United States Patent

[11] 3,593,580

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[45] Patented **July 20, 1971**

[73] Assignee **United States Steel Corporation**

[54] **ELECTRONIC PEAK-PICKER**
35 Claims, 9 Drawing Figs.

[52] **U.S. Cl.** **73/343.5**, 73/341, 73/351
[51] **Int. Cl.** **G01k 7/02**, G01k 13/08
[50] **Field of Search** 73/343.5, 351, 341

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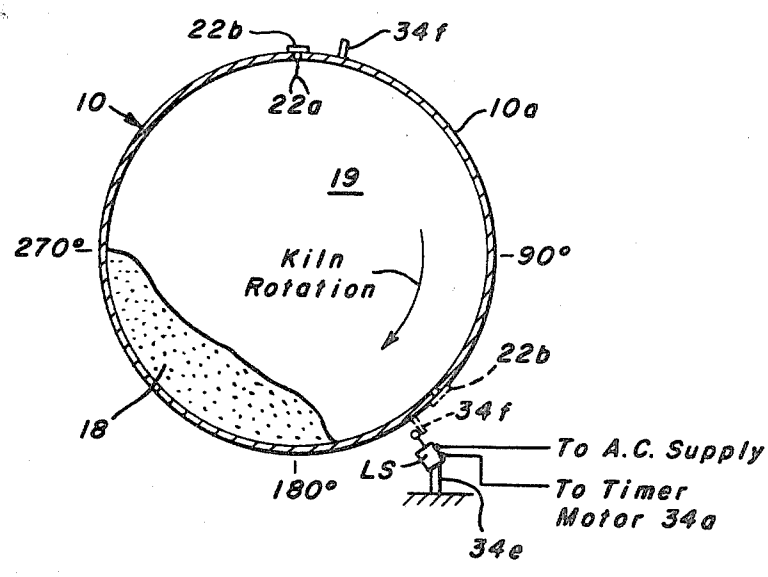
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Assistant Examiner—Frederick Shoon
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ABSTRACT: This invention relates to apparatus for determining the temperature of one of a kiln load and a heated fluid stream at a predetermined location on a longitudinal 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 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. 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 substantially minimum output signal respectively to the comparator module.



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SHEET 1 OF 5

FIG. 1.

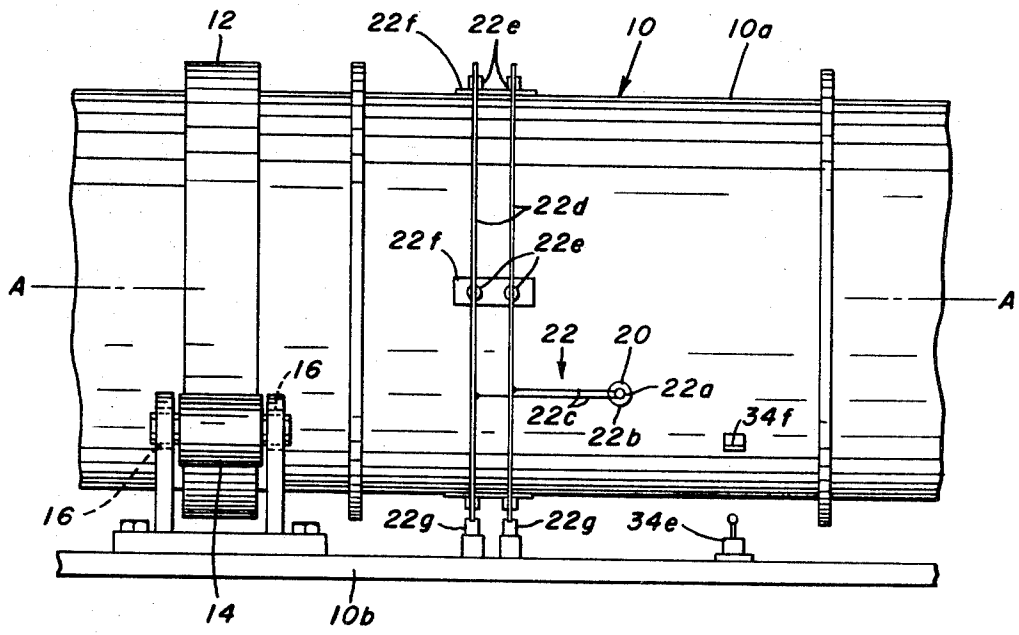
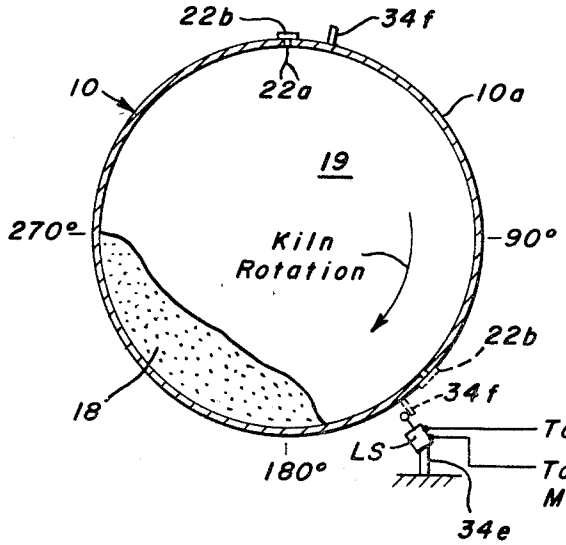


