Aug. 27, 1963 R. J. HANCE 3,101,618

ROTARY KILN SHELL TEMPERATURE SCANNING SYSTEM

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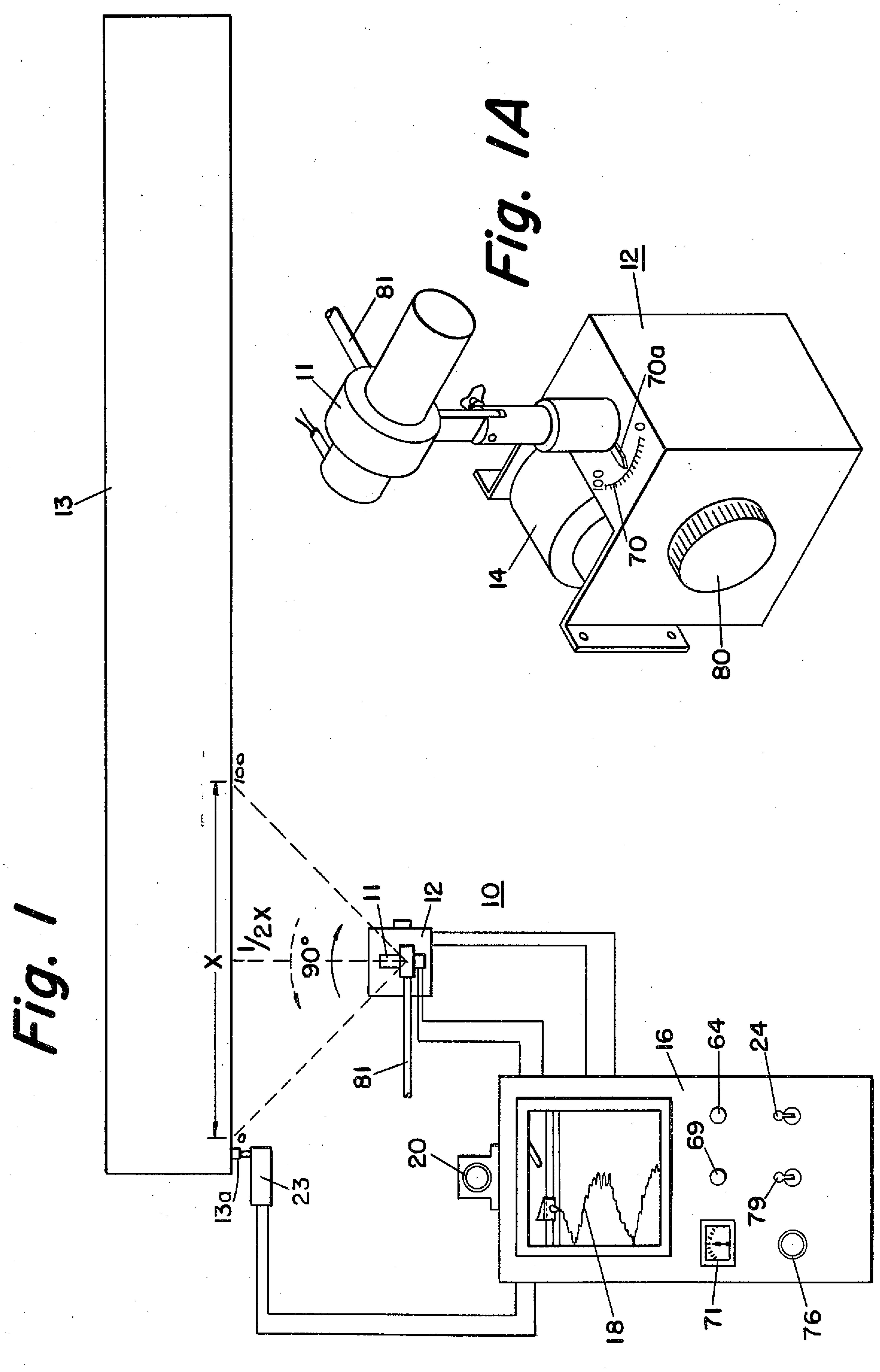

