ROTARY KILNS AND DRYERS

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1.0 SCOPE

This data sheet covers:

- rotary kilns (refractory-lined) used in the cement, lime, activated carbon, metal ore, and similar processes. Rotary dryers (not refractory-lined) used to dry such material as stone, wood chips, grain, sodium chloride, and ammonium nitrate prills.
- vertical kilns and vertical annular shaft kilns used for lime production.

Rotary dryers have burner systems and safety controls similar to rotary kilns. Many aspects of their steel shells, their mechanical and electrical drive and rotating components are also similar. Some kilns used for baking activated carbon have a stationary outer shell and a rotating inner tube with multiple burner fuel firing in between the shell and tube. Dryers operating below 400°F (205°C) may be indirectly heated using steam coils, air heat exchangers, or electrical resistance heaters, or directly heated using boiler flue gases. (See Data Sheet 6-9, *Industrial Ovens and Dryers*.)

Dryers processing combustible products have an inherent fire and explosion hazard not only with the combustible product, but also with the release of flammable gases, vapors, and dusts during material processing.

FM prefers the use of FM Approved (see Appendix A for defintion) equipment and devices such as fuel safety shutoff valves, supervisory switches, and combustion safeguards etc. Use these when available and suitable for the application.

Because of the size and arrangement of many of the installations, Approved equipment may not be available to meet specific installations or operating conditions. In these cases, select equipment from a reliable manufacturer with proven, satisfactory field experience.

1.1 Changes

July 2023. Interim revision. Minor editorial changes were made.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Introduction

The recommendations in this data sheet apply to rotary kilns, including cement kilns and lime kilns. Some recommendations do not apply to all kilns and dryers.

2.2 Equipment and Processes

2.2.1 Combustion Safety Controls and Equipment

2.2.1.1 Purge Permissives and Fan Interlocks

2.2.1.1.1 Provide a mandatory preventilation period to purge the kiln, the components of the exhaust gas system, and any horizontal ductwork leading to the stack. A repurge is not needed if the kiln temperature is above 1400°F (760°C). Make sure the purge:

- consists of at least five volume changes of fresh air for a continuous period. The purge time is calculated based on the airflow rate and volume of the system.
- provides airflow rate of at least 25% of that required for firing at maximum output. (It is not necessary to measure airflow for this purpose; 25% damper opening or 25% fan speed is all that is needed.)

In addition, ensure that the purge time is programmed into the controller and can not be changed by an operator. On older systems, verify that the purge time setting has not been reduced.

2.2.1.1.2 Provide interlocks to satisfy the following purge permissives before allowing the purge timer to start:

1. For oils and gaseous fuels, at least one main burner and igniter safety shutoff valve is closed if over 150,000 Btuh.
2. All required dampers are open to the purge position as applicable. (Interlock not necessary with manual burner operation.)

3. All fans required for purging including the induced draft fans, primary air or combustion fan, cooling fans, and preheater fans are running by means of airflow/pressure sensors/switches or shaft rotation switches. Use devices that are not subject to mechanical binding if subjected to a harsh environment. Also, electrically interlock the motors to prove motors are running.
4. If any permissive interlock is lost during the purge cycle, the purge must be restarted.

2.2.1.1.3 Provide interlocks to ensure that stoppage of an induced draft fan or other required fans (primary and secondary air fans) shuts down any fan following it in the order of actuation (except for needed cooling fans), and shuts off and locks out all fuel and ignition systems. If the kiln main baghouse I.D. fan stops, the kiln I.D. fan should stop. This should stop the firing of the kiln and precalciner, stop the feed and reduce cooling airflow.

2.2.1.2 Igniters

2.2.1.2.1 Interlock purge with the ignition cycle so that the ignition cycle can begin only after purge is complete.

2.2.1.2.2 Provide an additional minimum airflow interlock set at 25% of the full load mass airflow if the purge airflow rate exceeds 25% of the full load mass airflow. The additional interlock allows the airflow to be reduced to a minimum level for fuel light-off if the purge flow is higher than this. All fan interlocks must be satisfied before and during the ignition period.

2.2.1.2.3 Provide igniters that can promptly ignite the main burner at startup. Solid fuels such as pulverized coal can be ignited by the warmup burner. On older kilns where the warmup burner is ignited manually, do not allow the fuel to enter the combustion chamber more than approximately 10 seconds if it does not ignite. Allow at least one minute between attempts to lightoff and assure airflow is proper for lightoff. Igniters might be impractical on precalciners burners that do not have a detectable flame. Some burner designs may require a low fire start interlock to help ensure an optimum fuel-air mix near the pilot flame. Ignition energy requirements will vary, depending upon the location of igniter with respect to the main burner, main burner fuel input, and the firing conditions for which igniter operation is required, i.e., interrupted, intermittent, or continuous operation. Refer to Data Sheet 6-4 *Oil- and Gas-Fired Single-Burner Boilers*.

2.2.1.2.4 Preferably use an interrupted pilot that deenergizes when the main flame trial-for-ignition period is over. If an intermittent pilot is used, provide separate flame supervision. If a Class 1 igniter is used (ignition energy is at least 10% of the main fuel input), it is only necessary to supervise the pilot flame.

2.2.1.2.5 Install igniters and flame sensing element(s) securely so that the position of each with respect to the main flame will not change. Provide observation ports so that these positions can be easily observed when igniter and/or main burner are firing. These units should be readily accessible for inspection and cleaning.

2.2.1.2.6 Provide an interlock to prove automatic retractable igniters are fully inserted before the ignition cycle can proceed.

2.2.1.2.7 All fuel interlocks must be satisfied before the ignition cycle can proceed.

2.2.1.3 Flame Supervision

2.2.1.3.1 Provide combustion safeguards and flame scanners to supervise the pilot and main burner flames, and to provide an acceptable sequence of operation during purge, ignition, firing and shutdown. Arrange the combustion safeguard to shut off all fuel supplies and ignition sources whenever any interlock is not satisfied. Flame scanners can be bypassed when the kiln operating temperature is stabilized above 1400°F (760°C); provide an interlock to prohibit bypassing below this temperature and to activate scanners if the temperature drops blow this value. Poor combustion is not always recognized by a flame scanner; operators must be relied upon to verify proper combustion. Use optical (infrared) pyrometer/color TV cameras in lieu of flame scanners where harsh conditions such as a dusty environment make the use of flame scanners impractical. Air can be used for cooling scanners and can help to keep scanner cells clear of dust.

2.2.1.3.2 For manual operations, follow procedures to ensure proper purge and other conditions necessary for a successful lightoff.

2.2.1.3.3 Use oxygen, CO, CO_2 and combustibles analyzers as an operator aid to help determine if combustion conditions are safe both during warmup and normal operation. These types of devices can be found at the back end of the kiln, and in the precipitator. Continuous emissions monitoring (CEM) of the exhaust may also be required by environmental regulatory agencies such as the EPA.

2.2.1.3.4 Prove igniter flame at a location where it will effectively ignite the main burner. A main burner should ignite immediately, even when the igniter is reduced to a minimum of flame capable of holding the flame sensing relay of the combustion safeguard in the energized (flame present) position.

2.2.1.3.5 Limit the pilot trial-for-ignition period to 10 seconds for gaseous fuels and light oils, and 15 seconds for heavy oils (no. 5 and no. 6).

2.2.1.3.6 Limit the main flame trial-for-ignition to 15 seconds for heavy oils. Limit the main flame trial-for-ignition to 15 seconds for gaseous fuels and light oils, if the fuel input is 2,500,000 Btuh or less; limit it to 10 seconds if the fuel input is greater than 2,500,000 Btuh. If extra time is needed for fuel to travel through a long burner pipe, the trial-for-ignition period can be increased to account for this.

2.2.1.3.7 A recycle type of combustion safeguard with one attempt to reignite (recycle) is permitted on automatic-lighted burners for units with a fuel input of 2,500,000 Btuh or less.

2.2.1.4 Safety Shutoff Valves (Oil and Gas)

2.2.1.4.1 Install two safety shutoff valves, one with proof-of-closure, for each gas- or oil-fired main burner and fuel-fired igniter greater than 400,000 Btuh fuel input (one valve with proof-of-closure from 150,000 Btuh to 400,000 Btuh).

2.2.1.4.2 Provide permanent and ready means for making periodic tightness checks of the main gas safety shutoff valves. This can be accomplished manually using test cocks downstream of each valve, or automatically by means of a device which does a pressure test between the safety shutoff valves at each startup and shutdown.

2.2.1.4.3 For a multiburner arrangement where the burners operate as a single system, provide two safety shutoff valves, one with proof-of-closure, or one main safety shutoff valve with proof-of-closure and one safety shutoff valve for each burner. It is desirable to have safety shutoff valves located as close as possible to the burners. If the distance between the main safety shutoff valves and a burner is more than approximately 10 ft (3 m), consider installing an individual safety shutoff valve at the burner.

2.2.1.5 Fuel Interlocks

2.2.1.5.1 Provide high and low pressure interlocks for gas and low pressure interlocks for oil (where the oil pump is not integral with the burner assembly) for both main and igniter fuel supplies (if the igniter fuel input is greater than 2.5 million Btuh or is not an interrupted type). Set switches at no more than 150% of normal pressure for high pressure, and no less than 50% of normal pressure (just after the regulator) for low pressure. Interlock with the fuel safety shutoff valves. See Figures 1 and 2.

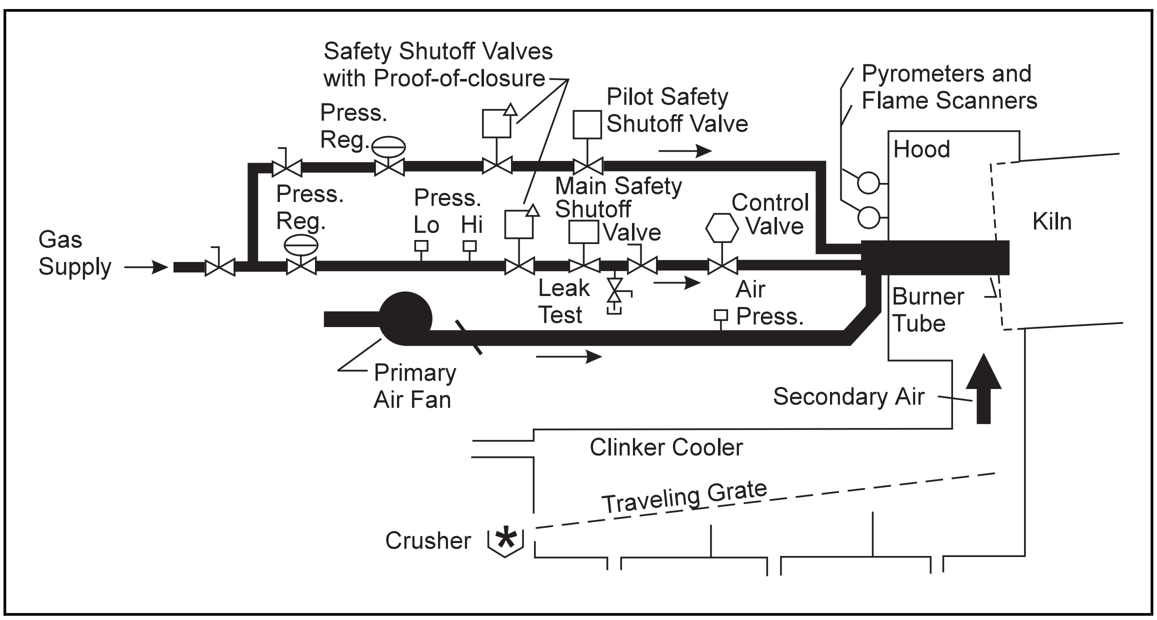


Fig. 1. Typical natural gas-fired burner arrangement.

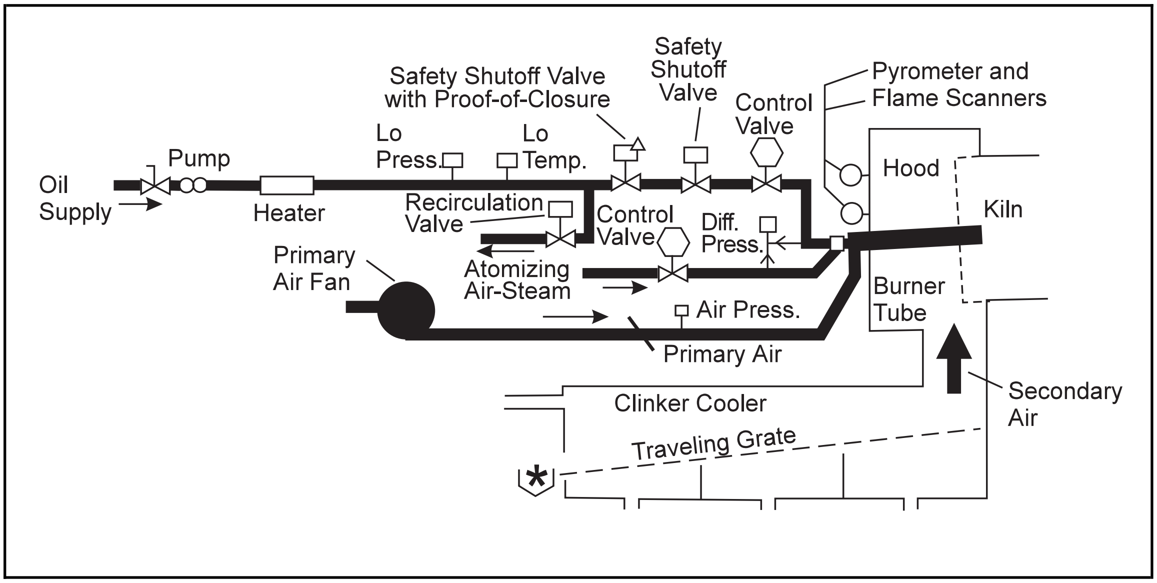


Fig. 2. Typical oil-fired burner arrangement. The igniter is not shown. See Figure 1 for a typical igniter arrangement.

2.2.1.5.2 Provide a low atomizing pressure or atomizing medium-oil differential pressure interlock for steam- or air-atomized fuel oil burners. This prevents fuel oil from entering the burners when the atomizing medium is lost or impaired.

2.2.1.5.3 Provide a low and high temperature interlock for oil that must be heated for proper atomization. A low temperature condition should result in shutting off the supply of oil to the burner. A high oil temperature condition should result in either shutting off the supply of heat to the oil heater or bypassing the heater to avoid overpressurization of the oil piping. If there is a constantly attended control room, these interlocks can be used for alarm purposes only, giving the operator time to take corrective action.

2.2.1.6 Pulverized Coal-Fired Burners

2.2.1.6.1 Provide gas- or oil-fired pilots or igniters to ensure the pulverized coal ignites reliably. A Class 1 igniter is preferred, but a Class 2 igniter should be provided as a minimum. Pulverized coal can be ignited by the warmup burner that is used to bring the kiln up to normal temperature. See Figure 3.

2.2.1.6.2 Provide flame supervision for the pulverized coal burner. Two flame scanners may be arranged so that either one will alarm when flame outage is detected. Detection of flame outage by both should cause a burner trip. Upon loss of all flame from the igniters, supplementary burners and the pulverized coal burner, a master fuel trip of all fuel inputs should be activated.

In some types of rotary kiln burner systems, such as cement kilns, it is difficult or impractical to provide flame supervision for the pulverized coal-fired burner. The combined interference of the clinker dust and unburned pulverized coal prevents the infrared or ultraviolet detectors from operating reliably without nuisance shutdowns.