FIG. 2.



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By

Attorney

FIG. 3.

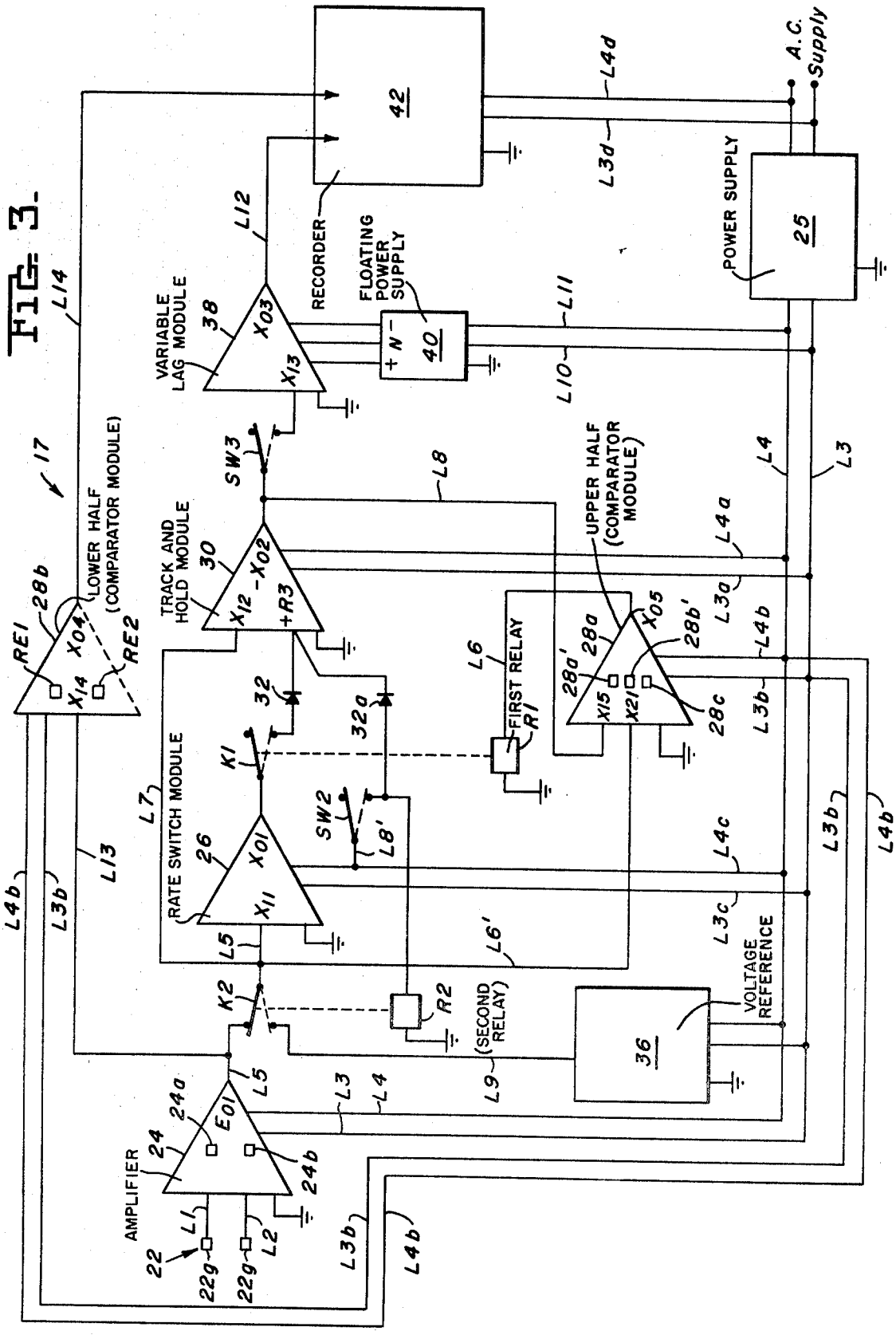

42
RECORDER
FLOATING POWER SUPPLY
40
+ N −
VARIABLE LAG MODULE
38
X03
X13
L12
L14
L11
L10
POWER SUPPLY
25
A.C. Supply
L4d
L3d
17
LOWER HALF (COMPARATOR MODULE)
28b
RE1
RE2
X04
X14
TRACK AND HOLD MODULE
30
X12 -X02
+R3
SW3
L8
UPPER HALF (COMPARATOR MODULE)
L4
L3
L4a
