Advantages of Distributed Control Systems for the Modern Glass Plant

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ADVANTAGES OF DISTRIBUTED CONTROL SYSTEMS FOR THE MODERN GLASS PLANT

I. Introduction

Controls and control systems have undergone a quiet revolution in the past 10 years. For many years, discrete device control systems such as pneumatic controllers and electronic analog controllers have been instrumental in the glass industry. Since the 1960's, computers have been instrumental in the areas of plant monitoring and supervisory control. Although analog controllers performed the primary control functicns, the computer allowed for optimization calculations and the reporting and archiving of large amounts of plant data.

About 10 years ago, discrete device control systems and computer-based control system technology merged to create today's distributed digital control system.

The modern distributed control system combines the advantages of discrete controllers and computers, simultaneously eliminating many of the disadvantages. Digital control, introduced by computers, is maintained with all its advantages: setpoints and tuning parameters do not drift, complex algorithms can easily be implemented, plantwide data acquisition is possible, etc. Hardware problems and massive control failure, also introduced by computers are eliminated because control is distributed, similar to the discrete controller concept (see Figures 1-4).[1]

The glass industry has recognized the importance of distributed control systems (DCS) and, in many cases, is in the process of installing DCS as glass tank rebuilds occur.

In 1986, AFG Industries Inc. had completed plans for a massive modernization program. At that time, AFG operated four 500 to 550 ton/day float lines, producing glass for the architectural and commercial markets. Rapid growth had pushed AFG into the ranks of the Fortune 500 companies.

An extensive modernization program and plans called for complete rebuilds at their Cinnaminson, New Jersey and Jerry Run, West Virginia float lines. In addition, greenfield plants were planned at Victorville, California and Springhill, Kansas. The decision was made to utilize distributed control systems on these float lines.

II. Distributed Control at AFG

The concept behind distributed control is to distribute control functionality down to the lowest possible level to minimize the effect of a controller failure. Typically, control is segmented by process. Each Process Control Unit (PCU) communicates over a data highway, but is independent. (see Figure 5).

A system overview of AFG's Victorville plant is shown in Figure 5. Each set of cabinets contains independent redundant power supplies, redundant control modules, slave modules and I/O terminations. Each PCU communicates over a redundant data highway to a centralized CRT-based operator console capable of monitoring and controlling all the field devices and sensors in an entire glass plant. Separate Batch/Furnace and Bath/Lehr operator consoles are functionally equivalent, providing redundancy here also. Since a complete on-line back-up control system exists in parallel with the primary system, failure possibilities are greatly reduced.

AFG segmented the control task into four process areas; the batch plant, furnace, tin bath and annealing lehr. Virtually identical control equipment is utilized regardless of the process, which simplifies maintenance and minimizes spare part requirements (see Figure 6).

Figure 6 illustrates the system architecture utilized by AFG. The area inside the dotted line details the modules and terminations inside a PCU cabinet.

Typically, only the slave modules and terminations change, depending on the type of I/O coming into the cabinet. All other hardware is identical regardless of whether the PCU is controlling the melter or the batch plant.

Starting at the bottom of Figure 6, termination boards accept hardwired field I/O. Thermocouple and RTD inputs are cable connected from their terminations to slave modules, which provide linearization, security and engineering unit conversion. Redundant analog master modules multiplex up to 64 inputs from the analog slave modules.

Termination boards can be located in a separate cabinet from the electronics. These termination cabinets can then be located in a harsh environment. Standard cable connections link the two cabinets.

All other analog and digital I/O are brought into the distributed control system through various slave modules that communicate directly with redundant multifunction controllers. The multifunction controllers provide all the discrete and analog control functions necessary for the batch plant through the annealing lehr.

Each PCU cabinet contains modules that communicate with the plant loop data highway. Each PCU then becomes a node on the loop enabling any I/O signal to be available for monitoring or control purposes at the operator console.

III. Distributed Control System Software

The need for writing lines of code in Basic or Fortran is eliminated by pre-programmed control algorithms, arranged in different configurations to suit the application. The pre-programmed algorithms are called function codes (See Figure 7). A library of function codes is resident on-board each intelligent module, such as the multifunction controllers utilized by AFG. To configure a particular control strategy, these function codes are arranged in a particular sequence (see Figures 8 and 9).

