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ABSTRACT: This invention relates to apparatus for determining the temperature of one of a kiln load and a heated fluid stream at a predetermined location on a longitudinal axis of a kiln having the heated fluid stream passing therethrough and for heating the kiln load. The apparatus has a temperature-responsive means connected to the kiln at the predetermined location and rotatable with the kiln to cyclically pass through the kiln load and the heated fluid stream to produce a temperature signal. A rate switch module is connected to the temperature-responsive means for producing a blocking output from an increasing voltage input from the temperature-responsive means while the temperature-responsive means is passing through the fluid stream and a tracking output from a decreasing voltage input from the temperature-responsive means while the temperature-responsive means is passing through the kiln load. Alternatively, the rate switch module produces a blocking output from a decreasing voltage input from the temperature-responsive means while the temperature-responsive means is passing through the heated fluid stream. In addition, the apparatus has a first relay, a comparator module connected to the temperature-responsive means and to the first relay, and a track and hold module connected to the temperature-responsive means and to the comparator module and operable to provide a substantially maximum output signal and a substantially minimum output signal to the comparator module when the temperature-responsive means is passing through the fluid stream and the kiln load respectively so that when the temperature signal is less than the maximum output signal and greater than the minimum output signal respectively, the first relay is energized by the comparator module.

The rate switch module is operable while the rate switch module is receiving a decreasing temperature signal and an increasing temperature signal respectively to produce the tracking output thereby causing the output signal of the track and hold module to follow the temperature signal being fed to the track and hold module and to then produce the blocking output, thereby holding the output signal of the track and hold module at a substantially minimum temperature signal and a substantially maximum temperature signal respectively. The comparator module then is operable to deenergize the first relay when the temperature signal is greater than the output signal of the track and hold module and less than the output signal of the track and hold module respectively, and reset means are connectable to the track and hold module to apply a tracking output to the track and hold module and operable to connect the track and hold module to a substantially maximum temperature signal and a substantially minimum temperature signal respectively, thereby producing a substantially maximum output signal and a substantially minimum output signal respectively to the comparator module.
**FIG. 8.**

Increasing Load Temperature—100% Electrical Lag, RC = 18 Sec.

- Kiln Tc Reading
- Load Temp. Signal
- Avg. Lag
- Direction of Chart Movement
- Chart Speed: 30 in/HR.

**FIG. 9.**

Decreasing Gas Temperature—100% Electrical Lag, RC = 18 Sec.

- Kiln Tc Reading
- Gas Temp. Signal
- Avg. Lag
- Direction of Chart Movement
- Chart Speed: 30 in/HR.
BACKGROUND OF THE INVENTION

Conventional cylindrical rotary kilns are used to manufacture products, such as Portland cement clinkers, which clinkers require heat treatment to promote chemical reactions. The kiln is usually driven by a variable-speed providing a rotation in the range of about 20 to 80 revolutions per hour. The slope of the kiln is generally of the order of one-half inch per foot or slightly steeper. The raw feed is fed into the upper end of the kiln, may comprise either dry powder, filter cake containing about 18 percent to 22 percent moisture, or a slurry containing about 30 percent to 50 percent moisture.

In the manufacture of Portland cement clinker, the following four zones are inherent to the process:

1. The drying zone begins at the feed end of a wet process kiln, and, depending on the length of the kiln, will extend from about 60 to 200 feet along the kiln. To expedite drying of the kiln feed, strings of chains are suspended from the inside surface of the kiln shell and function as a heat transfer medium and pulverizer.

2. In the preheating zone the raw material or kiln feed is heated to a temperature at which the chemical reactions begin to take place.

3. In the calcining zone the calcium carbonate (representing about 70 percent to 85 percent by weight of the kiln feed) is decomposed with the liberation of CO₂. The temperature range in the calcining zone is usually from about 1,600°C to 1,800°C.

4. The kiln feed is further heated in the burning zone to a temperature to cause the combination of the argillaceous and calcareous components to produce calcium silicates, aluminates, and ferrites. This combination is mainly an exothermic reaction which requires temperatures in the range of about 1,900°C to 2,700°C. The product, known as cement clinker, is discharged from the kiln, quenched, cooled and conveyed to storage.