L3a
L4b
28a
28b'
28a'
X05
X15
X21
28c
L3b
FIRST RELAY
R1
L6
32
32a
K1
RATE SWITCH MODULE
L7
26
X01
X11
SW2
L8'
L4c
L3b
L4b
L13
L5
L6'
L3c
VOLTAGE REFERENCE
K2
R2
(SECOND RELAY)
L9
36
AMPLIFIER
24
24a
24b
E01
L1
L2
22
22g
L3
L4

FIG. 4.

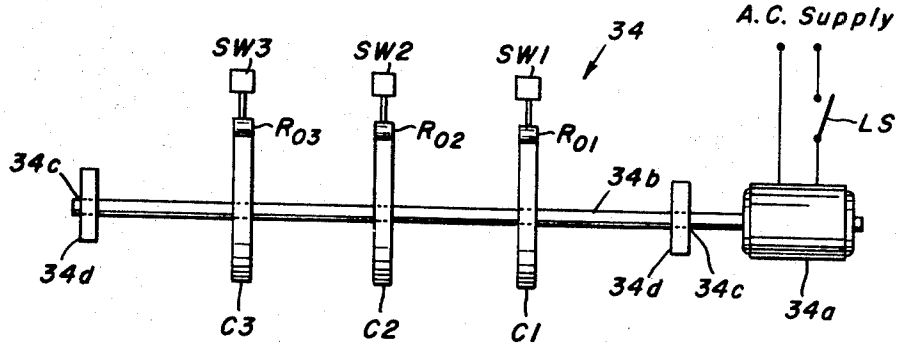


FIG. 5.

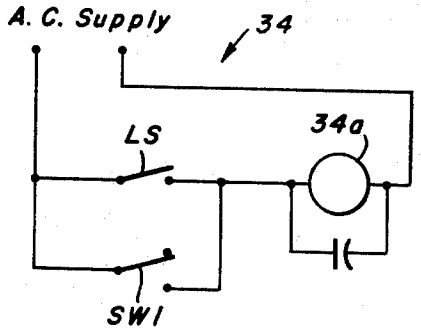


FIG. 7.

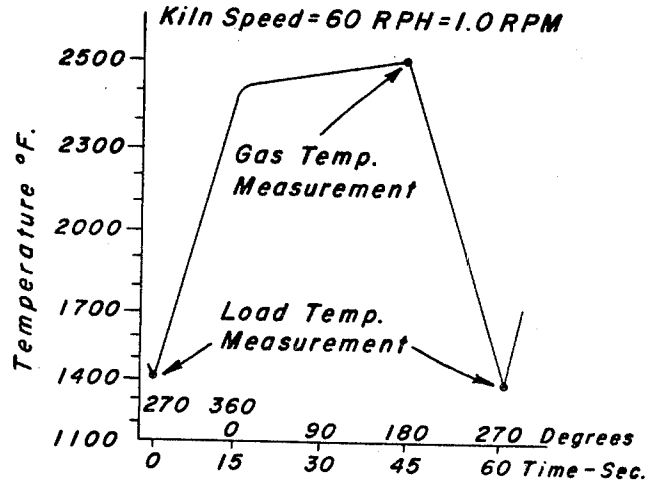


FIG. 6.

