

Fire Station Pressure Control

A fire station requires a system to control the pressure of the water supply. The pressure must remain constant. The system consists of 3 large pumps, 1 small pump, 1 variable frequency drive (VFD) and a pressure transducer. Please refer to Figure 1 and 2 for the hardware diagrams.

Y0, Y2, Y4 and Y6 control the operation of the pumps and Y1, Y3, Y5 and Y7 control if the pumps are to be powered by the variable frequency drive or by the 3 Φ power.

The system will operate in the following manner,

1. Small pump #1 (for nighttime light load operation) will start first. After VFD reaches 50 Hz. wait 15 seconds. If the water pressure has not reached the preset value then stop pump #1 and wait for 3 seconds, then start large pump #2 with the VFD. After VFD reaches 50 Hz., switch the pump's power to the 3 Φ power and wait 15 seconds. If the pressure still hasn't achieved the preset, start pump #3 and perform the same operation as pump #2. If it still hasn't reached preset, start pump #4.
2. If the pressure is greater than the preset for 10 seconds than shut off one pump. Continue shutting off pumps every 10 seconds, until the pressure is at the preset or until small pump #1 is the only one operating.
3. If only one large pump runs at a light load and its VFD frequency is < 30 Hz., switch to small pump #1 to conserve electricity.
4. If only one large pump is necessary to achieve preset pressure, then every two hours switch to an alternate pump, such that, all pumps will wear and tear at the same rate.
5. Every 10 to 20 days, a signal shall be initiated to exercise the fire prevention equipment for 10 minutes.

A state diagram will be used to implement this system. There will be 13 states in the diagram, which will be differentiated by,

R5 R4 Y6 Y4 Y2 Y0

Where,

Y0	small pump #1
Y2	large pump #2
Y4	large pump #3
Y6	large pump #4
R4	column indicator
R5	column indicator

Please refer to Figure 3 for the state diagram.