For these types of kiln burner systems, provide flame supervision for the gas or oil igniters in main burners at least until the main combustion zone is heated above 1400°F (760°C) and the pulverized coal burner combustion has stabilized. Above 1400°F (760°C) the temperature of the combustion zone is an ignition source for most fuels including gas, oil, and pulverized coal, and the flame scanners can be bypassed. Provide a temperature interlock to act as a permissive for bypassing; if temperature drops below 1400°F (760°C), the flame scanner logic should automatically come back on line.

Pyrometer or TV camera monitoring of the burner flame can be used in lieu of conventional flame scanners after the warmup period when above 1400°F (760°C), and for some kilns might be a more practical type of flame monitoring. Flame shape is very important to not only proper kiln operation, but also to refractory life. This type of flame monitoring will help the operator to better control the flame shape.

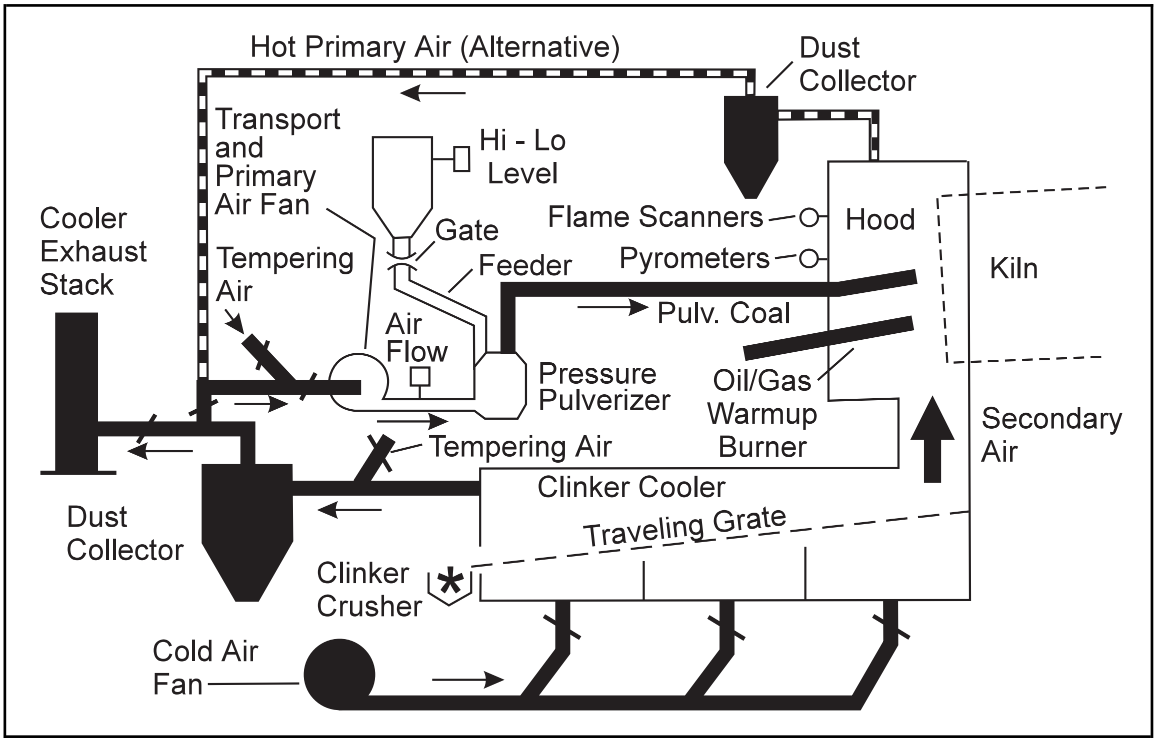


Fig. 3. Typical coal-fired burner arrangement.

2.2.1.6.3 Provide interlocks to ensure operation in the order given below. If failure occurs during the sequence, interlocks should automatically shut down all of the equipment in the order of operation.

1. Start the induced draft, forced draft (or secondary air) and recirculation fans, and open dampers to purge the kiln, coolers, preheaters, and exhaust processing equipment. Some ancillary equipment may be purged and started as an individual unit when isolated from the kiln system.

2. Purge according to Section 2.2.1.1.

3. Start direct-fired air heaters where provided. Appropriate combustion safety controls should be provided for the air heater burner systems. (See Data Sheet 6-8, *Combustion Air Heaters*.)

4. Start the gas or oil igniters.

5. Start the primary air fan.

6. Start the coal pulverizer.

7. Start the coal feeder. Adjust the coal feed to the burner for the equivalent of a low fire start.

2.2.1.7 Alarms, Indicators, Combustible Analyzer Interlocks and Communication

2.2.1.7.1 Provide adequate means for communication between the control center and the kiln and preheater burners, raw material feeder, and coolers. This is especially important on remote controlled units. Public address systems, plug-in telephone units, carrier current, and two-way portable radios may be used. Explosions can occur if the activities of the equipment operator at the burners is not communicated to the control center operator. This is particularly true during critical operations such as lighting-off, bringing the unit up to temperature, or during upset conditions involving flame instability.

2.2.1.7.2 Monitor the status of operating equipment, including position of valves, vital damper settings, kiln speed, raw material feed, and other operating conditions. This will allow the operating situation to be evaluated.

2.2.1.7.3 Provide adequate annunciators and alarms to aid normal operation and warn operators of abnormal conditions developing. Provide alarm systems that give both audible and visual indication of abnormal conditions. Means may be provided to silence the audible alarm, but the visual indication should remain until the condition has returned to normal.

1. Provide ‘‘First Out’’ indication for all safety interlocks that will initiate a fuel trip to help the operator determine the initiating condition.

2. Provide similar interlocks to initiate an alarm when off-normal conditions are detected that would result in a burner trip, if left uncorrected. Although not required as a tripping interlock, important alarms in this category include failure of a burner valve to close following a burner trip; loss of power to combustion control system; loss of kiln drive system and loss of raw material feed.

3. Provide oxygen and combustibles analyzer-recorders to monitor the kiln exit flue gas. Alarm at 5000 ppm combustibles, or 2000 ppm carbon monoxide (CO) if the analyzer detects only CO and not hydrogen (or methane (CH_4) when burning coal). Attention must be given to this type of instrument to consider it reliable. Some analyzers do not respond very quickly, especially if sampling lines are too long or are plugged. Analyzers can give poor readings if any air leaks into the back end of the kiln or into the sampling line, causing dilution of the sample. See Data Sheet 6-11, *Thermal and Regenerative Catalytic Oxidizers* and Data Sheet 5-49, *Gas and Vapor Detectors and Analysis Systems*, for recommendations on combustible analyzer maintenance.

4. When an electrostatic precipitator (ESP) is provided on the kiln exhaust system, depower the precipitator preferably at 1% (10,000 ppm) flammable gas concentration and no more than 2% (20,000 ppm) maximum. If the analyzer only detects CO, the above levels should be reduced by half because the total flammable content might actually be more than double that of the CO level. The LEL of the gas mix will be much lower than that of CO alone. Also reduce the alarm and trip setpoints if the response time is more than 10 seconds. A response time of two to three seconds is considered very good. If percent of LEL is used as a unit for alarm readouts rather than parts per million, the setpoints should also consider that the LEL is lowered (about 20% should be adequate) due to elevated temperatures of the exhaust gas. Consider shutting down the burner system when 2% flammable gas concentration is detected. Oxygen should be sensed in the precipitator and alarmed at 5%. Oxygen levels of 8% or higher significantly increase the explosion potential. Air leakage will cause such high O_2 levels in the ESP. During startup and shutdown, O_2 levels will normally be high.

5. Monitor the kiln drive motor for amperage. Activate an alarm if the amperage exceeds the maximum full load for more than 20 seconds. High amperage can indicate increased load. This can be caused by excess coating buildup inside the kiln (for refractory-lined kilns with coatings) or improper raw material mix, but can also be caused by mechanical problems. Excess coating will increase temperature, and the burner fuel must be cut back. In a cement kiln, if the clinker load liquifies, a reaction breaks down the refractory and ultimately overheats the shell. On dual drive kilns, the amperage difference between the two drive motors should be within a tolerance specified by the manufacturer.

6. Monitor product feed rate versus fuel input (for temperature control).

7. Alarm dry feed level on the feed conveyor where applicable; low level could result in a feed interruption. For slurries, monitor feed tank level, scale weight and flow to the kiln.

8. Monitor bearing temperatures of critical components such as the carrying rollers, drive gear set and I.D. fans.

9. Monitor vibration of critical fans and motors or take readings by hand monthly. This is particularly important for I.D fans subject to dust buildup on the blades. Vibration trending should be used in making decisions to perform maintenance. Vibration limits should be specified by the equipment manufacturer.

2.2.2 Temperature Control

2.2.2.1 Monitor the outside of a refractory-lined kiln shell for temperature near the hot end of the kiln. A traveling or rotating infrared camera permanently mounted outside the kiln is commonly used for this purpose. Shut down the kiln if shell temperature is excessive (not for a small hot spot).

2.2.2.2 Install a temperature sensor or pyrometer in the kiln burning zone or dryer combustion chamber to assure normal operating temperature before startup of raw material feed, to monitor temperature during normal operation, to provide a process control input for automated systems and to provide a signal to a high temperature cutout. For calcining kilns, also monitor temperature in the drying and calcining zones for process control and early detection of upset conditions. Feed temperature or gas temperature can be monitored depending on the depth of the thermocouple well. Normally gas temperature will be monitored at the cooler end of the kiln.

2.2.2.3 Monitor kiln back-end gas temperature. Temperature should be steady for a constant material feed. Kiln stability is closely related to back-end temperature in a calcining kiln.

2.2.2.4 Interlock exhaust temperature to open the exhaust cooling water flow valve (if so equipped) wide on excess temperature, and to depower the electrostatic precipitator and shut off the supply of fuel to the kiln.

2.2.2.5 Install thermocouples on the discharge side of the kiln cooler. These monitor product discharge (such as clinker) temperature or ambient air temperature above the product or clinker. They also alarm upon high temperature (about 10% over normal) of the feed leaving the cooler and discharging to a conveyor. A high, high temperature (about 20% over normal) condition should be interlocked to stop product or clinker discharge from the cooler and divert it to a bypass chute. Normal temperature is typically about 150°F (65°C).

2.2.2.6 Monitor primary and secondary air temperature.

2.2.3 Preheaters/Precalciners

2.2.3.1 Protect fired preheater combustion equipment according to Section 2.2.1. Fuel injection into a precalciner might not produce a visible flame, however, the stabilizing burner should be equipped with flame supervision at least during warmup if practical. Fuel injection flow should also be monitored. Use a thermocouple if flame scanning is impractical.

2.2.3.2 Install a high temperature switch/sensor interlocked to shut off the supply of fuel to a fired preheater/precalciner. If the preheater outlet temperature exceeds its setpoint, stop precalciner firing and reduce or stop kiln firing.

2.2.3.3 Monitor flow of feed material through the preheater and alarm high/low feed flow conditions. Control of raw materials is important; for example, high alkalis, chlorides and sulfates in the raw material for a cement process can contribute to plugging the preheater. Bypassing some of the kiln exit gases around the preheater sometimes controls alkalis (see Fig. 4). Some alkalis are needed to promote coating formation.

2.2.3.4 Alarm all fans for low airflow including the bypass gas fan and quench air fan as applicable. Also monitor and alarm secondary airflow through cooler recoup and branch ducts as applicable. Damper and variable orifice positions should be monitored.

2.2.3.5 Monitor and alarm fired preheater exit gas for O_2 out of range (limits set by the manufacturer) and high CO (2000 ppm).

2.2.4 Grate Type Outlet Coolers

2.2.4.1 Monitor/alarm the cooler for high undergrate pressure. High pressure indicates increasing product (clinker) depth and improper cooling.

2.2.4.2 Maintain slightly negative hood air pressure above the grate using cooler exhaust damper control. If secondary air temperature becomes dangerously high, it might be necessary as a last resort, to introduce extra cooling air into the cooler. This will result in positive pressure.

2.2.4.3 Maintain control of cooling air and grate speed such that the grates, cooler drive, clinker crusher and cooler walls do not become overheated.

2.2.4.4 Alarm for loss of cooler grate speed. For dry kilns, if the cooler stops, the kiln should shut down.

2.2.4.5 Alarm the clinker breakers/hamermills for low rotational speed.

2.2.5 Product Discharge Belt Conveyors

2.2.5.1 Protect conveyors against fire in accordance with Data Sheet 7-11, *Conveyors*.

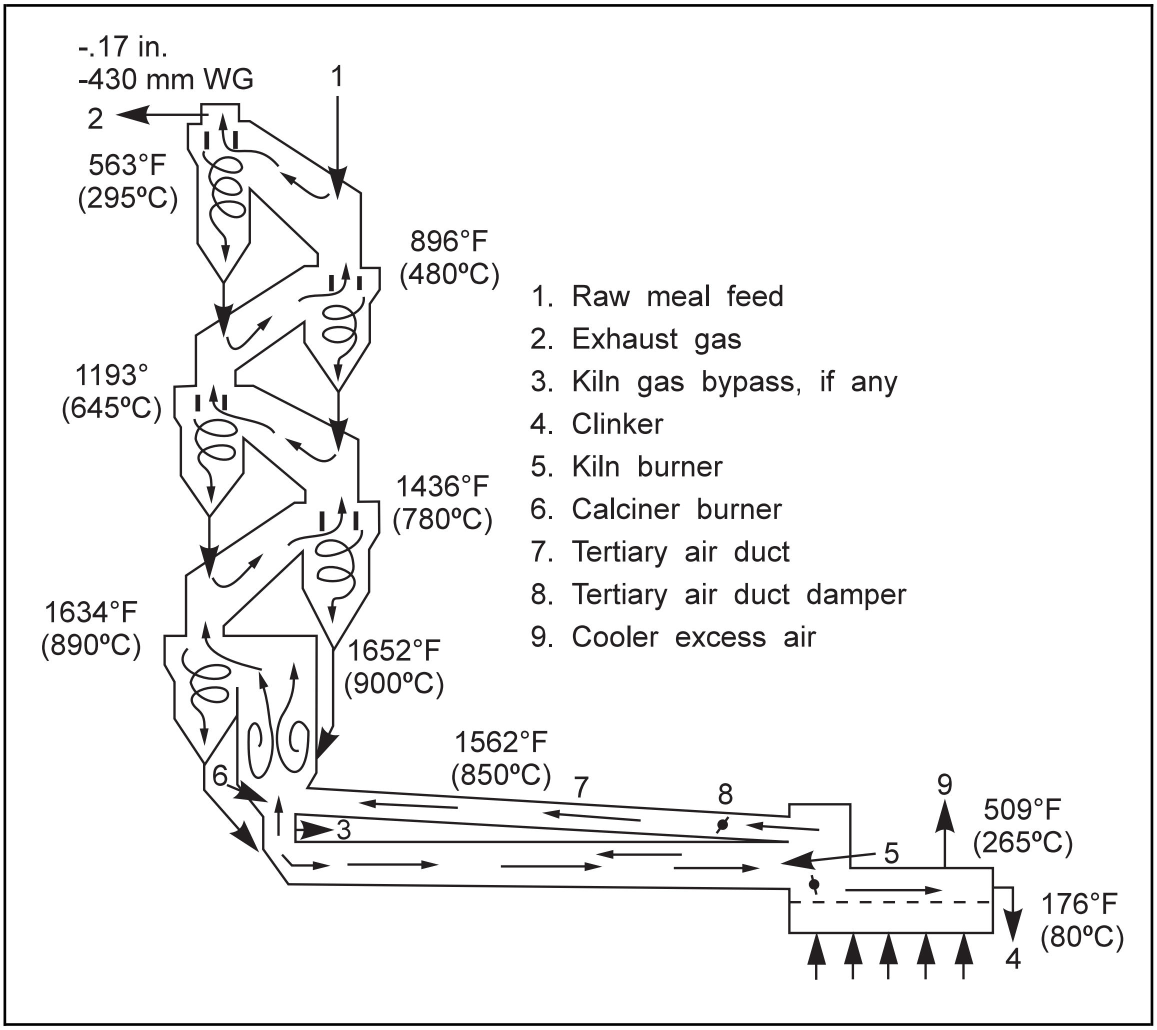


Fig. 4. A five-stage suspension preheater system with an in-line calciner for a dry-process kiln.
Courtesy of the Fuller — F.L. Smidth Co.