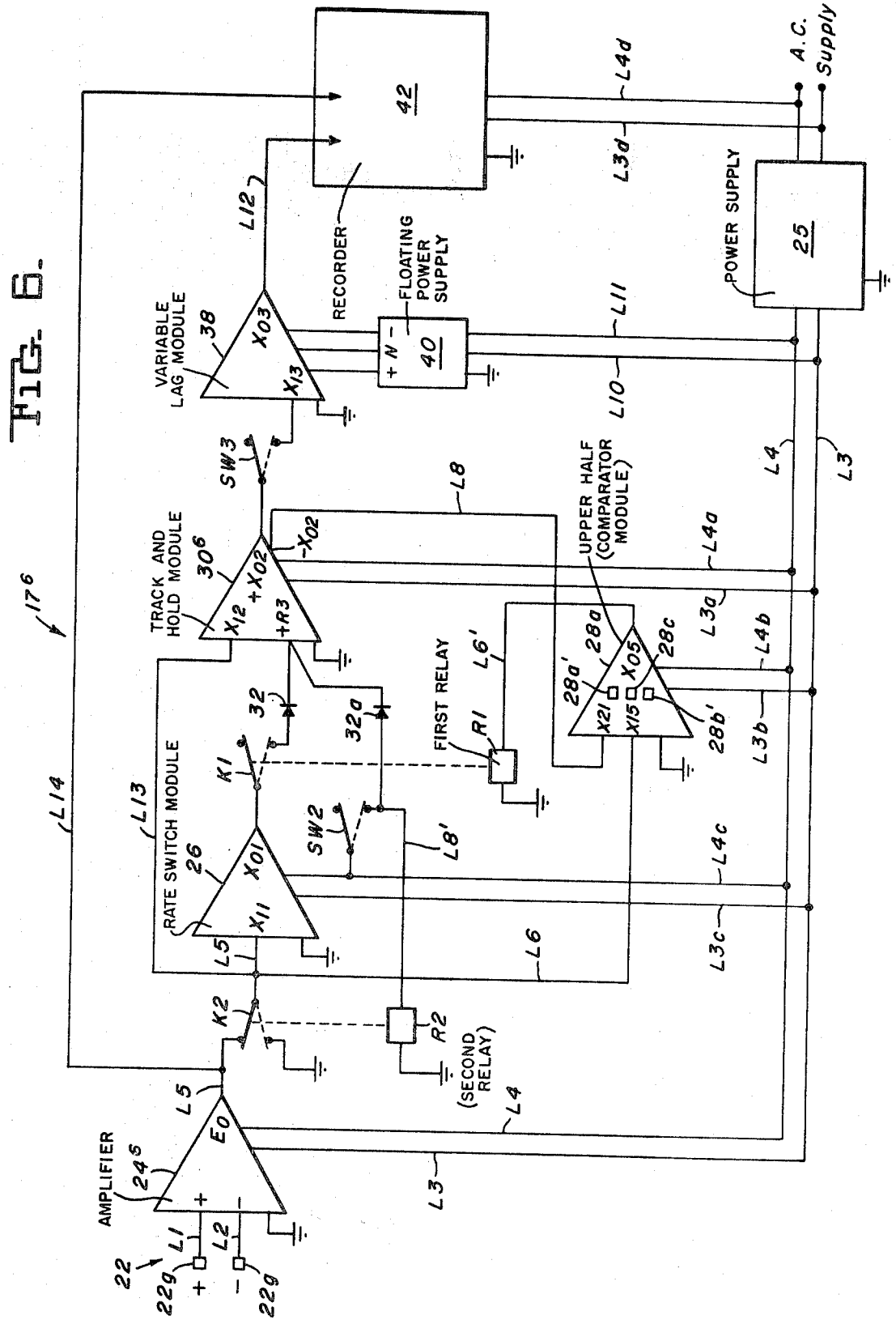
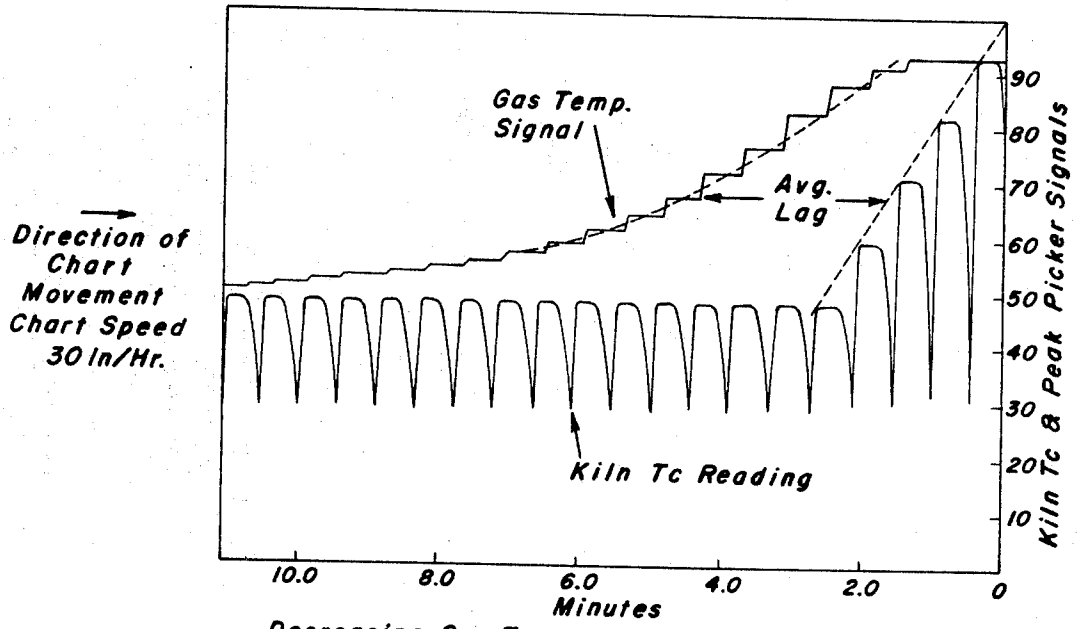
