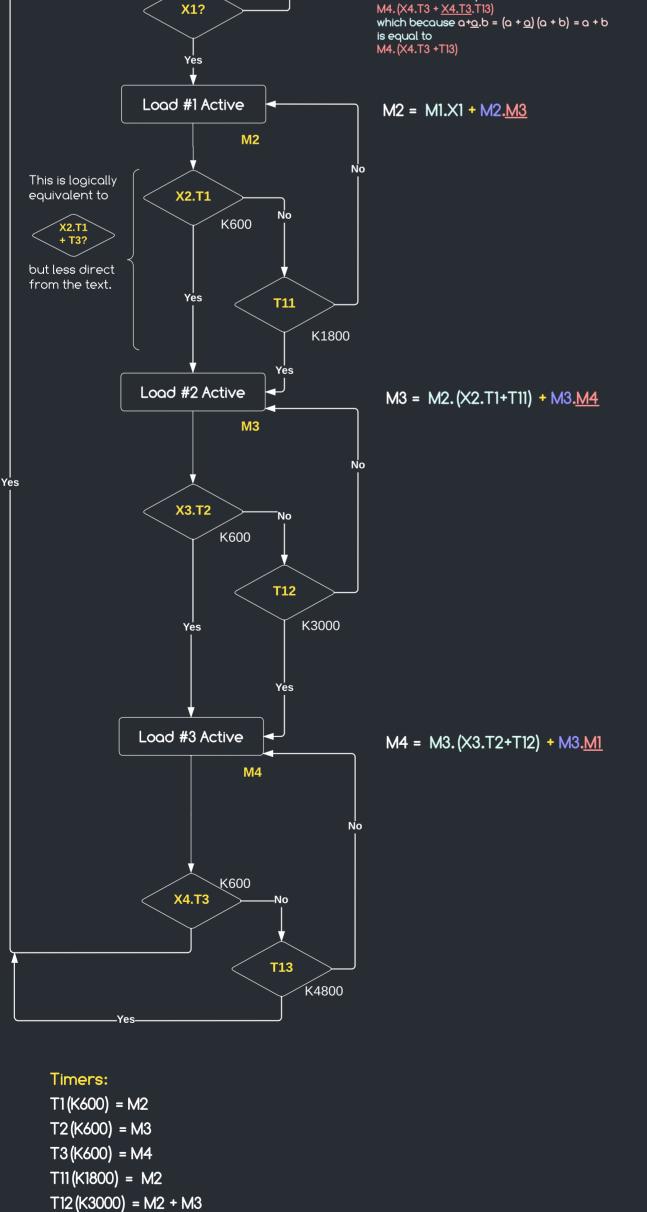
Boolean Expressions:

<u>M0</u>

Wait State

M1

Νo



T13(K4800) = M2 + M3 + M4

Outputs:

Y1 = M2Y2 = M3Y3 = M4 //Time spent starting from the state M2

Q8)

A chemical system consists of 3 tanks with 5 pumps to transfer the liquid contents through the system.

Each tank has two sensors to detect EMPTY and FULL states. Tank #2 has a heater and an associated temperature sensor. Tank #3 has a stirring arm to mix liquids A and B coming from tanks 1 and 2, respectively. Tank #3 has enough capacity to accommodate the contents of tanks 1 and 2.

The system has two modes of operation: MIXING and WASHING modes. A two-position mode

selection switch enables the operator to choose between the two modes.

and 2 are filled simultaneously with liquids A and B through pumps 1 and 2, respectively. When a tank FULL sensor becomes ON, the corresponding pump (1 or 2) is stopped. When tank

Upon pressing a START pushbutton with the mode selection switch on MIXING position, tanks 1

#1 is FULL, pump1 is stopped and pump3 is activated to transfer liquid A to tank #3. When tank #2 is FULL, pump2 is stopped and the heater is activated to raise the temperature of liquid B to a required value indicated by the temperature sensor becoming ON. When this happens the heater is turned OFF and pump4 is activated to transfer heated liquid B to tank #3.

When a tank EMPTY sensor becomes ON, the corresponding pump (3 or 4) is stopped. The stirring arm is activated when either liquid A or heated liquid B starts to be pumped into tank #3. Stirring of liquid A and heated liquid B continues for 5 minutes timed from the

moment when both tanks 1 and 2 are empty. Afterwards the mixture is pumped out of tank #3 through activation of pump 5. When tank #3 is EMPTY, pump5 is stopped. This marks the end

of the mixing process. It can be repeated by pressing the START pushbutton with the mode selection switch on MIXING. If the START pushbutton is pressed with the mode selection switch on WASHING position, water is pumped into tank #3 through pump 6 and the stirring arm is activated. When tank #3 is FULL, pump 6 is stopped is stopped and stirring continues for 3 more minutes. Afterwards the stirring arm is stopped and pump5 is activated to discharge the water out of

When tank #3 is EMPTY, this marks the end of one step of washing. The WASHING process

consists of 3 repeated steps. After the third step, the WASHING mode is finished and it can be

repeated by pressing the START pushbutton with mode selection switch on WASHING position.