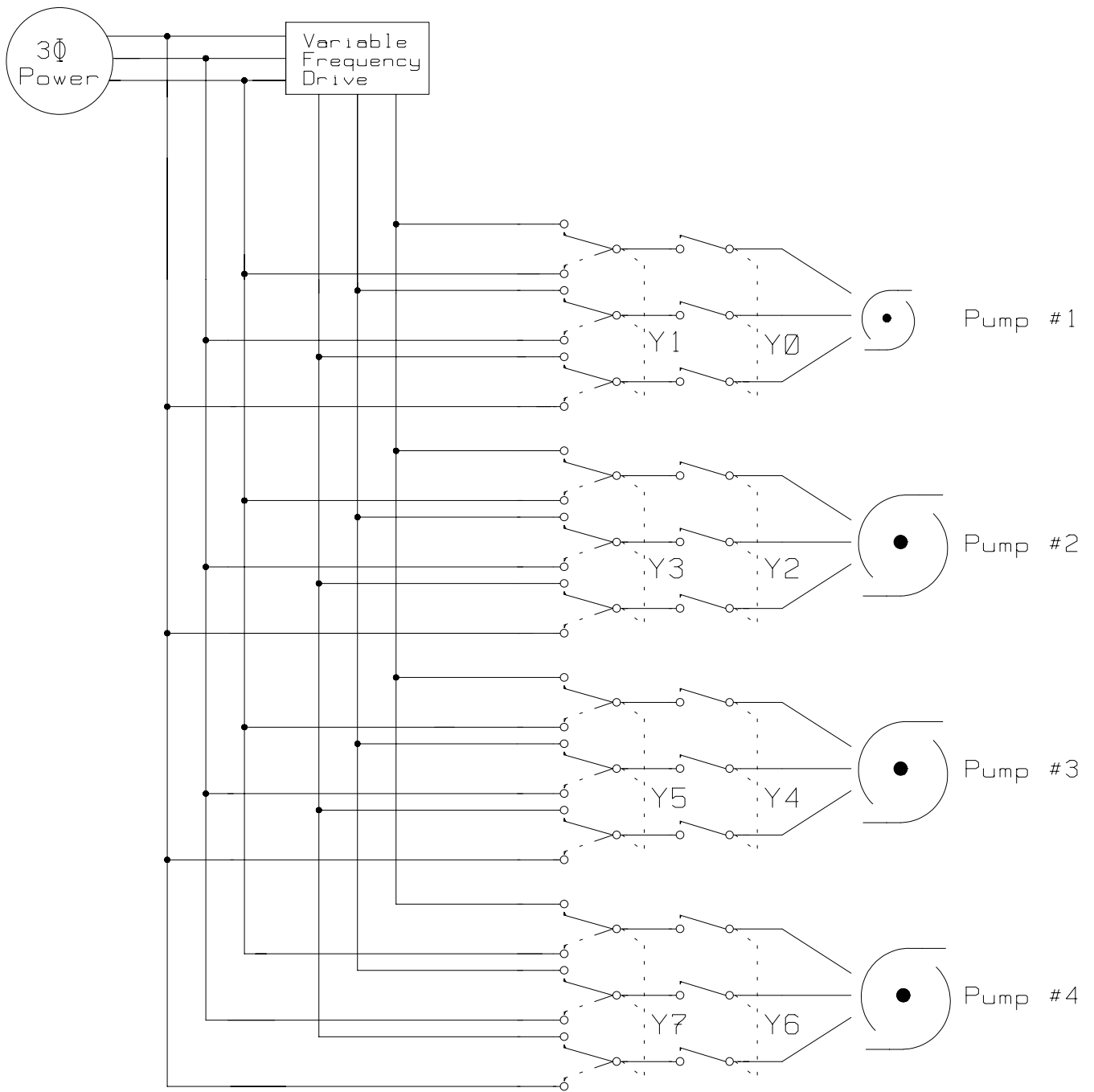


Figure 1. Pressure control pump wiring diagram

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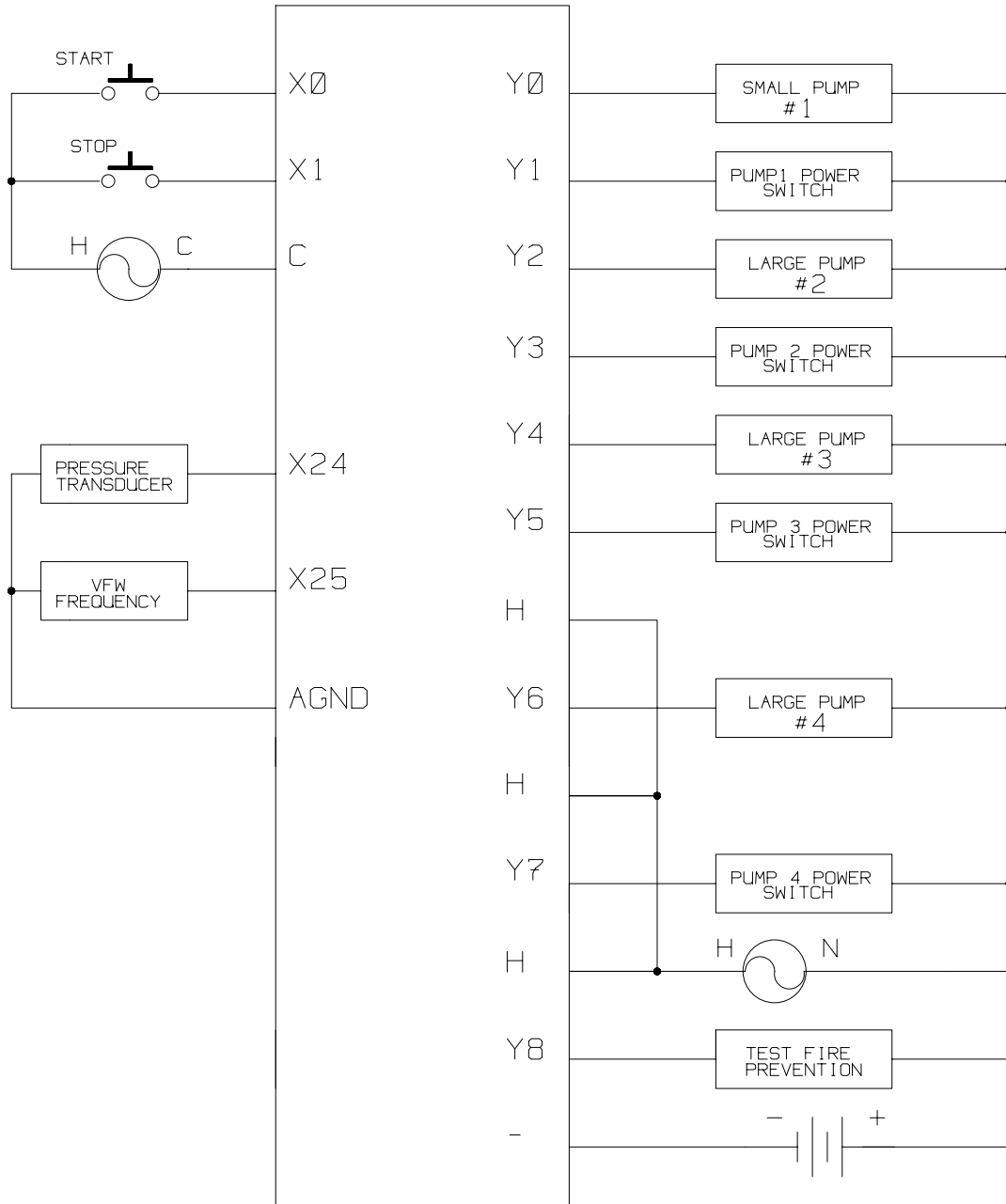


