TROUBLESHOOTING AND MAINTAINING ELECTRONIC KILN CONTROLS

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Electronic control systems are quickly becoming commonplace at many mills. At the same time, many systems have been installed for a few years and, like all equipment, parts are going to wear out and need to be replaced. This paper will attempt to cover 1) the similarities and differences between electronic and pneumatic systems, 2) some of the electrical components and how they work, 3) how to maintain an electronic system, and 4) what to do when your system won't work.

COMPARISON BETWEEN PNEUMATIC AND ELECTRONIC SYSTEMS

Electronic systems with computer control are surprisingly analogous to pneumatic equipment. Control in both systems is based on the same principles of process control. The bellows, valves, and levers in a pneumatic system are designed to simulate mathematical relationships. In the computer these are simulated by electrical signals which we see as numbers. For example, the valve response (gain) to a deviation from set point (error) might be changed by changing the length of a lever in a pneumatic system, whereas a number would be changed in an electronic system.

Pneumatic and electronic systems both take some measured input (dry- or wet-bulb temperature) and control a process condition (heat, spray, or vent). There are many other things that both systems can do. We will quickly look at these and then discuss things that can only be done easily with electronic systems.

It is often argued that more precise temperature measurement or control can be obtained with an electronic system. This is probably true; however, this is not a sufficient reason to switch to electronic controls. For our purposes, both systems can adequately measure temperature. Also, if properly maintained, either system can control temperature quite adequately for the purpose of drying lumber. Libraries of schedules and automatic schedule changes are possible with both a pneumatic system (using cams) and an electronic system. These assure that the kiln is run consistently from charge to charge and frees you up for maintenance and other work.

An electronic system offers the ability to monitor and even control the kiln from a remote location (such as the office or home). It can also provide a record of all temperatures, actuator positions, steam pressure, operator interactions, and other information. This allows you to troubleshoot past kiln performance almost as if you had sat there and watched it run.

In an electronic system, the control scheme is represented by software (programming language or ladder logic) and can be switched without changing the hardware. For example, set point changes now commonly based on time could just as easily be based on TDAL, or some other signal (maybe initiated by lumber weight, a moisture sensor in the wood, or steam demand). Also, the variable which is compared to the set point to determine valve position could be changed by software. An example of this is control based on exiting- or entering-air. Similarly, elaborate zone control schemes would be almost impossible, or prohibitively expensive, without electronic control.

Electronic systems can conveniently display a lot of indirect information (calculated variables) about the process. A few examples are EMC, steam consumption, steam demand, maintenance schedules, alarms, and estimated drying times.

There are several advantages with respect to maintenance in an all-electronic system. There is no compressor so water does not freeze in air lines during cold weather, there are no moving parts in the controller to be fouled (no oil in needle valves), no gas bulbs to calibrate and change, autotuning is possible for PID loops, and generally components are replaced rather than repaired. Electronic systems do require different skills and equipment to maintain. I wanted to say more complex skills and equipment, however, depending on your generation, this may or may not be true.

Electronic systems also offer the potential for integrated steam management utilizing delayed starts and steam priorities for kilns. Electricity management is also possible by avoiding startups or reducing fan speeds during peak-demand periods for the mill. Inventory tracking and quality control procedures could also be worked into an electronic control system.

The parallels between the hardware in pneumatic and electronic systems are shown in Table 1. When changing from a pneumatic to an electronic system, the new equipment will be a lot easier to understand if you can see an analogy between the new and old components.

Table 1. Comparison of equipment in electronic and pneumatic systems.

FUNCTION	PNEUMATIC	ELECTRONIC
Temperature measurement	Gas bulb	Thermocouple or RTD
Transmission of temperature signal to controller	Capillary tube (vapor pressure from bulb)	Wires (voltage or current)
Set point input	Set with knob, position of pointer	Keyboard or file
Comparison of measured temperature to set point (obtain error)	Position of mechanical elements in controller	Subtract numbers
Decide on signal to send to actuator based on error	Position of mechanical elements in controller	Mathematical calculation
Transmission of signal from controller to actuator	Air line (3-15 psi signal, for example)	Wires (4-20 mA signal, for example)
Actuator positioning	Air pressure on diaphragm and size of spring	Servo motor or positioner[1]

[1]Many systems use a current-to-pneumatic convertor and send an air signal to the valve.

Speaking of switching systems, there are many good reasons why your next new kiln will probably be an electronic system. However, existing pneumatic systems should not be replaced unless you have a good reason. If your pneumatic system is well-maintained, simply changing to a computer for control probably won't make for better lumber. The mechanical components that are being controlled (valves, coils, traps, fans, etc.) and the way you operate the kiln (baffles, stacking, appropriate MC checks, product segregation, etc.) have more to do with producing a quality product than the type of controller.

COMPONENTS IN AN ELECTRONIC SYSTEM

Referring to Table 1, let's step through the components you are likely to see in an electronic system.