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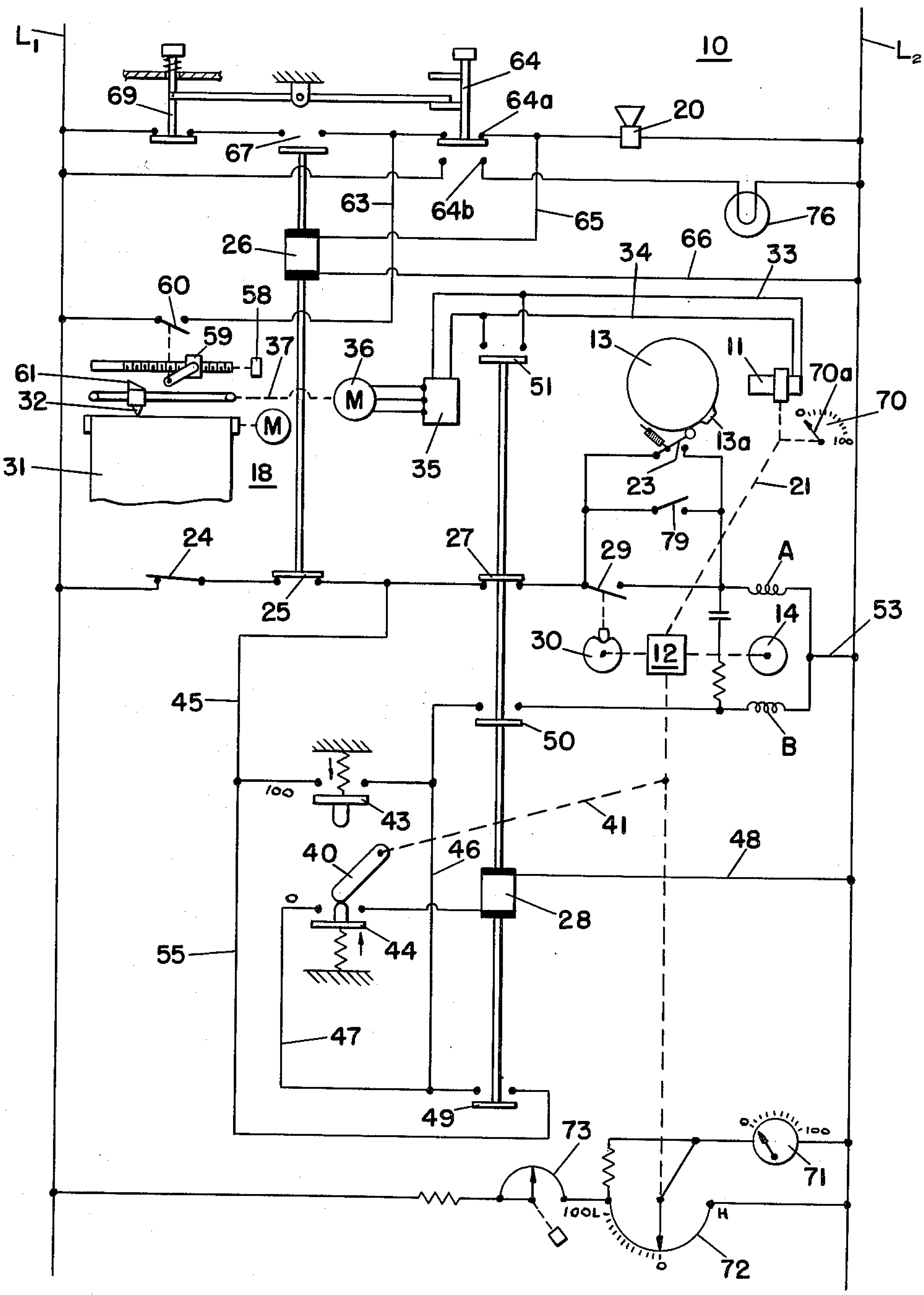
Fig. 2



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ROTARY KILN SHELL TEMPERATURE SCANNING SYSTEM

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This invention relates to a temperature scanning system for rotary kiln shells and has for an object the provision of a system for detecting "hot spots" of a rotary kiln shell at temperatures below the visible range.