An indicator lamp should be turned ON during all the steps of the WASHING mode.

Inputs: START P.B.: XO FULL Sensors of Tanks 1->3: X1->X3

EMPTY Sensors of Tanks 1->3: X4->X6

<u>M13</u>

Wait State

X0?

Yes

X7?

Pump 2 Active

X2?

Heater Active

X10?

Yes

Pump 4 Active

+ Stirring

X5?

Just Stirring

X4?

Yes

Just Stirring for 5 Min.

T1?

K3000

Mixing

Yés

M1

Νo

Washing

Will get to this later.

Mode Selection Switch: X7

Tank 2 Temp. Sensor: X10

Pumps 1->5: Y1->Y5

Indicator Lamp: Y8

tank #3.

Pump 6: Y6 Heater: Y7 Stirring Arm: Y0

Outputs:

Flow Chart:

Pump 1 Active

X1?

Yes

Pump 3 Active

+ Stirring

X4?

Just Stirring

X5?

No

Upon pressing a START pushbutton with the mode selection switch on MIXING position, tanks 1 and 2 are filled simultaneously with liquids A and B through pumps 1 and 2, respectively.

// The tanks could be further in different states after activating each

pump. This is why a single state "Pump 1 & 2" active wouldn't do the job.

When tank #2 is FULL (X2), pump2 is stopped and the heater is activated

to raise the temperature of liquid B to a required value indicated by the

When this happens the heater is turned OFF and pump4 is activated to

When a tank EMPTY sensor (X4: Tank 1 EMPTY) and (X5: Tank 2 Empty)

The stirring arm is activated when either liquid A or heated liquid B starts

This means we will go back to states Pump 3 Active & Pump 4 Active and

Stirring of liquid A and heated liquid B continues for 5 minutes timed

We need to check that the other tank is empty before we can go into a

// Both tanks are empty here and we can end the parallel section.

from the moment when both tanks 1 and 2 are empty.

becomes ON, the corresponding pump (3 or 4) is stopped.

When tank #1 is FULL (X1), pump1 is stopped and pump3 is

activated to transfer liquid A to tank #3.

temperature sensor (X10) becoming ON.

transfer heated liquid B to tank #3.

to be pumped into tank #3.

state where we stir for 5 minutes.

(Further states pertain to tank 3)

include "Stirring"

Pump 1

Pump 3

Tank 3 (has stirring arm)

Pump 5

Tank 1

Pump 6

Pump 2

Pump 4

(has heater and Temp. sensor)

Afterwards the mixture is pumped out of tank #3 through activation Pump 5 Active of pump 5. When tank #3 is EMPTY, pump5 is stopped. This marks the end of the Νo mixing process. It can be repeated by pressing the START pushbutton with X6? the mode selection switch on MIXING. //Now let's consider the WASHING Boolean Expressions: M13 **Wait State** No X0? Yes Mixing Washing **X7?** If the START pushbutton is pressed with the mode selection switch on Yes No WASHING position, water is pumped into tank #3 through pump 6 and the stirring arm is activated. We have considered this Pump 6 Active + already. Stirring Νo **X3?** When tank #3 is FULL, pump 6 is stopped is stopped and stirring continues for 3 more minutes. Yes Stirring for 3 Yes **Minutes** Afterwards the stirring arm is stopped and pump5 is activated to discharge the water out of tank #3. T2? K1800 Pump 5 Active When tank #3 is EMPTY (X6), this marks the end of one step of washing. The WASHING process consists of 3 repeated steps. After X6? the third step, the WASHING mode is finished and it can be repeated by pressing the START pushbutton with mode selection switch on Yės WASHING position. C1? 3 Steps done. Back to Wait Do one more К3 washing cycle. State. M0 = M13 + M9.X6 + M12.X6.C1 + M0.M1.M2.M10M13 M13 = M13 + M0**Wait State** MO Νo X0? Mixing Washing **X7?** -No Yés M10 = M0.X0.X7 + M10.M11M1 = M0.X0.X7 + M1.<u>M3</u> M2 = M0.X0.X7 + M2.M4Pump 6 Active + Stirring Pump 1 Active Pump 2 Active **M10 M1** No X3? **X2?** X1? Yes Yes M3 = M1.X1 + M3.<u>M5</u> Yes M4 = M2.X2 + M4.M6 Yes M11 = M10.X3 + M11.<u>M12</u> Pump 3 Active Heater Active Stirring for 3 + Stirring **Minutes** M4 **M3 M11** Νo X10? **T2?** Νο K1800

Yes M6 = M4.X10 + M6.<u>M7</u>

M7 = M6.X5 + M7.M8

It's also "Just

Stirring" but with different activations.

M8 = M5.X5.M7.X4 + M8.M9

Technichally can be OR but generally use AND (waiting for both parallel branches) Here both finish together.

M6

Pump 4 Active + Stirring

X5?

Just Stirring

X4?

M8

M9

M9 = M8.T1 + M9.M0

K3000

Νo

No

M5 = M3.X4 + M5.<u>M8</u>

NoNo

Just Stirring for 5 Min.

T1?

Pump 5 Active

X6?

M5

Yes

X4?

Yes

Just Stirring

X5?

Νο

Yes M12 = M11.T2 + M12.M10.M0

M12

Pump 5 Active

X6?

Yes

C1?

Timers & Counter:

T1(K3000) = M8T2(K1800) = M11

C1(K3) = M12.X6

RST(C1) = M0*

Outputs:

Y1 = M1

Y2 = M2

Y3 = M3

Y4 = M6

Y6 = M10

//Stirring

Y8 = M10 + M11 + M12

Y7 = M4

Y5 = M9 + M12

К3

Y0 = + M3 + M6 + M5 + M7 + M8 + M10 + M11

// Pump 1

// Pump 2

// Pump 3

// Pump 4

// Pump 5

// Pump 6

// Heater

// Indicator

Νo

A system has 'START' and 'STOP' push-buttons in addition to three loads. It also has three push-buttons: 'PB 1-2-3', 'PB 2-3-1' and 'PB 3-1-2'.

It is required to develop a PLC program to control this system in the following manner:

- If the 'START' and 'PB 1-2-3' push-buttons are pressed simultaneously, the system operates in MODE A. In this mode load #1 is activated for 5 sec. then deactivated. Afterwards load #2 is activated for 5 sec. then deactivated. Finally load #3 is activated for 5 sec. then deactivated which marks the end of MODE A operation.
- Similarly if the 'START' and 'PB 2-3-1' push-buttons are pressed simultaneously, the system operates in MODE B. In this mode the loads are activated as before but with the sequence load #2 then 3 then 1.

• Similarly if the 'START' and 'PB 3-1-2' push-buttons are pressed simultaneously, the

system operates in MODE C. In this mode the loads are activated as before but with the sequence load #3 then 1 then 2.

• While the system is operating in any mode, pressing the 'STOP' push-button ends this

mode. Afterwards the system can be operated in any mode as before. While the

system is operating in any mode, pressing any push-button other than the 'STOP' push-button should have no effect.

• Each mode of operation has a special indicator, which should be turned ON while the

system is operating in this mode and turned OFF otherwise.

Inputs:

Start P.B.: X1

Outputs:

3 Loads: Y1->Y3

Pushbutton PB1-2-3: X2

Pushbutton PB2-3-1: X3

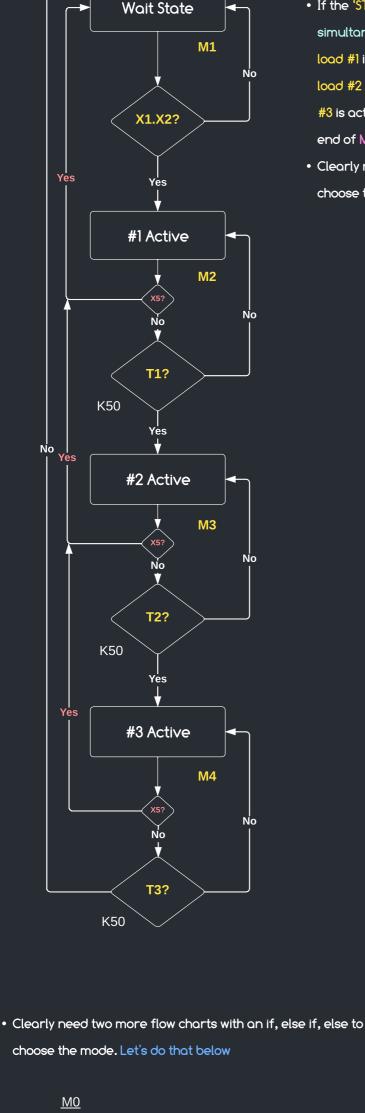
Stop P.B. : X5

Pushbutton PB3-1-2: X4

<u>M0</u>

Flow Chart:

3 indicators: Y11->Y13



Wait State

M1

Clearly need two more flow charts with an if, else if, else to choose the mode. Let's do that below

• If the 'START' and 'PB 1-2-3' push-buttons are pressed

end of MODE A operation.

simultaneously, the system operates in MODE A. In this mode

load #1 is activated for 5 sec. then deactivated. Afterwards

load #2 is activated for 5 sec. then deactivated. Finally load #3 is activated for 5 sec. then deactivated which marks the



ORB

ANI X5

// First term

OR M3
OR M4

LD MI
ANI M2
ANI M5

ORI M0
// Whole Expression

// First & Second & Third term

// First & Second term

LD M2

OR M10 AND X5

8M I/A

At this point we're only missing one problem from the handouts (Q10)