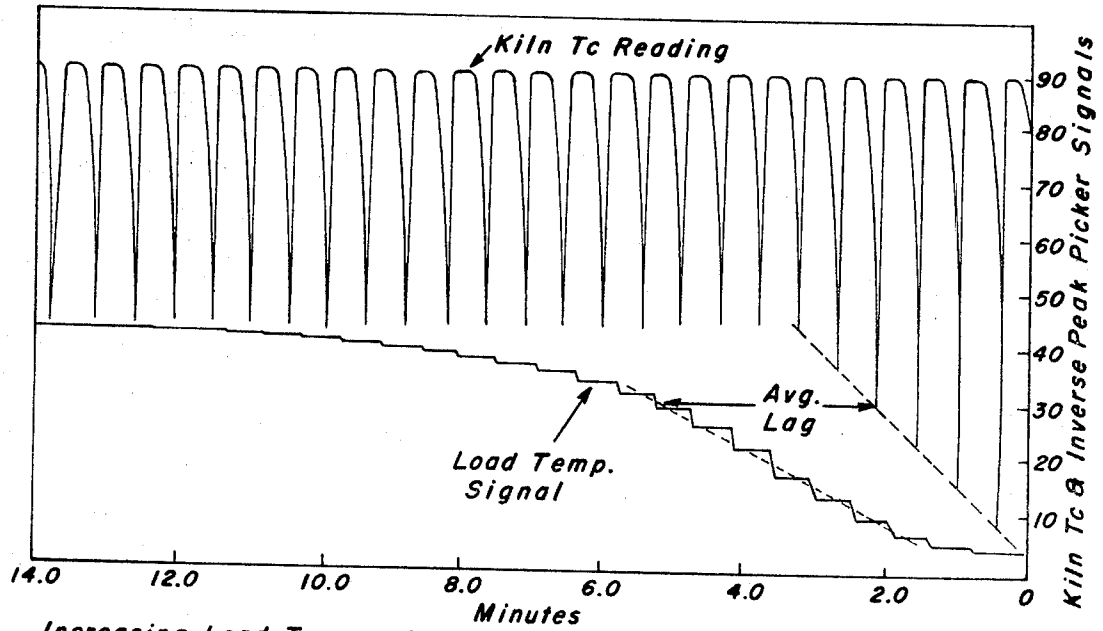