Figure 2. Pressure control hardware diagram

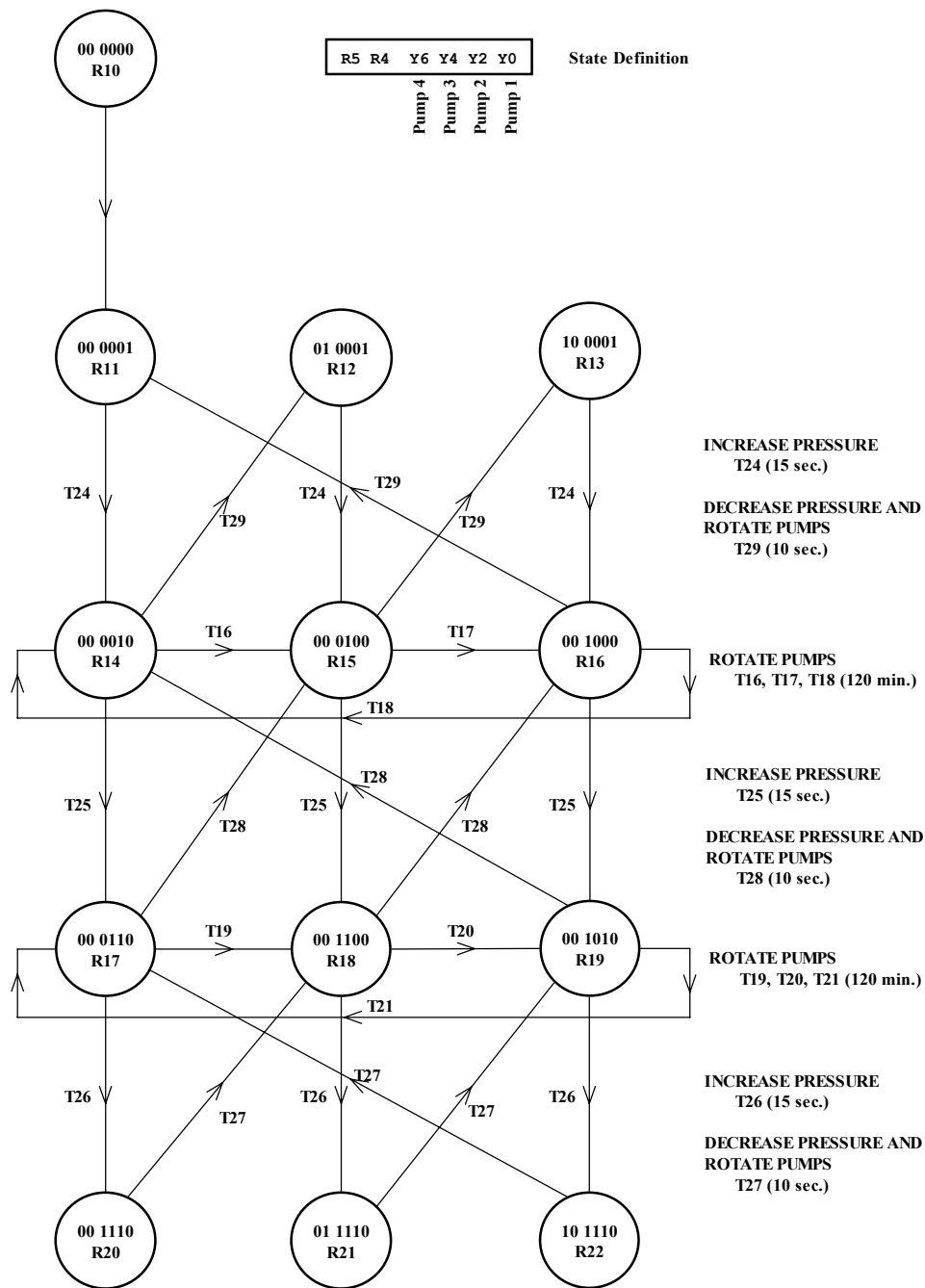


Figure 3. Pressure control state diagram

The state diagram depicts the transition between one state (which pumps are on) and another state. Timers control the transitions. I.e. a transition will occur from state R11 to state R14 when timer T24 has timed-out. A breakdown of the timers follows,

