

Chapter 6

ELECTRICAL & CONTROLS

Maintenance of extrusion plant electrical and control equipment requires specialized skills and advanced training in both electrical and electronic technology, and it is beyond the scope of this manual to teach those skills. For that training you will need to rely on the services of trade and technical schools, as well as specialized training and seminars offered by equipment vendors and contractors.

For the purposes of this manual we have attempted to provide help in two areas:

- for those extrusion personnel who are not trained in electrical/electronic work (people who work in production, management, etc.), a general background in these technical areas, and
- for maintenance professionals, some specific recommendations and helpful hints specifically for extrusion press electrical and control maintenance, as gathered from various sources.

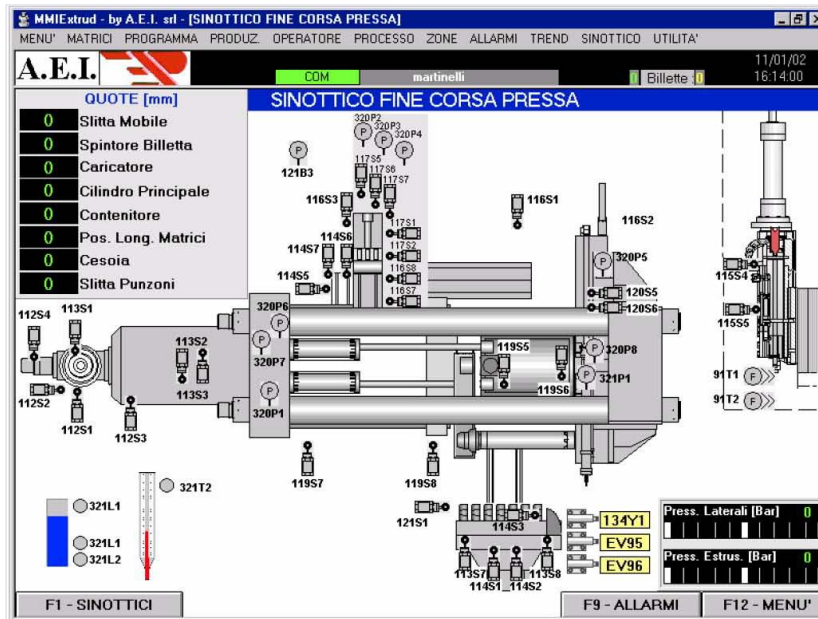
One excellent reference is the paper, "Extrusion Press Electrical Systems," by David Turnipseed. Originally presented at the AEC Press Maintenance Seminar, in , November, 1991, it is reprinted here with his permission, beginning on page 6-11. For this Third Edition he has provided "Tips for Successful Electrical Trouble Shooting of Extrusion Equipment", page 6-16.

Press Controls - Background

Until the late 1970's, extrusion presses were controlled almost exclusively by relay logic. Relays, timers, and other electro-mechanical devices "hard wired" together in an intricate scheme, permitted control of complex press movements in precisely the correct sequence. Each action --- perhaps an operator pushing a button, or a mechanical arm tripping a limit switch --- might initiate other actions, or simply enable or prohibit others from taking place. Relay logic is a highly developed technology, and the electro-mechanical devices employed have been refined to a degree of high reliability over the years. It was not uncommon for presses controlled by relay logic to operate with very good reliability.



Figure 6-2: Modern control desk for entire press line with graphic operator interface (Photo courtesy of Presezzi Extrusion)



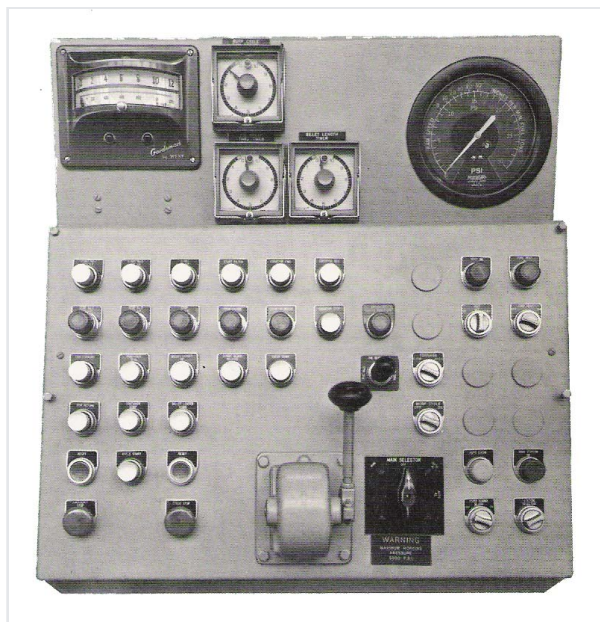


Figure 6-1: Controls from a 1970's Farrel press

Why change from relay logic? First of all, the atmosphere around presses is usually contaminated by airborne dirt and oils in the form of aerosol mists, a clear enemy of electromechanical contacts. When you open a relay cabinet near an extrusion press you will likely find the inside dirty and oil coated. Also, electromechanical relays have a relatively short life (compared to electronics), as the many cycles of operation eventually lead to fatigue failures. Trouble-shooting to find problems can be slow and difficult. Hard-wired logic is also inflexible, and fine tuning press cycles to optimize the dead cycles was an art, requiring an experienced hand with stopwatch and screwdriver, making small adjustments to limit switches in a trial-and-error process while the press was stopped or operating at limited capacity.

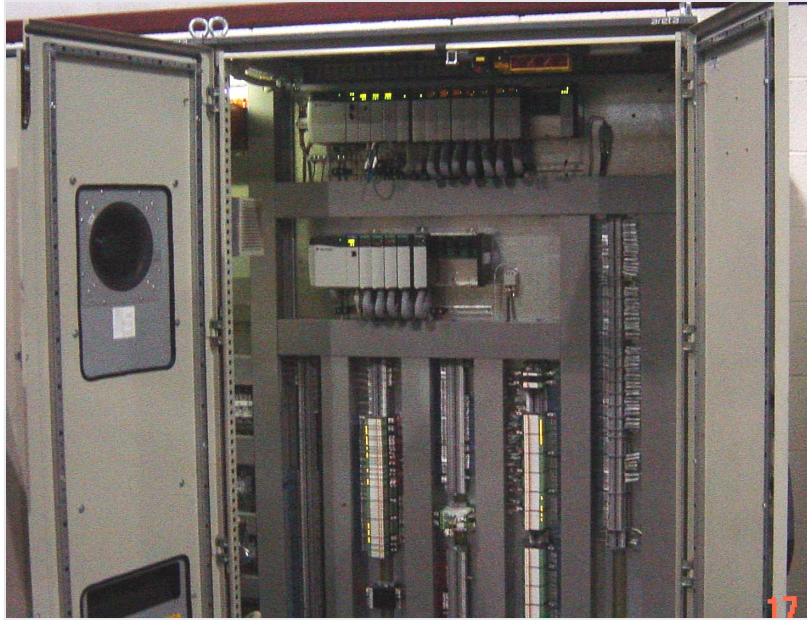


Figure 6-3: Inside a modern press PLC control cabinet (Photo courtesy of Presezzi Extrusion)

When the microprocessor era arrived in the 1970's, many extruders with outdated or unreliable relay systems began to replace their old relay cabinets with the new Programmable Controllers (a name later changed to Programmable Logic Controllers, or PLC's, to distinguish them from Personal Computers). Usually, converting a press to PLC control involved removing the old, oil-soaked relay control cabinet and installing a simple PLC cabinet. Sometimes there was not even a circuit diagram to work from. A maintenance electrician who knew the operating sequence and relay logic of the press (but didn't know PLC's) would work with a contract PLC programmer, who had never seen an extrusion press, to create together a workable operating program for the press. It was common to use the PLC simply to replace relays.

Before long, however, creative minds began to see other possibilities in the new controls, touching off a wave of innovation that is still growing. Following are listed some of the advantages and innovative applications of PLC's that make them the choice for every press today:

- Even greater reliability and "up time" are possible.
- Encoders and transducers can replace most limit switches, improving reliability and flexibility.
- Back-travel of the ram may be automatically adjusted according to the billet length, to reduce dead time.
- Tuning of press functions for minimum dead cycle is simpler -- done entirely on the programming terminal while the press remains in service.
- Press logic may also be revised quickly and easily from the programming terminal, without wiring changes.

- Diagnostic programs permit instant detection and explanation of faults -- on the operator's panel or even remotely in the maintenance shop.
- More sophisticated logic sequences are possible -- steps may be performed concurrently.
- Mathematical capabilities of PLC's increase the possibilities for data gathering and quantitative control logic.
- Variable or fuzzy logic allows additional possibilities for improvements in process control.
- PLC's offer quicker response to input information.
- Simpler operator interfaces are available -- touch screens, mouse input, and graphical on-screen representations. These reduce operator training time and improve understanding of the press and controls.
- Communication with other computers -- including data gathering and remote (auto) set-up of operating parameters -- is possible.
- A history of maintenance problems may be automatically recorded and transmitted.