42
RECORDER
FLOATING POWER SUPPLY
40
POWER SUPPLY
25
A.C. Supply
L4d
L3d
L12
L11
L10
L4
L3
VARIABLE LAG MODULE
38
X03
X13
SW3
L8
TRACK AND HOLD MODULE
306
-X02
X12 +X02
+R3
UPPER HALF (COMPARATOR MODULE)
L4a
L3a
L4b
L3b
28a
28c
28a'
28b'
X21
X05
X15
L6'
FIRST RELAY
R1
32
32a
K1
SW2
L8'
RATE SWITCH MODULE
26
X01
X11
L13
L14
L5
L6
L4c
L3c
K2
R2
(SECOND RELAY)
AMPLIFIER
24s
E0
L1
L2
22
22g
176

FIG. 8.



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

FIG. 9.



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

Direction of Chart Movement
Chart Speed 30 In/Hr.

ELECTRONIC PEAK-PICKER

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, 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 CO_2. The temperature range in the calcining zone is usually from about 1,600° to 1,800° F.
4. The kiln feed is further heated in the *burning zone* to a temperature to cause the combination of the argilaceous 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° to 2,700° F. 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 will vary 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 overbalance 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 can be 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.

Conventional apparatus for measuring kiln temperature are of the type shown in the following patents: U.S. Pat. Nos. 2,109,396, to McCoy issued Feb. 22, 1938; 2,303,843, to Knoblanch issued Dec. 1, 1942; 2,428,129, to Smith issued Sept. 30, 1947; 2,907,209, to Woch issued Oct. 6, 1959; 3,103,817, to Ludwig issued Sept. 17, 1963.

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 practices 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 then 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. 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.

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 **10***b*. 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 **10***a* (FIGS.**1**, **2**) of the kiln **10**. The kiln **10** has a heated fluid stream **19** (FIG. **2**) such as for example CO_2,O_2 and N_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 **10***a* 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 **22***a* (FIGS. **1**,**2**, for example a Type K sheathed thermocouple specified by the Instrument Society of America, Pittsburgh, Pa.) mounted by means of a bracket **22***b* (FIGS. **1**,**2**) on the shell **10***a* and projecting into the interior of the shell **10***a* (FIG. **2**). The thermocouple **22***a* is connected by lines **22***c* (FIG. **1**) to slip rings **22***d* (FIG. **1**) mounted by means of insulators **22***e* upstanding from brackets **22***f* on the shell **10***a*. In order to transmit the thermocouple signals to the rest of the apparatus **17**, brushes **22***g* (FIGS0 **1**,**3**) are mounted on the frame **10***b* of the kiln **10** and biased by springs (not shown) into contact with the slip rings **22***d*. As shown in FIG. **3** the brushes **22***g* 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 **24***a* and inverse output **24***b* and manufactured by Consolidated Electrodynamics, 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_{11} 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 Electrodynamics, 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. at about 270°—180°, FIG. **2**, of each cycle) to the rate switch module **26** from the amplifier **24** while the thermocouple **22***a* 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. at about 180°—270°, FIG. **2**, of each cycle) while the thermocouple **22***a* is passing through the kiln load **18**. Lines **L3***c*, **L4***c* 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 **28***a* and a lower half **28***b* (FIG. **3**), for example, of the Type 19–501–2 with a Type 222026–05 delta coefficient **28***a*′, a Type 222017–04 input coefficient **28***b*′ fixed at *a* equals 1 and a Type 222025–01 Zener diode **28***c* manufactured by Consolidated Electrodynamics, Devar Kinetics Division, a subsidiary of Bell and Howell, Bridgeport, Conn. Lines **L3***b*, **L4***b* connect the upper half **28***a* and the lower half **28***b* of the comparator module to the power supply **25**. Line **L6**′ connects terminal **X21** of the upper half **28***a* of the comparator module **28** to the temperature signal from amplifier **24** and line **L6** connects the output X_{05} of the upper half **28***a* of the comparator module to a first relay **R1** (FIG. **3**).