The present thermocouple systems employed in conventional kilns comprise a single thermocouple connected to a pair of solid collector rings. However, as the single thermocouple moves through the kiln feed and gas streams, it gives a cyclic response because the difference in temperature between these two streams varies as much as about 800°F. The thermocouple signal will depend upon the response time of the thermocouple and, since the thermocouple is massive and in the feed stream for a relatively short period (10—15 seconds at normal kiln speed), a satisfactory measure of the feed temperature is not obtained. Furthermore, these cyclic response signals are difficult to evaluate and handle in process control systems.

Alternatively, several thermocouples (usually three or four) with equal peripheral spacing on the kiln, are connected to a pair of solid collector rings. These plural thermocouples provide an average temperature signal, alleviating to a large extent the cyclic characteristics of the single thermocouple. However, the parameter needed in the successful operation of a conventional kiln is feed temperature and this system does not provide a good measurement of such temperatures. The gas temperature signals overlap the feed temperature signals so that changes in the feed temperature may not be discernible.

Another conventional system employs several thermocouples (usually about four) having equal peripheral spacing on the kiln, with each thermocouple connected to an insulated quadrant of a pair of split collector rings.

This system is the best of the three conventional systems because the collector ring brushes are located to obtain the signal as the thermocouple passes through the feed stream. However, a cyclic response is obtained because, as the thermocouple leaves the gas stream and enters the feed stream, it is at the gas temperature and as it travels through the feed stream it cools rapidly. As in the case of the single thermocouple, cyclic response signals are difficult to evaluate and to handle in process control systems.


OBJECTS OF THE INVENTION

It is the general object of this invention to avoid and overcome the foregoing and other difficulties of and objections to prior art practises by the provision of control apparatus which will:

1. track, hold, average and record the maximum value of cyclic varying temperature signals from inside a rotary kiln,
2. provide a true measure of the gas temperature in the kiln,
3. track, hold, average and record the minimum value of such signals,
4. provide means to measure the constancy of the fuel and feed flow through the rotary kiln, and
5. provide constant level signals related to temperature and flow conditions in the kiln that can be readily used for kiln control.

BRIEF SUMMARY OF THE INVENTION

The aforesaid objects of this invention, and other objects which will become apparent as the description proceeds, are achieved by providing apparatus for determining the temperature of a kiln load and a heated fluid stream at a predetermined location on a longitudinal axis of a kiln having the heated fluid stream passing therethrough and for heating the kiln load. The apparatus has a temperature-responsive means connected to the kiln at the predetermined location and rotatable with the kiln to cyclically pass through the kiln load and the heated fluid stream to produce a temperature signal; a rate switch module connected to the temperature-responsive means for producing a blocking output from an increasing voltage input from the temperature-responsive means while the temperature-responsive means is passing through the fluid stream and a tracking output from a decreasing voltage input from the temperature-responsive means while the temperature-responsive means is passing through the kiln load. Alternatively, the rate switch module produces a blocking output from a decreasing voltage input from the temperature-responsive means while the temperature-responsive means is passing through the kiln load and a tracking output from an increasing voltage input from the temperature-responsive means while the temperature-responsive means is passing through the heated fluid stream. The apparatus has a first relay; a comparator module connected to the temperature-responsive means and to the first relay; and a track and hold module connected to the temperature-responsive means and to the comparator module and operable to provide a substantially maximum output signal and a substantially minimum output signal to the comparator module when the temperature-responsive means is passing through the fluid stream and the kiln load respectively so that when the temperature signal is less than the maximum output signal and greater than the minimum output signal respectively the first relay is energized by the comparator module.

The rate switch module is operable while the rate switch module is receiving a decreasing temperature signal to increase output signal to the tracking output thereby producing the output signal of the track and hold module and in the event the temperature signal is less than the maximum output signal and greater than the minimum output signal respectively the first relay is energized by the comparator module.