The temperature of the outer surface of a rotary kiln is important to operating personnel as it provides information about the condition of the refractory lining and material coating over the lining inside a typical cement kiln. This material coating is several inches thick and is produced in the burning zone of a kiln during normal operation. Depending upon kiln length, diameter, fuel rate and type, type of feed and production capacity, the burning zone may extend twenty-five to forty feet from the firing end of a kiln. When preheated raw material reaches the burning zone during transport through the kiln, it is in a plastic state and adheres to the refractory lining. The coating serves to protect the underlying refractories and kiln shell from the high temperature and erosion in the burning zone and acts as a "runway" upon which the clinker is transported through the kiln.

The coating is constantly being lost and reformed, depending upon variations in feed rate, fuel rate, burning zone temperature, kiln speed and type of feed. When sections of the coating fall off and are not replaced, serious damage to the refractory lining and kiln shell is inevitable, unless the kiln operator is informed of this condition and takes corrective action quickly. Kiln coating and lining failure is predicted by the formation of hot spots which appear on the outer surface of the shell. The lifetime of a lining is ordinarily from about three months to a year and it is a natural function in kiln operation to try to prolong the lining life as long as possible.

Heretofore, temperature-sensitive crayons and contact pyrometers have been used for spot checks in suspected troublesome areas, attempts have been made to employ radiation pyrometers; however, to date such systems have been complicated and expensive. Until now most kiln operators have relied upon visual inspection of both the inside and the exterior of a kiln to detect loss of coating. Such practice is inadequate due to the poor visibility of conditions in a kiln and the unavailability of an operator to continuously check the entire periphery of the burning zone for hot spots. By the time an operator notices a visible hot spot on the kiln exterior (discoloring of the shell appears at approximately 800° F.) extensive refractory damage has already occurred.

Since a typical shutdown for rebricking a patch can cost a producer several thousands of dollars in lost production due to down time, it is particularly desirable that there be some means for detecting and warning of the formation of hot spots. Such information allows an operator to take remedial action and prevent a shutdown. The remedial action taken depends upon the local conditions. It may include repositioning the burner pipe, slightly reducing fuel rate, increasing combustion air, or changing kiln speed to change dimensions of the burning zone to form more coating. The sooner the remedial action is taken, the less extensive it has to be. A kiln can be severely damaged within twenty minutes, but normally the rate of change of shell temperature is slow when a hot spot is developing.

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In accordance with the present invention, there is provided a system suited for measuring the temperature of the outside surface of a rotary kiln to provide an advance warning of the formation of hot spots. In such system, a radiant energy detector is rotatably supported to view the kiln. A reversible drive means is provided for rotating the detector about a fixed axis cyclically to scan a predetermined area of the kiln. The total area of the kiln to be scanned can be accomplished by rotation of the radiant energy detector through an angle of about 90° and such scanning is effected in small incremental steps. To accomplish this, there is provided control switch means in circuit with a drive means and operated during each revolution of the kiln to rotate the detector through a fraction of its scanning cycle. When the detector has been rotated through its complete scanning cycle, its direction of rotation is reversed so as to move the detector in one continuous movement back to its original starting position to repeat the scanning cycle. To accomplish this, there is provided a first limit switch means in circuit with the drive means and operated by arrival of the detector at the end of the scanning cycle to reverse the rotation of the reversible drive means and return the detector to its starting position. A second limit switch means at the starting position is in circuit with the first limit switch means and the drive means to stop the reverse rotation of the drive means preparatory to repeating the scanning cycle of the detector. A measuring and recording means is connected to the output of the detector to record the temperature of the kiln and means is provided for disconnecting the output of the detector from the recorder during the reverse rotation of the detector. Associated with the recorder is means for presetting the hot spot temperature. The system also includes alarm means in circuit with an alarm switch and means operated by the recorder in response to the output of the detector to close the alarm switch and operate the alarm when the temperature of the kiln shell reaches the preset hot spot temperature.

For a more detailed description of the invention and for further objects and advantages thereof, reference is to be had to the following description, taken in conjunction with the accompanying drawings in which:

FIG. 1 is a diagrammatic view of a system embodying the present invention;

FIG. 1A is a fractional view of the scanner comprising the radiant energy detector and drive means therefor shown in FIG. 1; and

FIG. 2 is a schematic wiring diagram of the system shown in FIG. 1.