Function codes can be reused as required. The multifunction controllers utilized by AFG each have an on-board library of approximately 150 different function codes and memory space for a 10,000 function code configuration. Each multifunction controller can handle up to 128 control loops.

The tool for configuring the multifunction controllers is a personal computer (PC) based engineering work station. A CAD Package allows the user to configure function code sequences by calling up the various function code numbers and connecting the blocks together.

An entire page of control logic is visible on the PC screen (see Figures 8 & 9). When the engineering work station is connected to the plant loop, live data is available for de-bugging purposes. When the engineer is satisfied that the control logic is correct, he compiles it, and is notified of any mistakes (i.e. digital input to an analog function code, etc.). He can then download the configurations over the plant loop to any controller module. Instant documentation of this logic is then available via a plotter or printer attached to the PC.

This tool brings control system configuration into the hands of plant personnel. Outside computer expertise is not necessary to change control logic!

IV. Operator Interface

CRT-based operator consoles provide a common operation window to the entire batch plant, melter, tin bath and lehr. Displays that allow control access permit the operator to manipulate any control loop or final control element in the entire system. Three CRT/Keyboard consoles permit simultaneous control access for up to three operators.

Alarms are brought to the operator's attention, including alarms that indicate problems with the control system itself. Alarm management features allow the operator to respond to alarms by plant area or priority.

Trends are viewed on the CRT's, not on trend recorders. This allows the operator to manipulate trends (live data) by expanding the horizontal and vertical axes, panning forward or backward in time, etc. to examine process events.

Logs are printed out by operator demand, time demand or event. They include alarms, process events, operator actions, trends, trip logs and snapshot logs.

The consoles are menu driven and engineered using a fill-in-the-blanks format. CRT graphics are designed on the engineering work station.

V. DCS Operating Results at AFG

Distributed control systems combining the batch plant, furnace, bath and lehr are now in operation at AFG's Jerry Run, Cinnaminson and Victorville plants. A number of beneficial results have been realized.

DCS makes operators familiar with all areas of the plant. They can move from process to process simply by changing CRT displays. They do not have to be familiar with different manufacturer's control equipment when moving from process to process.

AFG reports that operating personnel per shift have been reduced by 50%.

The ability to change control configurations, on-line, was very helpful; particularly during start-up. The function block approach allows for easy troubleshooting, particularly in the batch house. (See Appendices A & B for control logic description).

A central computer group or outside computer expertise is not needed to maintain the system. The system is user friendly to maintain and operate, thus AFG's expertise in process control has grown rapidly.

Previous control panels have been reduced to single 19" module racks. Less than one-half the space is required compared with previous hardware.

Configuration of bi-model (heat/cool) loops in the annealing lehr is practical. Loops are configured to use heating and cooling in tandem (not overlapping) modes in normal operation and in fixed or variable overlapping modes by operator selection.

VI. Future Plans

One of AFG's plans is to optimize furnace reversal by re-configuring the timing sequences involved in reversal while observing its effect on the process:

1. choose a reversal time
2. observe peak regenerator temperatures
3. make reversal time vary to maintain optimum regenerator temperature week to week
4. vary temperature to reduce fuel usage

Interaction between any of the control loops in any part of the plant is practical. Expansion of the control system is easy due to its modular nature. More I/O can be added by plugging additional slave modules into the cabinets.

In addition, DCS technology is evolving rapidly. Hardware changes are typically upward compatible. This means that as newer and more powerful modules are developed, they are compatible with the existing control system. This guards against obsolescence.

AFG plans to implement a corporate-wide communication system involving the DCS at each plant. A PC would be located remotely and communicate with each plant loop data highway via a phone modem.

VII. Conclusion

A distributed digital control system is a powerful tool for monitoring, controlling and optimizing an entire glass plant. It brings control configuration into the hands of the plant engineer. All control loops and I/O signals can be concentrated into a central control room.

Once all the plant I/O and local controllers are hardwired into a DCS, it becomes a tool whose value is limited only by the imagination of the plant engineering and operating personnel.