The tracking output thereby causes the output signal of the track and hold module to be fed to the track and hold module and to then produce the blocking output thereby holding the output signal of the track and hold module at a substantially minimum temperature signal and a substantially maximum temperature signal respectively. The
comparator module then is operable to deenergize the first relay when the temperature signal is greater than the output signal of the track and hold module and less than the output signal of the track and hold module respectively. Reset means are connectable to the track and hold module to apply to a tracking output to the track and hold module and operable to connect the track and hold module to a substantially maximum temperature signal and a substantially minimum temperature signal respectively thereby producing a substantially maximum output signal and a substantially minimum output signal respectively to the comparator module.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

For a better understanding of this invention reference should be had to the accompanying drawings, wherein like numerals of reference indicate similar parts throughout the several views and wherein:

FIG. 1 is a fragmentary side elevational view of a portion of a kiln and showing the temperature-responsive means of the apparatus of the present invention;

FIG. 2 is a schematic cross-sectional view showing one cycle of the operation of the apparatus;

FIG. 3 is a schematic wiring diagram of the apparatus for measuring the load temperature;

FIG. 4 is a plan view of the reset means for the apparatus;

FIG. 5 is a schematic wiring diagram of the holding switch, limit switch and timer motor of the reset means;

FIG. 6 is a view similar to FIG. 4 of an alternative embodiment of the apparatus for measuring the heated fluid temperature;

FIG. 7 is a graph showing typical operation temperatures during one cycle of operation of the apparatus;

FIG. 8 is a recording of the simulated kiln thermocouple signal and gas temperature signal; and

FIG. 9 is a recording of the simulated kiln thermocouple signal and load temperature signal.

Although the principles of this invention are broadly applicable to the minimum or maximum operating temperature in an operating process in any predetermined period of time, this invention is particularly adapted for use in conjunction with apparatus for determining a minimum load temperature and maximum fluid stream temperature in a kiln, and hence it has been so illustrated and will be so described.

DETAILED DESCRIPTION

With specific reference to the form of this invention illustrated in the drawings, and referring particularly to FIG. 1, a rotary kiln for the manufacture of products, such as Portland cement clinker, is indicated generally by the reference numeral 10.

This rotary kiln 10 (FIG. 1) has tires 12, only one of which is shown in FIG. 1, rotatable on rollers 14, which rollers 14 are journaled in bearings 16 upstanding from a frame 10b. The kiln 10 is rotated at a typical speed of about 60 r.p.h. by conventional drive means such as a girth gear, pinion and motor (all not shown).

An apparatus 17 (FIG. 3) is utilized for determining a temperature of a kiln load 18 (FIG. 2) at a predetermined location, such as for example a location 20 (FIG. 1) in a drying zone located on the longitudinal axis A-A (FIG. 1) of a shell 10a (FIGS. 1, 2) of the kiln 10. The kiln 10 has a heated fluid stream 19 (FIG. 2) such as for example CO. 2, N 2, O 2, and H 2, resulting from the burning of, for example, powdered coal and passing through the kiln 10 and utilized for heating the kiln load 18.

This apparatus 17 has temperature-responsive means 22 (FIGS. 1, 3) connected to the shell 10a at the predetermined location 20 and rotatable with the kiln 10 to cyclically pass through the kiln load 18 and the fluid stream 19 to produce a temperature signal.

TEMPERATURE-RESPONSIVE MEANS 22

The temperature-responsive means 22 has a thermocouple 22a (FIGS. 1, 2, for example a Type K thermocouple specified by the Instrument Society of America, Pittsburgh, Pa.) mounted by means of a bracket 22b (FIGS. 1, 2) on the shell 10a and projecting into the interior of the shell 10a (FIG. 2). The thermocouple 22a is connected by lines 22c (FIG. 1) to slip rings 22d (FIG. 1) mounted by means of insulators 22e upstanding from brackets 22f on the shell 10a. In order to transmit the thermocouple signals to the rest of the apparatus 17, brushes 22g (FIGS. 1, 3) are mounted on the frame 10b of the kiln 10 and biased by springs (not shown) into contact with the slip rings 22d. As shown in FIG. 3 the brushes 22g are connected by lines L1, L2 to amplifier means 24.