2.2.5.2 Monitor product conveyors for excessive temperature. High temperature should cause an alarm. High, high temperature should be interlocked to either activate cooling water spray or bypass material exiting the kiln cooler away from the conveyor. Shut down the kiln as a last resort or if the conveyor stops. If the kiln is shut down, engage the auxiliary drive.

2.2.5.3 Replace worn conveyor belts because frayed belts are more easily ignited.

2.2.5.4 Interlock and alarm conveyor belts for speed. A loss of belt speed should divert discharge away from the conveyor, or shut down the kiln, including the material feed, the supply of fuel and discharge from the cooler. The auxiliary drive must be engaged if the kiln is shut down.

2.2.5.5 If a combustible belt conveyor is used rather than a noncombustible conveyor such as a pan or plate type conveyor, use a high temperature belt material. It is preferable to arrange the conveyor such that the belt is turned over each time around, allowing for better cooling of the belt.

2.2.6 Waste Incineration and Oxygen Enrichment

2.2.6.1 Interlock waste fuel (such as tires, medical waste, noncondensable gases [NCGs], turpentine byproducts etc.) feed with temperature. The kiln should be at normal operating temperature (1400°F [760°C] minimum) before starting waste fuel feed.

2.2.6.2 Provide safety shutoff valves (per Section 2.2.1.4) interlocked with temperature, and fuel interlocks (per Section 2.2.1.5) for gaseous and liquid fuels. For solid fuels, provide gates interlocked with temperature.

2.2.6.3 Provide two safety shutoff valves for oxygen injection lines. Interlock with the main fuel safety control circuit and with high/low temperature. Also provide a pressure regulator and high pressure switch interlocked to shut off the supply of oxygen. The kiln should be up to operating temperature (1400°F [760°C] minimum) before oxygen feed to the kiln is permitted. Monitoring back-end O_2 is important.

2.2.6.4 On NCG systems, provide a flame arrester as close as possible to the kiln burner. On low volume high concentration (LVHC) systems, provide rupture disks in the ductwork spaced at a distance less than the ‘‘run up’’ distance for transition to detonation.

2.2.7 Vertical and Annular Shaft Kilns (non-rotating)

2.2.7.1 Protect combustion equipment according to Section 2.2.1.

2.2.7.2 Inspect support members and perform NDE (VT, MT or UT) on support member welds every five years if practical. Pay particular attention to support beams that hold inner cylinders in place. Inspect combustion chamber support members for damage and cracking if refractory that insulates these membersis damaged and when refractory is being replaced.

2.2.7.3 Inspect refractory for damage and thinning during shutdown periods.

2.2.7.4 Monitor the kiln for product plugging and temperature.

2.3 Electrical

2.3.1 For electrical installations, conform to NFPA 70, the National Electrical Code (NEC®) or other locally accepted code.

Note: NEC® is a copyrighted publication of the National Fire Protection Association (NFPA), Quincy, MA 02269.

2.3.2 Ensure both ac and dc safety control circuits are two-wire types, one side grounded, and not over nominal 120 volts (in the U.S.) or the voltage specified by local standards. Ensure all safety control switching is in the hot ungrounded conductor and overcurrent protection is provided. In addition, ensure noncurrent carrying metal parts, such as equipment enclosures and conduit, are grounded.

2.3.3 In unusual cases where an ungrounded dc power supply cannot be avoided, locate all switching in one conductor and provide ground fault protection.

2.3.4 Contain electrical equipment in dust-tight enclosures when exposed to a dusty environment to prevent malfunction of electrical contacts. Burner front areas are not normally classified as hazardous.

2.4 Protection

2.4.1 Arrange fuel supplies safely as outlined in the following data sheets:

- Data Sheet 7-32, *Ignitable Liquid Operations*
- Data Sheet 7-88, *Ignitable Liquid Storage Tank*
- Data Sheet 7-54, *Natural Gas and Gas Piping*
- Data Sheet 7-55, *Liquefied Petroleum Gas (LPG) in Stationary Installations*
- Data Sheet 7-57, Pulp and Paper Mills
- Data Sheet 6-13, *Waste Fuel-Fired Facilities*
- Data Sheet 8-10, *Coal and Charcoal Storage*

Keep the gaseous and liquid fuels free from all foreign matter. Remove welding beads, chips, scale, dust and debris from both newly installed fuel piping and piping that has been opened for alteration or maintenance. Install suitable strainers, filters, drip legs, etc. Vent air from piping to prevent difficulty lighting off.

2.4.2 Provide each oil- or gas-fired burner with a manually-operated fuel shutoff valve for emergency closing in case of fire. Prominently mark the valve and locate it for easy access, preferably outside the firing building.

2.4.3 Recognize the fire hazards of oil piping leaking or rupturing near the burner. Pay particular attention to flexible connections, hoses, swivel joints, etc. Good housekeeping is important.

Inspect braided oil hoses periodically according to manufacturer's recommendations, and commit to a replacement frequency based on usage and consultation with the hose or burner manufacturer. Older hoses may not flex properly and may cause leaks to develop at threaded connections in the fuel piping, especially if there are 90 degree bends. Hoses that are bulged, stiff or corroded may indicate this condition. Hoses are subject to both tensile and compressive stresses, to internal pressure, and to the extremes of temperature, vibration, corrosive atmospheres, physical impact and reactive forces.

Use double braided, noncombustible hoses. Hoses should be designed for the oil being fired and should be capable of withstanding four times the normal maximum operating pressure. Hose couplings and fittings and minimum bending radius should be in accordance with manufacturer's instructions. If 90 degree bends are necessary, use 90 degree elbows. Valves should be installed upstream of hoses. Flexible hoses are a likely place for a fuel leak to develop and should be examined carefully.

2.4.4 Provide portable dry chemical or CO_2 fire extinguishers for manually fighting liquid fuel fires at the burner hood. Also, provide a small hose station located out of the weather, or a hydrant with hose and nozzle located in a housing near the discharge end of the kiln.

2.4.5 Provide fire protection at oil- or other liquid fuel-fired burners that are located indoors. Automatic sprinklers, or a water deluge system activated from the control room, can be used. Consider the potential for freezeup when deciding what type of fire protection scheme to use. For density requirements, refer to Data Sheet 3-26, *Fire Protection for Nonstorage Occupancies*.

2.4.6 Provide a heat detector above oil burners if fire protection is not provided. Select a temperature rating approximately 50°F (30°C) above the highest anticipated ambient temperature. The detector may be wired as an interlock into the combustion safeguard circuit, or as an alarm to an annunciator panel in a constantly attended control room. Operators should have the ability to remotely secure the flow of oil to the kiln. If nuisance tripping caused by faulty detectors is a concern, two detectors mounted at the same location may be wired such that activation of one detector will bring in an alarm, and activation of both detectors will cause a trip. Detectors should have visible indication to show when one has been activated.

2.4.7 Provide automatic sprinkler protection or another acceptable method of cable fire protection, such as Approved fire protective coating, inside cable tunnels located beneath kilns. Refer to Data Sheet 5-31/14-5, *Cables and Bus Bars*.

2.4.8 Do not keep ignitable liquids including bearing oil for the carrying rollers inside piers unless stored properly.

2.4.9 For wood chip rotary dryer systems, refer to Data Sheet 7-10, *Wood Processing and Woodworking Facilities* for fire and explosion detection/protection recommendations. Spark detection/extinguishing, equipment waterspray deluge, high temperature interlocks and process isolation are needed. Install separators to remove heavy or metallic particles from the dryer feed, particles that could cause impact sparks.

2.4.10 Install thermocouples inside rotary dryers and bakers to detect temperature excursions and fires. Install them also inside off-gas ducts leading from these units to incinerators. If it is impractical to install thermocouples inside, monitor the inlet and exit temperatures.

2.5 Operation and Maintenance

2.5.1 General

2.5.1.1 Establish and implement a rotary kiln and dryer inspection, testing and maintenance program. See Data Sheet 9-0, *Asset Integrity*, for guidance on developing an asset integrity program.

Train operators to operate the kiln and its ancillary equipment. Keep operating instructions in the control room for reference. See Section 2.5.8, Operation and Data Sheet 10-8, *Operators*, for operator guidance.

Operators should:

- be trained to follow standard and emergency operating procedures.
- know the hazards of failing to follow standard and emergency operating procedures.
- be able to detect conditions that can lead to an upset and take appropriate action based on the three main kiln (for typical large kilns) operating variables (back-end temperature, burning zone temperature, and back-end oxygen).
- be able to recognize poor combustion through experience and with the tools that are available.

- have the authority to make immediate shutdown decisions.
- be familiar with all alarms and interlocks and the purpose they serve.
- communicate well with the instrument technicians who service this equipment.

2.5.1.2 Inspect and test safety controls at least annually. Follow specific manufacturer maintenance instructions. Consider testing safety controls by operating one safety device at each scheduled shutdown (after cooldown period) to ensure proper emergency functioning. Test the auxiliary drive weekly. (See Sections 2.5.8.5 and 2.5.9.2.15.) Failure to make periodic checks can result in fire or explosion damage, or mechanical or electrical breakdown, and can also contribute to accidental shutdown and production loss.

2.5.1.3 Prepare a carefully planned inspection test procedure and perform the tests at prescribed intervals. Record tests on a safety-control inspection and testing report. The report lists the controls to be tested, their condition, and the proper sequence and methods of performing the tests. The operator or inspector should prepare the report which should be reviewed by a supervising official.

2.5.1.4 Well trained personnel familiar with the equipment and the specific functions of the various safety controls should perform the tests. Correct defects immediately.

2.5.1.5 Maintain all equipment by following the routine recommended by the manufacturer of the various components. Maintenance details and schedules depend on the equipment and the operating conditions, and may also depend on the risk associated with the equipment or component.

2.5.1.6 Investigate all equipment at set intervals for wear and deteriorating conditions. Revise this scheduling according to experience with the installation. Defective equipment or poor maintenance can result in more frequent maintenance intervals, requiring equipment shutdown or the removal of control components from service. Out-of-service control components increase the exposure of the unit to operating hazards.

2.5.1.7 The controls and safety devices function under severe operating conditions. Establish the frequency and quality of maintenance so that the entire unit, including alarms and interlocks, will safely and reliably operate.

2.5.2 Alignment, Shell Runout and Carrying Rollers

2.5.2.1 Perform a kiln mechanical and alignment survey annually; this frequency can be adjusted according to a specific kiln's application and operation history. This is the best defense against breakdown. Depending upon the procedure used, this can be done during operation or after shutdown. A hot survey will indicate conditions experienced during normal operation, and is preferable. Make carrying roller corrections as necessary. Pier elevation, pier centerline, pier transverse levelness, pier downhill slope, kiln horizontal and vertical alignment and thrust alignment should all be checked. If pier corrections, carrying roller frame adjustments or grout repair are needed, this work must be performed by qualified personnel. The pier elevations must be correct according to plan, the pier centerlines must line up, the piers must be level within a specified tolerance across their width, and the piers must conform to a specified slope. The kiln shell should line up with the pier centerlines and should slope the same as the carrying roller frames (vertical alignment).

Shell runout indicates the degree of shell distortion or warping (not ovality) and is sometimes measured before a planned shutdown. Temperatures must be equalized on both sides of the kiln, or measured and recorded at each measurement point. Results can be used to initially decide whether a section of shell must be replaced, or whether a kiln alignment is needed. Runout measurements are taken at a number of locations along the length of the kiln. The distance between the shell and a fixed reference is measured at twelve positions around the shell circumference at each location. The average runout is calculated first. Then the difference between each runout measurement and the average is taken. The total runout is calculated by determining the difference between the most positive and most negative reading. Temperature differences must be used to determine if there is any *temporary* warping.

2.5.2.2 The carrying roller downhill bearings should be lightly and evenly thrusted. Ideally, the carrying rollers should all be parallel to each other and to the kiln axis. The kiln *thrust roller* should receive most of the downhill thrust unless the manufacturer allows ‘‘floating’’ the kiln. Moving one side of the carrying roller bearing assemblies inward (‘‘cutting the roller’’) will change the thrust of the kiln either up or down depending on the direction of rotation of the kiln; this is done when ‘‘floating’’ the kiln. The riding rings and pads should be in full contact; they might have to wear in over time to achieve this rather than cutting the rollers (moving rollers inward at an angle to the kiln shell axis).

If a carrying roller thrust plate is heavily thrusted, the end plate temperature will be high. If thrust pressure is excessive, lubricating oil will be squeezed out and dry friction, indicated by a high pitched noise, will damage the thrust washer. When noise is observed, neutralize the roller (adjusted parallel to kiln axis). If ignored, internal parts that assist with lubrication will be damaged as the shaft moves forward due to excessive thrust washer wear. This will interrupt lubrication to both the uphill and downhill bushing, causing noise at both sides of the roller assembly. When this occurs, shut down the kiln immediately in a controlled manner. If a roller continues to turn without lubrication to the bushing, the bushing bolts can shear; this will allow the bushing to rotate until the shaft is no longer supported and drops onto the housing, resulting in substantial damage. Drive amperage will rise suddenly if this happens.

2.5.2.3 The contact faces of the carrying roller and riding ring should be true (flat, smooth and parallel with the carrying roller shaft). If the outer edges of these faces are peened outward (the edges should be round), they need true-up. Carrying rollers will need to be adjusted after resurfacing. If there is a ‘‘V’’ opening between the roller and riding ring, the point contact and concentrated loading can result in serious damage if left uncorrected: This problem can arise because of roller and riding ring surfaces out of true, a tilted carrying roller support frame (caused by pier settling or grout deterioration), a bent frame (with rigid bearings), riding ring wobble or worn bushings.

If the skewing angle is in the wrong direction at any roller causing opposing thrust at that roller, the roller and riding ring surfaces will wear excessively.

A poorly adjusted carrying roller will thrust against the retaining bar creating friction. Too much friction can wear the riding ring into the retaining bars, and this will eventually cut the riding ring and lock the riding ring and retaining bars together. If this occurs at a thrust riding ring, the main gear and pinion might move off center as the retaining bar wears. This excessively wears the teeth.

Kiln misalignment will lead to continuous trouble with the shell, riding rings, carrying and thrust rollers and possibly the ring gear and pinion. Poor thrust alignment and carrying roller misadjustment will unnecessarily wear the carrying rollers. Misalignment caused by deformation at the riding rings can sometimes be corrected by pad (filler bar) replacement. Excessive shell warping or shell bend (dogleg) must be corrected by replacing a section of shell.

If the kiln drive becomes overloaded and trips, and the auxiliary drive is unable to turn the kiln, the shell, the thrust roller and carrying roller thrust plates will be severely damaged. If after repairs are completed the kiln is started with a warped shell, damage can be done to the carrying roller assemblies, gear teeth, thrust roller and kiln end seals. If a section of shell is to be replaced, the other sections must be aligned (no bend or dog leg) and not warped.

2.5.2.4 Keep the area of the shaft between the roller and bearing housing clean to help prevent damaging the oil seals and contaminating the oil. Noise and temperature rise at the roller assemblies can also be caused by lubricating oil contamination and/or sludge buildup, in which case oil must be changed and sludge either dissolved or manually removed.

2.5.2.5 Monitor all carrying rollers after an adjustment, especially if the roller was adjusted to relieve a high temperature condition. Bushings wear during startup and from abrasives. The bushing contour will change to match the radius of the shaft If wear is excessive, the bushing will have the same contour as the shaft and will be thinner in the middle section. (See Fig. 5.) Ridges will develop on the bushing.

Also, if there is too much shaft pressure on the bushing, the high temperature developed can cause a ripple-like distortion to the shaft and bushing. (See Fig. 6.) When adjustments are made to rollers, the pressure from the shaft to bushing changes angle. This can cause the shaft to rise up when it contacts the high part of the bushing where it changes from being worn to unworn. (The middle of the bushing will be thinned and worn into the shape of the shaft) If the shaft and bushing have distortion ripples, the high spots will come into contact. If either of these two things happen, concentrated loading, interference with lubrication and high temperatures will result. The end result can be bushing failure and even more serious damage if the bushing bolts shear as already described.

It is important that the bushings remain parallel with the shaft If they cannot pivot (the support beam on which the bushing rests has a permanent coating of lubricant), point contact and concentrated loading will occur diagonally at the ends of the bushing, resulting in a mechanical breakdown. (See Fig. 7.) This is a problem with rigid, independent half-sleeve bushings and not with connected, self-aligning bearing assemblies. Spherical antifriction, bearings are also sometimes used. They are self-aligning.

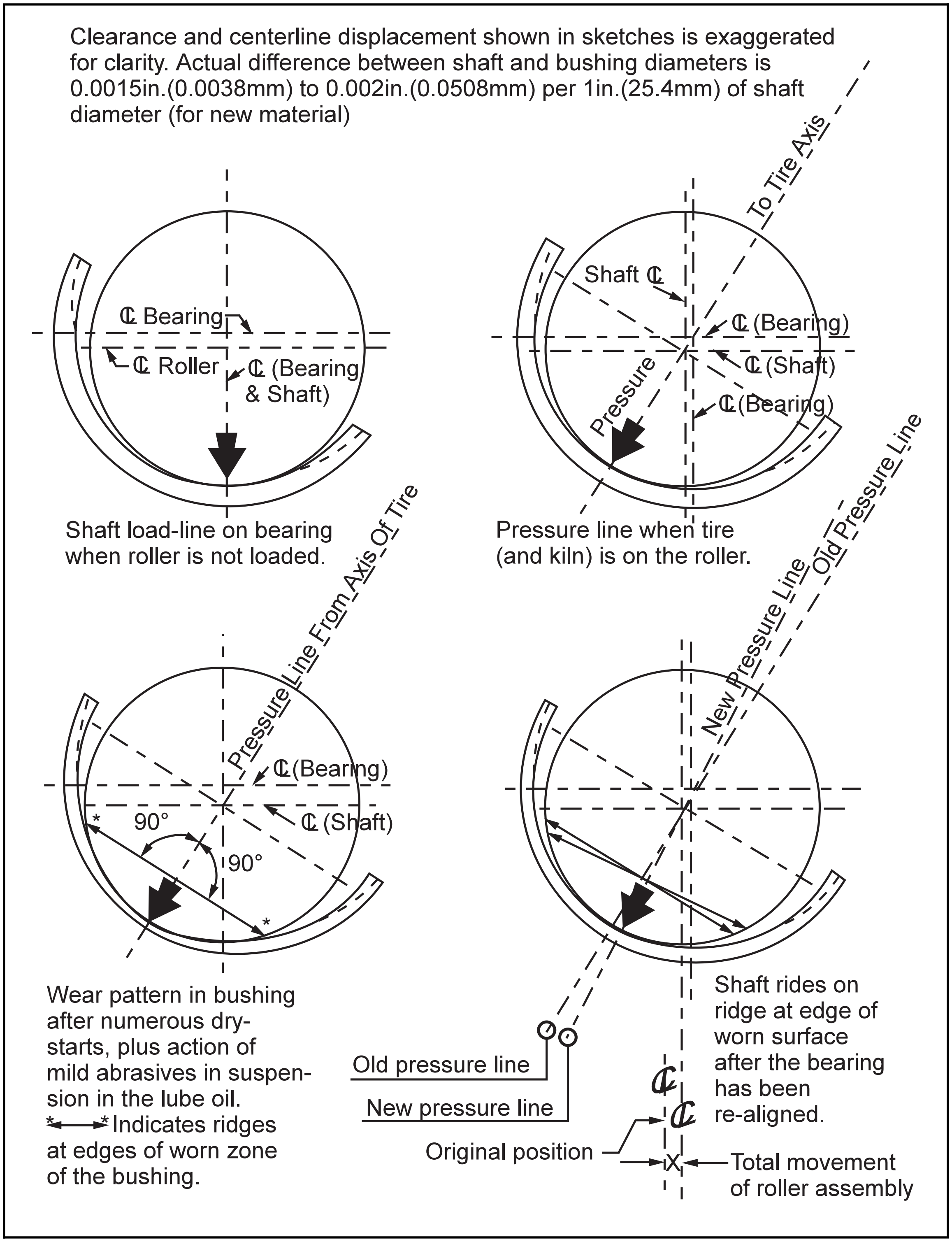
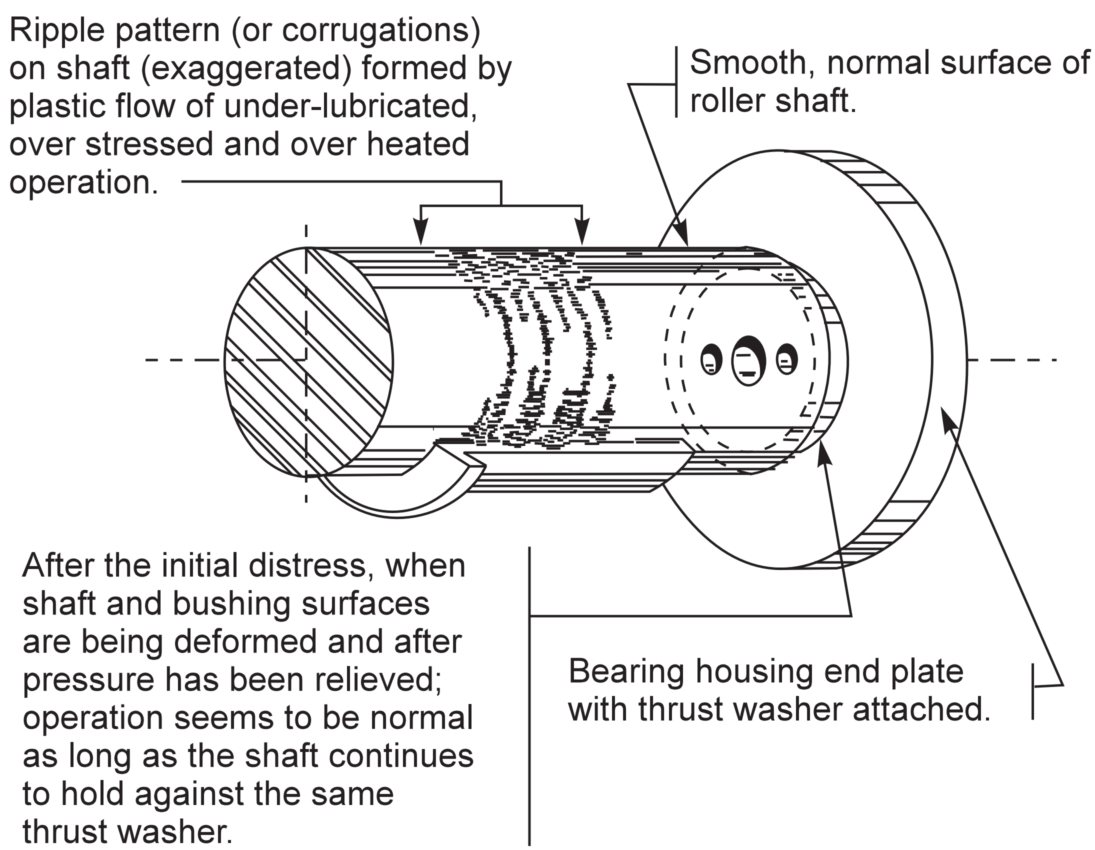


Fig. 5. Carrying roller load angles and bushing wear patterns. Courtesy of the Fuller Company.



The corrugation pattern, shown above, may be at a very low profile and the actual condition may not have been noticed (or reported) for maintenance records. When the shaft travels away from the loaded thrust washer, pressure increases when crown and groove contours are joined as the shaft moves along the bushing. It is possible that there will not be a totally dry contact condition (with an audible distress signal), but extreme pressure will be indicated by sight and odor when hot oil vapor excapes from the bearing housing. Metal and oil temperatures will rise rapidly, possibly above 300°F(149°C) in this situation. Roller adjustment which led to this condition, must be reversed for gradual relief from pressure and heat. The shaft must be repaired for normal operation with a new bushing.

Fig. 6. Carrying roller shaft distortion due to plastic flow. Courtesy of the Fuller Company.

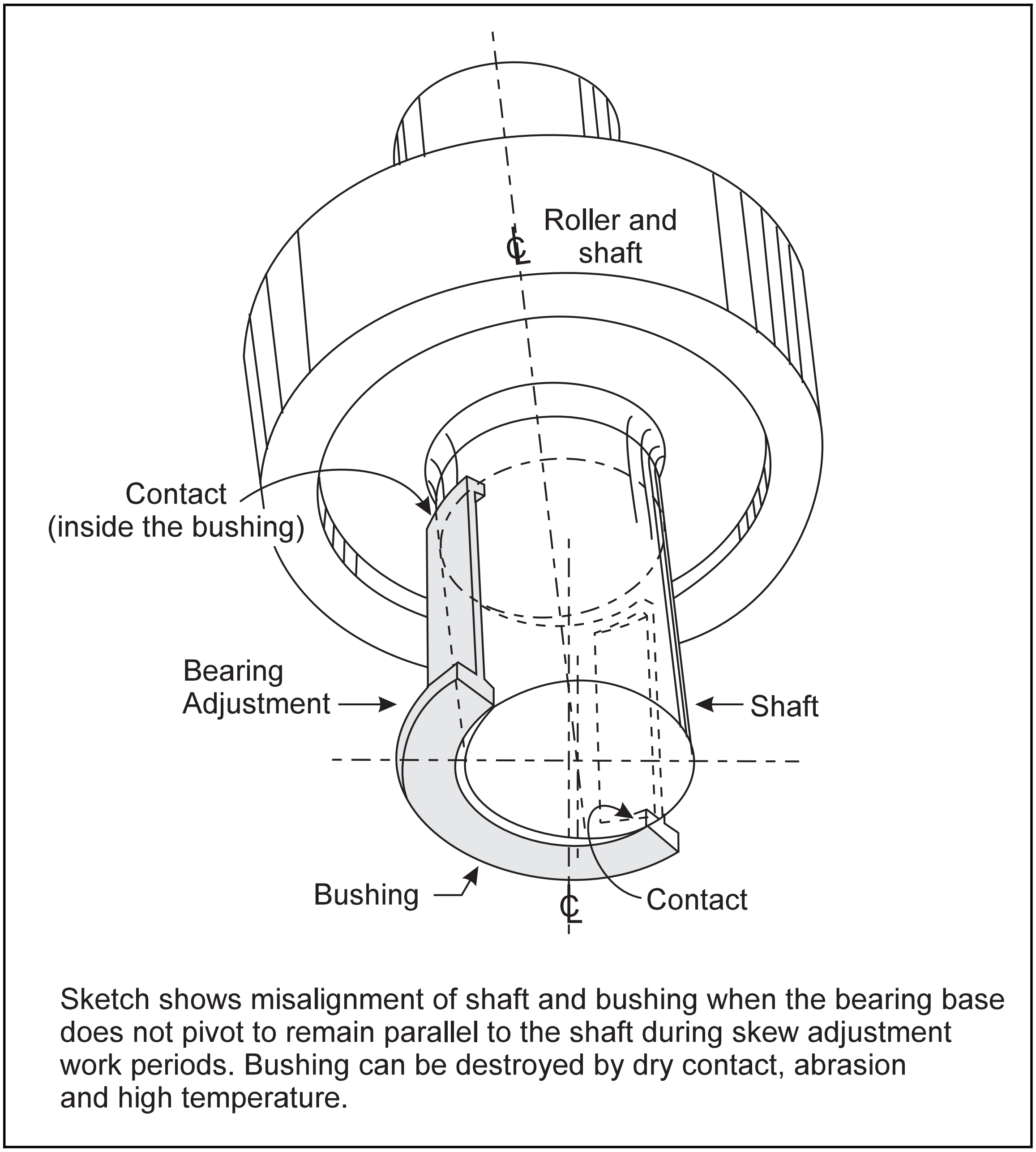


Fig. 7. Carrying roller shaft-bushing misalignment. Courtesy of the Fuller Company.

2.5.3 Ring Gear and Pinion

2.5.3.1 Follow manufacturer's recommendations for initially wearing in a new gear or pinion.

2.5.3.2 Change oil semi-annually or when the oil is contaminated as indicated by oil tests. If the oil contains abrasives, gear tooth wear will be excessive. This is especially true for high torque, low speed gears.

2.5.3.3 Use oil specified by the gear manufacturer. Low speed gears require thicker oil with additives that cause better adherence to the gear teeth.

2.5.3.4 Check gear alignment annually. Kiln misalignment and mechanical problems such as a warped shell will cause ring gear and pinions to misalign. This will increasingly wear and possibly overload gear teeth. Overloaded gear teeth can result in pitting fatigue which in turn will interfere with lubrication, accelerate wear and possibly cause tooth breakage. The driving pinion will wear much quicker due to the increased cycles (being smaller), and also because sliding friction is away from the pitch line. (The metal pulls away from it.)

If the main gear and pinion centerlines do not match (part of the teeth do not mesh when the gear and pinion extend over the ends of each other), there will be uneven wear, and step patterns will form along the length of the teeth. If there is then a change in the kiln thrusting causing the relative gear positioning to change, gear teeth can overstress and break if high spots mesh.

2.5.4 Shell Warpage, Creep, Ovality and Riding Ring-Pad Clearance

2.5.4.1 Check creep at each riding ring once a week and record results. This will help to evaluate problems and plan for repairs ahead of scheduled shutdowns. Creep monitoring devices can be installed at each riding ring if desired. These devices are sometimes used as an input to control logic during the warmup period.

2.5.4.2 Also record riding ring (tire) and shell temperature at each pier once a week; increasing temperature differential indicates decreasing clearance and a refractory problem.

2.5.4.3 Do not lubricate the pad surfaces unless it is recommended by the manufacturer to lightly lubricate the pads to reduce wear caused by creep. Lubrication will cause the shell pads to slip inside the riding ring bore, and will prevent the riding rings from being driven by friction with the shell pads. If a shell section is choked inside a riding ring, lubrication is not a valid solution. This practice will hide mechanical problems and might also make creep measurements irrelevant. A powder type of lubricant mixed with water is usually used.

2.5.4.4 Lubricate the sides of the riding rings to prevent wear between the rings and retaining bars. Use a lubricant recommended by the kiln manufacturer.

2.5.4.5 If using cold clearance measurement of the pads at top dead center to calculate the difference (Δd) between shell outside diameter (including pads) and carrying roller bore, reduce this measurement to account for relative expansion of the shell and riding ring. Ovality of the shell must also be considered. The clearance measurement is not equal to the difference between riding ring bore and shell (including pad thickness) diameters. Clearance = $\Delta d(\pi)/2$.

Periodically measure ovality using an ovality meter mounted at bottom dead center. Repeat the test by starting the tracing at points on the kiln 90° apart. The paper tracing will show flat spots as well as creep and clearance. This data can be analyzed and used to decide a course of action if ovality is excessive.

Ovality is expressed as a percentage of shell diameter. It equals the clearance divided by the inside diameter. Ovality is due to clearance and sag caused by the unsupported part of the kiln at top dead center and excessive load where the rollers support the shell (about the 5 and 7 o'clock positions). Ovality or flattening of the shell and tire can occur at the top and bottom due to inadequate tire cross sectional area or increased load. About 0.3 to 0.5% ovality is considered normal. Larger diameter kilns experience more ovality.

2.5.5 Welding Repairs

2.5.5.1 Follow manufacturer's recommendations for weld repairs. Kiln manufacturers quite often use AWS or ASME procedures. Welders completing the repairs should be qualified for the procedures specified. Proper preheat, interpass and post heat treatments are necessary to prevent weld-induced stresses.

2.5.6 Routine Nondestructive Examination (NDE)

2.5.6.1 Perform nondestructive examination (NDE) on all weld repairs, including temporary repairs to the shell, riding rings, bull gear and other gears using appropriate methods. Welds to the carrying rollers, roller support frames, and bull gear support members should be examined at least visually.

2.5.6.2 Perform NDE of critical kiln components in accordance with Table 1 about every three years and more often if conditions warrant such as a known crack. Risk-centered maintenance can be used to determine actual frequency of NDE for various components. Unusual operating conditions that place stress on a particular component could indicate a need for NDE, e.g., vertical misalignment at one pier could excessively load the carrying rollers, or a warped shell might be causing excess ring gear stress. A qualified engineer should determine whether a crack should be monitored or repaired. The decision to repair will depend on the depth of the crack and how fast it is growing.

Table 1. NDE of Kiln Components

Component	*Type of NDE*
Ring gear teeth and support members	VT[3], Eddy current, UT[2], MT[1]
Pinion gear	VT, Eddy current, UT, MT
Carrying rollers	VT, MT, UT
Riding rings	VT, MT, UT
Retaining ring welds for dryers having an inner drum	VT, UT, MT
Inner tube or drum of dryers and bakers	VT, UT
Girth welds for kilns with backing plate type construction	VT, UT, MT
Planetary cooler attachment welds	VT, UT, MT
Clinker crusher grinding drum where thickness changes near discharge opening	VT, UT

Note 1. Magnetic particle
Note 2. Ultrasonic
Note 3. Visual

2.5.7 Refractory

2.5.7.1 Monitor refractory condition continuously and check thickness during shutdowns and at least annually. Refractory thickness normally varies between 4.5 in. (11.3 cm) at the cold end and 12 in. (30 cm) at the hot end. Insulated two-layer systems are now used on new kilns, and are very beneficial if installed on older kilns. Infrared monitoring of the shell can be used to monitor refractory thickness after new refractory is installed. Establish baseline temperatures and record trends.

Damaged refractory is the most serious type of kiln upset. Refractory failure is likely at the riding ring sections due to ovality pinch points. Damaged refractory can cause shell warpage and vice versa. Coating fallout or overheated coating can also damage the refractory.

2.5.7.2 Replace thinning refractory before it dislodges if possible.

2.5.7.3 Align burners to prevent flame impingement on the refractory.

2.5.7.4 Use a flexible anchoring system if castable refractory is used. For example, the patented Johnson Insulated Castable System uses stainless steel anchors welded to the shell on nine inch centers. Mineral wool blocks with holes for the anchors are installed next to the shell. The castable refractory is installed over the mineral wool blocks.

2.5.7.5 Depending on the operating conditions and resulting refractory design, there can be long lead times to obtain refractory. Consider these lead times when planning for refractory repair and/or replacement.

2.5.8 Operation

2.5.8.1 Provide a sufficient startup and shutdown period to prevent thermally induced stress (typically about 16 to 24 hours for large refractory-lined kilns). This is even more critical in cold climates. Allow more time during cold spells and also for very large kilns and kilns with extra thick refractory linings. The refractory does not expand as fast as the kiln shell and can be damaged if warm-up and cool-down periods are not long enough. The auxiliary drive must be engaged after shutdown. At first, the auxiliary drive will turn the kiln continuously for a specified time. Then a specified jacking schedule will be followed. When the jacking schedule is complete, the kiln must be turned one half a turn at least every 24 hours.

Heating a rotary kiln too rapidly can also damage the shell because the pads choke in the riding ring bore. (The ring will not expand at the same rate as the shell.) Follow manufacturer recommendations.

Do not operate the kiln on full speed until it reaches normal operating temperature.

Be careful when starting clinker cooler or secondary air fans not to blow out the burner flame by using an excessive airflow rate.

2.5.8.2 Do not operate the kiln for long periods with known misalignment or other problems such as a badly warped shell, excess clearance between riding rings and filler pads, broken bull gear spring plates, and damaged refractory. These types of problems can lead to mechanical breakdowns and should be corrected as soon as practical. Cool hot spots with air and repair refractory as soon as possible. Repair all large cracks including riding ring cracks, shell cracks and pad weld cracks during shutdown periods. Welding can induce stress in large cast parts. A decision must be made whether to monitor cracks for growth or repair. See Section 2.5.5, Welding Repairs, and Section 2.5.6, Routine Nondestructive Examination.

A badly warped (distorted or bent) shell can be indicated in several ways. The ovality near a carrying roller should be no more than 0.3% — 0.5% based on the kiln diameter. (See Section 2.5.4) A runout reading of 1 in. (25 mm) near a carrying roller or the main gear is considered excessive; this much runout further away should be monitored. A runout reading of 3 to 4 in. (75-100 mm) midspan is normally considered excessive.

2.5.8.3 For refractory-lined kilns, if material flow to the kiln is interrupted, reduce the burner fuel supply to prevent overheating. The kiln should be shut down if an interruption to feed exceeds 10 minutes for a wet or dry kiln, or three minutes for kilns with preheater/precalciners. Feed hopper level should be monitored.

2.5.8.4 Operating personnel should completely walk around the kiln at least once per shift and note such things as unusual noises, carrying roller bearing assembly temperature and noise, roller-tire contact during a complete revolution, vibrations, movements, shell hot spots, shell cracks, oil levels, etc.

2.5.8.5 Test the auxiliary kiln drive weekly. If the drive (or generator) is powered by an internal combustion engine, run the engine each week for a minimum of 15 minutes or until the engine is warmed up (might take up to an hour). Inspect batteries weekly. The auxiliary drive must be available in case of power loss or main drive failure to prevent shell warpage. There should be a separate auxiliary motor to drive the kiln in case of main motor failure, and not merely a backup generator.

2.5.8.6 Visually inspect riding rings each shift and check for broken retainer bars and also listen for noises that indicate this condition. For riding rings that experience the most thermal stress, ring proximity sensors can be installed to indicate a shifted ring caused by broken retainer bars.

2.5.8.7 Operate the kiln to minimize the formation of dust rings. Dust rings form for different reasons. Operating the kiln in a stable manner with minimal upsets and cycling should help. Temperature transients can be a significant factor. Proper burning is important. Control of raw material alkalis and fineness can have a positive effect also. It is preferable that rings be knocked down gradually to prevent the cooler overload. Knocking down these rings floods the cooler, resulting in higher than normal undergrate pressure and increased temperature. The kiln speed is usually decreased to reduce the increased temperature. When this fails, use water to cool the outlet conveyor and shut down the operation if necessary. Back-end draft can be used to indicate the formation or loss of rings. Note that draft will be affected if an inspection door at the back-end or a fuel chamber door has been opened, or if a cooling air damper (sometimes used to cool the I.D. fan) position has been changed.

2.5.8.8 Develop a documented procedure to address product slides which can interfere with combustion.

2.5.8.9 For kilns that use chains for heat exchange, monitor the chain temperature (measure product temperature after chains). (See Fig. 8.) If the chain temperature exceeds 1600°F (871°C), and excess oxygen is 4% or greater, the chains will burn. Oxygen levels must be kept low during shutdown while the temperature is high. A wet shutdown (kiln is shut down before empty) is preferable and will keep the chains cooler (more cleanup is needed after shutdown, however). Enrichment oxygen, if used, must be tightly secured.

2.5.8.10 Inspect the feed and discharge end seals daily. Excessive leakage into the back-end will result in unreliable exhaust readings (temperature, CO, CO_2, O_2). The operator relies on these readings for proper operation. Tramp air entering the kiln's front end can also lead to improper combustion. Lubrication of seals using a powdered lubricant is often done to minimize friction and wear.

2.5.8.11 Provide a backup instrument air supply if it is critical to process, burner or safety control.

2.5.8.12 Grease combustion hood slide runners (if applicable) in accordance with manufacturer's recommendations to facilitate ease of kiln expansion.

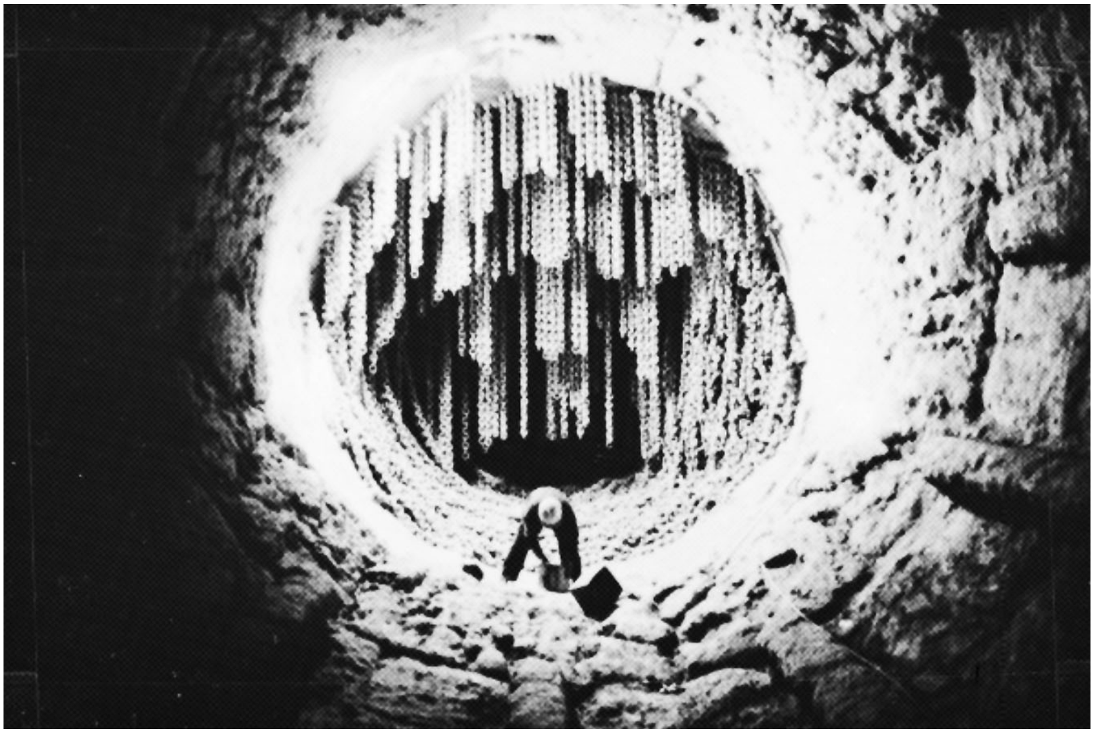


Fig. 8. Chains in a dry process cement kiln.

2.5.8.13 Process Control for Calcining Kilns

2.5.8.13.1 Control the three basic variables (back-end temperature, burning zone temperature and exit gas oxygen) by varying the fuel rate, I.D. fan speed and/or kiln speed. See Figure 9 for an illustration of typical kiln instrumentation. Modern kilns are fully automated using control schemes such as PID and fuzzy logic. The operator must still monitor the operation and be knowledgeable enough to control the kiln manually if the automatic control system malfunctions or is unable to handle an upset.

2.5.8.13.2 Maintain kiln stability by properly controlling back-end temperature and by operating the kiln with a small amount of excess oxygen (0.4 to 2.5% is the normal range needed for a stable operation). Normally feed is not varied, but it might be better to slow down the kiln if necessary and make small changes to maintain kiln stability rather than allow a kiln upset and cycling to occur.

Cycling is an unstable condition. The burning zone temperature cycles up and down despite (and possibly because of) corrections made by operators. In a calcining kiln, product feed temperatures vary along the length of the kiln; firing rate changes affect these temperatures. When the feed arrives in the burning zone several hours later, this zone will in turn be affected by higher or lower than normal feed temperature. Fuel changes should be gradual to prevent an upset. Too much fuel can also lead to kiln overheating or poor combustion. Sometimes production must be slowed down to prevent an upset leading to cycling. It is also possible that if the kiln is not running at full capacity, an increase in production can cause the kiln to stabilize because it will inherently operate better at full load.

Changes to the feed rate or feed composition can lead to cycling if operators do not anticipate the changes. Adjustments should never be delayed. A steady feed rate is essential to kiln stability. Dust return should also be steady by using a surge bin or metering device.

If dusty conditions prevail, observe feed under and behind the flame before making decisions after an upset occurs.

2.5.8.13.3 Ensure that operators are thoroughly familiar with actions to be taken based on the 27 combinations of the three basic variables (high, low or normal). These actions will also depend upon whether the burning

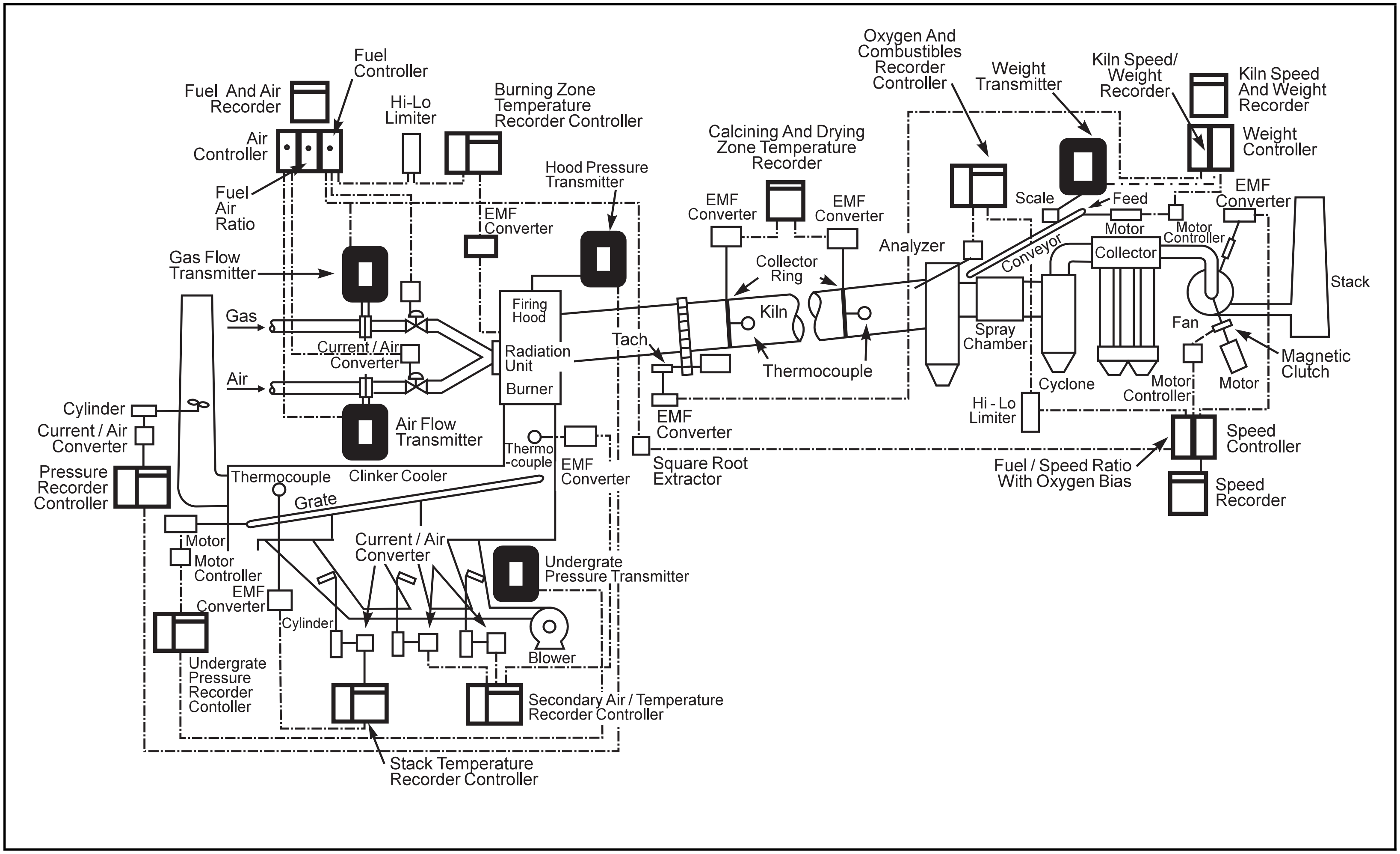


Fig. 9. Typical instrumentation for cement kiln and cooler. **Note:** Combustion safety controls and cooler baghouse not shown. (Courtesy of The Foxboro Co.)

zone temperature is slightly high or low and whether the oxygen is in the upper part or lower part of the normal range (when normal). These guidelines should be readily available in the control room.

2.5.8.13.4 Adjust flame whenever small red spots appear on the kiln shell. Air cooling of the shell can help to promote coating formation. If a bright red, hot spot larger than 3 ft (1 m) in diameter appears, the kiln must be shut down. If the kiln is rotated intermittently after shutdown, rotate the kiln until dark, cooler feed covers the hot spot. Then the kiln can be jacked over according to the regular schedule; however, full turns will be needed to make sure that the hot spot is always on the bottom when the kiln is stopped, until the kiln is cooled down.

Adjust flame direction in small steps and only during stable conditions. The flame should not impinge on the coating or the feed bed. Once the flame is stable, the primary air pipe position should be left alone.

2.5.8.13.5 Normally secondary air temperature is held constant, however, maintaining normal temperature should not be attempted if the kiln has been slowed down due to an upset because cooler overheating will result when less feed is being discharged from the kiln.

2.5.9 Mechanical Inspection Guidelines

2.5.9.1 Inspections

The following guidelines are for a large kiln such as a cement kiln. Not all of the following applies to some equipment. FM rotary kiln inspections are grouped under three headings. These are:

1. Operating — performed with the unit in service.
2. Shutdown — performed with unit not operating. Reasons may be routine idle periods, routine maintenance, service modification or partial dismantle for corrective maintenance. Inspection should include a startup if possible.
3. Dismantle — performed as part of a ‘‘take-apart’’ inspection. There is not a specific time frame; the time can vary with manufacturer’s recommendation, operating conditions, type of service, age of unit, and equipment failure experience.

2.5.9.2 Operating Inspections for Fully Assembled Equipment

Compare the following items with the parameters established by the manufacturer of the equipment.

2.5.9.2.1 Verify availability of startup and shutdown procedures (standard and emergency). Operators should use these procedures and have the authority to make critical decisions.

2.5.9.2.2 Verify operating conditions are within manufacturer’s parameters for:

1. Load
2. Speed
3. Temperature (hot zone and back end)
4. Back-end oxygen

2.5.9.2.3 Look for hot spots (easier to spot at night on both preheater equipment and the kiln), especially near the hot end of the kiln. Look for flat spots or blisters, especially near each riding ring. These indicate a hot spot and breakdown of refractory. Examine the shell for repairs, verify repairs were completed correctly, and document any follow-up activity.

2.5.9.2.4 Visually check supporting piers for indications of settling and/or tipping. Check for pier vibration and movement of the carrying roller frames.

2.5.9.2.5 Visually check thrust rollers. Check if riding ring floats between the thrust rollers (commonly done, but not always recommended) or if one of the rollers is rotating. If rotation or the thrust roller and carrying roller surfaces are not smooth, the thrust roller shaft and bushing may be damaged. If the thrust roller appears to be tilted, there could be excess bushing wear caused by overloading of the thrust roller. If the thrust roller rises up during rotation, it is probably not adjusted properly (thrust roller centerline should be about 1⁄16-1⁄8 in. (1.6-3.2 mm) and no more than 1⁄4 in. (6.4 mm) past the carrying roller frame centerline in the direction of the downward side of kiln rotation. An uphill thrust roller rotating could be a sign of misadjusted and overloaded carrying rollers. If the kiln is equipped with a hydraulically-actuated thrust assembly, the thrust roller will automatically adjust the thrust; the carrying rollers should not be adjusted to move the kiln uphill. If the kiln floats, it will periodically move up and down between the thrust rollers. If the kiln is equipped with a single, hydraulically-operated thrust roller, the roller will be adjusted automatically using a limit switch.

2.5.9.2.6 Visually check carrying rollers for wear and pitting. Look for eccentric movement of the riding rings and check if both rollers remain in full contact during a complete revolution. A warped shell can lift a riding ring off of the roller or wear can cause incomplete contact across the face of the roller. Look for spalling or corrosion indicating poor contact or incorrect skewing. Making sure skewing is parallel will correct this condition if done soon enough. If the rollers are convex and the associated riding ring concave, rollers may be overadjusted. This condition will cause problems when the kiln is being warmed up or shut down. Check both bearing assemblies of each roller for abnormally high temperature and squealing noises. Check for shaft cleanliness between the roller and bearing housing. Check to see if a riding ring is riding over the edge of the tire on one side.

2.5.9.2.7 Check each carrying roller to see if it is thrusted uphill or downhill by measuring the distance between the roller and housing on both sides. Or tap on the end of each carrying roller assembly with a hammer; the thrusted end will sound more solid. Some kilns have an inspection cap to view the thrust position. Most kilns should be thrusted against the downhill carrying roller bearing, causing the kiln to be pushed uphill. If some of the uphill bearings are thrusted, the kiln will be pushed downhill and the thrust roller could be overloaded. (If it is carrying any load, the thrust roller will be rotating.)

2.5.9.2.8 Visually check pad and retaining bar welds. Check if retaining bars are worn or cutting into the tires.

2.5.9.2.9 Verify that graphite blocks used to lubricate carrying rollers are in contact with the roller and free to move in their retainers.

2.5.9.2.10 Check creep at each riding ring. Compare with recent records. Look for large differences between readings at each pier.

2.5.9.2.11 Check for oil leaks at each carrying roller bearing end seal.

2.5.9.2.12 Visually check the driving gears (ring and pinion) for lubrication and wear. Pinion teeth wear more rapidly than the ring gear teeth. Worn pinion teeth will accelerate wear of ring gear teeth. Check if the gear and pinion centerlines match. If the centerlines are not lined up, the ring gear pitch line might be worn off if the gear rubs against the guard. Check if pitch lines are separated (preferable), or matched or even overlapping; align gears if overlapping.

2.5.9.2.13 Verify that the auxiliary drive system is functional in the event of main drive failure.

2.5.9.2.14 Verify the auxiliary drive is started and run at least weekly. Verify that there is an auxiliary drive motor rather than just a generator that powers the main drive motor. The generator, typically diesel powered, should be tested. Maintain an adequate fuel supply. It might not be practical or advisable to run the auxiliary drive motor itself unless it can be operated without being engaged to the main reducer gears.

2.5.9.2.15 Visually check auxiliary drive gears for lubrication, clearance and wear, if applicable.

2.5.9.2.16 Inspect reducer gear oil levels and bearing temperatures.

2.5.9.2.17 Check adequacy and operation of gear lubricating oil system and check for leaks. Oil should be changed as indicated by testing. If it is a spray type system, install an operational warning device to indicate air pressure loss and test the device periodically.

2.5.9.2.18 Check water or air cooling system of the carrying and thrust roller lubricating system, if installed. If it is water cooled, review winter (cold climate) operating procedures such as lay up.

2.5.9.2.19 Inspect drive motors.

2.5.9.2.20 On small kilns/dryers with annular synchronous motor and rotor secured to shell (no gear set or clutches) pay special attention to maintaining acceptable air gap.

2.5.9.2.21 On dual drive kilns, pay attention to dual drive synchronization. Amperage should be steady. Monitor the voltages or currents of the field and armature for each motor for periodic variations that can indicate an imbalance. There might be a slight difference in amperage between the two motors due to instrument errors; this should remain within a certain tolerance during steady state conditions. Properly aligning both gear sets is important. Kiln drive motors are normally dc, however, some installations are using variable frequency ac motors; the variable frequency drives stay balanced inherently.

2.5.9.2.22 Check maintenance and cleanliness of dust filters on air intakes for drive motors.

2.5.9.2.23 Inspect raw material feed pumps and motors. A feed interruption can lead to a serious upset.

2.5.9.2.24 Inspect all fans including the induced draft fans, primary air fans, forced draft fans, recirculating fans, combustion fans, cooling fans and preheater fans.

2.5.9.2.25 Verify interlocks are installed to shut down the supply of fuel in case the induced draft fan, primary air fan or other required fans (needed for proper combustion) malfunction.

2.5.9.2.26 Verify interlocks are tested. Check records and observe test if possible.

2.5.9.2.27 Verify periodic vibration readings on induced draft fans. Check records.

2.5.9.2.28 Check for main drive and fan vibration trends.

2.5.9.2.29 Visually check condition of piping, hoses, flexible connections, swivel joints, etc.

2.5.9.2.30 Maintain general good housekeeping practices.

2.5.9.3 Shutdown Inspections

In addition to the feasible items included in Section 2.5.9.2, observe the following items where possible during a scheduled shutdown. As applicable, witness tests or verify data from logs.

2.5.9.3.1 Visually check kiln shell for cracks. Visually check for indications of warping or blistering of the kiln shell which would signify a hot spot and refractory breakdown. Examine old repairs. Verify whether follow-up activity is needed to check old repairs.

2.5.9.3.2 Verify symmetrical air gap on kilns with annular synchronous motors and rotors secured to shell.

2.5.9.3.3 Visually check all the way around the main gear for uniform contact across the gear teeth.

2.5.9.3.4 Verify pinion and main gear mesh is adjusted to remove any pitch line overlap. Account for thermal expansion effects on gear mesh at full operation.

2.5.9.3.5 Inspect refractory for failure or excessive wear including:

- abrasion
- spalling
- chemical attack
- slagging
- proper installation to allow flexing of shell and thermal expansion
- proper refractory composition for each kiln zone.

2.5.9.3.6 Visually check the chain shoe system.

2.5.9.3.7 Observe chains for oxidation, scaling and fluxing.

2.5.9.3.8 Inspect drive motors, gears, and fans.

2.5.9.3.9 Inspect the primary air pipe for warping.

2.5.9.4 Dismantle Inspection of Kiln Components

2.5.9.4.1 Inspect kiln components during major disassembly at regular intervals recommended by the manufacturer or when necessary as determined by operating conditions. In addition to all possible operating and shutdown inspection items, observe or verify the following items:

a) Refractory inspection and repair.

b) Condition of carrying roller bushings (important), and downhill thrust roller bushing. If wear is excessive, the bushing will have the same contour as the shaft and will be thinner at the middle part of the bushing. There might also be high spots or ripples along the longitudinal axis. Worn bushings should be replaced. For spherical anti-friction bearings, measure roller-to-race clearance.

c) Condition of gas and dust seals.

d) NDE of all welds at riding rings if indications are present.

e) Ring gear and pinion. Inspect for broken teeth or cracks. If indications are found, prove the condition by NDE of entire gear. Check the ring gear flange or spring plates for cracks. Measure pinion bearing roller-to-race clearance.

f) Conduct undercover inspection of enclosed gear reducer.

g) Condition and balance of I.D. fan rotor.

h) Alignment of piers/carrying frames.

i) Verify horizontal and vertical alignment of shell together with proper contact and loading of the carrying rollers and the thrust roller.

j) Perform motor, gear and fan checks.

k) Where service is done by an outside contractor, verify work is accomplished from service sheets and made a permanent part of plant records. Permanent records should be kept for in-house work also.

l) After satisfactorily testing and operating the unit (following major dismantling), compare existing baseline data with present temperatures and vibration signature to verify proper operating condition.

2.6 Contingency Planning

2.6.1 Equipment Contingency Planning

When a rotary kiln or dryer breakdown would result in an unplanned outage to site processes and systems considered key to the continuity of operations, develop and maintain a documented, viable rotary kiln or dryer equipment contingency plan per Data Sheet 9-0, *Asset Integrity*. See Appendix C of that data sheet for guidance on the process of developing and maintaining a viable equipment contingency plan. Also refer to sparing, rental, and redundant equipment mitigation strategy guidance in that data sheet.

In addition, include the following elements in the contingency planning process specific to rotary kilns or dryers:

A. Kiln or dryer operation, conditions and design.

B. Kiln or dryer repairs and/or replacement of key components using qualified contractors.

2.6.2 Sparing

Sparing can be a mitigation strategy to reduce the downtime caused by a rotary kiln or dryer breakdown depending on the type, compatibility, availability, fitness for the intended service, and viability of the sparing. For general sparing guidance, see Data Sheet 9-0, *Asset Integrity*.

2.6.2.1 Routine Spares

Routine rotary kiln or dryer spares are spares that are considered to be consumables. These spares are expected to be put into service under normal operating conditions over the course of the life of the rotary kiln or dryer, but not reduce equipment downtime in the event of a breakdown. This can include sparing recommended by the original equipment manufacturer. See Section 3.2 for routine spare guidance.

2.6.2.2 Equipment Breakdown Spares

2.6.2.2.1 Equipment breakdown spares for rotary kilns or dryers are spares intended to be used in the event of an unplanned outage of a rotary kiln or dryer to reduce downtime and restore operations. Provide the following equipment breakdown spares for rotary kilns or dryers:

A. Ring gear segment (depending on the design and if gear has been reversed)

B. Pinion gear (to drive the ring gear)

C. Thrust rollers and bushings (bearings)

D. Internals for gear reducer

E. I.D. fan rotor and other critical fan rotors, and couplings (especially fluid couplings)

F. Kiln drive motor and couplings/clutches

G. Carrying rollers and bushings (bearings). Keep one of each size if they are not the same.

2.6.2.2.2 For lime kilns at integrated pulp and paper plants, and at stand-alone lime facilities where the exposure can be mitigated using equipment contingency plan guidance, the equipment breakdown spares listed above do not apply.

2.6.2.2.3 Maintain the viability of rotary kiln or dryer equipment breakdown spares in accordance with Data Sheet 9-0, *Asset Integrity*.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Loss History

A study of 43 losses during a recent 12 year period showed the largest percentage were caused bymechanical breakdown, followed by fire and explosions, overheating and refractory collapse.

3.2 Routine Spares

The following are common routine spares for a rotary kiln or dryer. Store and maintain the routine spares per the original equipment manufacturer's recommendations to maintain viability. Refer to Data Sheet 9-0, *Asset Integrity*, for additional guidance.

- Refractory and associated anchoring system components for minor/temporary repairs

4.0 REFERENCES

4.1 FM

Data Sheet 3-26, *Fire Protection for Nonstorage Occupancies*
Data Sheet 5-17/14-20, *Motors and Adjustable Speed Drives*
Data Sheet 5-20/14-22, *Electrical Testing*
Data Sheet 5-31/14-5, *Cables and Bus Bars*
Data Sheet 5-49, *Gas and Vapor Detectors and Analysis Systems*
Data Sheet 6-2, *Pulverized Coal-Fired Boilers*
Data Sheet 6-4, *Oil- and Gas-Fired Single-Burner Boilers*
Data Sheet 6-5, *Oil- or Gas-Fired Multiple Burner Boilers*
Data Sheet 6-8, *Combustion Air Heaters*
Data Sheet 6-9, *Industrial Ovens and Dryers*
Data Sheet 6-11, *Fume Incinerators*
Data Sheet 6-13, *Waste Fuel-Fired Facilities*
Data Sheet 7-10, *Wood Processing and Woodworking Facilities*
Data Sheet 7-11, *Conveyors*
Data Sheet 7-32, *Ignitable Liquid Operations*
Data Sheet 7-54, *Natural Gas and Gas Piping*
Data Sheet 7-55, *Liquefied Petroleum Gas (LPG) in Stationary Installations*
Data Sheet 7-88, *Ignitable Liquid Storage Tanks*
Data Sheet 8-10, *Coal and Charcoal Storage*
Data Sheet 9-0, *Asset Integrity*
Data Sheet 13-7, Gears
Data Sheet 13-18, *Industrial Clutches and Clutch Couplings*
Data Sheet 13-24, *Fans and Blowers*

4.2 NFPA Standards

NFPA 30, *Flammable and Combustible Liquids Code*
NFPA 54, *National Fuel Gas Code*
NFPA 70, *National Electrical Code*
NFPA 85, *Boiler and Combustion Systems Hazards Code*
NFPA 86, *Ovens and Furnaces*

4.3 Others

ANSI B31.1, *Power Piping*.

APPENDIX A GLOSSARY OF TERMS

Approved: references to ''Approved'' in this data sheet means the product and services have satisfied the criteria for FM Approval. Refer to the *Approval Guide*, a publication of FM Approvals, for a complete listing of products and services that are FM Approved.

Burning zone: the hottest part of a cement kiln near the discharge end where combustion takes place. Many chemical reactions take place here, and feed is transformed or ''burned'' into the finished product such as cement clinker.

Bushing: typically a 180° sleeve type bearing used to support carrying roller shafts. The bushings can be independent or a connected assembly type. Some kilns have spherical anti-friction type bearings.

Calcining: part of the process that takes place inside lime, cement and alumina kiln systems. CO_2 is driven off the product during this stage of kiln pyroprocessing. In long dry or wet process kilns, calcining occurs near the middle of the kiln. In suspension preheater kilns, the calciner is either part of the extended riser duct, or a separate vessel integrated with the riser duct and the bottom cyclones.

Carrying roller: also called trunnion, support roller or plain roller. Two rollers are mounted at each kiln support pier. The kiln riding rings (tires) rotate on these rollers. The kiln vertical load and part of the axial thrust load is supported by the rollers.

Carrying roller assembly: consists of the roller, shafts, uphill and downhill bearing, bearing housing, thrust plates and mounting frame.

Combustion hood: front end section of kiln which supports the burner pipe and where secondary air enters. The hood is sometimes allowed to roll over a slide runner for expansion, and an air seal is provided between the kiln shell and the hood.

Cooler chimney: used to exhaust excess grate cooler air and maintain proper hood pressure by means of a damper. **Note:** These are not used anymore because the cooler excess air is not allowed to escape to the atmosphere. Modern pollution control equipment is used to protect the environment and to fulfill the functions of the former chimney damper.

Drive: the main motor and reducer gears that turn the pinion which engages with the bull gear.

Dust rings: solid rings often form inside some kilns such as cement and lime kilns. This usually occurs in the rear of the burning zone and sometimes in the chain section. The formation of dust rings is not fully understood. Alkalies in the feed and dust return are factors. Uneven heating (temperatures being varied too much) can contribute to the problem. Dust rings can actually benefit the kiln operation because they form natural dams which increase the residence times of the feed in various parts of the kiln. Dust rings breaking off can trigger an avalanche of feed towards the discharge end, flood the cooler and initiate a kiln upset. Rings can break off naturally or be knocked down intentionally by different methods.

End seals: air seals at either end of the kiln installed to prevent leakage of tramp air into the kiln.

Feeder: delivers material being processed to the top of the kiln.

Grate cooler: a moving grate type cooler with air blown in from underneath. Used to cool product discharged from the kiln. Every second or third row of grate plates moves forwards and backwards to transport the clinker across the cooler grates.

Grout: cement or epoxy material installed between pier tops and roller assembly subplates to maintain alignment and protect shims from moisture. The material selected should be nonshrinkable.

Hot alignment: carrying rollers are adjusted when the kiln is operating and up to normal temperature.

Hot survey: kiln alignment checks are made when the kiln is operating and up to normal temperature. (Depending on the methods used, some checks such as an internal survey will have to be done when the kiln is shut down.)

Induced draft (I.D.) fan: main fan that creates the draft for pulling combustion air into the kiln and exhausting their products of combustion to pollution control equipment.

Pads: also called filler bars. Plates welded or bolted to the shell and shaped to fit the shell contour. The pads support the riding rings and provide a wear surface for the shell as well as a way to correct for shell irregularities.

Pier: cement structure for supporting the kiln at several locations along its length.

Pinion: the gear which drives the kiln bull gear. Can be reversed to extend service life.

Planetary cooler: also called a satellite cooler or integral tube type cooler. One of a series of large tubes attached to the discharge end of a rotary kiln and used for cooling the product discharged from the kiln using direct contact air cooling. The tubes (usually about ten) are supported by frames welded to the kiln shell. These coolers can be found on lime kilns.

Precalciner: used to calcine the preheated raw meal in a suspension preheater before it enters the kiln. Different types of precalciner systems are integrated with the bottom (hot) part of the preheater.

Preheater: equipment used to preheat raw meal before it enters the kiln. The preheater typically consists of several stages of cyclones connected via riser ducts. Modern systems utilize four to six stages. The raw meal is fed in at the top and is then preheated by the exhaust gases that rise counterflow to the feed. The calcining is initiated at the bottom stage.

Primary air fan: supplies primary combustion air to the kiln's firing zone through the primary air pipe of the burner. In coal-fired systems, it is also used to convey the coal.

Retainer bars: also called stop bars. Used to prevent riding rings from slipping off the pads.

Riding ring: also called a tire or tyre. It is used to support the kiln and rotates on the carrying rollers. The riding ring is mounted over the shell pads, and the shell pads drive the riding ring through friction. Can be a single piece or segmented (2 pieces).

Ring gear: also called girth gear or bull gear. Main kiln gear attached to the shell using a firmly mounted flange or a flexible spring plate system. Used for rotating the kiln. Normally a straight spur gear that is reversible. Mounted near the thrust riding ring.

Secondary air: secondary combustion air is supplied by undergrate cooling air fans (with a grate type cooler). The air is heated as the clinker is being cooled. The air then enters the kiln's firing zone.

Shims: hardware used to minimize excess pad clearance.

Skewing: also called canting or cutting. Adjusting a carrying roller so that its longitudinal axis is at an angle to the axial centerline of the kiln rather than parallel to the centerline. Rollers are skewed to control thrust and uphill-downhill movement of the kiln.

Tertiary air: combustion air for a fired precalciner. The air is supplied by the secondary air system via a tertiary air duct.

Thrust roller: used to absorb most of the kiln axial thrust and typically mounted on the pier nearest the ring gear. There can be two thrust rollers. One is uphill and one is downhill of the riding ring. Or, there can be one thrust roller mounted downhill of the riding ring. The latter is equipped with a hydraulic actuator for automatic adjustment.

APPENDIX B DOCUMENT REVISION HISTORY

The purpose of this appendix is to capture the changes that were made to this document each time it was published. Please note that section numbers refer specifically to those in the version published on the date shown (i.e., the section numbers are not always the same from version to version).

July 2023. Interim revision. Minor editorial changes were made.

January 2023. Interim revision. Minor editorial changes were made.

July 2021. Interim revision. The following significant changes were made:

A. Clarified the difference between a lime kiln and a cement kiln.

B. Updated the equipment contingency plan and sparing guidance for lime kilns.

January 2021. Minor editorial changes were made.

July 2020. Interim revision. Updated contingency planning and sparing guidance.

April 2012. Terminology related to ignitable liquids has been revised to provide increased clarity and consistency with regard to FM Global's loss prevention recommendations for ignitable liquid hazards.

January 2008. Appendix B ″Document Revision History″ was updated.

May 2005. OS/DS renumbered from 6-17/13-20 to 6-17.

May 2003. Minor editorial changes were made for this revision.

January 2001. The following changes were made:

- Some information was added to Section 3.2.3 on the use of analyzers and temperature monitoring for a safe startup. It has also been stated that operators must have authority to shut down the kiln during abnormal conditions (3.2.3 and 2.5.1.1).

September 2000. This revision of the document was reorganized to provide a consistent format.

September 1999. Minor revision. Editorial.

May 1999. Added recommendation to section 3.4 Preheaters/Precalciners and 3.18.3 Shut down Inspections.

January 1999. Minor editorial changes.

October 1998. Rewritten.

September 1998. Revision.

January 1998. Minor revision. Corrected DS cross-references.

June 1990. The August 1979 publication of this Data Sheet is reaffirmed.

APPENDIX C TROUBLESHOOTING

Troubleshooting information for various mechanical problems are in Table 2. Figure 10 provides information for solving tire-retainer wear problems. Figure 11 provides solutions for abnormal shell rotation and improper gear mesh. Figure 12 provides solutions for hot roller bearings.

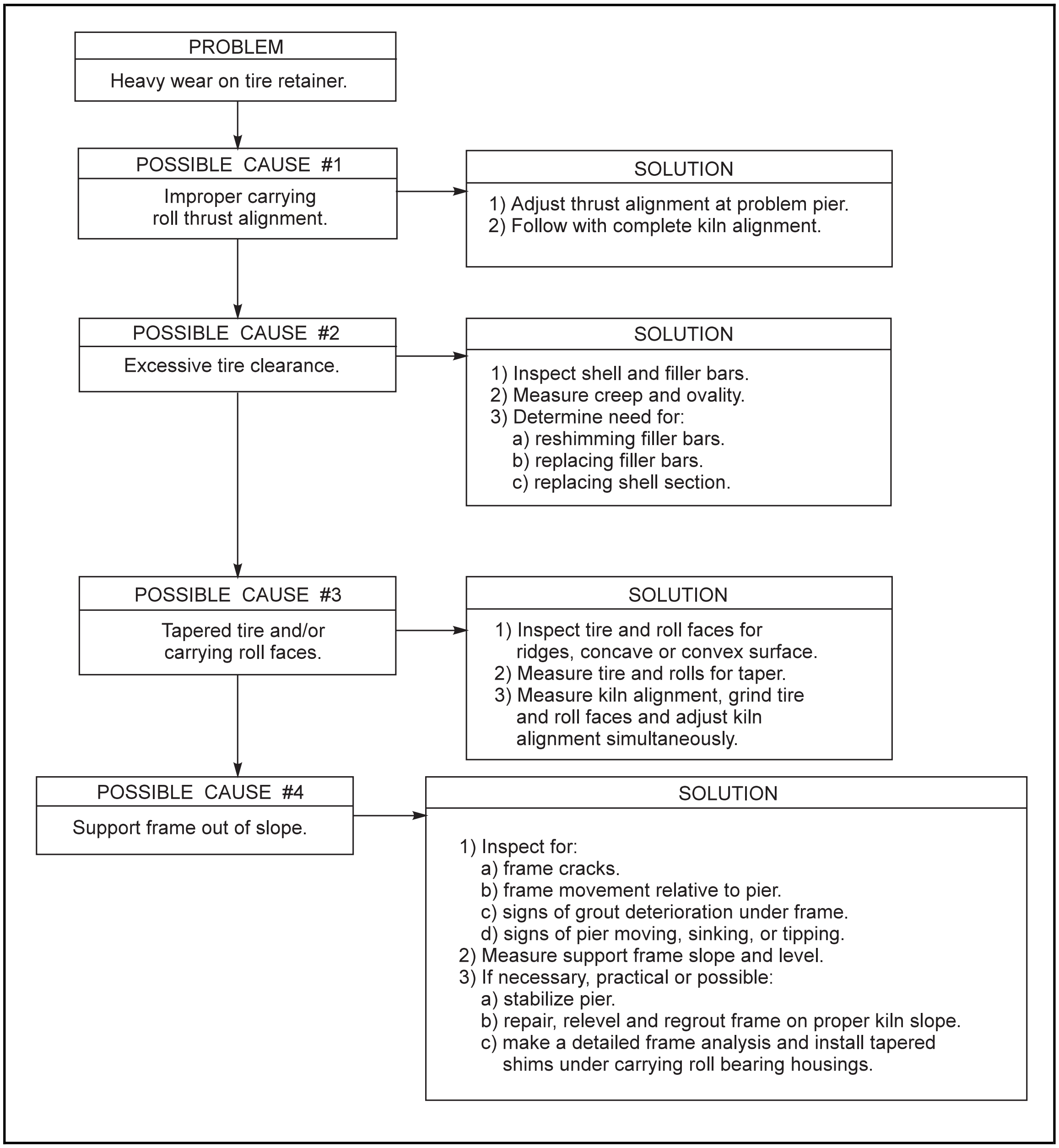


Fig. 10. Troubleshooting problems with excessive riding ring (tire) wear. Courtesy of A-C Equipment Services Corp.