Appendix A

Furnace, Tin Bath and Annealing Lehr

Regulatory Control

(all points monitored/controlled from operator consoles)

Furnace

Melter Pressure - Single element loop controller simultaneously controls two hot fan inlet dampers and the stack damper. Each damper control signal is cascaded from the melter pressure station or the operator can manually control each separately.

Oil Temperature - Single element loop controller to fuel oil temperature bypass valve.

Glass Level Control - Single element control to batch charger speed.

Dilution Air Flow - Dilution air is temperature and pressure compensated. A cascade setpoint is developed from a single element controller based on either canal pyrometer or thermocouple temperature. This allows dilution air flow to be controlled based on a process variable of air flow (no cascade) or temperature (cascade).

Oil & Gas Fuel Flow - Single loop controller whose setpoint is either operator selectable per burner or cascaded based on operator selectable total fuel flow with tunable distribution parameters to each burner. Gas and oil flow are pressure and temperature compensated. Oil and gas can be burned simultaneously.

Air Flow Control - Single loop controller based on air flow or cascaded setpoint from fuel flow.

Cooling Tower Fan - Digital on/off based on temperature.

Hotwell & Coldwell Pumps - Digital on/off based on levels.

Reversal Logic - Digital logic based on either time, temperature, or operator action.

Tin Bath

Hydrogen Flow -Hydrogen is temperature and pressure compensated. Cascade control loop is also used based on percent H_2 desired in nitrogen mix.

Nitrogen Flow - Single element controller. Pressure and temperature compensated. Miscellaneous digital controls.

Annealing Lehr

Heating and Cooling Zones - Single element controller whose process variable is the zone temperature and the setpoint is operator selectable. Some zones are heating or cooling only. Heat/cool zones can control to independent setpoints or a common cascaded operator selectable setpoint.

Various operator controls for on/off of cooling fans, etc.

Appendix B

Batch Plant Control

All points are monitored/controlled from the operator consoles with back-up local panels in the batch plant. CRT screens in operator consoles are designed to enable the operator to control and monitor the entire batch plant. Operator is alarmed if the following occurs:

emergency stop
cycle time long
plugging detected
water valve failure
scale overweight
metal detected
scale off-zero

control system alarm

(flashing alarm indicators are touch points to take operator to another screen)

Each scale can be operated in manual mode even if the entire weigh mix system is in auto. The sequence of feeding and discharging each scale is visible to the operator. The sequence of the checkscale is also visible. Sequences proceed automatically unless a condition is not met. Sequence will stop and operator must take some action (i.e. if checkscale is overweight, sequence will stop and operator can either accept or reject).

The mixer can be selected by the operator to operate either in manual or auto. The operator can select either mixer or any batch bin through the CRT screen and keyboard also.

All items on the screens with a number next to them indicate pop-up control. The operator enters the number through the keyboard and the device appears in the lower right hand section of the CRT (the blank rectangle). The device can then be turned on or off (see Figures 10 and 11).

References

1 Lukas, Michael P., "Distributed Control Systems", pgs. 1-16, including figures on pgs. 7 and 10.

General references include conversations with the following:

Greg Little, Electrical Project Engineer, AFG Industries Inc.
Bryan Jones, Systems Engineer, Bailey Controls Company
John Turk, Systems Engineer, Bailey Controls Company
Michel Sussman, Systems Engineer, Bailey Controls Company

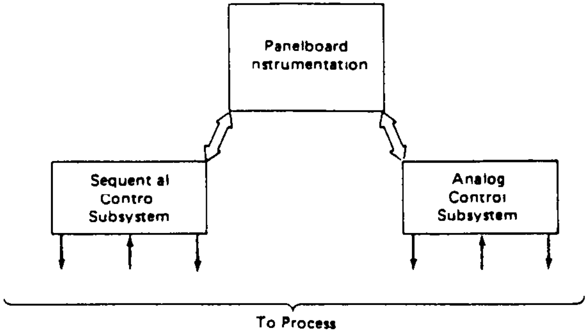

FIGURE 1 Discrete Controllers

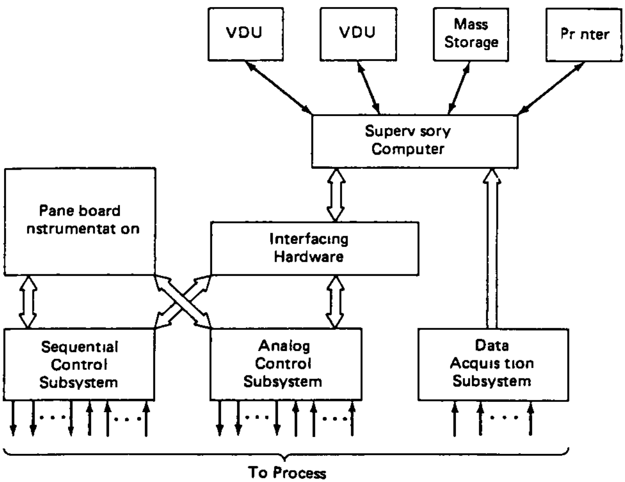

FIGURE 2 Discrete Controller with Supervisory Computer

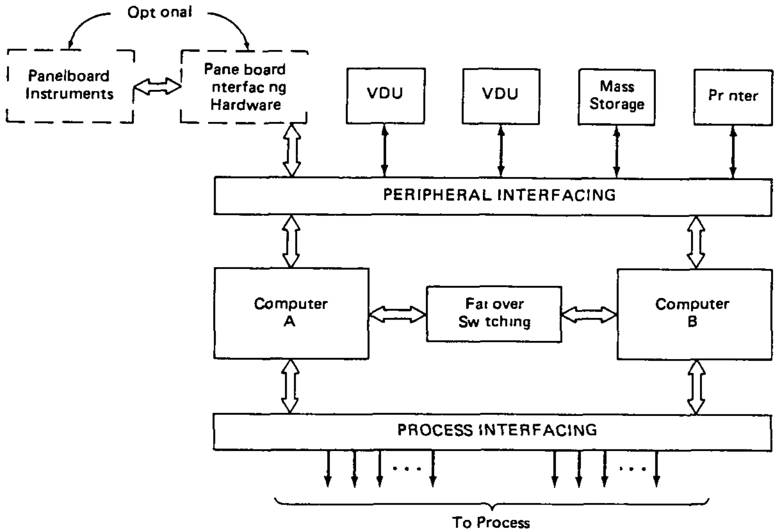

FIGURE 3 Introduction of Direct Digital Control

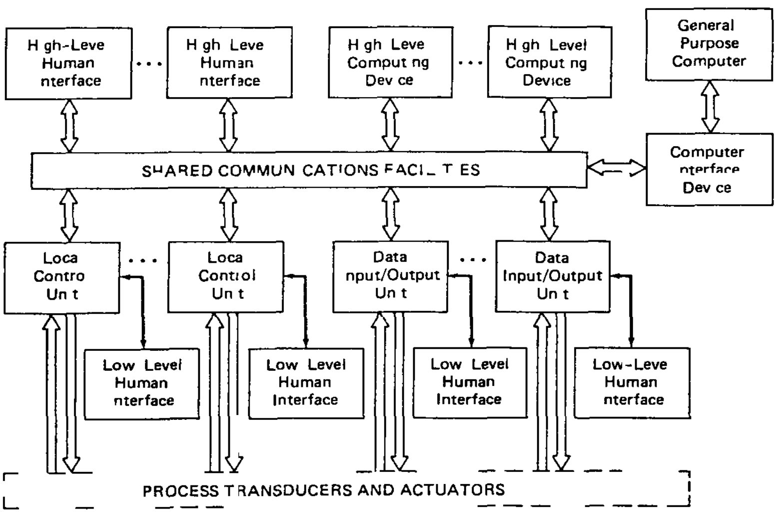

FIGURE 4 Distributed Digital Control System

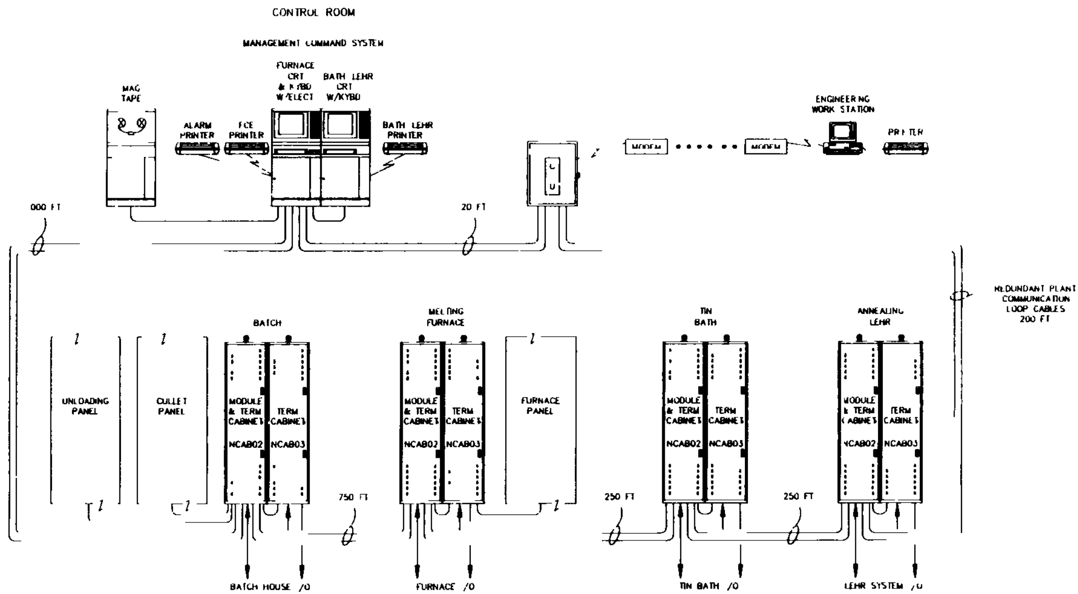

FIGURE 5 System Overview Diagram

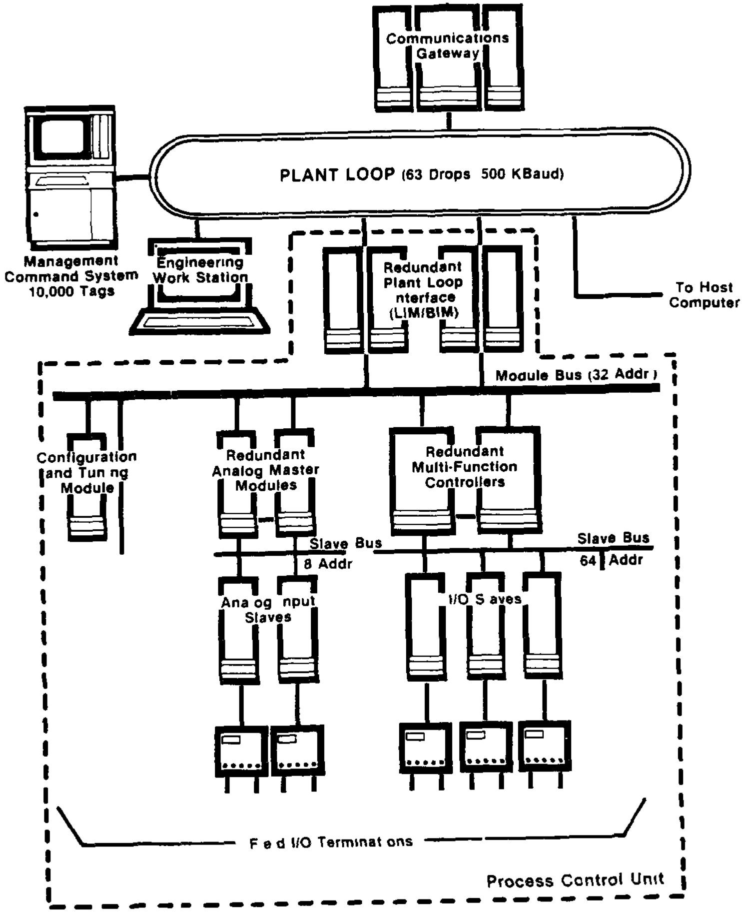

FIGURE 6 System Architecture

Function Block Type	Function Block Type	Function Block Type	Function Block Type	Function Block Type
Station Station Interface Logic Station Interface Logic Station Indicator Station Remote Manual Set Constant BASIC Station Manual Auto Cascade Station Manual Auto Ratio Station Manual Auto **Control** Pulse Positioner PID Control Error Input PID Control PV & SP Input Adapt Smith Predictor Sequence Generator Device Driver Sequence Monitor Device Monitor Sequence Manager General Digital Controller **Computing** Function Generator Manual Set Constant Lead/Lag High/Low Limiter Square Root	**Computing (cont'd)** Rate Limiter Sum (4 inputs) Sum (2 inputs) Multiply Divide Time Delay Analog Constant Digital Sum (4 inputs) with Gains Regression Moving Average Integrator Polynomial Interpolation Matrix Addition Matrix Multiplication Trigonometric Exponential Natural Exponential Logarithms Power **Signal Select** High Select Low Select Transfer Analog Digital Buffer Analog Buffer Boolean Signal Multiplexer	**Signal Select (cont'd)** Real Signal Multiplexer Real Signal Demultiplexer **Signal Status** High Low Alarm Test Quality Slave Select Digital Readback Check **Logic** Trip NOT Memory Timer Qualified OR AND (2 inputs) AND (4 inputs) OR (2 inputs) OR (4 inputs) Manual Set Switch Digital Transfer Up/Down Counter Elapsed Timer Exclusive OR 5 Input Rung 10 Input Rung 20 Input Rung **Module Bus I/O** Analog Input/PCU Analog Output/PCU	**Module Bus I/O** Digital Input PCU Analog Input List Digital Input List Module Status Monitor **Communications Loop I/O** Analog Input Plant Analog Output Exception Report Digital Input Plant Digital Output Exception Report Remote Control Switch Trend Analog Input Superloop Digital Input Superloop **Field I/O** Control Interface Slave Digital Output Group Digital Input Group Pulse Rate Indicator Redundant Analog Input Redundant Digital Input Pulse Input Period BCD Input BCD Output Pulse Input/Totalization Digital Output Buffer Remote I/O	**Field I/O** Slave Default Definition Pulse Train [illegible] Definition **Executive** Executive Extended Executive **Other** Integer Switch Set Integer Segment Configure BASIC Invoke BASIC BASIC Real Output BASIC Boolean Output Sequence of Events Boolean Recipe Table Real Recipe Table Jumper Master Control Delay Invoke C C Allocation

FIGURE 7 User Definable Function Codes

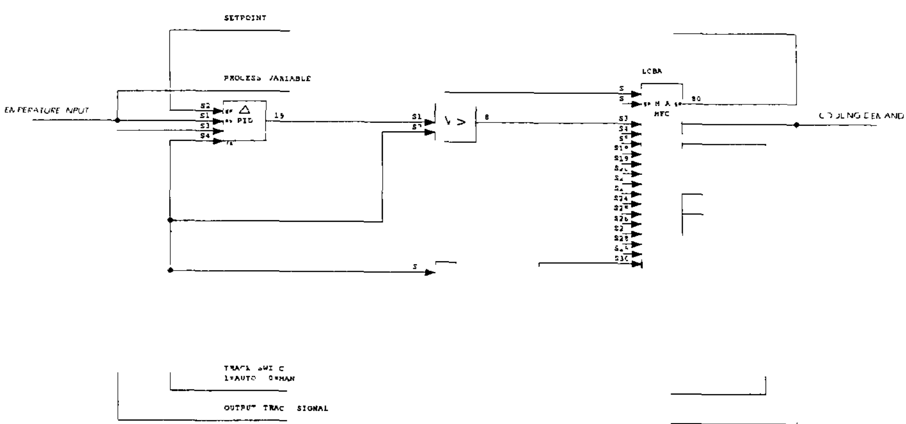

FIGURE 8 NETWORK 90 Configuration Lehr Cooling

00 21 15 04/11/07

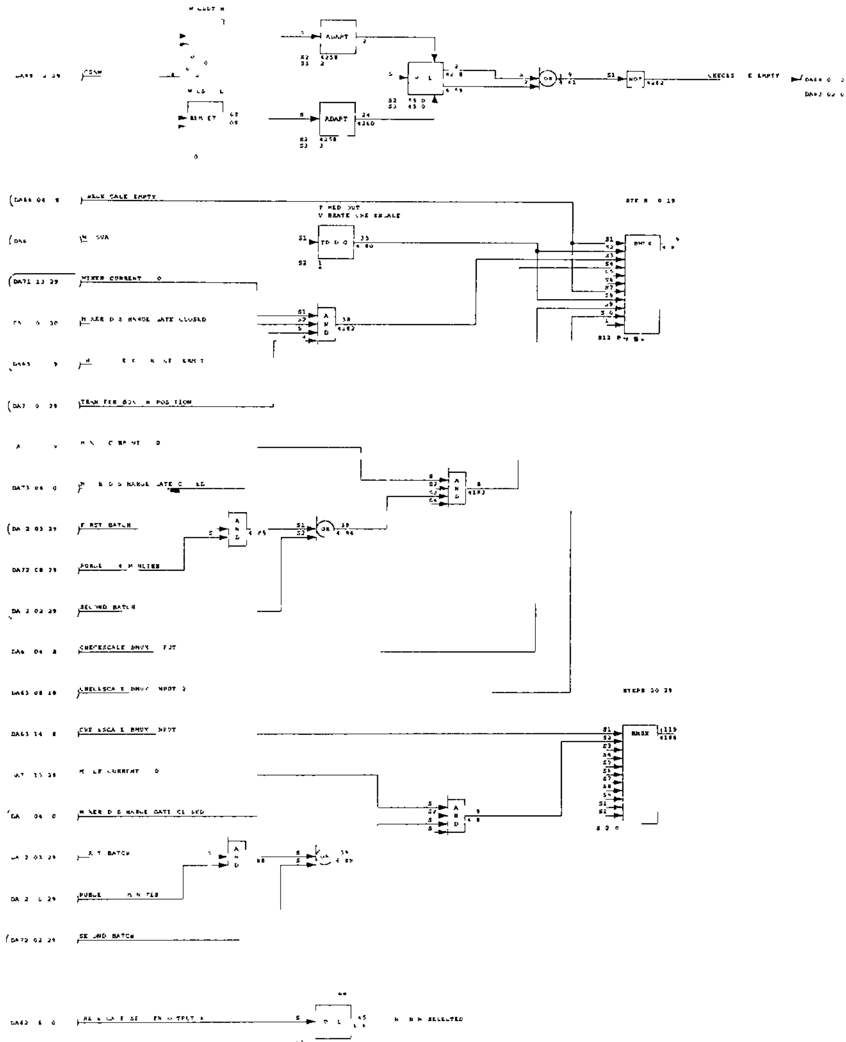

FIGURE 9 NETWORK 90 Configuration Check Scale Sequence

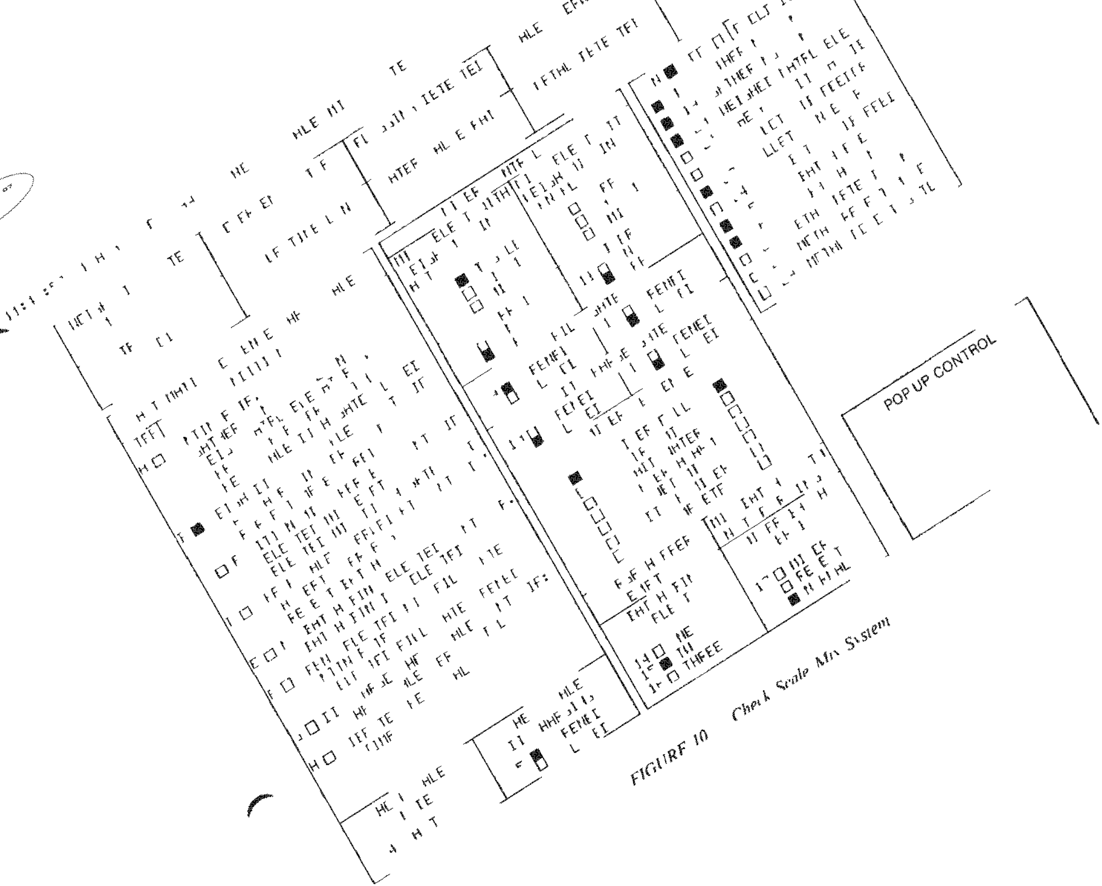

FIGURE 10 Check Scale Mix System

00 21 17 04 11 07

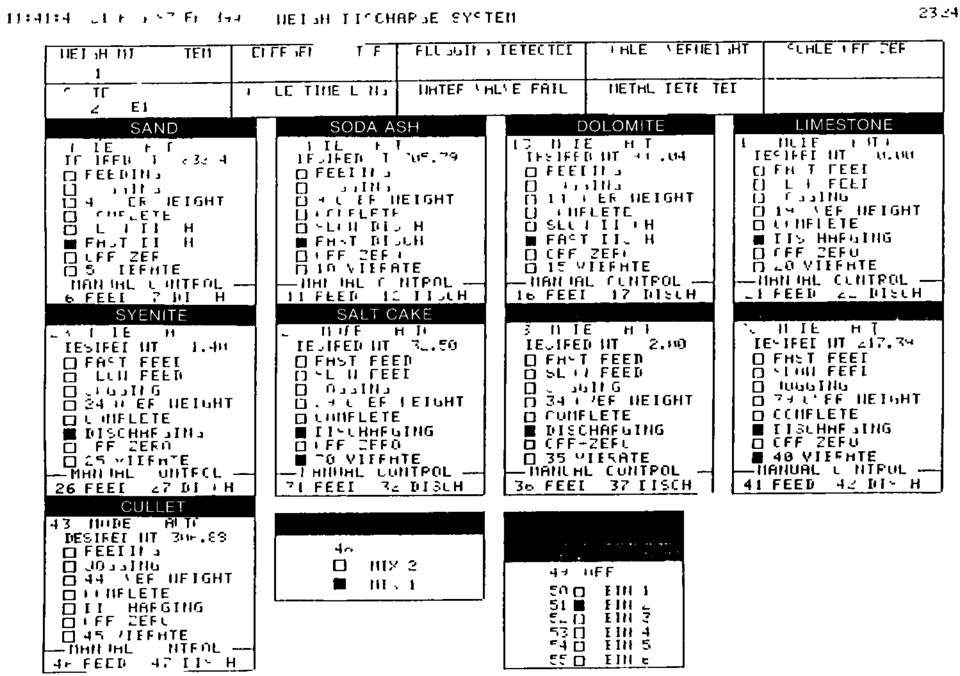

FIGURE 11 Weigh/Discharge System

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