AMPLIFIER MEANS 24

The amplifier means or amplifier 24 is, for example, of the Type 19-101A millivolt preamplifier with temperature compensation 24a and inverse output 24b and manufactured by Consolidated Electrodyamics, Devar Kinetics Division, a subsidiary of Bell and Howell, Bridgeport, Connecticut. The amplifier 24 (FIG. 3) is connected by lines L3, L4 to a power supply 25 (i.e. about ±18 v. DC) which power supply 25 in turn is connected to a voltage supply indicated by the legend "AC Supply." The output EO1 of amplifier 24 (i.e. about 0–10 v. DC) is connected by line L5 through a contact K2 of a second relay R2 (FIG. 3) as hereinafter explained in detail to an input X 1, of a rate switch module 26.

RATE SWITCH MODULE 26

The rate switch module 26 may be, for example, of the Type 19-415 manufactured by Consolidated Electrodyamics, Devar Kinetics Division, a subsidiary of Bell and Howell, Bridgeport, Conn. The rate switch module 26 produces a blocking output (i.e. about less than +18 v. DC to –18 v. DC) from an increasing voltage input (i.e. about 270°–180°, FIG. 2, of each cycle) to the rate switch module 26 from the amplifier 24 while the thermocouple 22a is passing through the fluid stream 19 (FIG. 2) and a tracking output (i.e. about +18 v. DC) from a decreasing voltage input from the amplifier 24 (i.e. about 180°–270°, FIG. 2, of each cycle) while the thermocouple 22a is passing through the kiln load 18. Lines L3c, L4c connect the rate switch module 26 to the power supply 25. The rate switch module 26 provides a full range positive output for an increasing voltage input, and a full range negative output for an input voltage with negative slope with respect to time. The output voltage is switched from positive to negative when the input voltage reaches a maximum value and in the opposite direction when the input reaches a minimum value.

COMPARATOR MODULE

A comparator module has an upper half 28a and a lower half 28b (FIG. 3), for example, of the Type 19-501-2 with a Type 220226-05 delta coefficient 28b', a Type 22017-04 input coefficient 28b' fixed at a equals 1 and a Type 220225-01 Zener diode 28c manufactured by Consolidated Electrodyamics, Devar Kinetics Division, a subsidiary of Bell and Howell, Bridgeport, Conn. Lines L3b, L4b connect the upper half 28a and the lower half 28b of the comparator module to the power supply 25. Line L6' connects terminal X21 of the upper half 28b of the comparator module 28 to the temperature signal from amplifier 24 and line L6 connects the output X6 of the upper half 28b of the comparator module to a first relay R1 (FIG. 3).

The lower half 28b of the comparator module (shown in the upper central portion of FIG. 3) receives the temperature input signal via line L13, amplifies it and sends it via line L14 to the recorder 42.
The upper half 28a of the comparator module (shown in the lower central portion of FIG. 3) has inputs X15,X21 which are DC input voltages of opposite polarity. The inputs X15,X21 are fed via their input coefficient resistors (not shown) to the input of a very high gain amplifier (not shown). Due to this high gain, the output Xout is held at either maximum or minimum value according to which of the two inputs X15,X21 is greater.

Only a very small difference between inputs X15, X21 (less than about 0.01 percent) is required to swing the amplifier (not shown) from one state to the other. The Zener diode 28c across the amplifier (not shown) limits the output Xout to a maximum of about 10 volts ± ± ± 5 percent, and in the other direction to about zero output. If the diode 28c is reversed for the same tripping conditions, the output Xout is zero and about 10 volts of reverse polarity respectively.

Regenerative feedback is provided by a small resistor (not shown), the value of which resistor (not shown) determines the differential between up- and down-scale trip points.

**TRACK AND HOLD MODULE 30**

The input X30 of a track and hold module 30 (similar to Type 19-407 module manufactured by Consolidated Electrodynamic, Devar Kinetics Division, a subsidiary of Bell and Howell, Bridgeport, Connecticut) is connected by line L7 to the temperature signal from the amplifier 24 and the output Xout thereof by line L8 to terminal X30 of the upper half 28a of the comparator module. The track and hold module 30 is operable to provide a substantially maximum output signal to the input terminal X30 of the upper half 28a of comparator module when the thermocouple 22a is passing through the fluid stream 19 (i.e. at about 270°F-180°F, FIG. 2, of each cycle) so that at the time the temperature signal from the amplifier 24 terminal X30 of the upper portion 28a of the comparator module is less than the maximum output signal from the track and hold module 30 to terminal X30 of the upper half 28a of the comparator module, the first relay R1 is energized and contact K1 of relay R1 moves from the solid line position shown in FIG. 3 to the dotted line position shown in such FIG. 3, thus connecting the output Xout of relay switch module 26 through a blocking diode D2 to input R3 of the track and hold module 30.