The lower half **28***b* 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 28*a* 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 X_{05} 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 28*c* across the amplifier (not shown) limits the output X_{05} in one direction to a maximum of about 10 volts ± about 5 percent, and in the other direction to about zero output. If the diode 28*c* is reversed for the same tripping conditions, the output X_{05} 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 X_{12} of a track and hold module 30 (similar to Type 19–407 module manufactured by Consolidated Electrodynamics, 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 $-X_{02}$ thereof by line L8 to terminal X_{15} of the upper half 28*a* of the comparator module. The track and hold module 30 is operable to provide a substantially maximum output signal to the input terminal X_{15} of the upper half 28*a* of comparator module when the thermocouple 22*a* is passing through the fluid stream 19 (i.e. at about 270°—180°, FIG. 2, of each cycle) so that when the temperature signal from the amplifier 24 to terminal X_{21} of the upper portion 28*a* of the comparator module is less than the maximum output signal from the track and hold module 30 to terminal X_{15} of the upper half 28*a* 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 X_{01} of rate switch module 26 through a blocking diode 32 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 X_{12} 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 X_{01} of the rate switch module 26 thus causing the output signal from output $-X_{02}$ of the track and hold module 30 to follow the kiln load temperature signal from the amplifier 24 being fed to input X_{12} of the track and hold module 30 (i.e. at about 180°—270°, FIG. 2, of each cycle) and to then produce a fluid stream blocking output (i.e. at about 270°—180°, FIG. 2, of each cycle) thus holding the output signal from output $-X_{02}$ of the track and hold module 30 at a substantially minimum temperature signal to terminal X_{15} of the upper portion 28*a* of the comparator module. Almost simultaneously therewith the upper half 28*a* of the comparator module is operable to deenergize the first relay R1 (when the temperature signal from the amplifier 24 to terminal X_{21} of the upper half 28*a* of the comparator module is greater than the output signal from output $-X_{02}$ of the track and hold module 30 to terminal X_{15} 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).

RESET MEANS 34

The reset means 34 (FIGS. 4,5) has a timer motor 34*a*, provided with a shaft 34*b* (FIG. 4) journaled at 34*c* in end brackets 34*d*, the shaft 34*b* carrying cams C1,C2 and C3, (FIG. 4) which cams C1, C2, C3 engage respectively rollers R01,R02 and R03 (FIG. 4) of the switches SW1 (FIGS. 4,5), SW2 (FIGS. 3,4) and SW3. The timer motor 34*a* is energizable by closure of normally open limit switch LS (FIGS. 2, 4, 5) and is mounted on a bracket 34*e* (FIG. 2) by a tripper 34*f* (FIG. 2) extending from the shell 10*a* when the thermocouple 22*a* is at about 135° (FIG. 2) of each cycle. Cam C1 closes normally open holding switch SW1 (FIGS. 4,5) and the timer motor 34*a* (connected to the AC Supply through first the limit switch LS and now the holding switch SW1) runs through its timed cycle, about 15 seconds. Thereafter cam C3 closes and opens switch SW3 before cam C2 closes switch SW2 and while switch SW1 is closed. Then cam C2 closes and opens switch SW2 before cam C1 opens switch SW1. When cam C2 momentarily closes normally open switch SW2 (i.e. the dotted line position, FIG. 3), it connects input R3 of the track and hold module 30 (through blocking diode 32*a*) to a tracking output of about +18 v. from the power supply 25 through line L8 and thereby energizing relay R2 with attendant movement of contact K2 from the solid line position (FIG. 3) to the dotted line position (FIG. 3). The new position of contact K2 connects input X_{12} of the track and hold module 30 to a substantially maximum temperature signal (about −10 volts) via line L9 from a voltage reference 36 of, for example, the Type 19–603 manufactured by Consolidated Electrodynamics, Devar Kinetics Division, a subsidiary of Bell and Howell, Bridgeport, Conn. The voltage reference 36 is connected to the power supply 25. The application of the substantially maximum temperature signal to input X_{12} of the track and hold module 30 produces from output $-X_{02}$ thereof a substantially maximum output signal to terminal X_{15} of the upper portion 28*a* of the comparator module.

Thereafter cam C3 (FIG. 5) momentarily closes normally open switch S3 (i.e. the dotted line position, FIG. 3) to connect the output $-X_{02}$ of the track and hold module 30 to input X_{13} of a variable lag module 38 which, for example, is of the Type 19–412 manufactured by Consolidated Electrodynamics, Devar Kinetics Division, a subsidiary of Bell and Howell, Bridgeport, Connecticut. This variable lag module 38 (FIG. 3) is powered from a floating power supply 40 (the supply 40 being connected by lines L10,L11 to the power supply 25) and is connected by a line L12 to a recording means, such, as for example, a recorder 42 of the Type 18–301 series manufactured by Consolidated Electrodynamics, Devar Kinetics Division, a subsidiary of Bell and Howell, Bridgeport, Connecticut. The output signal from output $-X_{02}$ of the track and hold module 30 to input X_{13} of the variable lag module 38 is a substantially minimum temperature signal. The variable lag module 38 is operable through a resistance-capacitance circuit (not shown) to average successive substantially minimum temperature signals from the track and hold module 30 to produce a modulated record on the recorder 42 of such substantially minimum temperature signals. Switch SW3 is opened by cam C3. Thereafter cam C2 closes and opens switch SW2 before cam C1 opens switch SW1.

The adjustable lag module 38 provides an output voltage X_{03} through line L12 to recorder 42 which is a first order approximation of the input voltage X_{13}, delayed by an adjustable amount of time. The module 38 has an RC circuit (not shown) followed by a chopper stabilized operational amplifier (not shown) with an extremely high impedance and a gain of about +1.00±0.01 percent. The time lag is determined by the time constant of the RC circuit. A capacitor (not shown) has a fixed value and is built in the module 38. An externally mounted resistor (not shown) is the inverse time selector and has a selectable value in the range from about 0.01 to 800 repeats per minute.

CONTINUOUS THERMOCOUPLE TEMPERATURE

As shown in FIG. 3, a line L13 connects the continuous temperature signal from the amplifier 24 to terminal X_{14} and resistors RE1 (having a 22K ohm resistance) and RE2 (having a 22K ohm resistance) to enable the lower portion 28*b* 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 X_{04} of the lower portion 28*b* 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 17^6 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 24^6 (FIG. 6) and the voltage reference module 36 (FIG. 3) is not employed in the apparatus 17^6 (FIG. 6). Further, the signal inversion accomplished in the lower half 28*b* (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 22*g* has the + input signal connected to the + input to the amplifier 24^6 (FIG. 6) and the − signal input connected to the − input of the amplifier 24^6 (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 $-X_{02}$ from the track and hold module 30^6 is connected to the terminal input X_{21} of the upper half 28*a* of the comparator module and the line L6 (from the amplifier output E0 and line L5) extends to the terminal X_{15} of the upper half 28*a* of the comparator module 28. Again, in FIG. 3 the output $-X_{02}$ 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 $+X_{02}$ from the track and hold module 30^6 (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 17^6 (FIG. 6) has been reset and that the thermocouple 22*a* 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 X_{21} of the upper half 28*a* of the comparator has about 0 volts applied to it from the $-X_{02}$ output of the track and hold module 30^6, which $-X_{02}$ output was applied during the reset operation.

As the thermocouple 22*a* (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 22*g* (FIG. 6) also rises with attendant increase in the output EO of the amplifier 24^6. As a result the absolute value of the temperature signal input X_{15} of the upper half 28*a* of the comparator module 28 is greater than the absolute value of the track and hold input X_{21} of the upper half 28*a* of such comparator module, thus causing output X_{05} of the upper half 28*a* 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 X_{11} of the rate switch 26 causes the rate switch output X_{01} to go to +18 volts, which +18 volts is fed via the now closed contact K1 to the +R3 input of the track and hold module 30^6 to permit the track and hold module 30^6 to track the signal via its input X_{12}. The track and hold module 30^6 will track this input signal to input X_{12} as long as the temperature signal is rising and the output from output X_{01} of the rate switch 26 is +18 volts and relay R1 is energized.

When the thermocouple 22*a* reaches its maximum temperature (i.e. at about 150°, FIG. 2) the output X_{01} 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 X_{11} of the rate switch 26, with the result that the track and hold module 30^6 holds this last maximum signal. This maximum inverted signal is applied to input X21 of the upper half 28*a* of the comparator module.

When the thermocouple temperature is no longer maximum (i.e. at about 190°, FIG. 2), the input signal to input X_{15} of the upper half 28*a* of the comparator module has a signal of lower absolute value than the absolute value to comparator input X_{21}. The comparator output X_{05} 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 30^6 from accepting a new signal at input X_{12} unless such new signal is of greater absolute value than the absolute value of the comparator X_{21} input signal.

When the thermocouple 22*a* 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 34*a*, which timer motor 34*a* causes cam C1 to close holding switch SW1 and hold or seal the timer motor 34*a* to its timed cycle. Thereafter the timer motor 34*a* causes cam C3 to close switch SW3, thus applying the output X_{02} of the track and hold module 30^6 (i.e. the maximum signal) to the input X_{13} of the variable lag module 38. Such variable lag module 38 accepts and holds a percentage of the signal applied at input X_{13} depending on the RC value for the lag time of the variable lag module 38. The output X_{03} 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 +R3 input of the track and hold module 30^6, 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 X_{12} of the track and hold module 30^6, 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 22*a* 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 17^6 (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), 17^6 (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 17,17^6 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.

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 thereto 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,
      1. 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,
      2. 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
   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.

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 reinverting 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,

a. 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 connected 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, "(FIGSO 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

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