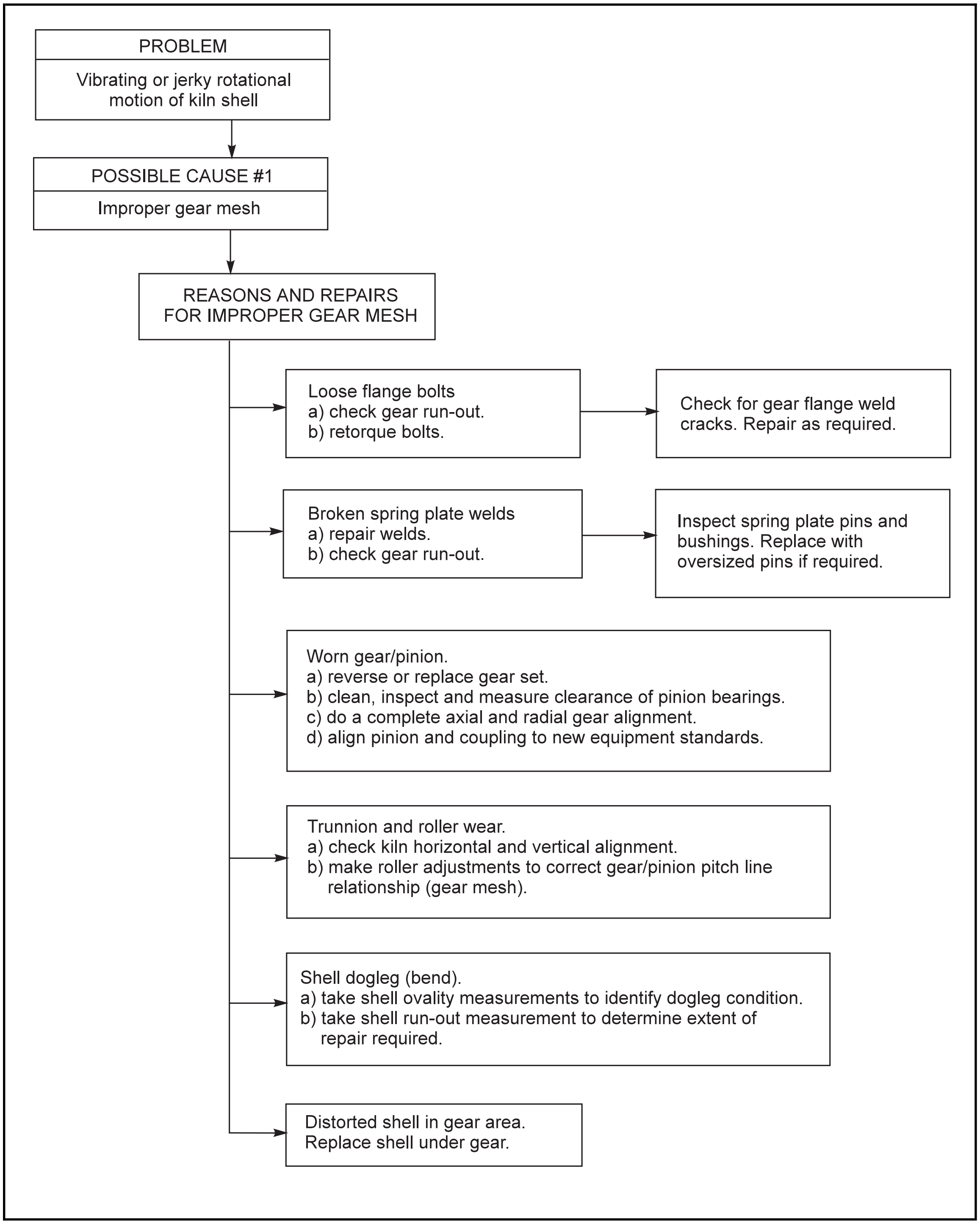


Fig. 11. Troubleshooting problems with abnormal shell rotation. Courtesy of A-C Equipment Services Corp.

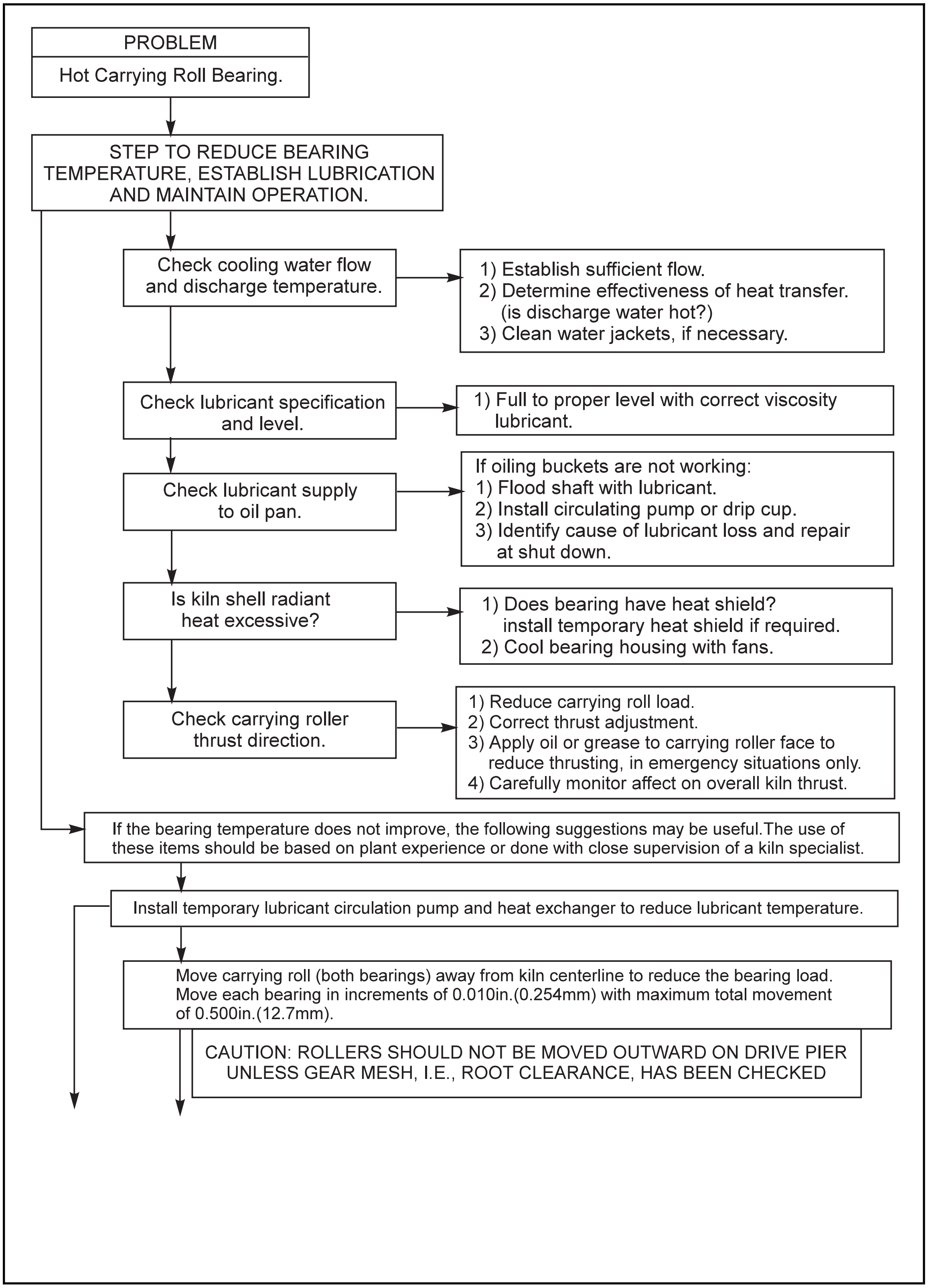


Fig. 12. Troubleshooting problems with hot carrying roller bearings. Courtesy of A-C Equipment Services Corp.

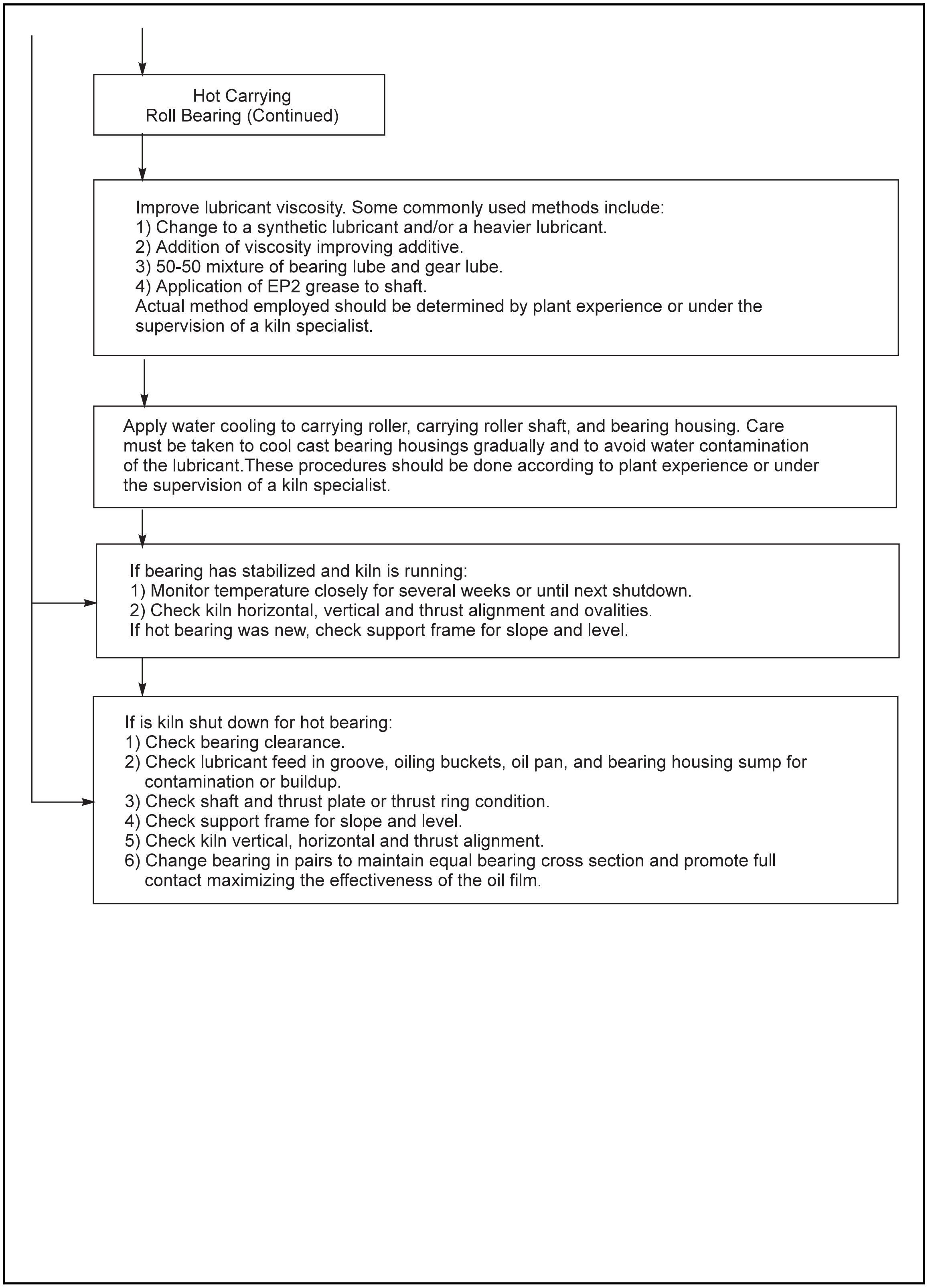


Fig. 12. Troubleshooting problems with hot carrying roller bearings. Courtesy of A-C Equipment Services Corp.

Table 2. Troubleshooting Various Mechanical Problems
Courtesy of A-C Equipment Services Corp.

Problem	*Cause*	*Solution*
Large swings in drive motor amps and kiln R.P.H.	1) Uneven buildup in kiln.	1) Requires correcting one of the following areas: a) operating parameters b) raw mix composition c) coal ash content d) burner pipe positioning
	2) Shell dofleg (bend).	2) Take shell ovality measurement to locate dogleg. Measure shell run-out in affected area to determine extent of problem.
	3) Imbalance of kiln internals.	3) Replace affected chain, dam, etc. Investigate cause of chain deterioration, i.e., temperature, metallurgy, kiln atmosphere.
	4) Kiln misalignment.	4) Check horizontal and vertical kiln alignment.
Excessive wear and/or air infiltration at air seals.	1) Kiln shell run-out.	1) Measure shell run-out at seal. Determine need for: a) shell replacement or realignment b) installation of alternative design seat c) modification of sealing surface to correct run-out condition
	2) Seal component wear.	2) Replace components as needed to renew seal effectiveness
	3) Seal lubrication.	3) Lubricate seals and check for proper movement of rollers if applicable.
	4) Seal counterweight (if applicable).	4) Check counterweight for freedom of movement. Check for proper amount of weight.
Filler bar chunking or slugging.	1) Embedded contaminants 2) Plate laminar tearing.	Lubricate tire inside diameter with graphite/water slurry. No oil.
Tire/roll face scaling.	Lack of graphite lubricant.	1) Replace or clean graphite lube block. 2) Free up the lube block in its holder.
Insufficient tire/roll face contact.	1) Kiln misalignment.	1) Complete check of horizontal, vertical and thrust alignment.
	2) Tapered or out of round tire or roll faces.	2) Regrind tire and roll faces.
	3) Support frame or pier problems.	3) See Tire Retainer Wear possible cause #4, Figure 10.
Thrust roll lifting out of bearing.	Roll positioned toward the uprunning side of the kiln centerline.	Position thrust roll 1/16-⅛ in. (1.59-3.175 mm) off kiln centerline toward the downrunning side.
Thrust roll face spalling or bearing hot.	1) Improper kiln thrust adjustment.	1) Check and adjust carrying roller thrust alignment.
	2) Kiln shell dogleg (bend), causing changes in kiln thrust.	2) Measure shell ovality/run-out to determine extent of problem.
	3) Low oil level.	3) Refill oil to correct level.
	4) Contamination/wear	4) Disassemble, clean and inspect at shutdown.
Carrying roll oil seals leaking.	1) Contamination in seal area.	1) Maintain a clean shaft in area between roller side face and bearing housing.
	2) Seal worn or damaged.	2) Replace seal.
	3) Shaft worn in seal area.	3) Rebuild and remachine shaft or replace shaft
Repeated refractory failure in same area.	1) Excessive kiln shell ovality, due to: a. clearance or shell distortion b. excessive load	1) Measure ovality to identify problem. a. reshim or replace filler bars or shell as required b. measure and adjust kiln centerline alignment
Coupling grids/teeth worn, dry and coated with powdery residue.	1) Oil separated from carrier in grease.	1) Relube with grease formulated especially for couplings.
	2) Coupling misalignment.	2) Realign coupling. Misalignment should be no more than 25 of coupling manufacturer's recommended maximum misalignment.

APPENDIX D NFPA STANDARDS

Additional information concerning fuel explosion prevention may be found in NFPA[1] 85, *Boiler and Combustion Systems Hazards Code*, and NFPA[1] 86, *Ovens and Furnaces*. NFPA[1] 85 includes recommendations for direct-firing systems for rotary kilns. Consult these standards for a more detailed explanation of system requirements and operating philosophy. With minor exceptions as to fuel gas-train arrangements, FM has no known conflicts with these standards.

Other related standards include NFPA[1] 54, *National Fuel Gas Code*; NFPA[1] 30, *Flammable and Combustible Liquids Code*; NFPA[1] No. 70, *National Electrical Code*; and ANSI[2] B31.1, *Power Piping*.

[1] *NFPA 30, 54, 70, 85 and 86 are copyrighted publications of the National Fire Protection Association (NFPA), Quincy, MA 02269.*
[2] *ANSI B31.1 is a copyrighted publication of American National Standards Institute, Inc., New York, NY 10018.*