The track and hold module 30 or dynamic response module is a general purpose memory circuit including a varactor-type Chopper stabilized amplifier (not shown) and an inverting general purpose output amplifier (not shown). Utilizing the inputs X30 and +R3, the module 30 is used as a track and hold module. The computing capacitor (not shown) and mode relay (not shown) are self-contained in the module 30.

**OPERATION**

The rate switch module 26 is operable while the rate switch module 26 is receiving a decreasing temperature signal from the amplifier 24 to produce a tracking output (i.e. about +18 v. DC) at output X30 of the rate switch module 26 thus causing the output signal from output Xout of the track and hold module 30 to follow the klin load temperature signal from the amplifier 24 being fed to input X13 of the track and hold module 30 (i.e. at about 180°F-270°F, FIG. 2, of each cycle) and to then produce a fluid stream blocking output (i.e. at about 270°F-180°F, FIG. 2, of each cycle) thus holding the output signal from output Xout of the track and hold module 30 at a substantially minimum temperature signal to terminal X30 of the upper portion 28a of the comparator module. Almost simultaneously therewith the upper half 28a of the comparator module is operable to deenergize the first relay R1 (when the temperature signal from the amplifier 24 to terminal X30 of the comparator module is at a maximum) to a substantially minimum temperature signal to output Xout of the track and hold module 30 to terminal X13 of the comparator module 28. Deenergization of relay R1 moves contact K1 from the dotted line position shown in FIG. 3 to the solid line position (FIG. 3).
CONTINUOUS THERMOCOUPLE TEMPERATURE

As shown in FIG. 3, a line L13 connects the continuous temperature signal from the amplifier 24 to terminal Xₐ and resistors RE1 (having a 22K ohm resistance) and RE2 (having a 22K ohm resistance) to enable the lower portion 28b of the comparator module to invert the negative (about 0 to -10 v. DC) signal to about 0 to +10 v. DC signal. Line 14 connects output Xₐ of the lower portion 28b of the comparator module to the recorder 42 which records the continuous thermocouple temperature.

ALTERNATIVE EMBODIMENTS

It will be understood by those skilled in the art that alternatively, as shown in FIG. 6, an apparatus 17th may be used for measuring the temperature of the heated fluid 19. In FIG. 6 the inverse temperature compensation in the preamplifier 24 (FIG. 3) is changed to standard temperature compensation in the amplifier 24 (FIG. 6) and the voltage reference module 36 (FIG. 3) is not employed in the apparatus 17th (FIG. 6).

Further, the signal inversion accomplished in the lower half 28b (FIG. 3) of the comparator module 28 using the resistors RE1, RE2 is not employed in FIG. 6. Additionally, the input signal from the brushes 22g has the + input signal connected to the + input of the amplifier 24v (FIG. 6) and the - input connected to the - input of the amplifier 24v (FIG. 6), the exact reverse of the connections in FIG. 3. With respect to the comparator module connections in FIG. 6 and in order for an increasing temperature to produce a positive signal, the output Xₐ from the track and hold module 30 is connected to the terminal input Xₐ of the upper half 28a of the comparator module and the line L6 (from the amplifier output E0 and line L5) extends to the terminal Xₐ of the upper half 28a of the comparator module 28. Again, in FIG. 3 the output -Xₐ from the track and hold module 30 (FIG. 3) is connected to the variable lag module 38 to obtain a 0- to 10-volt signal for the recorder 42. However, in FIG. 6 the output +Xₐ from the track and hold module 30 (FIG. 6) is connected to the variable lag module 38 since the input to the track and hold module 30 is already a 0- to +10-volt signal.

OPERATION

Assuming that the apparatus 17th (FIG. 6) has been reset and that the thermocouple 22a is in the kiln load 18 (i.e. at about 210°, FIG. 2), then the preamplifier output EO is minimum (i.e. about 0 volts) and such output EO is fed directly via line L14 to the recorder 42 to record the thermocouple temperature at all times. In addition, input Xₐ of the upper half 28a of the comparator has about 0 volts applied to it from the -Xₐ output of the track and hold module 30, which -Xₐ output was applied during the reset operation.