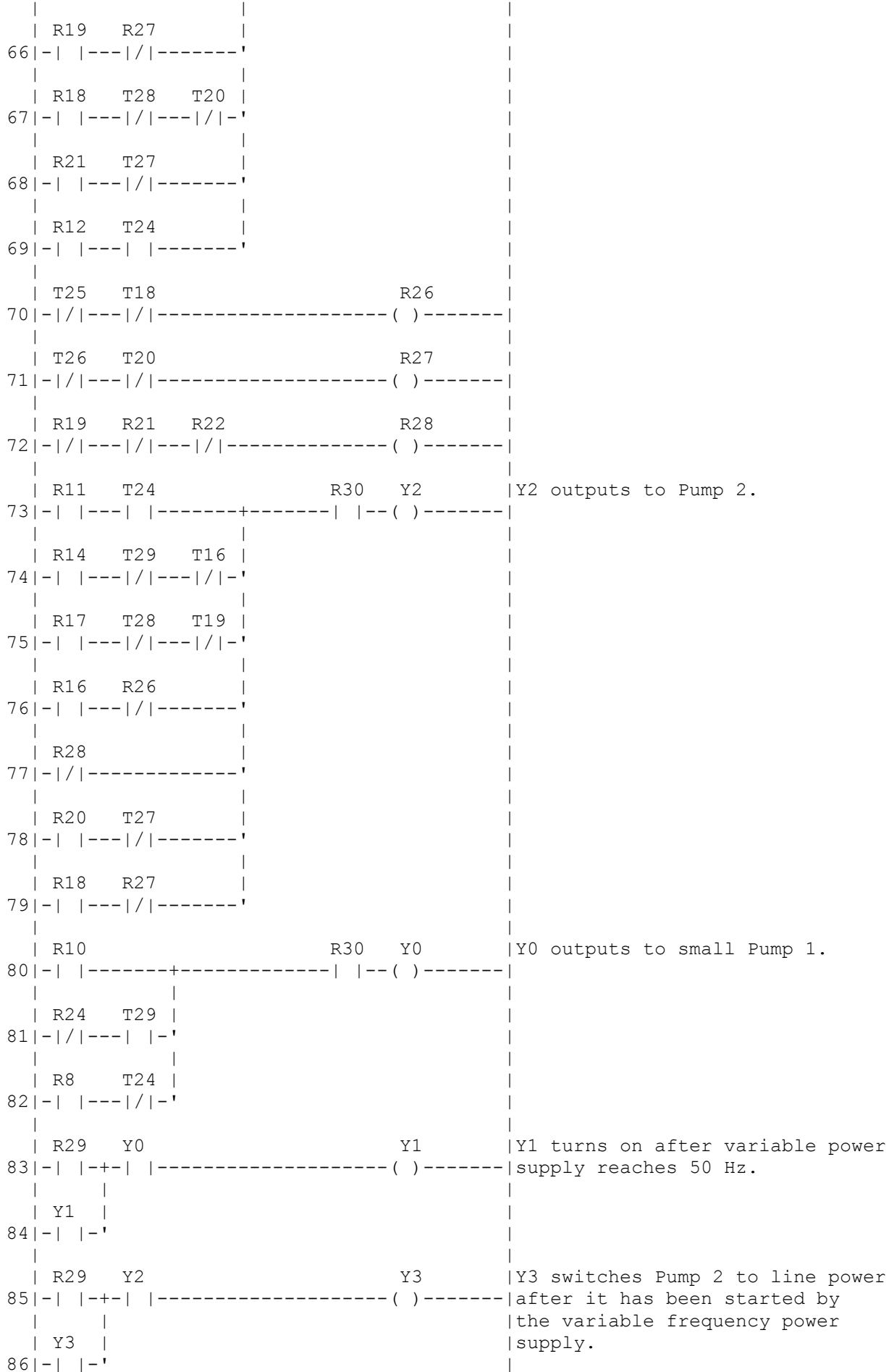
- T16, ..., T21 Rotate pumps after 2 hours of continuous operation.
- T24, ..., T26 Increase pressure by turning on another pump after 15 seconds.
- T27, ..., T29 Decrease pressure by turning off a pump after 10 seconds and at the same time rotate the pumps.

The following is the RLL that performs all the necessary tasks,

1	X0 X1 R30	X0 is START pushbutton. X1 is normally closed STOP pushbutton.
2	R30	
3	C8 -----[A25*60/1023]---	X25 is frequency input from variable frequency power supply. 0..60 Hz = 0..5V
4	T1 T31 -/ ----- (1)-----	Generate a square wave T31 with 0.01 second ON and 0.99 second off each cycle.
5	T31 T1 ----- (1)-----	
6	T31 R91 R31 ----- ^----- ()-----	R31 pulses every second on the second.
7	R31 -/ ----- (J)-----	The following will be scanned exactly once per second.
8	R5 R4 Y6 R6 -/ --- / --- / ----- ()-----	(R5,R4,Y6,Y4,Y2,Y0) is state in the state diagram.
9	R5 R4 Y6 R7 -/ --- / --- ----- ()-----	R6, R7 are rows of states.
10	Y4 Y2 Y0 R8 -/ --- / --- ----- ()-----	R8 means only Pump 1 is on in state R11, R12 or R13.
11	Y6 Y4 Y2 R9 ----- ----- ()-----	R9 means Pumps 2, 3, 4 all ON in state R20, R21 or R22.
12	R6 Y4 Y2 Y0 R10 ----- / --- / ----- / --- ()-----	R10, R11, ..., R22 are the individual states in the state diagram.
13	R6 R8 R11 ----- ----- ()-----	
14	R4 Y6 R12 ----- ----- ()-----	
15	R5 Y6 R13 ----- ----- ()-----	
16	R6 Y4 Y2 R14 ----- ----- ()-----	
17	R6 Y4 Y2 R15 ----- ----- ()-----	
18	R7 Y4 Y2 R16 ----- ----- ()-----	
19	R6 Y4 Y2 R17 ----- ----- ()-----	
20	R7 Y4 Y2 R18 ----- ----- ()-----	
21	R7 Y4 Y2 R19 ----- ----- ()-----	