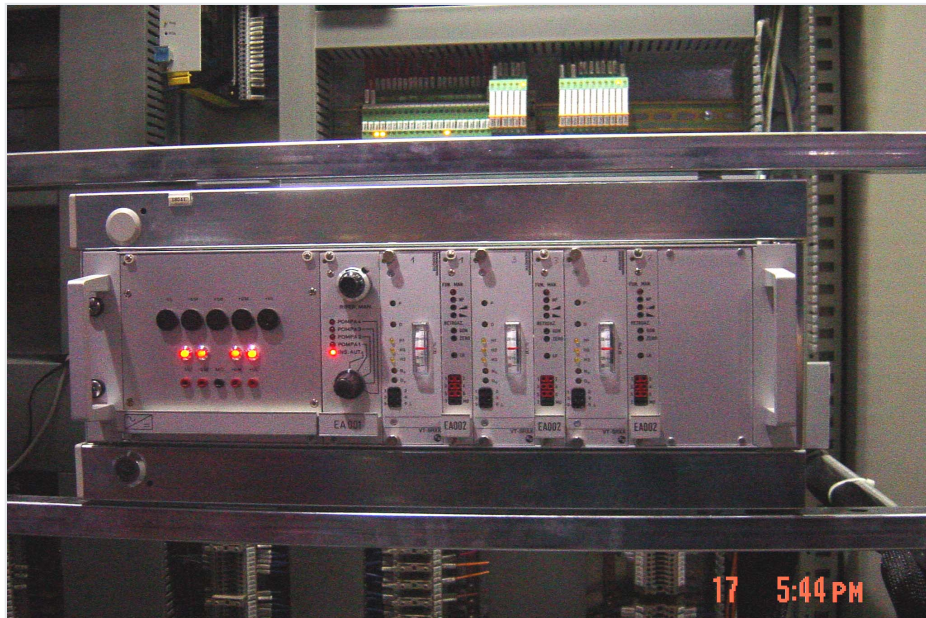


Figure 6-5: Modern electronic servo controls (Photo courtesy of Presezzi Extrusion)

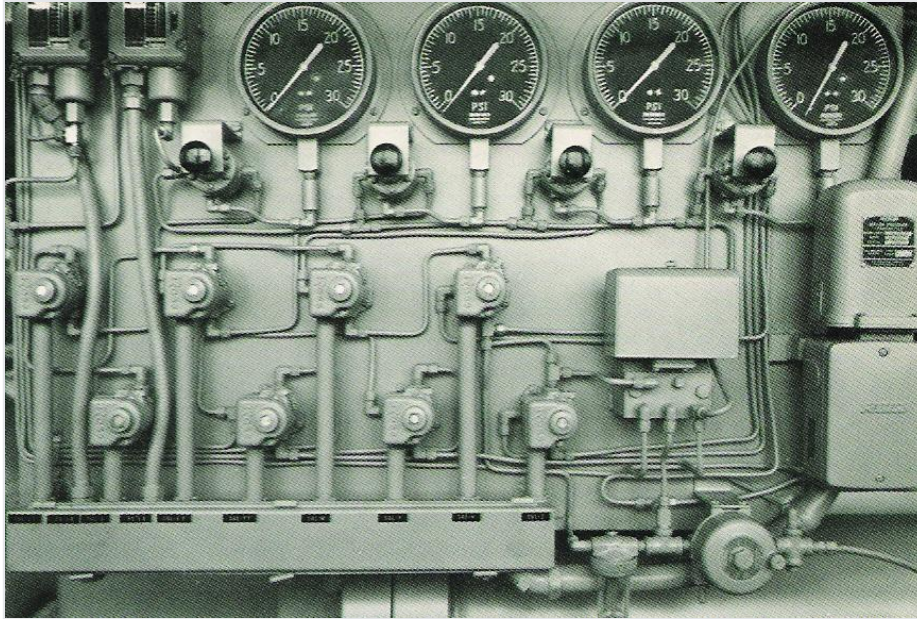


Figure 6-4: Old Farrel pneumatic servo controls for press hydraulics

Maintenance of Control Equipment¹

ATTENTION: Servicing energized industrial control equipment can be hazardous. Severe injury or death can result from electrical shock, burn, or unintended actuation of controlled equipment. Recommended practice is to disconnect and lock-out control equipment from power sources, and release stored energy, if present. Refer to **National Fire Protection Association Standard No. NFPA70E, Part II** and (as applicable) **OSHA rules for Control of Hazardous Energy Sources (Lock-out/Tag-out)** and **OSHA Electrical Safety Related Work Practices** for safety related work practices, including procedural requirements for lock-out-tag-out, and appropriate work practices, personnel qualifications and training requirements where it is not feasible to de-energize and lock-out or tag-out electric circuits and equipment before working on or near exposed circuit parts.

Periodic Inspection: Industrial control equipment should be inspected periodically. Inspection intervals should be based on environmental and operating conditions and adjusted as indicated by experience. An initial inspection within 3 to 4 months after installation is suggested. See **National Electrical Manufacturers Association (NEMA) Standard No. ICS 1.3, Preventive Maintenance of Industrial Control and Systems Equipment**, for general guidelines for setting up a periodic maintenance program. Some specific guidelines are listed below.

Contamination: Keep cabinet doors closed and locked to keep the interiors clean and to prevent unauthorized access.

¹ Portions adapted from "Maintenance of Industrial Control Equipment," Allen-Bradley Division of Rockwell Automation, Publication C-111, March 1995. 1201 South Second Street, Milwaukee WI 53204.

If inspection reveals that dust, dirt, moisture or other contamination has reached the control equipment, the cause must be eliminated. This could indicate an incorrectly selected or ineffective enclosure, unsealed enclosure openings (conduit or other) or incorrect operating procedures. Replace any improperly selected enclosure with one that is suitable for the environmental conditions -- refer to **NEMA Standard No. 250, Enclosures for Electrical Equipment** for enclosure type descriptions and test criteria. Replace any damaged or embrittled elastomer seals and repair or replace any other damaged or malfunctioning parts (e.g., hinges, fasteners, etc.).

Dirty, wet or contaminated control devices must be replaced unless they can be cleaned effectively by vacuuming or wiping with a soft cloth. Compressed air is not recommended for cleaning because it may displace dirt, dust, or debris into other parts or equipment, or damage delicate parts.

Cooling Devices: Inspect blowers and fans used for forced air cooling. Replace any that have bent, chipped, or missing blades, or if the shaft does not turn freely. Apply power momentarily to check operation. If unit does not operate, check and replace wiring, fuse, or blower or fan motor as appropriate. Clean or change air filters as recommended in the product manual. Also, clean fins of heat exchangers so convection cooling is not impaired.

Also see page 6-12 for additional suggestions for maintaining the correct atmospheric conditions for PLC controls.

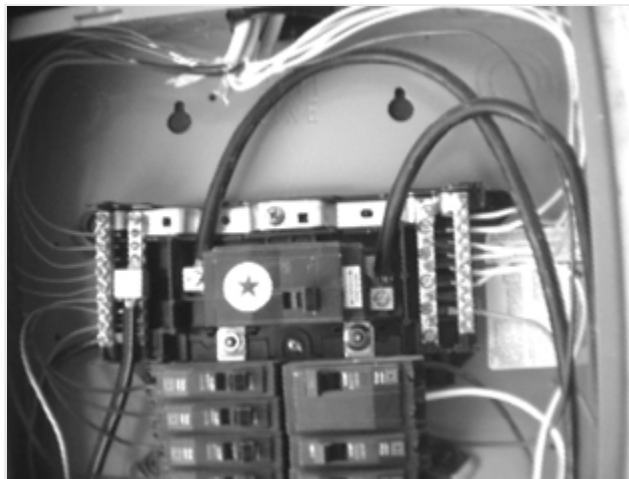


Figure 6-6: Faulty electrical junction identified by infrared scan.

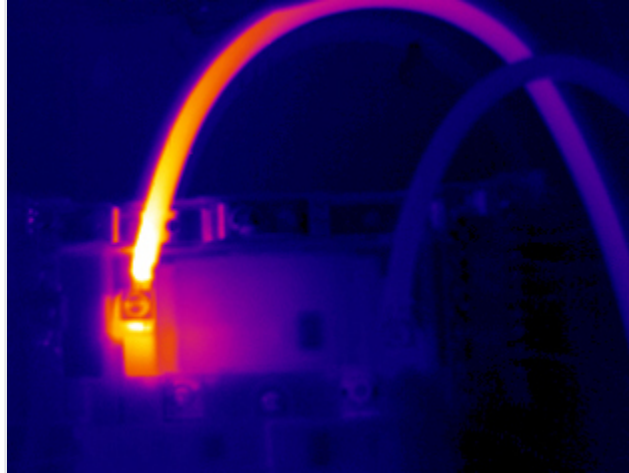
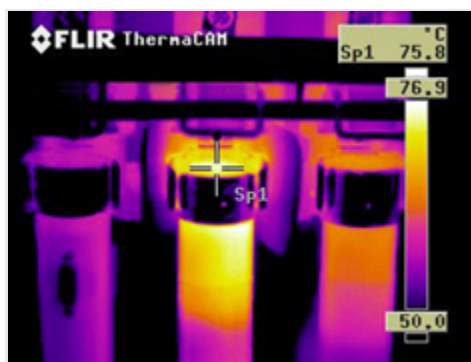


Figure 6-7: Overheated fuse block identified by infrared scan.



Operating Mechanisms: Check for proper functioning and freedom from sticking or binding. Replace any broken, deformed or badly worn parts or assemblies according to individual product renewal parts lists. Check for and retighten securely any loose fasteners. Lubricate if specified in individual product instructions.

Note: Most magnetic starters, contactors and relays are designed to operate without lubrication -- do not lubricate these devices because oil or grease on the pole faces (mating surfaces) of the operating magnet may cause the device to stick in the "ON" mode. Some parts of other devices are factory lubricated -- if lubrication during use or maintenance of these devices is needed, it will be specified in their individual instructions. If in doubt, consult the manufacturer of the device.

Contacts: Check contacts for excessive wear and dirt accumulations every 6 months. Vacuum or wipe contacts with a soft cloth if necessary to remove dirt. Contacts are not harmed by discoloration and slight pitting. Contacts should never be filed, as dressing only shortens contact life. Contact spray cleaners should not be used as their residues on magnet pole faces or in operating mechanisms may cause sticking, and on contacts can interfere with electrical continuity. Contacts should only be replaced after silver has become badly worn. Always replace contacts in complete sets to avoid misalignment and uneven contact pressure.

Terminals: Loose connections in power circuits can cause overheating that can lead to equipment malfunction or failure. Loose connections in control circuits can cause control malfunctions. Loose bonding or grounding connections can increase hazards of electrical shock and contribute to electromagnetic interference (EMI). Check the tightness of all terminals and bus bar connections every 6 months and tighten securely any loose connections. Replace any parts or wiring damaged by overheating, and any broken wires or bonding straps. Maintain the correct terminal strips for the type of wire used.

Infrared scans are recommended for detecting heat build-up or faulty connections -- see page 6-13.

Arc Hoods: Check for cracks, breaks, or deep erosion. Arc hoods and arc chutes should be replaced if damaged or deeply eroded.

Coils: If a coil exhibits evidence of overheating (cracked, melted or burned insulation), it must be replaced. In that event, check for and correct over-voltage or under-voltage conditions, which can cause coil failure. Be sure to clean any residues of melted coil insulation from other parts of the device or replace such parts.

Batteries: Replace batteries periodically as specified in product manual or if a battery shows signs of electrolyte leakage. Use tools to handle batteries that have leaked electrolyte; most electrolytes are corrosive and can cause burns. Dispose of the old battery in accordance with instructions supplied with the new battery or as specified in the manual for the product.

Pilot Lights: Replace any burned out lamps or damaged lenses.

Devices:

ATTENTION: Use of other than factory recommended test equipment for solid state controls may result in damage to the control or test equipment or unintended actuation of the controlled equipment. Refer to the paragraph titled HIGH VOLTAGE TESTING.

Solid state devices require little more than a periodic visual inspection. Discolored, charred or burned components may indicate the need to replace the component or circuit board. Necessary replacements should be made only at the PC board or plug-in component level. Printed circuit boards should be inspected

to determine whether they are properly seated in the edge board connectors. Board locking tabs should also be in place. Solid state devices must also be protected from contamination, and cooling provisions must be maintained -- refer to the paragraphs titled CONTAMINATION and COOLING DEVICES on previous pages. Solvents should not be used on printed circuit boards.

High Voltage Testing: High voltage insulation resistance (IR) and dielectric withstanding voltage (DWV) tests should not be used to check solid state control equipment. When measuring IR or DWV of electrical equipment such as transformers or motors, any solid state device used for control or monitoring must be disconnected before performing the test. Even though no damage is readily apparent after an IR or DWV test, the solid state devices are degraded, and repeated application of high voltage can lead to failure.

Locking and Interlocking Devices: Check these devices for proper working condition and capability of performing their intended functions. Make any necessary replacements only with the correct renewal parts or kits. Adjust or repair only in accordance with the manufacturer's instructions.

Maintenance After a Fault Condition: Opening of the short circuit protective device (such as fuses or circuit breakers) in a properly coordinated motor branch circuit is an indication of a fault condition in excess of operating overload. Such conditions can cause damage to control equipment. Before restoring power, the fault condition must be corrected and any necessary repairs or replacements must be made to restore the control equipment to good working order. Refer to **NEMA Standards Publication No. ICS-2. Part ICS2-302** for procedures.

Be sure to maintain the correct fuse sizes, as over time incorrect fuses are often used and not corrected. Label all fuse holders with the proper size fuses to be used, and check visually to be sure that the correct sizes are used.

Replacements: Use only replacement parts and devices recommended by the manufacturer to maintain the integrity of the equipment. Make sure the parts are properly matched to the model, series end revision level of the equipment.

Final Check Out: After maintenance or repair of industrial controls, always test the control system for proper functioning under controlled conditions that avoid hazards in the event of a control malfunction. For additional information, refer to **NEMA ICS 1.3, PREVENTIVE MAINTENANCE OF INDUSTRIAL CONTROL AND SYSTEMS EQUIPMENT**, published by the **National Electrical Manufacturers Association**, and **NFPA70B, ELECTRICAL EQUIPMENT MAINTENANCE**, published by the **National Fire Protection Association**.

Identification: Proper maintenance requires complete identification of wires and components, and an accurate circuit diagram. Maintain a clean, orderly cabinet with coded wire colors and numbered wire markers. Maintain up-to-date schematic drawings.

Maintenance of Remote Input/Output (I/O) Devices see also page 6-13

Check limit switches for loose mountings, loose wires, loose arms, etc.; check limit switches for proper tripping. Check the position of proximity switches for proper actuation. The lenses of photoelectric switches require periodic cleaning with a soft dry cloth, and reflective devices used in conjunction with photoelectric switches also require periodic cleaning. Do not use solvents or cleaning agents on the lenses or reflectors. Replace any damaged lenses and reflectors.

Check solenoid valves for overheating or chattering. The armature may be misaligned or the contact carrier not free; replace as needed. Also check for proper voltage.

Clean and check for loose or broken solenoid covers or terminal connections, and for damaged or broken conduit.

Maintenance of Container Heating see also pages 6-14 and 3-15

Several basic problems combine to make container heating systems more difficult to maintain. First, the high sheath temperatures of the elements and at the terminal connections adversely affect reliability. Purchase only elements with alloy steel sheathing selected for high-temperature properties. Regularly check for corrosion of the heating elements.

Second, the terminal connections are small and difficult to make properly, and they must operate at high temperatures. Use nickel or nickel-clad copper wires and make the terminal connections very carefully. Regularly check the connections for tightness.

Third, because the container must move thousands and thousands of times each year, the wires must also move and flex. Use extra flexible, over-sized wires for the power leads, and replace the thermocouple wires often as it is relatively inexpensive.

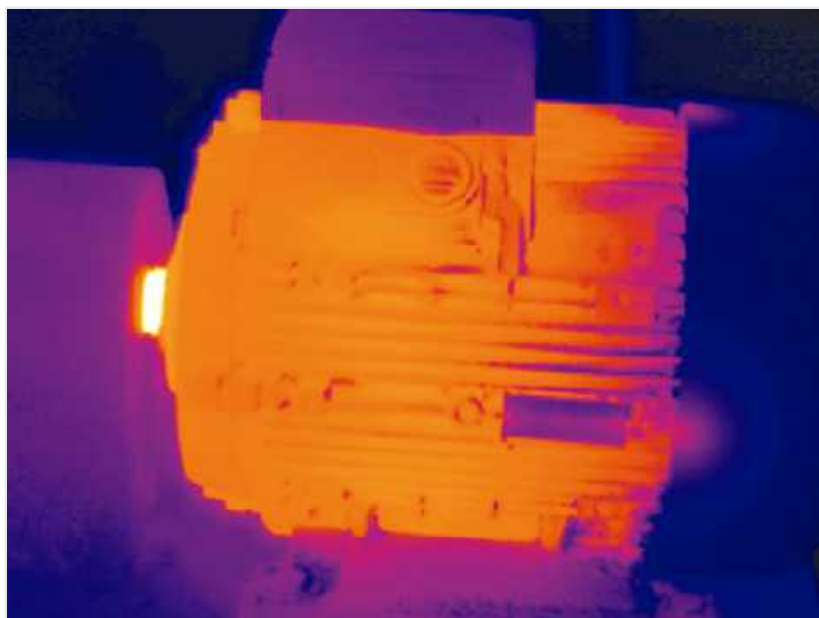
Finally, maintenance and calibration of temperature control instruments is difficult and is usually best contracted to firms which specialize in instrument repair and maintenance.

Maintenance of Electric Motors see also page 6-14

Clean and lubricate motors annually. If the windings become coated with oil and dirt they will run hotter, leading to premature motor failure. Likewise, clogged openings in the motor frame may result in the loss of effective cooling. Check the motor windings with a megohmmeter annually. Also check and record the no-load amps of each motor.



Figure 6-8: Electric motor, same motor seen with infrared shows overheating due to windings.



Check the condition and alignment of pump-motor couplings annually and lubricate them, according to manufacturer's recommendations and plant service history.

The following information on electric motor maintenance and failure analysis is taken from presentations by Phil Dibb at AEC Extrusion Press Maintenance Seminars in 1999:

Motor failure studies indicate that the most common causes of motor failures are mechanical:

- An IEEE survey covering motors 250 HP and greater indicated bearings as the cause of 44% of failures and windings 25%.
- Petrochemical industry statistics for all motors show that mechanical causes account for 75% of failures.
- A Norwegian study of motors 10 to 1000 HP showed that bearings, rotors, and shafts account for 75% of failures and stators less than 20%.