As the thermocouple 22a (FIG. 2) enters the heated fluid stream 19 (i.e. at about 270°, FIG. 2) and its sensed temperature rises, the millivolt output from the brushes 22g (FIG. 6) also rises with attendant increase in the output EO of the amplifier 24v. As a result the absolute value of the temperature signal input Xₐ of the upper half 28a of the comparator module 28 is greater than the absolute value of the track and hold input Xₐ of the upper half 28a of such comparator module, thus causing output Xₐ of the upper half 28a of the comparator 28 to energize relay R1 and move contact K1 to the closed or dotted line position shown in FIG. 6.

A positive increasing signal (as the thermocouple temperature rises) at input Xₐ of the rate switch 26 causes the rate switch output Xₐ to go to +18 volts, which +18 volts is fed via the now closed contact K1 to the + input of the track and hold module 30 to track the signal via its input Xₐ. The track and hold module 30 will track this input signal to input Xₐ as long as the temperature signal is rising and the output from output Xₐ of the rate switch 26 is +18 volts and relay R1 is energized.

When the thermocouple 22a reaches its maximum temperature (i.e. at about 150°, FIG. 2) the output Xₐ of the rate switch 26 is no longer +18 volts due to the nonpositive slope (i.e. about 0) of the input signal to input Xₐ of the rate switch 26, with the result that the track and hold module 30 holds this last maximum signal. This maximum inverted signal is applied to input X₂ of the upper half 28a of the comparator module.

When the thermocouple temperature is no longer maximum (i.e. at about 190°, FIG. 2), the input signal to input Xₐ of the upper half 28a of the comparator module has a signal of lower absolute value than the absolute value of temperature signal Xₐ. The comparator module output Xₐ goes to about 0 volts and deenergizes relay R1 with resultant opening of contact K1 (i.e. solid line position, FIG. 6), thus preventing the track and hold module 30 from accepting a new signal at input Xₐ unless such new signal is of greater absolute value than the absolute value of the comparator Xₐ input signal.

When the thermocouple 22a is in the kiln load 18 (i.e. at about 210°, FIG. 2), the limit switch LS (FIGS. 2, 4, 5) is tripped, thereby starting the timer motor 34a, which timer motor 34a causes cam C1 to close holding switch SW1 and hold or seal the timer motor 34a to its timed cycle. Thereafter the timer motor 34a causes cam C3 to close switch SW3, thus applying the output Xₐ of the track and hold module 30 (i.e. the maximum signal) to the input Xₐ of the variable lag module 38. Such variable lag module 38 accepts and holds a percentage of the signal applied at input Xₐ depending on the RC value for the lag time of the variable lag module 38. The output Xₐ of the variable lag module 38 is fed continuously via line L12 to the recorder 42. Cam C3 then opens SW3.

When switch SW2 is closed, about +18 volts is applied to the +K3 input of the track and hold module 30, thus energizing relay R2 with resultant movement of contact K2 from the solid line position (FIG. 6) to the dotted line position shown in such figure. As a result about 0 volts is applied to the input Xₐ of the track and hold module 30, which 0 volts is a minimum signal value and the starting reference point for the next cycle of operation.

Thereafter, switches SW2, SW1 open, contact K2 moves from the dotted line position (FIG. 6) to the solid line position (FIG. 6) and the system is reset. The thermocouple 22a leaves the kiln load (i.e. at about 270°, FIG. 2), the thermocouple temperature begins to rise again and the above-described cycle of operation repeats itself.

FIG. 7 shows typical temperatures achieved during one cycle of operation of the apparatus 17 (FIG. 3) and the apparatus 17th (FIG. 6). FIG. 8 shows a simulated typical recording on the recorder 42 of the kiln temperature signal and gas temperature signal and FIG. 9 shows a simulated typical recording of the kiln temperature signal and load temperature signal.