Referring to FIG. 1, there is shown a system **10** embodying the present invention in which a radiant energy detector **11** is mounted on a reversible drive unit **12**, FIG. 1A. The radiant energy detector **11**, while it may be of any suitable type, preferably is of the type of radiation pyrometer disclosed in U.S. Letters Patent No. 2,813,203, Machler and Reissue, No. 23,615, Fastie equipped with a calcium fluoride window. It is positioned to view the kiln shell. The drive unit **12** is so mounted with respect to the kiln **13** that the radiant energy detector **11** sights along the portion of the kiln shell which is desired to be scanned. The length of the kiln to be scanned during a scanning cycle is indicated by the dotted lines in FIG. 1. The total angle of scan during each cycle is approximately 85° to 90°. The drive unit **12** is positioned with respect to the kiln **13** so that the distance from the radiant energy detector **11** perpendicular to the kiln shell **13** is about one-half the linear length of the portion of the kiln to be scanned. Thus where it is desired to scan x feet of kiln surface, the scanner (combination of the drive unit **12** and radiant energy detector

11) is mounted one-half x distance from the surface and on a perpendicular from the center of the x distance section of the kiln 13. As a practical matter, the length of kiln section to be scanned by a single unit operated in accordance with this invention should preferably not exceed about sixty feet in order to provide an adequate target area at the limits of the scan.

The drive unit 12 includes an electric motor 14, FIG. 1A, the circuit connections to which are connected to a control circuit, to be described in more detail in connection with FIG. 2, associated with a control panel 16, FIG. 1. The control panel 16 also is provided with a measuring and recording instrument 18 which is electrically connected to the output from the radiant detector 11. The instrument 18 may be of any suitable type such for example as shown in U.S. Letters Patent No. 1,935,732, Squibb or No. 2,113,164, Williams. During each revolution of the rotary kiln 13 a limit switch 23 is actuated thereby to cause the drive unit motor 14 to drive forward rotating the radiant energy detector 11 in a clockwise direction as viewed in FIG. 1. For each actuation of switch 23 the radiant energy detector 11 rotates only through a fraction or increment of a scanning cycle, for example about three and one-half degrees, during each revolution of the rotary kiln 13 and thus it takes about twenty-four revolutions of the rotary kiln 13 for the radiant energy detector 11 to complete its scanning cycle of approximately 90° rotation. The three and one-half degree steps of rotation result in a small overlap to insure complete scanning of the selected kiln section.

When a hot spot is detected, an alarm 20 is sounded to provide an audible signal to the operator of the formation of a hot spot on the rotary kiln shell and scanning is automatically stopped so that the detector points to the hot spot. If no hot spot is detected a scan is completed. After the radiant energy detector 11 reaches the end of its scanning cycle, the drive motor 14 of the drive unit 12 is automatically reversed driving the radiant energy detector 11 quickly, continuously in a reverse direction until it again reaches its starting position preparatory to repeating the scanning cycle. This reverse movement of the radiant energy detector 11 from the end of its cycle to the beginning of its cycle takes place in a relatively short time, for example in the order of about twenty seconds. The time for completing a scanning cycle, since the cycle is made in about twenty-four fractional steps and the normal speed of rotation of the rotary kiln is in the order of sixty to eighty r.p.h., is about eighteen to twenty-five minutes.

As the radiant energy detector 11 is rotated through its full cycle of movement of approximately 90°, the physical shape of the target area on the kiln shell changes from an abnormal ellipse at either end of its travel to a circle when the unit is perpendicular to the kiln 13, as shown in FIG. 1. As the radiant energy detector 11 is rotated, the distance from it to the target at either end of its travel is approximately the square root of twice the distance that the radiant energy detector 11 is at mid-travel. However, it has been found that change in target dimensions with distance does not sufficiently adversely affect the accuracy of the reading of the radiant energy detector 11 to prevent use of the type of scanning employed. The target area increases as the square of its diameter, the diameter increases as a linear function of the distance from the kiln 13 to the radiant energy detector 11, and the intensity of radiant energy decreases as an inverse square of the distance from the target to the radiant energy detector 11. The effect of this change in physical dimension of the target through one increment of the scanning cycle is also minimized because the actual temperature record is that of a band around the kiln, the width of the band being equal to the target diameter. The band width increases as the target changes from a circle to an ellipse and is equal to the major axis of the ellipse. The intensity of radiation at the end of the ellipse farthest away from the radiant energy detector 11 decreases and approaches zero so that the net effect of this intensity approaches that of a circle similar to the original target.

Reference will now be made to FIG. 2 for a more detailed description of the operation of the system. In this view the parts are positioned at zero ready to begin a scan. In FIG. 2 there has been diagrammatically illustrated an end view of the rotary kiln 13. The radiant energy detector 11 is positioned to scan the surface of the kiln in the manner described above. The reversible drive unit 12 has been indicated by broken line 21 as being mechanically connected to the radiant energy detector 11. The rotary kiln 13 is provided on its periphery with a shoe or cam 13*a* which is adapted to close a kiln limit or cycle switch 23. The length of the shoe 13*a* is determined by the speed of rotation of the kiln and the diameter of the kiln. In general, the length of the shoe 13*a* is such that for each revolution of the kiln 13 the contacts of switch 23 will be closed for at least one-quarter second and less than about three-quarters second. During the momentary closure of the contacts of the kiln limit switch 23, there is completed a circuit from line L1 through a manual switch 24, through the normally closed contacts 25 of relay 26, through the normally closed contacts 27 of relay 28, through the contacts of kiln limit switch 23 and through the motor winding A of reversible motor 14 to the opposite side of the line L2. This causes the motor 14 to drive forward moving the radiant energy detector 11 in a clockwise direction from its starting or zero position as viewed in FIG. 1. As soon as the drive unit 12 starts to move, a drive unit limit switch 29 mounted inside the drive unit gear housing and actuated by a cam 30 mounted on an idler gear of the drive unit, closes and maintains the circuit to the winding A of motor 14 for forward rotation until the cam 30 has made one complete revolution. It will be noted that switch 29 is in parallel with switch 23. The drive unit limit switch 29 then opens, deenergizing the motor winding A and stopping rotation of the drive unit 12. The above sequence permits the radiant energy detector 11 to be rotated $\frac{1}{24}$ of its total span or cycle of rotation. Each time the kiln 13 rotates, this action is repeated until the drive unit 12 has traveled from zero to 100% of its total movement to complete the scanning cycle.

While the foregoing scanning cycle is taking place, the temperature of the kiln shell 13 is being detected by the radiant energy detector 11 and recorded on a chart 31 by a marker or pen 32 of the measuring and recording instrument 18. The output from the radiant energy detector 11 is connected by way of conductors 33 and 34 to the measuring circuit 35 of recorder 18 having an amplifier which in turn has its output connected to the balancing motor 36 of the instrument 18. The motor 36 is mechanically connected as indicated by broken line 37 to the pen or marker 32 to drive the latter relative to the chart 31 in accordance with the temperature of the kiln 13. Thus the instrument 18 will continuously record the temperature of the kiln shell during the complete scanning cycle made by the radiant energy detector 11.

When the drive unit 12 has moved the radiant energy detector 11 to the 100% end of the scanning cycle, the switch-operating member 40, which is mechanically connected to the drive unit 12 as indicated by broken line 41, will likewise have moved to the 100% position. This movement of member 40 causes the normally open contacts of the spring-biased limit switch 43 to close. Since the contacts of limit switch 44 are spring-biased closed at all times except at zero position, there is completed a circuit for energizing the coil of relay 28. This circuit may be traced from line L1 through the manual switch 24, through the normally closed contacts 25, through conductor 45 and now closed switch 43, thence through conductors 46 and 47, through normally closed switch 44 and the coil of relay 28 and conductor 48 to the other side of the line L2. When the circuit is completed through the coil of relay 28, the contacts thereof are moved in an upward direction as viewed in FIG. 2 causing the normally open contacts 49, 50 and 51 to close while opening the normally closed contacts 27. Closure of contacts 50 energize the motor winding B for reverse rotation of drive motor 14. This circuit may be traced from line L1 through switch 24, normally closed contacts 25, conductor 45, through the now closed contacts of switch 43 and contacts 50 of relay 28 and thence through winding B and conductor 53 to line L2. Upon energization of winding B, the motor 14 reverses the rotation of drive unit 12 causing the switch-operating member 40 to reverse its direction of rotation, moving out of engagement with switch 43 and enabling the contacts thereof to return to open position. While this breaks the circuit through switch 43, it does not break the circuit through winding B, nor through the coil of relay 28, since there is an alternate or holding circuit. Such alternate circuit for relay 28 may be traced from line L1 through switch 24, through contacts 25, conductor 45 and conductor 55, through the now-closed contacts 49, conductor 47, the normally closed contacts of limit switch 44, through the relay coil 28 and through conductor 48 to line L2. The circuit for the motor winding B likewise is completed from line L1, through switch 24, contacts 25, conductors 45 and 55, contacts 49 and thence through conductor 46, the now-closed contacts 50, through motor winding B and conductor 53 to line L2.

The reverse motor winding B continues to be energized until the drive unit 12 has returned the radiant energy detector 11 and the switch-operating element 40 to the zero or the starting position for the next scanning cycle. When the switch-operating member 40 is in zero position, it opens the normally closed contacts of limit switch 44, breaking the electrical circuit through the coil of relay 28, thus causing the contacts 49, 50 and 51 thereof to return to their normally open positions while returning contacts 27 to the normally closed position, as shown in FIG. 2. During this reverse drive of the motor unit 12, it will be noted that the normally open contacts 51 are in closed position, thus shorting out the output signal from the radiant energy detector 11 and thereby providing a zero pen reading on the scale of the recorder 18. This serves as a point of reference for the start of the succeeding scanning cycle. With the various components of the system returned to the position illustrated in FIG. 2, the system is ready for repeating the scanning cycle.

When no hot spots occur, the temperature of the kiln shell as detected by the radiant energy detector 11 is recorded in normal manner on the chart 31 of recorder 18. When the scanning system is put into operation to record the kiln shell temperature, a predetermined high limit temperature is preset on the recorder 18. This has been diagrammatically illustrated in FIG. 2 by means of a manually operable knob 58 which is adapted to adjust an operator 59 for a switch 60 relative to the scale of the recorder 18. The switch operator 59 has been illustrated as being adapted for engagement by a cam 61 carried by the carriage for the marker or pen 32 of the recorder 18. Thus when the radiant energy detector 11 detects a hot spot on the kiln shell 13, the output millivolatge from the detector 11 to the amplifier 35 of the recorder 18 increases to a point exceeding that corresponding to the setting of the high limit switch 60 in the recorder 18 causing the cam 61 and operator 59 to close the contacts of switch 60. This energizes the coil of relay 26 by completing a circuit from line L1, through switch 60, conductor 63, the closed contacts 64*a* of a two-position acknowledge switch 64, conductor 65, the coil of relay 26 and conductor 66, the latter being connected to line L2. When the coil of relay 26 is energized, the normally open contacts 67 thereof are closed, completing a circuit from line L1 through the normally closed contacts of reset push button 69, the now closed contacts 67 of relay 26, the closed contacts 64*a* of the acknowledge switch 64, the coil of a warning bell or horn 20, the other end of which is connected to line L2, thus providing an audible alarm or signal to warn the operator that a hot spot has been detected on the kiln shell. When the coil of relay 26 is energized, its normally closed contacts 25 in circuit with the motor winding A opens, thus removing power from the motor 14 of the drive unit 12 and causing the radiant energy detector 11 to remain pointing at the segment of the kiln 13 in which the hot spot occurred. The position of the radiant energy detector 11 between its zero and 100% positions is indicated by a pointer 70*a* driven by the drive unit 12 and associated with a dial 70. This position of the hot spot may also be indicated on the panel 16 by means of an electrically operated position indicator 71. The position indicator 71 has been illustrated in FIG. 2 as a milliammeter which is connected across the line L1, L2 in series with a measuring slidewire 72, the resistance of which is adjusted in accordance with the position of the drive unit 12 during the scanning cycle of detector 11. An adjustable resistance 73 is provided for calibration purposes.