22	R7	R9	R20	()	
23	R4	R9	R21	()	
24	R5	R9	R22	()	
25	R14	R15	R16	R24	R24 means not in state R14, R15 or R16 (1 large pump ON)
26	R17	R18	R19	R25	R25 means not in state R17, R18, R19 (2 large pumps ON).
27				[C8]	C8 is the frequency
28				C0 [C8-50]	
29	R31		R29	()	R29 means C8 >= 50 Hz.
30				C0 [A24-400]	X24 is from pressure transducer A24 = pressure = 0...1023. 400 is pressure lower limit. R31 means A24 < lower limit.
31	R8	R29	R31	T24 (15)	T24 means small pump has not supplied enough pressure for 15 seconds.
32	R24	R29	R31	T25 (15)	T25 means 1 large pump is still not giving enough pressure for 15 seconds.
33	R25	R29	R31	T26 (15)	T26 means 2 large pumps are still not enough.
34				C0 [500-A24]	500 is pressure upper limit. R31 means A24 > upper limit. T27 means pressure has exceeded upper limit for at least 10
35	R9	R31		T27 (10)	seconds with 3 large pumps on. T28 means with 2 large pumps on for 10 seconds, pressure still
36	R25	R31		T28 (10)	exceeds upper limit. T29 means pressure is still too
37	R24	R31		T29 (10)	high with just 1 large pump on after 10 more seconds.
38	R14			T16 (7200)	T16 means we have been in State (0,0,0,0,1,0) for 7200 seconds.
39	R15			T17 (7200)	T17 means we have been in State (0,0,0,1,0,0) for 7200 seconds.
40	R16			T18 (7200)	T18 means we have been in State (0,0,1,0,0,0) for 7200 seconds.
41	R17			T19 (7200)	T19 means we have been in State (0,0,0,1,1,0) for 7200 seconds.
42	R18			T20 (7200)	T20 means we have been in State (0,0,1,1,0,0) for 7200 seconds.
43	R19			T21 (7200)	T21 means we have been in State (0,0,1,0,1,0) for 7200 seconds.

44	R15	T29	R30	R5	()	State (R5,R4,Y6,Y4,Y2,Y0) transition logic must be figured out by referring to the state diagram.
45	R19	T26				
46	R22	T27				
47	R13	T24				
48	R14	T29	R30	R4	()	R30 has to be on to enable transition to non-home state.
49	R18	T26				
50	R21	T27				
51	R12	T24				
52	T26	T19	R26		()	R26 is temporary relay to save logic.
53	T25	T17	R27		()	R27 is temporary internal relay.
54	R17	R26	R30	Y6	()	Y6 outputs to Pump 4.
55	R15	R27				
56	R16	T29	T18			
57	R19	T28	T21			
58	Y6	Y2	R22			
59	R22	T27				
60	R13	T24				
61	T25	T16	R26		()	R26 is temporary with a different meaning here.
62	T26	T21	R27		()	So is R27.
63	R14	R26	R30	Y4	()	Y4 outputs to Pump 3.
64	R15	T29	T17			
65	Y4	Y2	R21			



87	R28	Y4	Y5	Y5 switches Pump 3 to regular power.
	-	-+	()	
88	Y5			
	-	-'		
89	R28	Y6	Y7	Y7 switches Pump 4 to regular 3-phase power.
	-	-+	()	
90	Y7			
	-	-'		
91	T22		T23	Generate clock T23 that cycles 300 seconds off and 300 seconds on per 10-minute cycle.
	- /		(300)	
92	T23		T22	
	-		(300)	
93	T23	R93	R26	R26 pulses once per 10 minutes.
	-	^	()	
94	R26			Do the following only once per 10 minutes.
	- /		(J)	
95	C23		Y8	Whenever C23 is 0, turn on Y8 to exercise equipment.
	-		()	
96			C23	Count down C23 every 10 minutes.
			()	
97	C23		C23	When C23 reaches 0, reload it with 2160 (= 15 days).
	-		[2160]	
98			(E)	