SUMMARY OF THE ACHIEVEMENT OF THE OBJECTS OF THE INVENTION

It will be recognized by those skilled in the art that the objects of this invention have been achieved by providing an apparatus 17 (FIGS. 1—5, 17th (FIG. 6) for determining the temperature of a kiln load 18 or of a heated fluid stream 19 at a predetermined location 20 on a longitudinal axis A—A (FIG. 1) of a kiln 10 having the heated fluid stream 19 passing through the kiln 10 and for heating the kiln load 18. The apparatus 17, 17th will track, hold, average and record the maximum or minimum value of cyclic varying temperature signals from inside the rotary kiln 10; will provide a true measure of the gas temperature in the heated fluid stream 19 or the kiln load 18 in the kiln 10; will provide means for measuring the constancy of the fuel and kiln feed flow through the rotary kiln 10; and provide constant level signals related to temperature and flow conditions in the kiln 10, which conditions are readily usable in the control of the kiln 10.
3,593,580

While in accordance with the patent statutes preferred and alternative embodiments of this invention have been illustrated and described in detail, it is to be particularly understood that the invention is not limited there to or thereby.

We claim:

1. Apparatus for determining the temperature of a kiln load at a predetermined location on a longitudinal axis of a kiln having a heated fluid stream passing therethrough and for heating said kiln load, said apparatus having:
   a. a temperature-responsive means connected to said kiln at said predetermined location and rotatable with said kiln to cyclically pass through said kiln load and said heated fluid stream to produce a temperature signal,
   b. a rate switch module connected to said temperature-responsive means for producing a blocking output from an increasing voltage input from said temperature-responsive means while said temperature-responsive means is passing through said fluid stream and a tracking output from a decreasing voltage input from said temperature-responsive means while said temperature-responsive means is passing through said kiln load, c. a first relay,
   d. a comparator module connected to said temperature-responsive means and to said first relay,
   e. a track and hold module connected to said temperature-responsive means and to said comparator module and operable to provide a substantially maximum output signal to said comparator module when said temperature-responsive means is passing through said fluid stream so that when said temperature signal is less than said maximum output signal said first relay is energized by said comparator module,
   f. said rate switch module being operable while said rate switch module is receiving a decreasing temperature signal to produce said tracking output thereby causing the output signal of said track and hold module to follow said temperature signal being fed to said track and hold module and to then produce said blocking output thereby holding said output signal of said track and hold module at a substantially minimum temperature signal,
   g. said comparator module then being operable to deenergize said first relay when said temperature signal is greater than said output signal of said track and hold module, and
   h. reset means connectable to said track and hold module to apply a tracking output to said track and hold module and operable to connect said track and hold module to a substantially maximum temperature signal thereby producing a substantially maximum output signal to said comparator module.

2. The apparatus recited in claim 1 and having amplifier means connected to said temperature-responsive means for amplifying said temperature signal.

3. The apparatus recited in claim 2 wherein said amplifier means has means for cold junction reference junction compensation.

4. The apparatus recited in claim 2 wherein said amplifier means has means for inverting said temperature signal.

5. The apparatus recited in claim 4 and having said amplifier means connected to said comparator module and having means for reinveter said temperature signal and recording means connected to said comparator module for recording continuous temperature in said kiln.

6. The apparatus recited in claim 1 and having recording means connected to said temperature-responsive means for recording continuous temperature in said kiln.

7. The apparatus recited in claim 1 and having a variable-lag module connectable by said reset means to said track and hold module to receive a substantially minimum temperature signal from said track and hold module.

8. The apparatus recited in claim 7 and having recording means connected to said variable-lag module.

9. The apparatus recited in claim 7 and having floating power supply means connected to said variable-lag module.

10. The apparatus recited in claim 7 wherein said variable-lag module averages successive substantially minimum temperature signals from said track and hold module.

11. The apparatus recited in claim 10 and having recording means connected to said variable-lag module.

12. The apparatus recited in claim 10 and having floating power supply means connected to said variable-lag module.

13. The apparatus recited in claim 1 and having reference supply means connectable by said reset means to said track and hold module to provide said substantially maximum temperature signal to said track and hold module during resetting of said apparatus.

14. The apparatus recited in claim 1 and having power supply means connected to said rate switch module, said comparator module and said track and hold module.

15. The apparatus recited in claim 1 wherein said reset means has a limit switch operable by said kiln to start said reset means.