The warning alarm will continue to sound until the acknowledge switch 64 is moved to open its contacts 64*a* and close its contacts 64*b* which are in series circuit with a warning lamp 76. This completes the circuit to the warning lamp 76 and provides a visible alarm. Since several hours may elapse before the hot spot has been remedied, this permits a record of the condition of the remainder of the kiln 13 to be obtained without the audible alarm continuously sounding. When contacts 64*a* of the acknowledge switch are opened, it will be noticed that the coil of relay 26 is deenergized, thereby opening contacts 67 and returning contacts 25 to normally closed position. This enables the drive unit 12 and radiant energy detector 11 to continue the scanning operation in the manner previously described.

To reset the system 10 and extinguish the visible alarm 76, the reset button 69 is pushed which causes the acknowledge switch 64 to return to its initial position with its contacts 64*a* closed. This opens the contacts 64*b* and extinguishes the visible alarm signal 76. Normal operation of the system will then continue unless another hot spot is detected at which time the alarm 20 will again sound and the drive unit 12 will be stopped in the manner previously described.

In FIG. 2, it will be noted that there is illustrated a manually operated switch 79 in parallel with the kiln limit switch 23 and the drive unit limit switch 29. The manual switch 79 enables the radiant energy detector 11 to be rotated to sight any desired portion of the kiln shell 13. The manual stop switch 24 enables the radiant energy detector 11 to sight continuously on any desired section of the kiln 13 by moving the switch 24 to open position. For normal scanning operation, it is maintained in closed position, as illustrated in FIG. 2. The knob 80 permits manual operation of the drive unit 12, FIG. 1A.

In general, the instrument panel 16 should be installed at a location where it is protected from dirt and traffic but readily observed. The drive unit 12 should not be exposed to high temperatures, preferably not in excess of 150° F. Where the atmosphere in the area of the radiant energy detector 11 is dusty, there is preferably provided a flexible hose 81, FIG. 1, which is connected to the detector housing and to a low-pressure air supply, for example, in the order of three to five p.s.i.g. positive pressure.

While a preferred embodiment of the invention has been described and illustrated, it is to be understood that further modifications thereof may be made without departing from the scope of the appended claims.

What is claimed is:

1. In a system suited for measuring the temperature of a rotary kiln, a radiant energy detector, means rotatably supporting said detector to view the kiln, reversible drive means for rotating said detector about a fixed axis cyclically to scan a predetermined area of the kiln, control switch means in circuit with said drive means and operated during each revolution of the kiln to rotate said detector through a fraction of its scanning cycle, first limit-switch means in circuit with said drive means and operated upon arrival of said detector at the end of the scanning cycle to reverse the rotation of said reversible drive means and return said detector to its starting position, and second limit-switch means at the starting position in circuit with said first limit-switch means and said drive means to stop the reverse rotation of said drive means preparatory to repeating the scanning cycle of said detector.

2. In a system according to claim 1 including second control switch means in parallel circuit with said first-named control switch means, and cam means driven by said drive means to close said second control switch means during each revolution of the kiln to control the energization of the drive means.

3. In a system according to claim 2 including a recorder connected to the output of said detector to record the temperature of the kiln, and means to disconnect the output of the detector from said recorder during the reverse drive of said detector.

4. In a system according to claim 3 wherein said recorder includes means to preset the high temperature limit of the kiln, alarm means in circuit with a normally open switch, and means operated by said recorder in response to the output of said detector to close said normally open switch and operate said alarm means.

5. In a rotary kiln shell temperature scanning system of the type including a radiant energy detector, measuring and recording means, and alarm means actuated when a hot spot is detected the improvement of means to produce a scanning action between said detector and a portion of the kiln shell comprising a reversible motor drive unit, a pair of limit switches for said drive unit controlling actuation of said unit through an angle of about ninety degrees, a control switch for said drive unit operated by rotation of the kiln to initiate operation of said drive unit during each revolution of the kiln, a second control switch operated by said drive unit for producing an increment of rotation of said drive unit to cause rotation of the detector to view an adjacent area of the kiln, one of said limit switches in said drive unit producing a continuous reverse rotation thereof until stopped by said other limit switch to restore the detector to a starting position, and switch means disconnecting the output of the radiant energy detector from the measuring means during the continuous reverse rotation.

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