Temperature Measurement

Two types of temperature sensors are commonly used, thermocouples and resistance temperature detectors (RTDs). A thermocouple is pair of wires joined at both ends in which each wire is a different metal or alloy (Figure 1a). When the two junctions are at different temperatures, they exhibit a thermoelectric effect known as the "Seebeck effect" and current flows through the wires.

A voltmeter can be added to the circuit to measure a voltage difference (Figure 1b). This difference is related to the temperature difference between the junctions (J_1 and J_2). If you have thermocouples in your kiln, there is a voltmeter built into your control equipment. The voltage is read and converted into a temperature difference. Circuitry in the voltmeter also enables it to detect the temperature of the second junction (J_2). Adding the temperature difference to temperature at J_2 (known as "cold junction compensation") gives the temperature at J_1 (in the kiln). With the volt meter in the circuit, no current flows so the reading is independent of the wire length.

RTD's work because the electrical resistance of metals increases as temperature increases. Current is supplied to an RTD, the voltage drop is measured, and the resistance is calculated (Figure 2). To measure resistance as shown in Figure 2a requires 4 wires going from the RTD to the controller. This can be done less expensively (but less accurately) with three wires (Figure 2b). RTD's are more accurate than thermocouples; however, the placement of the sensor relative to the walls, the wood, and the heating coils is more important than whether a particular sensor is accurate to within 1° or 0.1° F. If you have RTD's in your kiln, there is circuitry built into the control equipment that sends a current to the RTD and measures the resistance.

Signal Conditioning

The signal from the temperature sensor may need to be amplified or conditioned prior to being read by the system's voltmeter. If the signal is amplified it is much like turning up the volume on a radio and the voltmeter has an easier time reading (hearing) the signal.

Signal conditioning may filter some of the noise out of the signal (Figure 3). The noise might come from electrical wires, equipment such as fans, or radio signals.

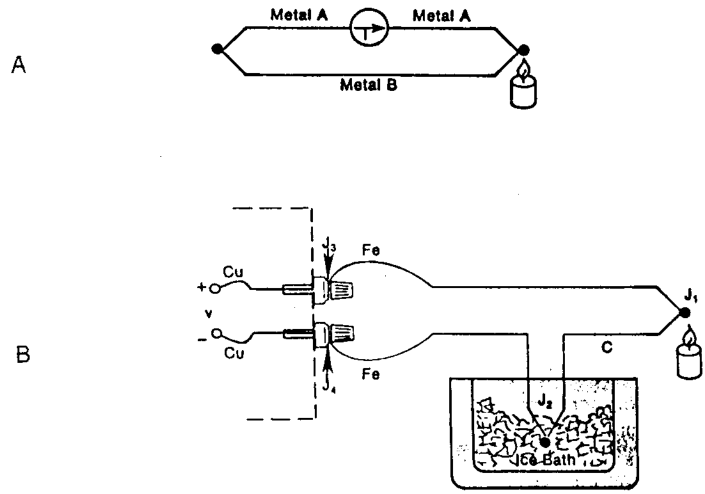


Figure 1. Principles of thermocouple usage. A - Current flows through wires of dissimilar metals. B - By keeping one junction at a known temperature, a voltage measurement can be used to determine temperature. Electronics replace the ice bath in modern systems. Drawings are from Omega Engineering's catalog.

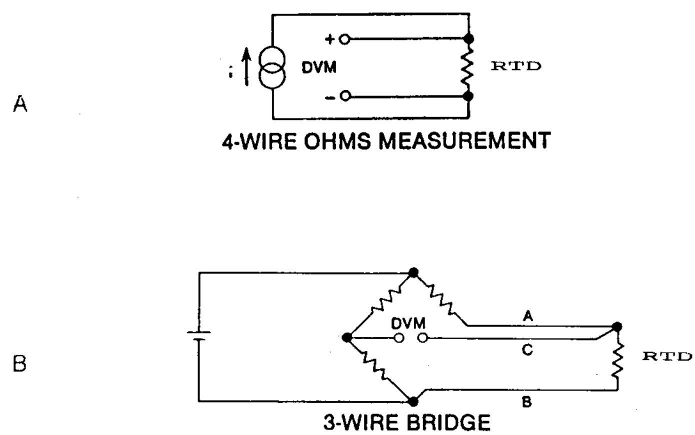


Figure 2. The resistor (RTD) is placed at the point where temperature is to be measured. A - In the four-wire arrangement, a known current is passed through the RTD and the voltage drop is measured. B - A bridge circuit is used in the three-wire RTD. DVM = digital volt meter. Drawings are from Omega Engineering's catalog.

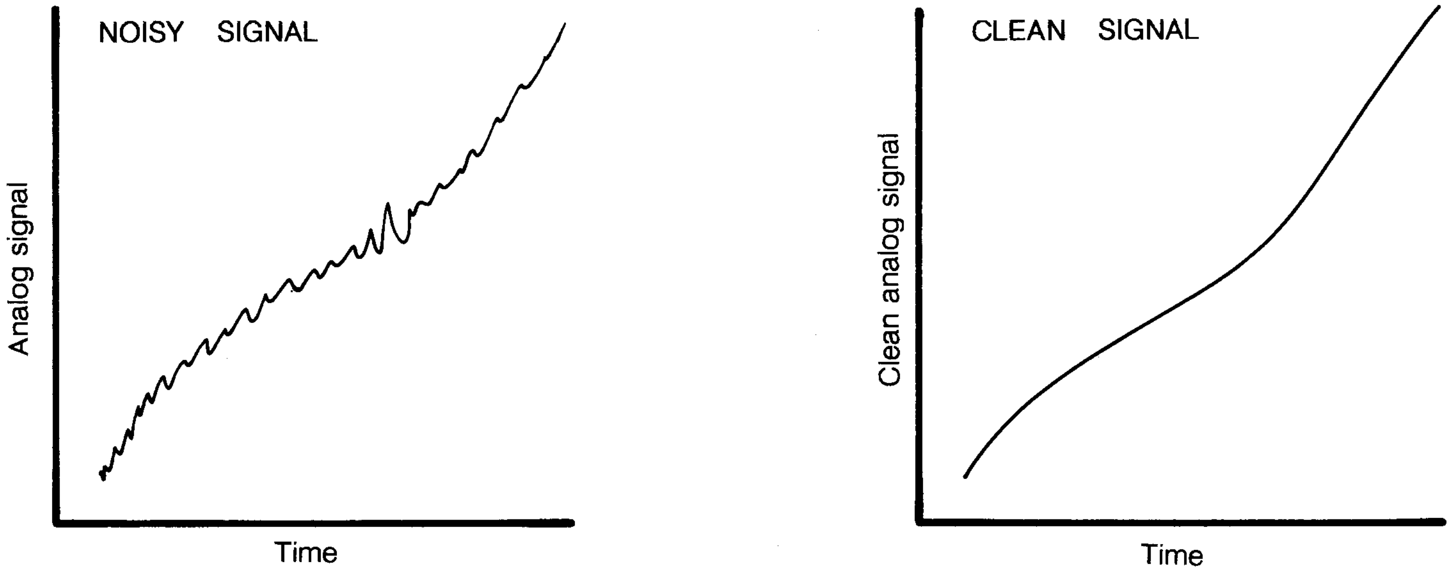


Figure 3. Signals from the temperature sensing equipment are conditioned.

Analog To Digital (A/D) Conversion

The type of signals we have discussed so far are analog. That is, they vary continuously. 0-5 v, 4-20 mA, 3-15 psi, and the needle on an older-type moisture meter (0-30%) are all examples of analog signals. The computer "thinks" using discrete numbers, not continuous analog signals. Within the computer, everything is stored as a series of 1's and 0's (binary) representing a circuit that is either on or off. Therefore, RTD or thermocouple signals must be converted to a digital value.

Usually 8 to 12 of these on/off values are used to represent the mA signal. These are called bits. If 8 bits are used for conversion, there are 256 possible values ($2^8=256$). It is more common to use 12 bits or 4096 possible values to obtain greater resolution of the signal ($2^{12}=4096$). Thus, the analog signal coming into the A/D convertor is divided into 4095 segments. Any value falling within a segment is assigned to the same digital value (Figure 4) ranging from 0 to 4095.

Controller

Internally, the controller has been programmed to associate each of the 4096 values to a certain temperature (Figure 4). In our example, the controller would know that 2319 is associated with 177°F. This temperature is then compared with the setpoint and an output value is determined. The output value will ultimately be converted into the actuator position.

Some older, pneumatic controllers simply open or close the valve (on/off or bang/bang control) if the temperature is below or above set point. Many pneumatic controllers proportion the actuator position depending on the difference (error) between the kiln temperature and the set point (P or proportional control). Additionally, some pneumatic controllers incorporate the amount of time the temperature has been off set point (I or integral or reset), and the rate at which the temperature in the kiln is changing (D or derivative or anticipatory) into the control decision. Classic 3-mode (PID) control combines all of these factors into the decision process. Three-mode control requires expensive hardware in a pneumatic system, while in an electronic system it can be accomplished with just a few lines of computer code.

Since most electronic systems have 3-mode control, it is important for the kiln operator to understand the criteria used by the controller to determine the valve position. If the operator is thinking on/off control and the controller is implementing 3-mode control, it is very difficult to guess what the actuator position should be or why it is staying open or closed.

As an example of the three-mode decision process, let's suppose that the kiln temperature is 177°F, the set point is 180°F, and the valve is 60% open. The 3-degree error causes the proportional mode of the controller to want to open the heat valve more. If the temperature had been below set point for a long time, the integral mode of the controller will also want to open the heat valve more (Figure 4a). This speeds the return to set point. If, on the other hand, the kiln had been at 185°F for the past hour and just cooled to 177°F, the integral term may work against the P mode and try to close the valve (even though the kiln is 3°F below set point) (Figure 4b). This helps prevent the over-temperature condition from reoccurring. If the temperature was 177°F and rising, the derivative mode anticipates that the temperature is on its way to 180°F and wants to close the valve to help prevent overshoot (Figure 4a and c). If the temperature was 177° and still

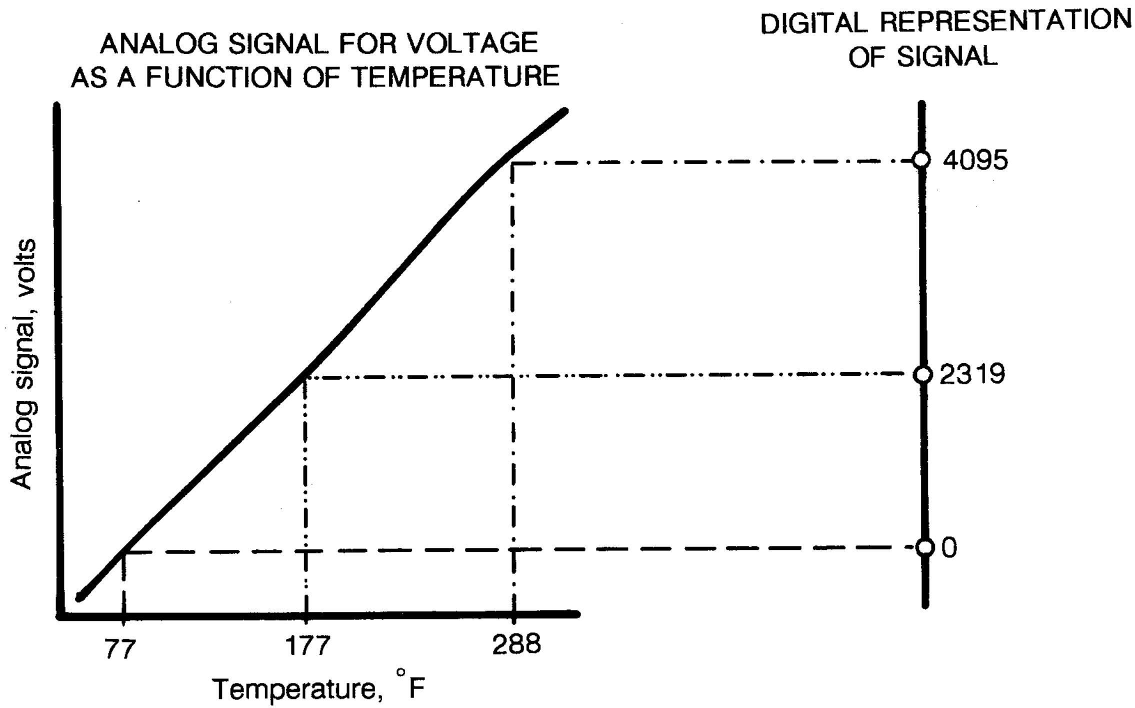
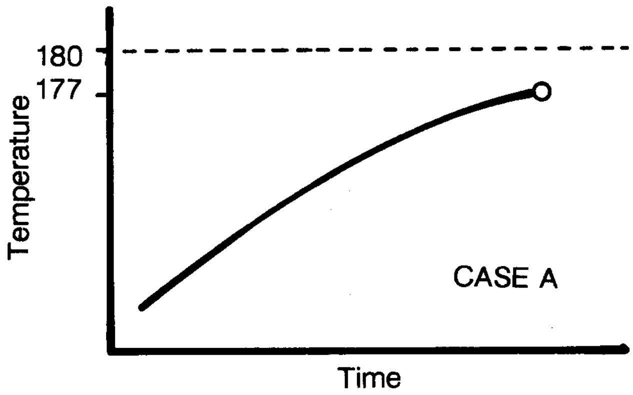
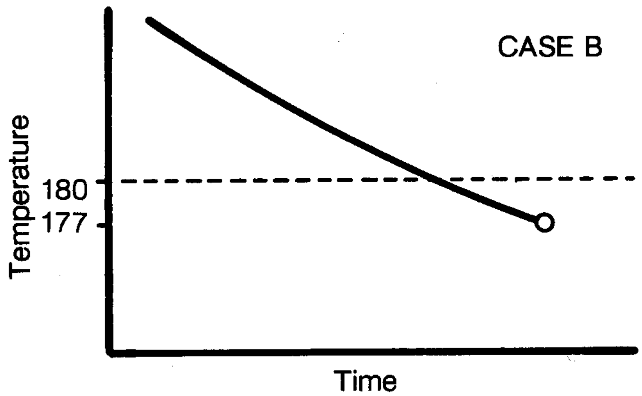
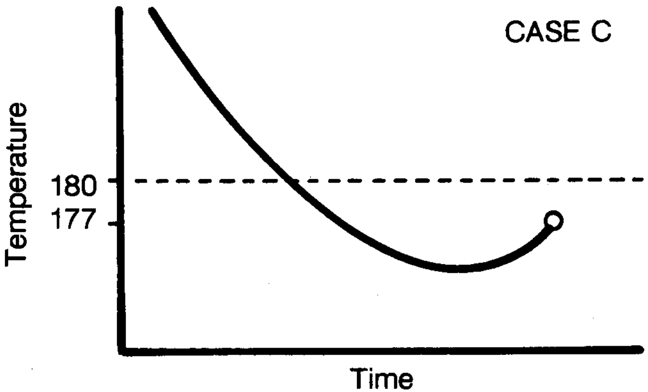


Figure 4. Conversion of an analog signal to digital representation.







WAY IN WHICH DIFFERENT MODES WILL ATTEMPT TO MOVE THE VALVE
ACTUAL VALVE MOTION DEPENDS ON TUNING OF KILN

	PROPORTIONAL	INTEGRAL	DERIVATIVE
CASE A	OPEN	OPEN	CLOSE
CASE B	OPEN	CLOSE	OPEN
CASE C	OPEN	CLOSE	CLOSE

Figure 5. Examples of 3-mode (PID) controller response. Kiln is at 177°F, 3°F below set point in each case.

decreasing, the derivative mode would tend to add to the proportional mode and open the valve more (Figure 4b).

To get the three modes all working in concert the controller must be tuned. Three values (gain or proportional band, integral or reset, and derivative) are set so that the valve does not over control or respond too slowly. The manufacturer does this for you when the equipment is installed. If these values are not set correctly, the kiln might come up to temperature too slowly, significantly overshoot the setpoint, or the temperature might oscillate after the kiln has come up to temperature. In addition to the PID settings, sometimes the actuator travel is restricted to a certain percent per minute to help dampen the controller response during large error periods such as fan reversal. This also helps prevent water hammer during startup.

Digital To Analog (D/A) Conversion

For our discussion, assume that the controller has decided the valve should be 62% open. Now the whole A/D process we used to get the temperature signal into the computer is reversed. Possible values for valve position are 0 to 100 percent and these correspond to 0 and 4095. Our value is 62% of the way between these limits or 2539. This digital value is sent to the D/A converter and a analog signal is created, usually 4-20 mA. The analog signal in this case is 13.92 mA or 62% of the way between 4 and 20 mA.

Signal Conditioning

The analog output signal might be changed to match the requirements of the valve, although with a matched, all-electronic system this step is not needed. If the valves are air-operated, a current to pneumatic convertor would be used to change the 4-20 mA signal into a 3-15 psi air signal or whatever is appropriate for the valve.

Distributed Versus Centralized Control

The above description is fairly general. Exactly how a particular system is configured can vary a lot. Two general schemes are centralized and distributed control.

Each decision process for which an actuator is moved based on a measurement is called a control loop. Thus the dry-bulb/heat coil for each heating zone and the wet-bulb/spray/vent are control loops.

If control is centralized, one controller or computer handles all of the control loops (Figure 6) for one or all kilns on the system. This has the advantage of less hardware so it's less expensive, but if the controller malfunctions, everything shuts down. This approach is software is intensive.

Distributed control means that for each control loop there is a separate device (controller) responsible for maintaining the kiln condition (temperature or humidity) at setpoint. Each of these remote devices is actually a computer. The main computer or loader sends the setpoints to each controller and gives the operator information from the controllers. One advantage is that the system can run without the computer or loader in place. Thus it can be doing other tasks or, if it malfunctions, the system can continue to run. In a distributed system there is more hardware to buy and maintain, although it might be easier to isolate problems.

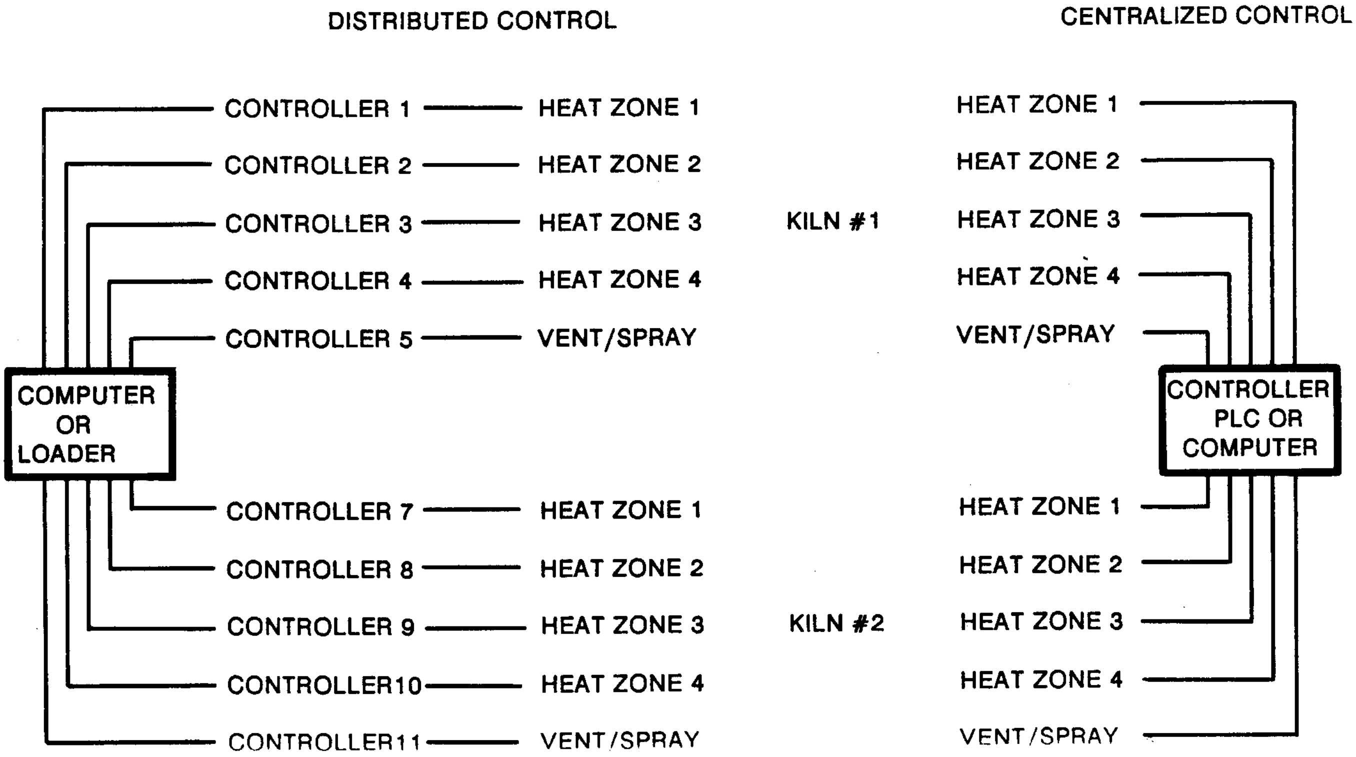


Figure 6. Distributed versus centralized control. Control of two kilns is shown for each system.

MAINTAINING THE SYSTEM

Most of the maintenance required on pneumatic kilns also needs to be done on kilns with electronic systems. Inspections, lubrication, coating (where applicable), replacement of worn parts, and other regular mechanical maintenance items are just as essential on electronic systems as on mechanical systems. The electrical components actually require minimal care.

Temperature sensors need to be protected from mechanical damage. Make it a habit to secure them (where applicable) at the same time as the baffles when loading and unloading the kiln. When inspecting the temperature sensors, watch for corrosion on the mounting brackets. Also check the integrity of the insulation on the wire. Bare wire touching the metal in the kiln will probably affect the temperature. If the wet-bulb thermocouples are not in a sheath, the exposed end of the wires should be coated. In fact, the ends of all wires and conduit should be sealed. Inside the kiln all wires should be in conduit or firmly attached to something so they cannot blow around. This will cold-work the wire and eventually cause failure. Also, long leads should be shielded (or in conduit) to prevent interference from electrical noise. Many of these wires carry very low voltage signals and can easily pick up noise from fan motors. Periodically the temperatures indicated by the controller should be independently verified with a hand-held thermocouple unit, or bucket of hot water and thermometer.

Controllers that are installed in the mill environment are industrial-hardened and can operate at temperatures up to 130° F if kept clean and dry. Computers that are installed in an air conditioned, clean room are probably not industrial-hardened. Aside from water, heat is the computer's worst enemy. Cooling of the machine will be impeded if dust accumulates inside the machine. Periodically the inside of the machine should be vacuumed by a computer technician, or better yet, learn to do it yourself. Do not have a chalk board in the same room as the computer. When you come in the nice cool room to eat lunch, do it away from the computer.

Floppy disks should be treated like a record or tape. Don't touch the recording media. Keep them clean, dry, and cool. Use storage boxes. Label all disks. Park the hard disk before turning off or moving the computer. This is like tying down the needle on a phonograph. Note that most of the newer hard disks park automatically when they are powered down. Never move the computer while it is operating.

Turn the monitor down, if possible, to save the screen. However, make sure the operators know the difference between the screen being turned down and a computer failure.

Programming updates might occasionally be obtained from the manufacturer. These reflect new control features or have small bugs worked out. In some cases the update might come on a chip which you insert, on disk that you load, or it might be downloaded by modem. In the last case you probable have to do nothing except give the manufacturer telephone access to the computer system.

Computer, D/A, A/D, and signal conditioning equipment should all be on an uninterruptable power supply (UPS). The most important function of the UPS is to protect the electronic equipment from spikes in the mill power supply. Only plug the computer equipment into the UPS. The UPS also maintains power to the electronic equipment during those short (5-second to 15-minute) power outages. During outages, some UPS systems signal the computer to initiate an orderly shut down of the kiln. Note that after a power outage, some systems may have a 1 to 5 minute delay built in before restart. This is to let the voltage stabilize and make sure it is on for good. Whether you have a UPS or not, do not quickly turn computer off and back on again. This can cause a voltage spike.

Power supplies convert the AC line current to DC current sources for the signal conditioning equipment. Every few months the output of these power supplies should be checked with a voltmeter. If the voltages start to drift, actuators or I/P converters will not open the valves the correct amount. Also, the thermocouple or RTD readings will all begin to drift. A second check of the power supplies should be done with the voltmeter on the AC setting. A reading other than zero indicates that there is AC noise in the DC signal and it's time for a new power supply. AC line noise can cause problems in the communications between the computer and the boards.

TROUBLESHOOTING

Troubleshooting is best accomplished by understanding the system and applying the same common sense that you would use in a pneumatic system. The amount of trouble shooting the manufacturers expect you to do depends mostly on the customer and capabilities of mill. They expect questions and can talk you through problems. Of course, the more you can do, the better it is for you and the manufacturer. Attempting your own trouble shooting by the phone call method is a good way to get familiar with you system's components. Fortunately you rarely have to do it.

The equipment you should have on hand includes a digital multimeter (3-1/2 digit minimum), a set of small tools, and, optionally, a hand-held device for reading thermocouples or RTDs.

Electronic systems tend to give a better indication of trouble spots than pneumatic systems simply because there are more sensors. For example, unusual temperature variation displayed on the screen might indicate an open service door, a inoperative fan, or a bad valve or trap. It won't tell you what the problem is, however, the observant operator will notice that there is a problem and go to investigate. Electronic systems can also be very elusive if you don't understand what's happening. Much of what happens you can't see and touch except with electronic instruments.

Very Unusual Temperature Indications

Thermocouples either work, or don't work. For our purposes they do not get out of calibration. If an errant temperature reading is way out of the range at which the kiln is operated, it's probably an indication that the thermocouple is bad. An open circuit will cause the voltage to drift and reach the upper or lower voltage limit for the A/D equipment. Often this appears as a high or low temperature that is obviously false (e.g. +280°F or -338°F) and does not change.

If this occurs, the first thing to check thermocouple continuity. Unhook the thermocouple from the panel and plug it into a hand-held device for reading thermocouples. These can be obtained for \$150 to \$200. If it reads correctly, the problem is not in the thermocouple. To be sure, have someone heat the tip of the thermocouple with a heat gun (blow dryer) or match. Heat it just enough to see that the temperature displayed on the hand-held unit responds.

If you don't have a hand-held thermocouple unit, find a multimeter (voltmeter). It will be hard to read the thermocouple voltage unless your voltmeter is very sensitive so the best you can probably do is to check the resistance. Set the multimeter for resistance and attach the leads of the thermocouple to the meter.

If the resistance is very high, it indicates an open circuit. For comparison, check the resistance on a second thermocouple of similar length. The two resistances should be similar.

A less preferable alternative (when no meter is available) is to switch two sets of thermocouple leads and see if the problem goes with the thermocouple or with the channel on which it is being read. Label the wires before you unhook them to be sure that they are put back in the correct location. An easier method is to attach a short (1-foot) thermocouple in place of the suspect thermocouple. If the channel works with the short thermocouple, then you know the problem is in the original thermocouple. If the problem mysteriously disappears when you reattach the thermocouple, it's possible that the connection was at fault.

When removing or attaching leads, remember that the boards to which they are attached are delicate electronic equipment. Use a proper-sized, nonmagnetic screwdriver. Do not touch the boards or any electrical connections - spikes of high voltage, even from you, can damage electronic equipment. Don't force anything. Don't turn any screws unless you know what they do - there are adjustment pots on the boards and the calibration may be altered.

A bad thermocouple can often be repaired by reconstructing the tip. Cut the last 1" off of the wires (the kiln end) and remake the thermocouple connection by twisting and soldering the wires. This procedure is simple and often solves the problem. If it doesn't, there is a break somewhere else in the wire. If you simply twist the wires, the thermocouple might work for a while, but the connection will eventually corrode. Replace any water resistant coating (silicone) the thermocouple had on it. The coating prevents water from traveling up the wire by capillary action and getting the controller wet. It also slows the response of the thermocouple.

The opposite of an open circuit would be a short. Measure the resistance of the bad thermocouple as indicated above. If it is significantly lower than a working thermocouple of similar length, it indicates that the thermocouple wires are touching at some point other than the tip. The entire thermocouple may need to be replaced.

Replacement thermocouple wire must be of the right type. It comes color coded:

-Type T, copper-constantan, is blue (+) and red (-)
(copper and copper-nickel)

-Type J, iron-constantan, is white (+) and red (-)
(iron and copper-nickel)

-Type K, Cromel-alumel, is yellow (+) and red (-)
(nickel-chromium and nickel aluminum)

are fairly common. The wrong wire type will give the wrong temperature. Also, hooking them up backward will give an ok reading at room temperature, but as you heat the tip of the thermocouple, the indicated temperature will go down.

RTD's are replaced, not repaired. Fortunately, they very rarely go bad. The easiest way to assure yourself that the problem is indeed the RTD is to switch the leads with another RTD and see if the problem moves to the new channel. If it does, replace the RTD. If you have an extra RTD on hand, attach it in place of suspect the RTD rather that switching leads.

If the errant temperature reading cannot be traced to the thermocouple or RTD, it might be best to contact the manufacturer. Most of the hardware is easy to troubleshoot if you are familiar with it; however, it's doubtful that you or the mill electrician can quickly solve a problem here. Beyond the thermocouple or RTD, the problem could be anywhere in the signal conversion or controller. Of course, it never hurts to know where the fuses and breakers are in your system. In some cases, there are very tiny fuses that you may not recognize unless you know what they are.

Actuator Doesn't Move Correctly

If a single actuator seems to respond incorrectly or not at all, stop and check the whole control loop associated with that actuator. If the problem seems to be with all actuators (valves and vents) concentrate your attention on the parts of the system that can affect all actuators simultaneously.

If, for example, a single control valve is fully open or closed, check the temperature measurement associated with that valve. An incorrect temperature reading might cause the controller to think that the valve should be fully open or fully closed. If you are confident in the temperature reading, compare it to the setpoint. If the temperature can't reach the setpoint despite the valve being fully opened or closed, then the control system may be operating correctly and the problem might be in the hardware. Check the same things you would for a pneumatic kiln - traps, steam supply, and hand-operated valves.

Finally, if you can't find a problem anywhere else in the control loop, trace system operation from the valve to the controller. The quickest way, if you have a maintenance menu built into the control system, is to work through the computer, tell the valve to open, and go out and see if it did. If it works this way and won't work when the kiln is running, the problem may be one for the manufacturer. Check the air supply to the valve (including valve diaphragm, supply pressure, and system leaks) or power to the electronic valve actuator (or I/P convertor). If it has power, check the analog control signal to make sure it is actually telling the valve to open or close. The problem will be in one of these places and you will have to find out why. The problem could be a bad fuse, broken wire, an open breaker, or a bad power supply. Remember that the fuses in the control panel may not look at all like the ones in a car or stereo. You will have to know what you are looking for. A breaker should not trip repeatedly. If this happens you need to find out why. Exactly what you check at this point will depend on your system.

Temperature Overshoot Or Oscillation

If the temperature oscillates around the setpoint or if the kiln initially overheats then comes back to setpoint, this can be tuned out with the 3-mode (PID) constants. Do not try this without first contacting the manufacturer. This should never have to be done unless you have changed something that affects the thermal capacity of the system. Things that might affect this are a large change in steam pressure, adding vent capacity, adding heating coils, or changing the valve size.

Disk Drive Errors

There are two kinds of hard disks, those that have crashed and those that will. When hard disks crash you usually get no information from them. Make sure you have the information from your hard disk backed up. The DOS backup command or many commercial software packages are available for this. Alternatively, as long as you don't mind losing everything else on the hard drive, at least have some way to restore your control software to the disk.

If you start to see occasional read/write errors to the disk, encounter an occasional unreadable file, or have very long seek times, it's a pretty good sign that your disk is on it's way out. Consider it good fortune that you got a little warning and plan how you are going to change disks without upsetting the operation.

CONCLUSION

The electronic controller is a tool that can tell you a lot about what is happening in the kiln. Learn all you can about what your system can do, but also know the limits of what the controller can tell you. Additionally, watch all of the usual, non-electronic things that tell you how the kiln is doing. For example pressure gauges on steam lines, temperatures, valve positions, vent positions, the moisture distributions, steam consumption, etc. There's a reason for everything you observe, try to make sense out of it.

When you have a problem, first check what you can yourself, consult with your electrician, then call the manufacturer. Usually you are just going to isolate the bad component and replace it. It's very important that when you don't understand it, leave it alone and get help. Don't be afraid to troubleshoot under the manufacturer's supervision. This is how you will learn more about your control system.