The principal causes of electrical failures in motors are:

- Restricted ventilation (cooling air)
- Overloading
- Frequent starting (larger motors)
- Protection devices not working or misapplied (over-current devices do not detect overheating)
- Terminal voltage variations
- Single phasing
- Improper application (wrong motor for the job)
- Insulation contamination (moisture or chemicals)
- Poor connections

To maintain adequate motor ventilation:

- Keep the winding air passages clear of dirt or oil:
- Brush and vacuum built-up dirt (preferred).
- Blow out dirt with compressed air (caution).
- Dry wipe and solvent clean.
- Clean or change air filters regularly or when plugged.
- Make sure air intakes and outlets are unrestricted.
- Have adequate air inlet and exhaust space.

Train operators to “respect” large motors when starting:

- Understand the consequences of too-frequent starting:
- Cost to rewind the motor
- Downtime for repairs or replacement
- Install timers to protect against frequent starting.
- The larger the motor, the more critical it is to prevent frequent starting.
- IEC starters have defined limits.

Verify that the motor protection is adequate:

- Proper overload relays:
- Installed on all three phases (not two)
- Sized to trip at proper current

- Insure that proper overloads are installed after a motor is changed.
- Provide over-temperature protection for critical motors.
- Microprocessor-type with adjustable settings (RTD's in motor required)

Verify that the protection works:

- Current and trip test overloads periodically.
- Function test over-temperature protection (use a decade box).
- Test other protective devices (large motors): locked rotor, phase balance, phase loss, voltage, etc.
- Some 3-phase microprocessor types are difficult to field test.

Allowable voltage and frequency variations (per NEMA MG 1-20.4S): successful rated load operation occurs if:

- At rated frequency the voltage is $\pm 10\%$
- At rated voltage the frequency is $\pm 5\%$
- With frequency $< \pm 5\%$ combined is $\pm 10\%$

Verify that the motor terminal voltage is adequate:

- Should not be more than 10% above or below rated.
- Insure that the voltage is balanced: 3.5% voltage imbalance can cause a 25% temperature rise (16 volts at 460).
- For long lead wires, motor voltage will be lower than starter voltage:
- Check voltage at "full" motor load.
- Be sure the measuring instrument is accurate.
- Check the conductor size and calculate the voltage drop.
- "Too high" voltage can cause unwanted heating --- it does not necessarily mean lower current.

Mechanical failure causes:

- Manufacturing defects (not controllable by the user)
- Shipping
- Storage
- Application and environment
- Installation
- Maintenance --- bearings are the number 1 problem

Bearing life:

- The rated life L-10 of a bearing is limited to fatigue endurance life only and does not consider factors such as lubrication, temperature, contamination, etc.
- Most bearings fail for reasons other than material fatigue --- primarily due to lubrication.

Bearing lubrication:

- Anti-friction bearings require lubrication --- there is no such thing as a true anti-friction bearing.
- Lubrication dramatically affects bearing life.
- Bearing life is only as good as lubricant life.

Grease Lubrication:

- Lubricating greases are thickened mineral or synthetic oils.
- Oil is removed from the grease during operation.
- The oil that is picked up by the bearing is gradually broken down by oxidation or lost by evaporation.
- Bleeding of the grease must take place to continue to supply a small quantity of oil,
- The supply of oil must keep up with the demand.
- In time the grease will oxidize or the oil in the grease near rotating parts may be depleted.
- Operating temperature affects the life of the grease
- A temperature rise of 15 – 20oF (8 – 11oC) can double the rate of oxidation.
- Use the correct grease for the application.
- High-temperature synthetic grease in most cases is not suitable for relatively low-temperature applications.
- The best type of lubricant is one which remains in close contact with bearing surfaces that require lubrication.
- Motor manufacturers pack their bearings with polyurea-based grease (example: Chevron SRI 2).
- Mixing of grease types is not recommended.
- Avoid mixing greases with different soap bases (for example, polyurea and lithium)

Re-lubrication:

- Bearings require periodic re-lubrication to achieve their service life.
- Re-lubrication interval depends on many factors:
- Bearing type and size
- Speed

- Operating temperature
- Grease type
- Operating environment
- Re-lubrication interval is defined as the time period, at the end of which 99% of the bearings are still reliably lubricated.
- Re-lubrication intervals are specified by the motor manufacturer based on the bearing manufacturer's recommendations.
- Re-lubrication must be with the correct volume of grease.
- The proper volume depends on the bearing size.
- Too much grease can be more damaging than too little.
- Determine the required grease volume listed in the equipment instruction manual, or use the following formula:

$$G = 0.114 DB$$

where:

G = grease quantity (ounces)

D = bearing outside diameter (inches)

B = bearing width (inches)

Periodic visual inspections of motors:

- Remove covers and check for:
- Plugged air passages between end turns
- Oil or grease on windings (indicates lubrication problems)
- Overheating of random windings or rotor

Visual inspections --- look for:

- Portions of winding discolored: indicates single-phasing or unbalanced voltage
- All windings discolored: indicates overload condition
- Rotor discolored or rotor fan deformed: indicates locked rotor damage, frequent starting, or long start time.
- Cracked winding varnish: indicates advanced age or overheating of insulation.
- Evidence of winding movement
- Shock loading, or poor end-turn bracing

- Spot discoloration at connections: indicates poor factory lead connections.
- Spot discoloration or melting on winding: indicates shorted turn insulation.
- Discolored terminal box connections: indicates overheating due to poor connections (will eventually fail), possibly inadequate crimp, lug, or bolt connection. Note: The following paper provides useful information about the maintenance of extrusion plant electrical equipment and controls. It was first presented by the author at the AEC Press Maintenance Seminar, in , November, 1991, and is reprinted here with his permission.

Extrusion Press Electrical Systems

by David Turnipseed

INTRODUCTION: System History

Ten years ago, when "automation" was discussed the term meant using sophisticated systems such as DC drives to replace motors with Powerstats or SCR rectifiers, and to sequence equipment functions with massive relay panels. The more relays, the more automated you were. During this time, microprocessor-based instruments, programmable controllers, and other electronics were on the market. However, most small companies were reluctant to take the step of implementing these new electronics due to the fear of the unknown. Lack of technical support, cost of repairs, and reliability of the product were all drawbacks.

During the past ten years, some companies have taken the step towards automation at enormous speed, whereas some have been slower and more cautious. No matter when the first steps were taken, any company which introduced the more sophisticated equipment has been forced to have more technical personnel or to provide more training for existing personnel, purchase additional trouble shooting aids, purchase expensive critical spare parts, and test the reliability of manufacturers' products in the plant environment. In addition, the companies have the responsibility of ensuring that maintenance personnel have kept up with ongoing changes so as not to be left in a bind should someone decide to leave.

Today, we talk of automation as installing programmable controllers, personal computers on the shop floor, infrared light beams, and AC inverters -- equipment that is microprocessor-based, intelligent, smart, operator-interfaced, etc. The definition of automation has changed dramatically during the last ten years, and, consequently, so has the way we operate to accommodate these changes.

Programmable Logic Controllers (PLC's)

General Information about PLC's. Programmable logic controllers come in all shapes and sizes -- cheap, expensive, large I/O capacity, small I/O capacity, power instruction sets, only relay logic instructions, communications ability, etc.

If your company is considering installing a PLC for new equipment, or upgrading existing equipment, choose the type that best fits the application and provides for future growth. Also, consider the economic reliability of the product, area support, and the experience of your current personnel. Unlike computers, you can purchase PLC's which have the capability to go for years without becoming obsolete if you have planned for future enhancements. Most important, make sure your plans are thorough in implementing a PLC system so that you will not have to add hardware.

Justification. How can you justify installing a PLC on a system that already works? Troubleshooting and flexibility are the two largest factors you can use in justifying this purchase. PLC's can open up a whole new world in troubleshooting. When using a PLC for troubleshooting, the electrician can often diagnose and correct problems without using meters or any other tools. The user can observe the logic sequence of a machine operation and determine the correct action to take. The user can also systematically program the PLC to catch intermittent problems.

To increase the capacity of troubleshooting, the user can program diagnostics for the maintenance personnel or the machine operator. The limit to the diagnostic system is only the amount of creative programming the user can come up with to show the cause of problems. A full diagnostic system can be designed with add-on equipment which will tell personnel what the problems are and suggest possible solutions.

Diagnosing machine problems often causes a large portion of downtime. Users of a PLC can realize a payback in a relatively short period of time. The PLC can be a powerful tool if used to its fullest capacity.

Flexibility. Flexibility is another big justification for the use of PLC's over conventional systems. Machine operations can be changed without any tools other than a programming terminal and can be done in a minimum amount of time. Enhancements, modifications, and sequence corrections can be worked out ahead of time and sometimes implemented without stopping the process. Work that would normally take hours in a conventional electrical system by changing wires and adding components can be done in minutes at the programmer's terminal. Also, a good PLC can diagnose itself, its software, its own system problems, and can tell the programmer if there is a problem with the design of the logic sequence before the process is implemented.

Training. PLC training should not be construed as a complex undertaking. Parts of the procedure include are: understanding control logic, learning basic electrical skills, and, the most basic of all, memorizing symbols. There are many fields that are more complex than learning to use a PLC. Any maintenance personnel which must trouble-shoot process problems should at least learn to use this tool.

Automation. A base is necessary to have automation and to continue with automation. The base for any automated system is the PLC. If you are interested in obtaining information from the process, there must be a source from which to obtain this information.

The PLC Environment

Air. Most reputable PLC's are well suited for plant environments. However, for best reliability, they need to be treated as a computer. The cleaner the operating environment, the less problems will occur. Keep the surrounding air as dust-free as possible and within the manufacturer's temperature specifications. All PLC's should be mounted in enclosed panels with forced, filtered outside air. If the panel is located in a high-temperature environment, or is mounted in a panel with other controls that produce heat, it may be necessary to install air-cooling devices. Also, if the panel is located in areas where there are corrosive contaminants in the air, it is imperative to have a cooled air system, which will allow no outside air to enter. Make sure all PLC's, like any other electrical devices, are protected from moisture.

Power. Cleanliness of the power that feeds power supplies for PLC's is as important as the cleanliness of the environment. Power in manufacturing facilities has a number of contaminants -- induced harmonics, surges and transients, dips and spikes, etc. The PLC's power supply is well suited, but cannot always handle every voltage problem that may exist in a plant environment. The cleaner the power coming to the PLC, the less you have to rely on the PLC's power supply to filter out any unwanted trash. Give your PLC as much filtering and protection as possible, with constant voltage transformers and isolation devices to stabilize the input power signal. Voltage systems can cause unexplainable occurrences of intermittent problems, and also decrease the life of components in your system.

System Design. Maintaining a proper design on the PLC system's architecture, hardware, and software is as important as physical conditions. PLC's work best when their design is as efficient as possible. The PLC's hardware doesn't work well with timing problems, and software problems occur, resulting in improperly coordinated logic functions. Careful thought needs to go into designing or making system changes.

Good Cabling Techniques. PLC's communicate with other PLC's, remote racks, computers, and some I/O devices with low voltage signals. It is always necessary to use good cabling techniques to obtain a good working system. Signal cables should be shielded, with good grounding techniques. All connections, whether solder connections or terminations, need to be of good quality. Most manufacturers can provide adequate guidelines to follow. Any low voltage signal cable or low voltage wire should be located as far as possible from higher voltages wires and higher frequency wires, such as AC drives, to prevent noise induction. There are always cases where this is unavoidable. If this occurs, make sure signal cables do not run parallel to other wires.

Maintaining Electrical Systems

Panel Wiring. Wiring is the backbone of electrical systems. Wires in panels, conduits, and any other place should be protected as much as possible against physical damage, electrical overloads, and corrosive contaminants. Specifically, panel wires should be kept neat and organized with wire numbers on all wires to decrease time during troubleshooting. Panel wiring should be color-coded to standards to allow determination of voltage levels visually.

Prints and Documentation. An important part of maintaining an electrical system is keeping good updated electrical prints. Prints should be easily accessible and legible. Prints also should be kept up to date with proper information on the prints for the user. Documentation on electrical devices should also be kept safe in an area where they can be accessed. If a PLC is involved, software documentation and the back-up copy should always be kept updated with current changes in order to trouble shoot properly, or excessive downtime can result. PLC documentation software has become as plentiful as brands of PLC's over the years. Now, you can choose a documentation package to custom design the way you personally want to arrange your information.

Fusing. Fusing of electrical systems is an area where proper upkeep is often overlooked. Most of the time, electrical systems, especially after years of operation, contain fuses that have been improperly replaced with fuses that are the wrong type or size or both. Many times, fuses are replaced with the closest available size or type and then forgotten. This can be a very dangerous condition and shows up later with damaged equipment and possible injury to personnel. Fuses smaller than design cause nuisance stops, and larger fuses allow high currents above design, causing failure. To help minimize these conditions, all fuse holders should be properly labeled in panels so that visual checks can be made to maintain proper integrity. All maintenance personnel should be trained to have proper knowledge of fuses and fuse applications.

Terminal Strips. Terminal strips are often misused. Specific types of terminal strips are designed for specific type connections. Some are designed for wire lugs, some for single bare end wire, and others for multiple wires. When used improperly, loose connections can result in intermittent power interruptions, and heat build-up from arcing. Wire connections should be re-tightened on a routine basis with the proper torque applied.

Infrared Testing. Infrared testing is the most efficient way of checking for bad wire connections. With infrared testing, an infrared camera is used to show heat dissipation, visually and on a temperature scale. Anything that causes excess heat will show up, such as loose wires at terminals, and bad contacts. Once found, they can be easily corrected. This system has proven to be one of the most cost-saving preventive maintenance items of all. Generally, this procedure is more economical to be done by an outside service with trained technicians rather than purchasing the expensive equipment, unless you have a very large facility.

Power Supplies. Another check for potential process problems is periodically checking output levels of low voltage power supplies. These voltage levels will drift from time to time due to ambient temperature swings, input power fluctuations, and bad environmental conditions. Some field components are designed to operate at certain voltage threshold levels. If these devices are operating on the borderline between good and bad, intermittent shutdown can occur. If levels are too high, possible damage may result. The period at which power supplies should be calibrated should be determined by the quality of the power supply and the sensitivity of the devices which they control.

PLC's. PLC's are relative easy to maintain as long as you keep a good working environment -- dust free and cool.

I/O Devices. I/O devices are the largest cause of downtime in electrical systems, input devices more often than output devices. Checking these field devices should be done on a constant, routine basis. Mounting, alignment, and terminal connections all fail time after time if close attention is neglected. Limit switch arms work loose along with mounting bolts. Photo eyes become misaligned and dirty. Proximity switches become out of range. Input devices with electronics need to be calibrated periodically for drift. Mechanically driven transducers need to be checked for alignment and tight couplings. It is very important to protect all field devices from physical and heat damage. Most failures result from looseness or physical damage causing excessive cost and downtime.

Output devices also must be checked for looseness. As with any operating device, output devices should have a good ground integrity and surge suppressor to prevent transient spikes.

Instrumentation. Instrumentation ranges from electromechanical to microprocessor-based, to a combination of both. Electromechanical devices such as older process controllers or modern chart recorders need periodic inspection and lubrication of moving parts, and calibration. Most non-mechanical instrumentation only needs periodic calibration and good environmental conditions. All electronic instrumentation should be checked with accurate calibration monthly by a trained technician.

Container Heating

Container heating is a process critical to all types of extrusion. Many times the major concern is keeping a container hot enough to run properly, not making sure this part of the system is working efficiently, economically, and preserving the life of components.

SCR Control. By using on-off control with an across the line starter, the controller provides full power to the system for a period of time and then no power, which results in heat loss. Also, contactors, another source of wear, continually cycle, causing transients in power lines and arcing on contacts due to high resistive loads. SCR control provides only the amount of power necessary to stabilize the load without excess power usage. Also, no contactor is needed, which completely eliminates one potential problem and maintains cleaner power.

Single Zone vs. Multiple Zone. With single zone control, there is a very large lag in the system. By supplying the same amount of heat to the container while measuring the temperature from the center (the hottest spot), the controlling variable is satisfied, leaving the remaining sections cooler. Measuring the temperature from any other location could cause overheating in the center, resulting in annealing of some areas of the container. Multiple-zone control gives you the ability to produce a more uniform heated product by supplying power only to areas that lose the most heat.

Electrical Connections. Routine checking of connections between container heating elements and wires is very important. There is much heat transfer between elements and the wires. Loose connections only add more, resulting in seizing. Good nickel-plated connections should always be used to reduce seizing. Make sure that the wires feeding the elements contain good insulation to handle temperature rise. Wires should be oversized to prevent excessive heat built up.

Servo Systems

Servo systems are like any other electronic controlling system except much more sensitive because of extremely low voltage signals. Servo systems on hydraulic extrusion presses control large process variables with a low voltage controlling method. This results in an extremely low tolerance for noise and mis-calibration. Signals in a servo system that are off only a few millivolts can cause enormous process problems. Calibration should be checked as often as necessary to keep the system running properly. There are also other areas that contribute to hydraulic and mechanical malfunctions.

Motors

Motors are another type of electromechanical device, which are usually run without attention until there is a problem. Initially, when motors are installed, correct alignment should be performed. Some motor applications are forgiving of misalignment, depending on the type of coupling, and some are not. All motor couplings should be aligned as closely as possible to prevent excessive radial loads on the motor bearings. Alignment should be rechecked periodically.

Lubrication. Motor lubrication is essential to good bearing life, but be cautious -- always perform lubrication according to the manufacturer's recommendations. Too much lubrication can be worse than none at all. Most manufacturers recommend lubrication at intervals from six months up to two years.

Terminals. Motor terminals can cause excessive problems in the field. Once a lug becomes loose, arcing starts, causing a high resistance at the terminal and then heat build up. This, in turn, causes a voltage drop and causes the motor to draw higher amperage. The larger the motor, the more inspection of terminals will be needed.

Contactors. Terminals at contactors also have the same potential problems. Wires work loose at the lugs, causing the same problems. Connections should be tightened at least every six months. Contacts on starters should be checked at the same time. Contacts take abuse, specifically the ones that start large motors. A quick check across the starter's contacts with an ohmmeter can show if they are good or bad.

Overheating. Depending on the application, the motor stator wiring may get dirty and hot, resulting in insulation breakdown after extended periods of time. It may be necessary to send the motor out to be cleaned and dipped in a new varnish and re-baked. This is also a good time to install new bearings.

SUMMARY

As technology of operating equipment advances, so does the need for technical ability to perform jobs which were not previously required. The more automation that exists in a plant, the more electrical components there will be. The more electrical components there are, the more susceptible you are to problems. Therefore, it is imperative to maintain a good electrical preventive maintenance program.

**by David Turnipseed**

About the Author: David Turnipseed is a second-generation press maintenance man, the son of Eugene Turnipseed, retired Maintenance Superintendent of William L Bonnell Co., Carthage, Tennessee. After several years working in maintenance and engineering in Bonnell plants, David served as Maintenance Manager for Indalex at Gainesville, Georgia, and with Belco Industries. He now is owner/Consultant at Aluminum Extrusion Marketplace. dturnipseed@aemarketplace.com

TIPS FOR SUCCESSFUL ELECTRICAL TROUBLE SHOOTING OF EXTRUSION EQUIPMENT

Tip #1 - Know the Process

Provide a written sequence of operation for each process. If one cannot be obtained from the OEM, write one in house. Understanding the operation of equipment processes is one of the most important fundamentals of troubleshooting and operation. Once the sequence of operation is understood, the technician as well as the operator can analyze system problems much faster. Most often, the operator is an essential tool for the technician to have and use. Having a complete understanding of the process can be accomplished without being an expert in the technical areas. Performing in-house training classes for the technical employees and the operators will be the most valuable time spent.

Tip #2 - Maintain System Documentation

Maintain **accurate** and **up-to-date electrical drawings** and **PLC ladder logic** printouts for all systems. Store updated drawings and printouts at the process equipment for quick access. No matter how good the documentation is, it is worthless without someone having access when needed. Also, even if the prints or documentation are accessible, the material must be up to date or it can actually hinder the process of diagnosing problems. Add to drawings any information that may be helpful to the electrician and comments to the documentation for clarification. There is no advantage to complicating or encrypting the

documentation, unless you want to keep the cycle of dependency on certain individuals to maintain their security. At one time systems were very limited relating to the amount of information that could be stored and processed on screens and printouts, but now the only limitation is ourselves.

Tip #3 - Internet Access

Internet access to readily available product information is one of the most valuable and underutilized resource tools attainable today. In the past, access to product manuals and documentation could take days but now is available in seconds. The ability to download product specifications and procedures is a great benefit when diagnosing equipment problems. So many times in our industry, the luxury to have internet access to unlimited available resources is reserved for higher status employees for a form of entertainment, rather than of benefit where it can be productive.

Tip #4 - Internet e-mail

With so many products and equipment purchases being made worldwide, the ability to communicate via **e-mail** is a necessity for obtaining assistance from outside resources quickly. With internet e-mail, answers can be available sooner than ever if that option is available to the technician.

Tip #5 – Provide & Maintain Proper Tools

Properly maintained electrical instruments are essential tools when performing electrical diagnosis. These tools are generally more delicate than mechanical tools with the exception of mechanical instruments. In order to have and maintain the integrity of these instruments someone must be in charge of providing and maintaining proper electrical tools. Today, tools of this nature can range from a basic analog VOM meter to laptop computers. Very often the following problems occur: someone has stolen what is needed, the instrument is damaged and unusable, or worst case, it cannot be located for use when needed. These types of tools have to be managed in order for them to be helpful. Many times employees who have the responsibility for diagnosing electrical problems, especially on the night shift, have not been trained or do not have access to the necessary tools, but are expected to diagnose problems in the same amount of time.

Tip #6 – Equipment Diagnostics

The definition of a Diagnostic Information System should be “Providing useful information to the operator and maintenance technician in human language to make quick and accurate problem-solving decisions.” The technology of computerized software diagnostic systems is the one single area that has advanced the most and has become the most underutilized product that is built into or added to control systems. The technological advancement without the increase in cost of memory and processing power, along with the availability of high level software, have provided an overwhelming opportunity to build an interface link between the human and machine world. The underutilized areas are:

a) **Outside Resources** – Many system control companies build standardized and tailored programs that provide time saving diagnostic information that is guaranteed to provide a quick return on the initial investment. The main reason for the lack of utilization of outside resources is the belief that these advanced systems can be engineered, implemented and maintained in-house while at the same time, educating the technical staff and improving the process all at a lower investment cost. A great concept, but with the cost of outside training and the cost of excessive downtime from not having the diagnostic systems in place, the financial objective is never realized. Once the method of trying to realize this cost saving plan has been established, now the waiting begins for the day to come for this abundant amount of time required to implement the same system. Another scenario may be to stumble on that seasoned expert that can be acquired to perform this task free of charge. Another limitation is “Who really wants to pay money for some intangible product like programming or any other service, whereas, our own people should have the talent and expertise from birth or from formal training paid for by a previous employer.” The technology is around but not the common sense of economics to take advantage of it.

One company that has made great advancements within the field of software diagnostics of the extrusion process is OAsys, a division of The Oilgear Company. Their experience with the extrusion industry has bred some of the most advanced and productive software systems in the industry.

b) **In-house Implementation with the Use of Offsite or In-house Training** – As mentioned previously, outside or contracted in-house training by outside vendors is very expensive and requires much of the employees’ valuable time needed to keep the equipment in operation. If the decision is made to send someone out for formal training, the theory is often to train one person and let that person train others to lower the expenses. This can be a successful plan as long as the person to be trained can be trusted to stay around once he or she has that new certificate added to their own resume and as long as it does not breed the infamous job security position with no motivation to share the knowledge with others. Continuous training is always important to be successful, but it should be done with some tools already in place that allow for time and resources to produce the initial objective.

Tip #7 – Implementing and Maintaining Procedures

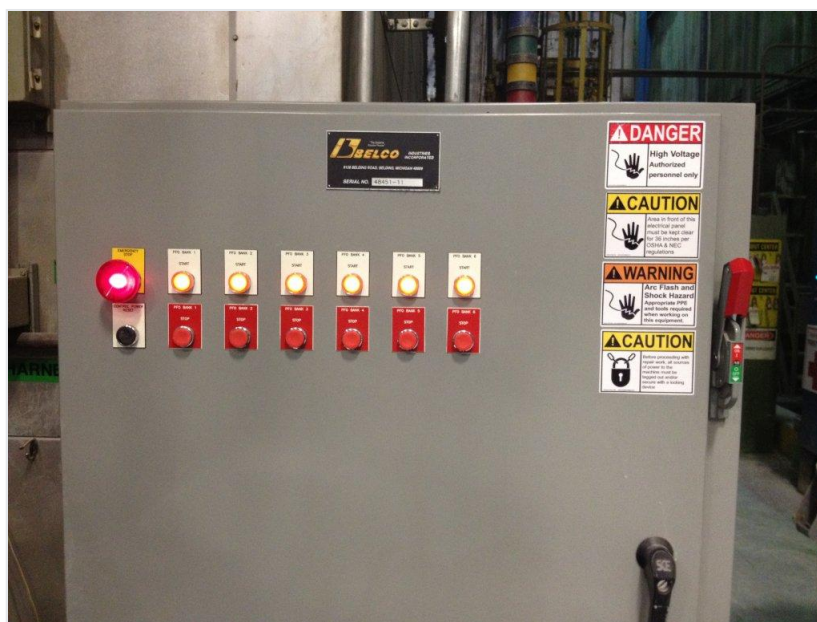
Written Procedures add discipline to maintaining the integrity and consistency of equipment processes. Establishing written procedures such as calibration and preventative maintenance programs will ensure a day-to-day consistency of the process control and the quality of the product. Any part of any process that requires attention should have a procedure with training that can be followed and documented to certify correct machine operation.

by David Turnipseed

Following are a few selected images and recommendations from a presentation by David Turnipseed of Aluminum Extrusion Marketplace about extrusion plant safety, from the AEC Press Maintenance Workshop, Atlanta, April 17, 2018. Contact: dturipseed@aemarketplace.com

“E-Stop” Emergency Stop Buttons

Emergency stop buttons can make the difference between life and death as well as the prevention of damage to equipment.



Layout - The layout of E-Stop buttons in strategic locations is vital for proper safety.

Identification - Personnel must know where the E-Stop buttons are and be able to readily identify and separate them from other buttons.

What E-Stop Buttons should look like:

- Red Mushroom Head

- Illuminated
- Yellow Label Background

DO NOT assume that purchased equipment contains all necessary E-Stop buttons for your environment.

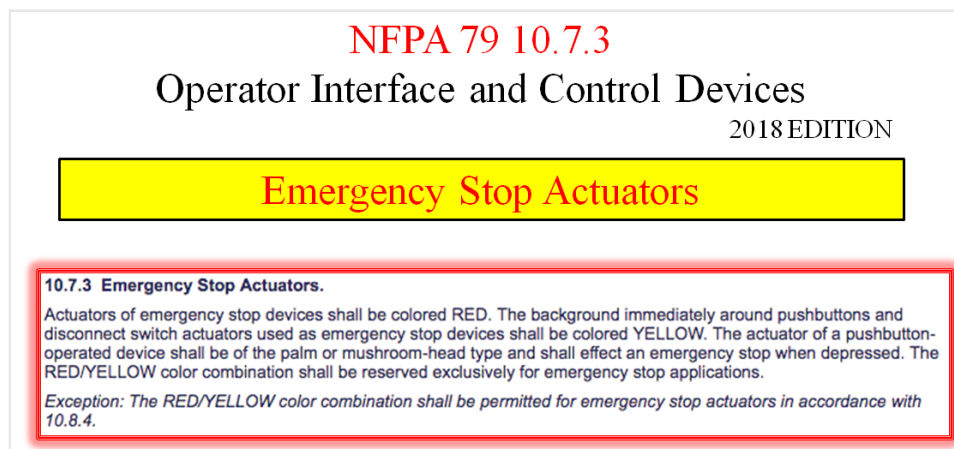
Personnel should be trained and comfortable when using the E-STOP buttons in their area but they should also understand that **E-STOP Buttons are not normally intended to be a way to turn control power off and shut down systems.**

Many systems require a systematic approach to the power-down sequence to prevent component damage.

Examples: (Why E-Stop Buttons Are Only for Emergency)

- Trapping excess heat in areas that could damage components.
- Trapping hydraulic fluids between components resulting in extreme pressure spikes.
- Opening multiple high inductive load contactors at the same time, producing excessive voltage spikes in control systems and possibly damaging electric/electronic components.

Further Reference: NFPA 79 Electrical Standard for Industrial Machinery (check for updates)

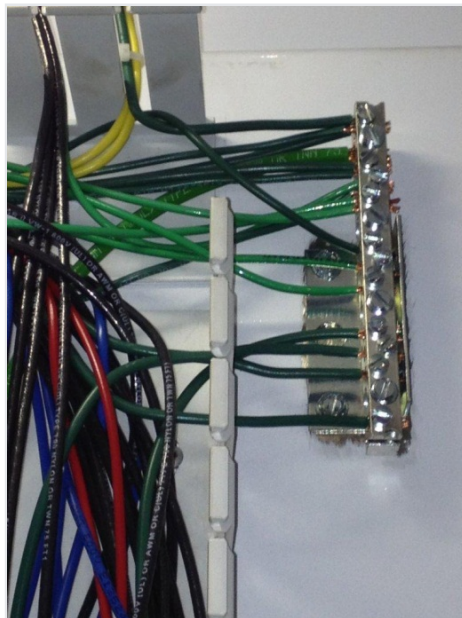


Grounding

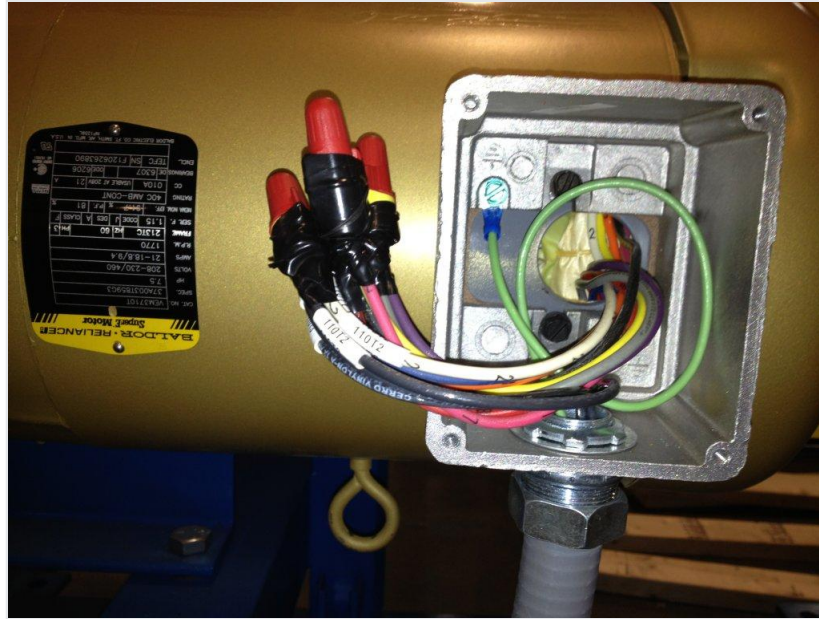
How many amps does it take cause death? 100 milliamps or 1/10th Amp

Current level (Milliamperes)	Probable Effect on Human Body
1 mA	Perception level. Slight tingling sensation. Still dangerous under certain conditions .
5mA	Slight shock felt; not painful but disturbing. Average individual can let go. However, strong involuntary reactions to shocks in this range may lead to injuries.
6mA - 16mA	Painful shock, begin to lose muscular control. Commonly referred to as the freezing current or "let-go" range.
17mA - 99mA	Extreme pain, respiratory arrest, severe muscular contractions . Individual cannot let go. Death is possible .
100mA - 2000mA	Ventricular fibrillation (uneven, uncoordinated pumping of the heart.) Muscular contraction and nerve damage begins to occur. Death is likely .
> 2,000mA	Cardiac arrest, internal organ damage, and severe burns. Death is probable.

OSHA TABLE http://www.osha.gov/SLTC/etools/construction/electrical_incidents/eleccurrent.html



Panel Grounding



Motor Grounding

What happens if a motor is isolated from ground and there is current leakage to the motor housing?

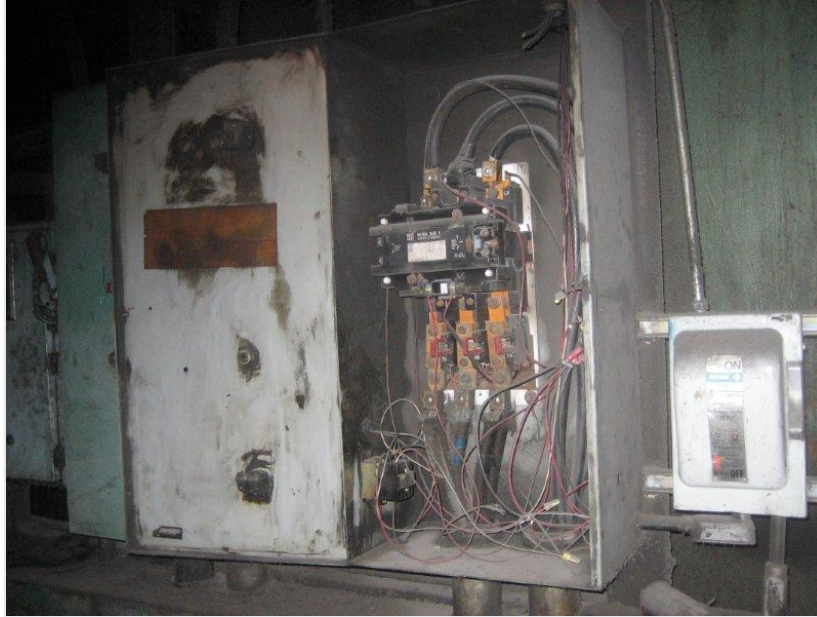
Follow Local Grounding Codes and NEC Article 250

Exposure

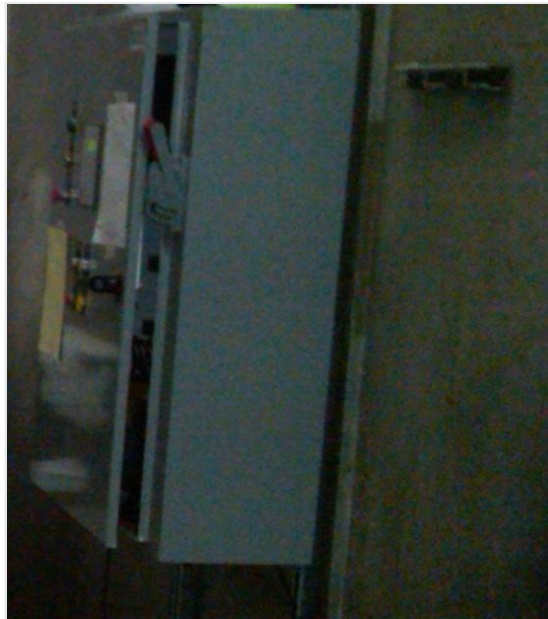
Examples of Direct Exposure Hazards: (actual plant photos)



Missing Covers



Open Panel Boxes



Open Panel Doors

Examples of Indirect Exposure Hazards



Unprotected Switchgear



Protected Switchgear with Guard Rail

AUDIT your equipment for direct or indirect exposure to personnel and environmental conditions.

- Check for missing covers, doors, etc..
- Look for areas that liquids and contaminants can enter.

- Set up inspection to maintain.

Enclosure Environment

While electrical panel enclosures are one of the best methods for protecting your electrical components they can also be one of the best methods for trapping their worst enemy, HEAT! Make sure your electrical enclosures have a way to rid themselves of heat being generated inside.

Protect against: Heat

- At a minimum provide a vent for heat to naturally escape on the side near the top of the enclosure since heat rises.
- Provide a vent (preferably filtered) on the side near the bottom for the coolest air near the ground to enter.
- For more air exchanges, add a powered fan.

REMEMBER: Keep air filters clean or changed.

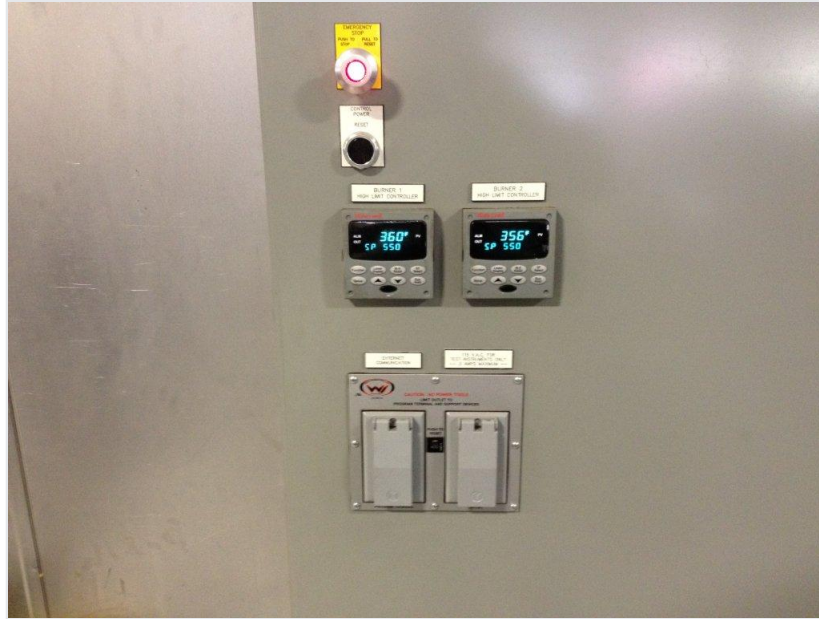
Protect against: Heat and Humidity: Air Condition

Reduce heat generation in panel if possible. Install NEMA 12 transformers outside of the enclosure if the environment allows.

Troubleshooting & Documentation

To simplify troubleshooting, proper labeling of components is needed, along with basic system information.

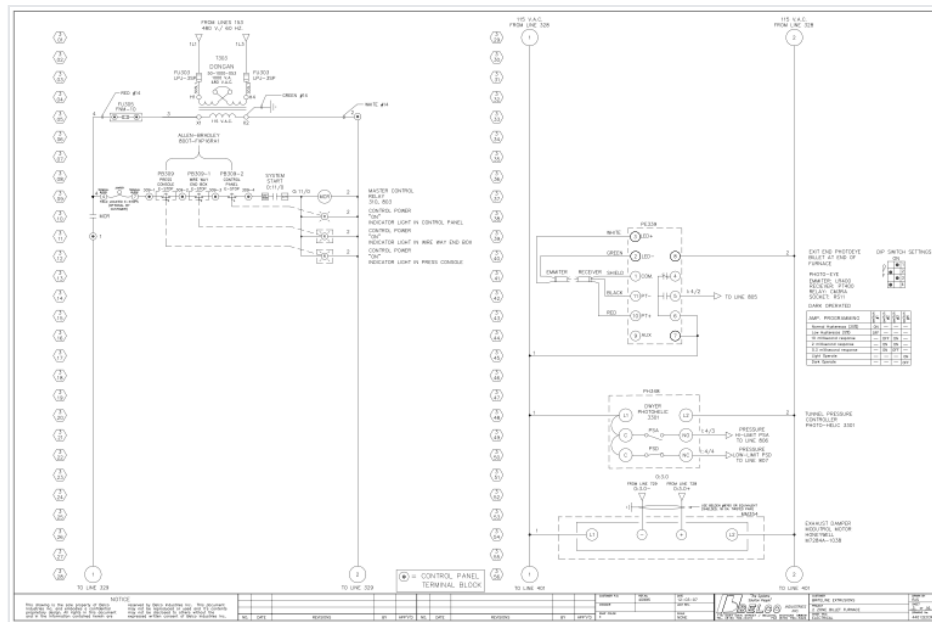
Component Labeling



External



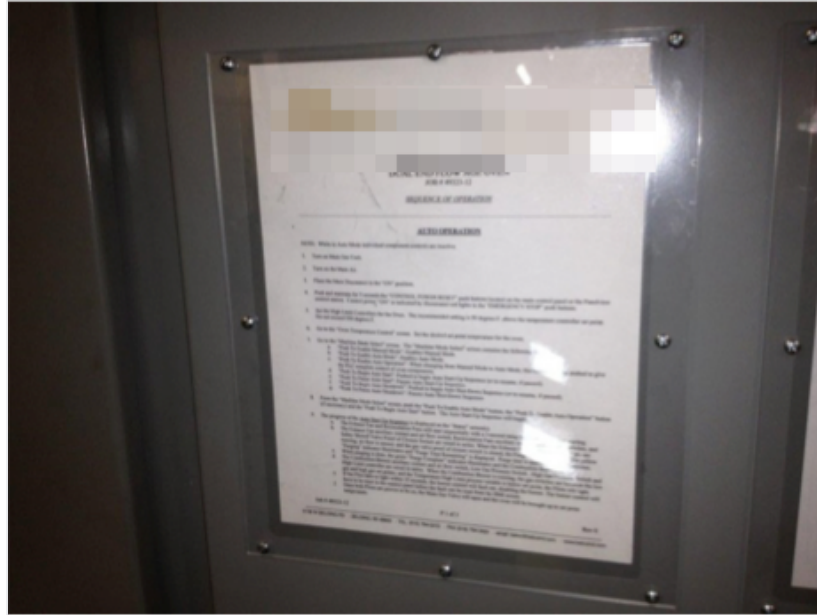
Internal



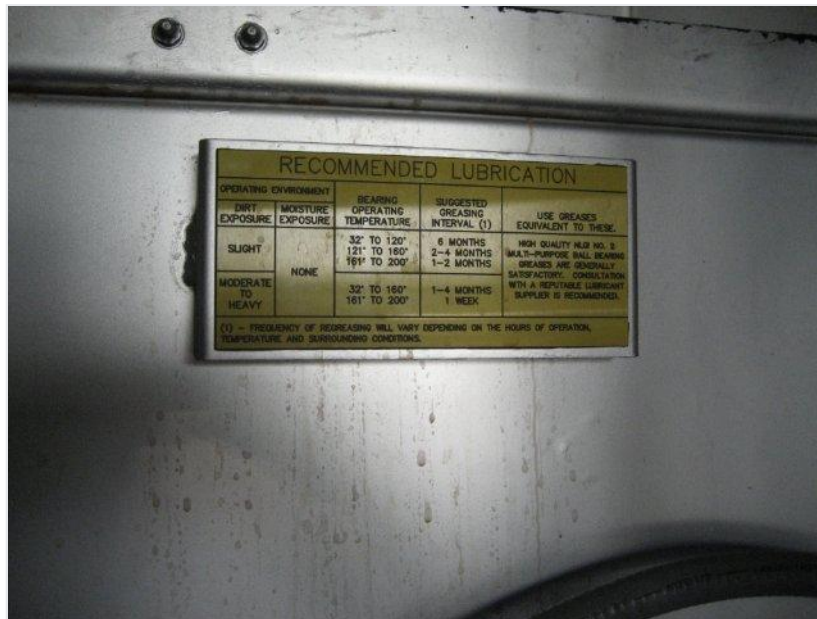
Electrical Schematics



Electrical Schematics are an excellent source for troubleshooting problems... If they are **updated** and **readily** available.



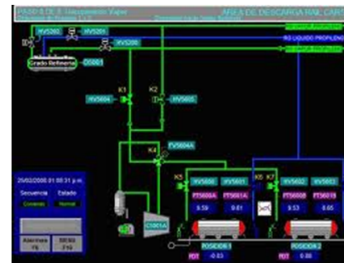
Start up and Shut Down Procedures



Maintenance Info Placard.

Operating procedures, maintenance info, etc., are a great source of information when troubleshooting.

Graphical displays are a powerful tool for displaying faults and showing the physical location



System Inputs

[illegible][illegible]

Troubleshooting - Diagnostics Fault Screens

Machine
Sequence

Loader Interlocks Screens							
Loader No.1 UP Interlocks				Loader No.2 UP Interlocks			
Loader at UP Limit				Loader at UP Limit			
Idr1 Fil Check Fault Msg.				Idr2 Fil Check Fault Msg.			
Fan Not at Retara Position				Fan Not at Retara Position			
Fan Signal Loader: DOWN ELS				Fan Signal Loader: DOWN ELS			
Container Not Closed Limit				Container Not Closed Limit			
Space Loader Interlock				Space Loader Interlock			
Air Pressure Off				Air Pressure Off			
Press Inhibit ON				Press Inhibit ON			
Loader Down Motion				Loader Down Motion			
Loader No.1 DOWN Interlocks				Loader No.2 DOWN Interlocks			
Loader at DOWN Limit				Loader at DOWN Limit			
Idr1 Fil Check Fault Msg.				Idr2 Fil Check Fault Msg.			
Space Loader Interlock				Space Loader Interlock			
Space Loader Interlock				Space Loader Interlock			
Press Inhibit ON				Press Inhibit ON			
Loader Up Motion				Loader Up Motion			
Main Menu Screen				Press Interlock Screens			
Motor Control Screen				Press Interlock Screens			
Press Setup Preview				Press Interlock Screens			
Press Setup Active				Press Interlock Screens			
Cycle Setup Screen				Press Interlock Screens			
Press Run Screen				Press Interlock Screens			
FLC I/O Screens				Press Interlock Screens			