16. The apparatus recited in claim 15 wherein said reset means has a first switch for holding said reset means in the energized condition.

17. The apparatus recited in claim 15 wherein said reset means has a second switch for connecting said track and hold module to said tracking signal.

18. The apparatus recited in claim 17 wherein said reset means has a second relay energizable by said second switch,
   a. said second relay being operable to connect said track and hold module to said substantially maximum temperature signal.

19. The apparatus recited in claim 15 wherein said reset means has a third switch connected to said track and hold module and a variable-lag module connectable by said switch to said track and hold module.

20. Apparatus for determining the temperature of a heated fluid stream at a predetermined location on a longitudinal axis of a kiln having a kiln load and said heated fluid stream passing therethrough and for heating said kiln load, said apparatus having:
   a. a temperature-responsive means connected to said kiln at said predetermined location and rotatable with said kiln to cyclically pass through said kiln load and said heated fluid stream to produce a temperature signal,
   b. a rate switch module connected to said temperature-responsive means for producing a blocking output from a decreasing voltage input from said temperature-responsive means while said temperature-responsive means is passing through said kiln load and a tracking output from an increasing voltage input from said temperature-responsive means while said temperature-responsive means is passing through said heated fluid stream, c. a first relay,
   d. a comparator module connected to said temperature-responsive means and to said first relay,
   e. a track and hold module connected to said temperature-responsive means and to said comparator module and operable to provide a substantially minimum output signal to said comparator module when said temperature-responsive means is passing through said kiln load so that when said temperature signal is greater than said minimum output signal, said first relay is energized by said comparator module.

1. said rate switch module being operable while said rate switch module is receiving an increasing temperature signal to produce said tracking output thereby causing the output signal of said track and hold module to follow said temperature signal being fed to said track and hold module and to then produce said blocking output thereby holding said output signal of said track and hold module at a substantially maximum temperature signal,
2. said comparator module then being operable to deenergize said first relay when said temperature signal is less than said output signal of said track and hold module, and

f. reset means connectable to said track and hold module to apply a tracking output to said track and hold module and operable to connect said track and hold module to a substantially maximum temperature signal thereby producing a substantially maximum output signal to said comparator module.

21. The apparatus recited in claim 20 and having amplifier means connected to said temperature-responsive means for amplifying said temperature signal.

22. The apparatus recited in claim 21 wherein said amplifier means has means for cold junction reference junction compensation.

23. The apparatus recited in claim 20 and having recording means connected to said temperature-responsive means for recording continuous temperature in said kiln.

24. The apparatus recited in claim 20 and having a variable-lag module connectable by said reset means to said track and hold module to receive a substantially maximum temperature signal from said track and hold module.

25. The apparatus recited in claim 24 and having recording means connected to said variable-lag module.

26. The apparatus recited in claim 24 and having floating power supply means connected to said variable-lag module.

27. The apparatus recited in claim 24 wherein said variable-lag module averages successive substantially minimum temperature signal from said track and hold module.

28. The apparatus recited in claim 27 and having recording means connected to said variable-lag module.

29. The apparatus recited in claim 27 and having floating power supply means connected to said variable-lag module.

30. The apparatus recited in claim 20 and having power supply means connected to said rate switch module, said comparator module and said track and hold module.

31. The apparatus recited in claim 20 wherein said reset means has a limit switch operable by said kiln to start said reset means.

32. The apparatus recited in claim 31 wherein said reset means has a first switch for holding said reset means in the energized condition.

33. The apparatus recited in claim 31 wherein said reset means has a second switch for connecting said track and hold module to said tracking signal.

34. The apparatus recited in claim 33 wherein said reset means has a second relay energizable by said second switch, and said second relay being operable to connect said track and hold module to said substantially maximum temperature signal.

35. The apparatus recited in claim 31 wherein said reset means has a third switch connectable to said track and hold module and a variable-lag module connectable by said switch to said track and hold module.
UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,593,580 Dated July 20, 1971

Inventor(s) Norman C. Ludwig (Deceased), et al.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 10, after "variable-speed" insert -- drive --.
Column 4, line 12, "(FIGS 1,3)" should read -- (FIGS. 1,3) --.

Signed and sealed this 18th day of April 1972.

(SEAL)
Attest.

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents