Small Batch Control Projects

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INTRODUCTION

Controlling small batch control processes has been a difficult problem for the control engineer. If the process has a large analog component then distributed control systems have been ideal, but they tend to be costly. Therefore, their usage has been limited to large jobs. If the process has little analog control and limited operator interface requirements, then programmable logic controllers (PLCs) can be good choices. However, small batch jobs often have several analog loops and the need for good operator interface. Thus, the engineer using the PLC usually ends up installing conventional analog controllers, switches, indicator lights, etc. Costs and complexity increase as the engineer puts together the various components. The result is often a very unsatisfying control system.

As a means of getting around these problems, vendors are now developing small, panel mount controllers. These controllers incorporate the analog and sequential control capability of distributed control systems with process oriented operator interface. In addition, the controllers can communicate with each other. This eliminates the cost and difficulty of hardwiring signals between units. To distinguish these controllers from conventional panel mounted controllers (which bear a superficial likeness for these programmable panel controllers) the new controllers are often called smart controllers.

CONTROLLER DESCRIPTIONS

Two basic functions must be carried out by the control system in a batch control application. The first is the analog control and operator interface. The second is the digital, sequential control.

From the faceplates, the smart analog controllers appear to be single loop controllers (see **Figure 1**). However, internally the controllers are microprocessor driven and must be capable of a wide range of functions. These functions must include alarming, analog conditioning and scaling, advanced control algorithms, process interlocking, and full communication with other controllers.

The smart digital controller is, however, a new breed of controller. It must perform complex digital control, communicate with the analog controllers (i.e. change setpoints, provide tracking signals, etc.), and a reasonable amount of operator interface. In addition, the digital controllers must be capable of being linked together to provide the I/O and logic power for complex applications. **Figure 2** shows such a controller.

The faceplate of the smart digital controller links directly to several specialized control blocks. The operator can change sequence modes, step numbers, and device modes from the faceplate.

In addition, each output of the smart digital controller is interfaced to the faceplate through a device driver function block (DDRIVE). This block can be controlled from the faceplate or the automatic sequence and does all of the base level interlocking (such as feedback checking, and waiting for device stroke time).

CONTROLLER CONFIGURATION

One of the banes of small batch control applications is that there has never been a standard batch control terminology as there has been in analog control. PLCs are configured via ladder logic. This works well with interlock control, but provides some difficulty with analog control. Process control vendors have often used either computer like languages or function blocks that are linked together. Each have their advantages depending upon the background of the engineer configuring the system and the maintenance staff providing support. Generally, as the application becomes more process oriented (i.e., more analog control and logic using analog signals), ladder logic is less advantageous and function blocks are better. To get a better appreciation of this, a few applications need to be considered.

Simple batch logic

A simple need in batch control is to open valves, check devices, and set timers. For the purposes of this discussion, consider the application where a valve is to be opened, a timer started. At the end of the timed period, control proceeds to the next step called for by the sequence. **Figure 3** shows a typical ladder logic approach. **Figure 4** shows the same logic in a function block format. Note that the logic is very similar. The only difference is that in the PLC the user had to install a timer in to delay the alarm from being set until the valve feedback had time to confirm the valve's position. This logic is built into the DDRIVE function block. In addition, the function block contains the alarm and interface capability since it directly ties to the faceplate of the smart controller. In the PLC, additional hardware and software would have to be constructed to allow the user to have this type of interface.

Integration of flow

In most applications, the batch control sequence has to scale and integrate analog values. Normally the integrated flow is compared to a target or recipe value. **Figure 5** shows a typical ladder logic configuration for analog scaling and **Figure 6** shows the integration logic.

In **Figure 5**, the analog value comes into the PLC logic as an 0 4095 value that is unscaled. The multiply block converts the range to the correct range in engineering units and the ADD block adds any necessary offset. **Figure 6** simply performs a trapezoid integration algorithm on the incoming scaled analog signal.

Figure 7 shows similar logic in a smart controller. Note that the function block algorithms of the smart controller are process oriented. In defense of the PLCs, newer PLCs are developing ladder logic components that are similar to the process oriented function blocks. The evolution of both products seems to be paralleling.

PROCESS APPLICATION

A major food processor in the midwest needed to install a pasteurizer for their product. A pasteurizer is basically no more then a series of automated conveyors traveling within a stainless steel shell. Within the shell there are multiple zones, each one of which must be controlled within prescribed temperature limits.

The control engineer is faced with the following problems:

1. To maximize production and reduce manpower, a fully automated startup and shutdown is necessary

2. To manage the process, full interlocking (with systems upstream and downstream) is necessary. The conveyors are all speed controlled and, therefore, each loop is under analog control. The speed of the conveyors is directly under the influence of the speed of product removal.

3. To minimize manpower costs, the equipment has to be capable of a fully automated Clean In-Place (CIP) sequence.

In the past, such an application would have been satisfied with the combination of a PLC, analog controllers, and a custom switch panel (see **Figure 8**). With a set of smart controllers a system can be designed with fewer components, far less wiring, and less communication problems. **Figure 9** shows the same application using smart controllers.

APPLICATION CONFIGURATION

The smart controller is designed to allow the engineer to solve control problems via a set of step logics' and via a matrix output for each step. This means that the user can divide the batch process into a series of discrete steps, each of which are fairly simple to solve. For illustration, the pasteurizer startup and normal run mode will be examined.

Step Matrix outputs are assigned to a matrix and given an output condition based upon the step number. **Table 1** shows the output matrix for the first six steps.

The individual step logics follow. Below is a written description of each step.

Step 1 - This step simply checks to make sure that all of the analog controllers are in automatic and the start input is on. **Figure 10** details this logic. Note that the smart digital controller need not be hardwired to the analog controller since the information is passed via the communication system.

Step 2 This step fills the levels of the pasteurizer pans. When the levels are full, control advances to the next step. **Figure 11** shows this logic.

Step 3 This step starts to heat up the pans. It does this by opening up auxiliary steam valves. When the temperature is above 190 F, control advances to the next step. **Figure 12** shows this logic.

Step 4 This step shuts down the steam valves and loads set points into the heat exchanger controllers. When the temperatures of all zones of the pasteurizer are above 195 F, then the conveyors are started. **Figure 13** shows this logic.

Step 5 This is the normal run phase of the pasteurization. Here the system monitors the feed inlet conveyor and discharge crowd switch. If the feed inlet crowd switch goes on, then not enough product is being fed to the conveyor. In this case, a signal is sent to the conveyor control logic of the analog controller to reduce speed. If the discharge crowd switch is on, then the product is not being removed fast enough from the conveyor In this case, the conveyors will all come to a stop. However, the heating control elements are kept on. If the stop pushbutton is energized, control goes to step 6. **Figure 14** shows this logic.

Step 6 This step is shutdown 1. Its purpose is to stop feeding product to the pasteurizer. Consequently, the feed conveyor is shutdown. When the restart pushbutton is energized control returns to step 5. If the start pushbutton goes off, control goes to step 8. **Figure 15** shows this logic.

Step 7 This step is Shutdown 2. All conveyors are stopped, but the control loops are unaffected. This leaves the pasteurizer warm for a restart. **Figure 16** shows this logic.

Step 8 This is the normal shutdown. All conveyors, pumps, etc. are shutdown by the matrix. All control loop setpoints are ramped to zero. **Figure 17** shows this logic.

CONCLUSIONS

Smart controllers offer several advantages in controlling small batch applications:

1. Entry costs are low.
2. Controllers can communicate with each other without hardwiring costs.
3. Smart controllers have function block algorithms that are process oriented.

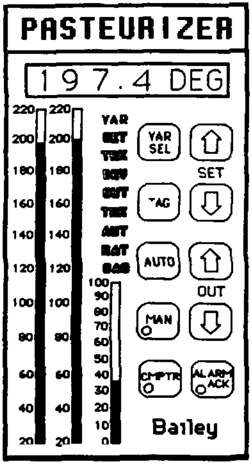


FIGURE 1 Smart Analog Controller

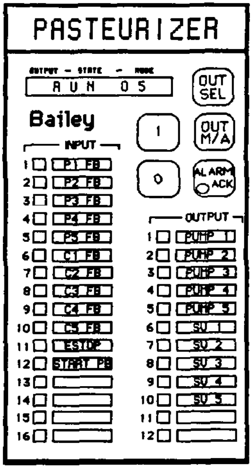


FIGURE 2 Smart Digital Controller

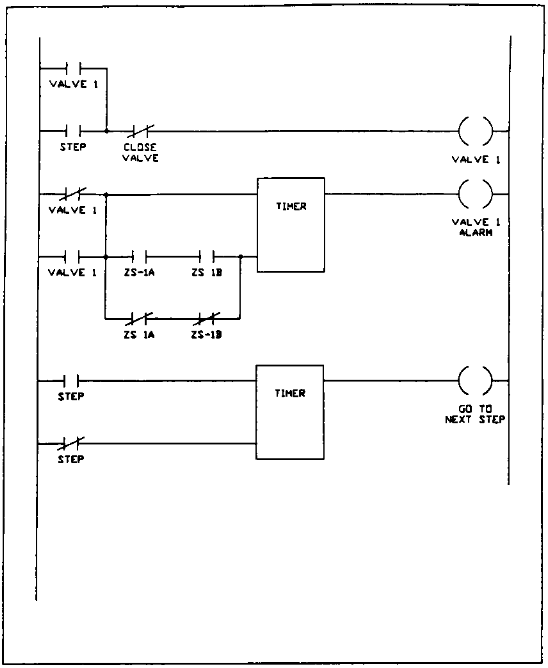


FIGURE 3 Simple Batch Logic Via PLC

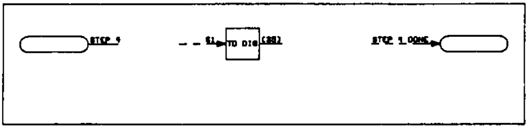


FIGURE 4 Timed Step Logic

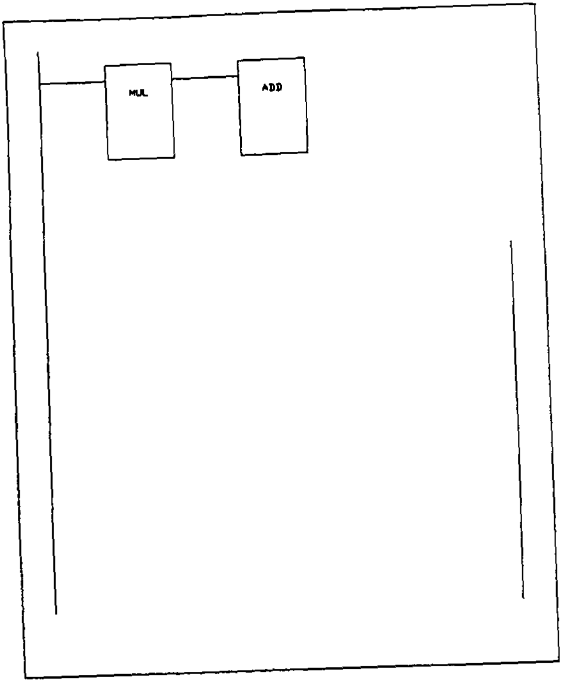


FIGURE 5 Scaling Analog Signal

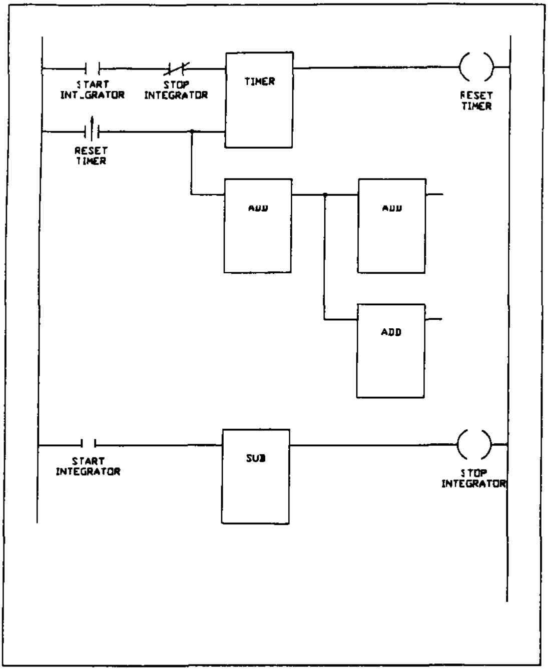


FIGURE 6 Simple Integration Via PLC

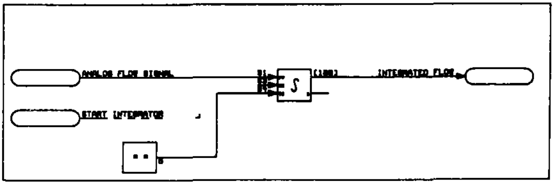


FIGURE 7 Integrate Flow

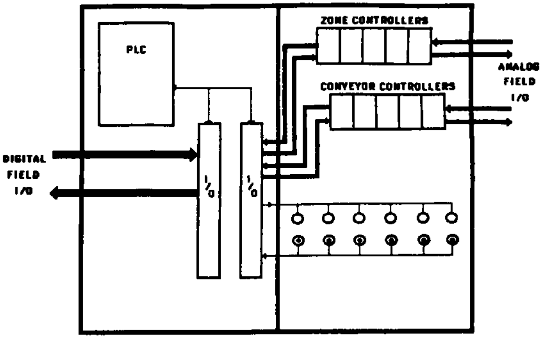


FIGURE 8 PLC with Analog Controllers

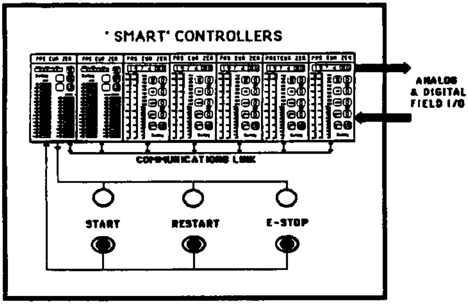
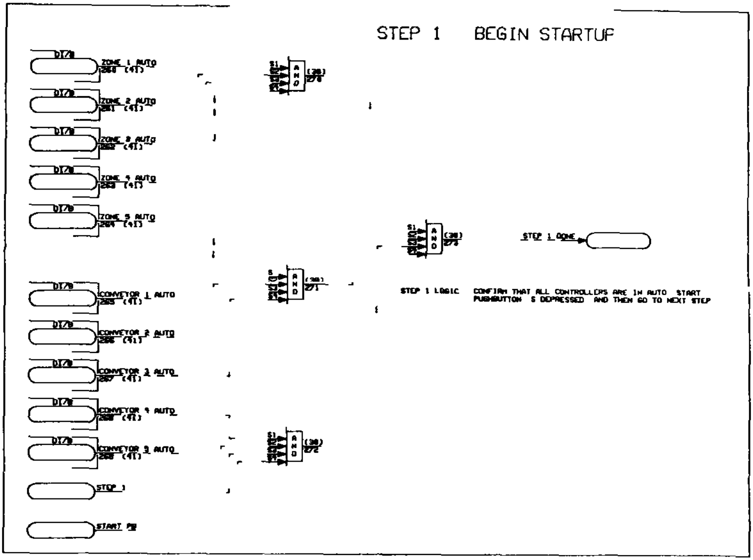


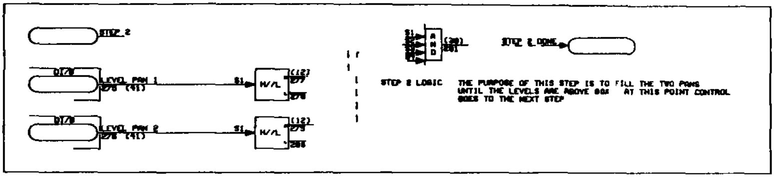
FIGURE 9 "Smart" Controllers

00 15 41 04 11 07



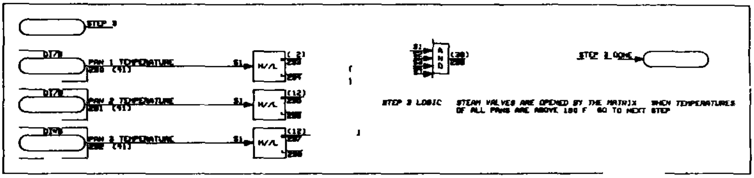
STEP 1 LOGIC CONFIRM THAT ALL CONTROLLERS ARE IN AUTO START PUSHBUTTON S DEPRESSED AND THEN GO TO NEXT STEP

FIGURE 10 Step 1 Logic



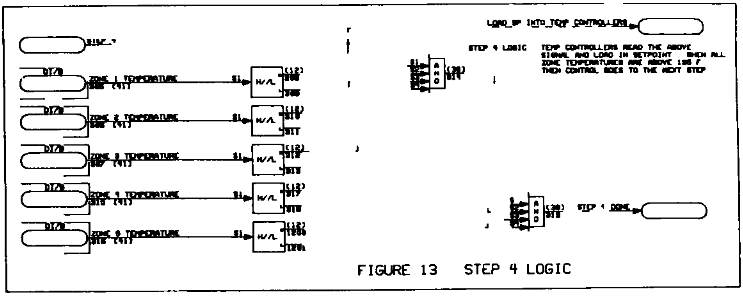
STEP 2 LOGIC THE PURPOSE OF THIS STEP IS TO FILL THE TWO PANS UNTIL THE LEVELS ARE ABOVE 80% AT THIS POINT CONTROL GOES TO THE NEXT STEP

FIGURE 11 Step 2 Logic



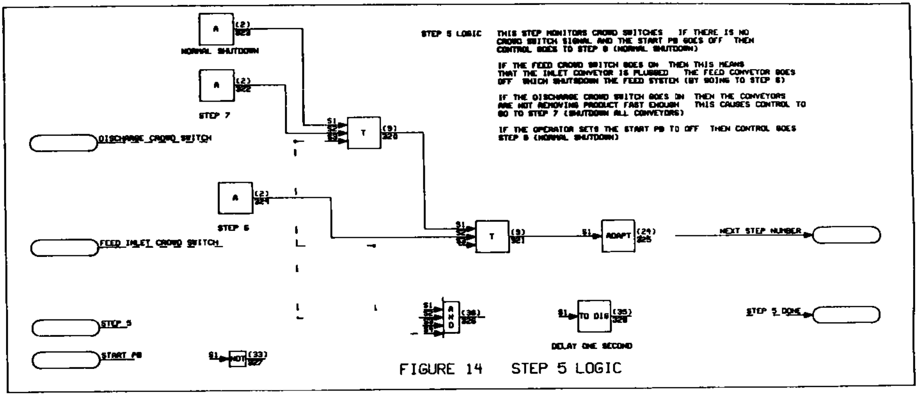
STEP 3 LOGIC STEAM VALVES ARE OPENED BY THE MATRIX WHEN TEMPERATURES OF ALL PANS ARE ABOVE 180 F GO TO NEXT STEP

FIGURE 12 Step 3 Logic



STEP 4 LOGIC TEMP CONTROLLERS READ THE ABOVE SIGNAL AND LOAD IN SETPOINT WHEN ALL ZONE TEMPERATURES ARE ABOVE 195 F THEN CONTROL GOES TO THE NEXT STEP

FIGURE 13 Step 4 Logic



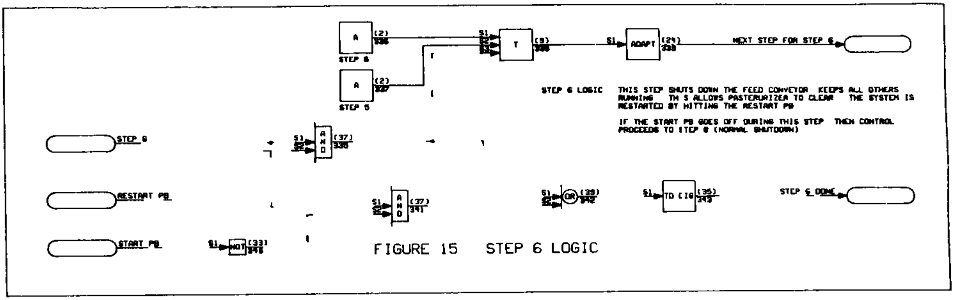
STEP 5 LOGIC THIS STEP MONITORS CROWD SWITCHES IF THERE IS NO CROWD SWITCH SIGNAL AND THE START PB GOES OFF THEN CONTROL GOES TO STEP 8 (NORMAL SHUTDOWN)

IF THE FEED CROWD SWITCH GOES ON THEN THIS MEANS THAT THE INLET CONVEYOR IS PLUGGED THE FEED CONVEYOR GOES OFF WHICH SHUTDOWN THE FEED SYSTEM (BY GOING TO STEP 6)

IF THE DISCHARGE CROWD SWITCH GOES ON THEN THE CONVEYORS ARE NOT REMOVING PRODUCT FAST ENOUGH THIS CAUSES CONTROL TO GO TO STEP 7 (SHUTDOWN ALL CONVEYORS)

IF THE OPERATOR SETS THE START PB TO OFF THEN CONTROL GOES STEP 8 (NORMAL SHUTDOWN)

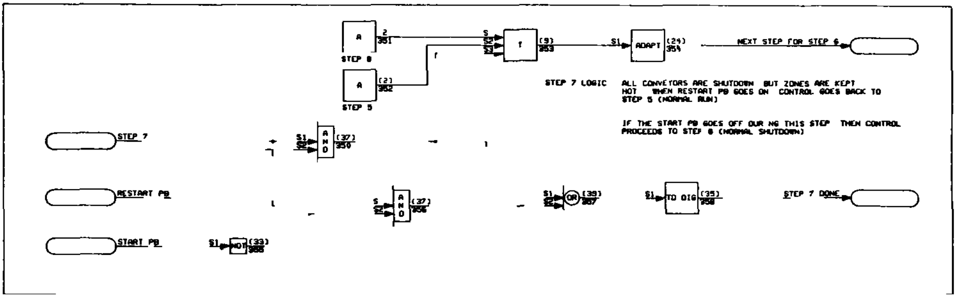
FIGURE 14 Step 5 Logic



STEP 6 LOGIC THIS STEP SHUTS DOWN THE FEED CONVEYOR KEEPS ALL OTHERS RUNNING TH S ALLOWS PASTERURIZER TO CLEAR THE SYSTEM IS RESTARTED BY HITTING THE RESTART PB

IF THE START PB GOES OFF DURING THIS STEP THEN CONTROL PROCEEDS TO STEP 8 (NORMAL SHUTDOWN)

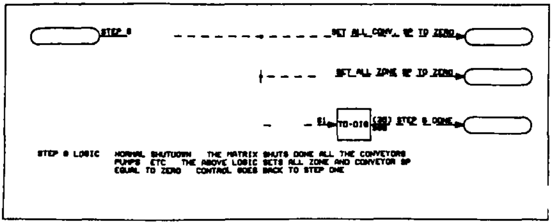
FIGURE 15 Step 6 Logic



STEP 7 LOGIC ALL CONVEYORS ARE SHUTDOWN BUT ZONES ARE KEPT HOT WHEN RESTART PB GOES ON CONTROL GOES BACK TO STEP 5 (NORMAL RUN)

IF THE START PB GOES OFF DURING THIS STEP THEN CONTROL PROCEEDS TO STEP 8 (NORMAL SHUTDOWN)

FIGURE 16 Step 7 Logic



STEP 8 LOGIC NORMAL SHUTDOWN THE MATRIX SHUTS DOWN ALL THE CONVEYORS PUMPS ETC THE ABOVE LOGIC SETS ALL ZONE AND CONVEYOR SP EQUAL TO ZERO CONTROL GOES BACK TO STEP ONE

FIGURE 17 Step 8 Logic

		STEP NAME	EMERGENCY STOP	BEGIN STARTUP	FILLING PANS WITH WATER	HEAT UP WITH SPARGE VALVES	SET ALL ZONE CONTROLLERS TO TEMP	NORMAL PASTEURIZATION	SHUTDOWN 1 STOP FEED	SHUTDOWN 2 STOP ALL CONVEYORS	SHUTDOWN 3 NORMAL SHUTDOWN			
	STEP NUMBER		0	1	2	3	4	5	6	7	8			
OUTPUT	AS NAME													
1	PUMP 1		0	0	0	0	1	1	1	1	0	0		
2	PUMP 2		0	0	0	0	1	1	1	1	0	0		
3	PUMP 3		0	0	0	0	1	1	1	1	0	0		
4	PUMP 4		0	0	0	0	1		1	1	0	0		
5	PUMP 5		0	0	0	0	1	1	1	1	0	0		
6	SPARE		0	0	0	0	0	0	0	0	0	0		
7	STEAM VALVE 1		0	0	0	1	0	0	0	0	0	0		
8	STEAM VALVE 2		0	0	0		0	0	0	0	0	0		
9	STEAM VALVE 3		0	0	0	1	0	0	0	0	0	0		
10	STEAM VALVE 4		0	0	0	1	0	0	0	0	0	0		
11	STEAM VALVE 5		0	0	0	1	0	0	0	0	0	0		
12	CONVEYOR 1		0	0	0	0	0	1	0	0	0	0		
13	CONVEYOR 2		0	0	0	0	0	1	1	0	0	0		
14	CONVEYOR 3		0	0	0	0	0	1	1	0	0	0		
15	CONVEYOR 4		0	0	0	0	0	1	1	0	0	0		
16	CONVEYOR 5		0	0	0	0	0	1	1	0	0	0		
17	WATER FILL VALVE 1		0	0	1	0	0	0	0	0	0	0		
18	WATER FILL VALVE 2		0	0	1	0	0	0	0	0	0	0		

TABLE 1 Step Matrix for Process

00 15 45 04 11 07

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