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(54) Safety systems for coal pulverizers.

(57) A safety control system for a coal pulverizer utilizes signals (20,22) representing net oxygen and carbon monoxide measurements of the pulverizer atmosphere. A signal (50) representing the rate of carbon monoxide change is derived form the signal (22) by a derivative controller (48). The signals (20,50) representing the net oxygen measurement and rate of carbon monoxide change are compared in respective comparing means (36,52) with respective setpoints (38,54) to generate control signals (46,62) for actuating alarms (26,28). The pulverized oxygen and actual carbon monoxide signals (20,22) are compared in respective comparing means (64,88) with respective setpoints (66,90) to generate control signals (74,98) for causing automatic inerting of the pulverizer by supplying carbon dioxide thereto.

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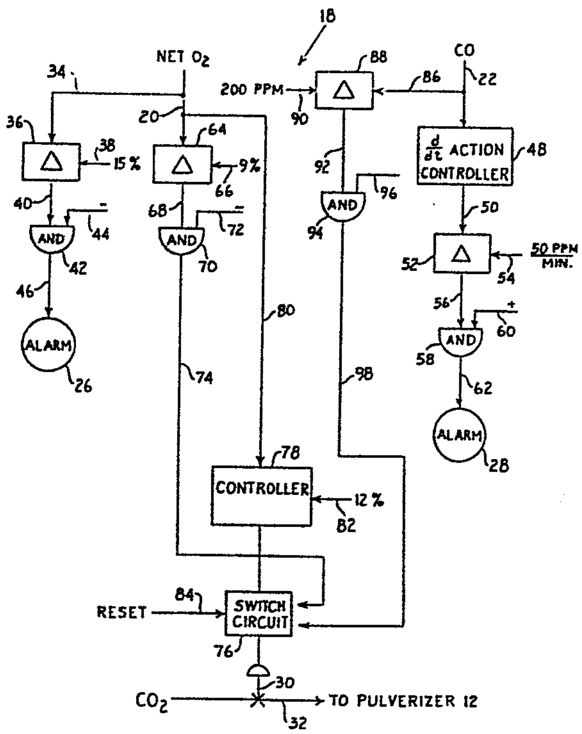
18
NET O2
CO
34
20
22
200 PPM
90
88
86
36
38
15 %
64
9%
66
d/dt ACTION CONTROLLER
48
92
96
AND
94
40
68
44
72
AND
42
AND
70
50
52
54
50 PPM/MIN.
46
56
60
58
AND
ALARM
26
80
74
98
62
ALARM
28
78
CONTROLLER
12 %
82
RESET
84
SWITCH CIRCUIT
76
30
CO2
32
TO PULVERIZER 12

FIG. 2

SAFETY SYSTEMS FOR COAL PULVERIZERS

This invention relates to safety systems for coal pulverizers.

Known pulverized-coal systems pulverize coal, deliver it to fuel-burning equipment, and accomplish complete combustion in the furnace with a minimum of excess air. The system operates as a continuous process and, within specified design limitations, the coal supply or feed can be varied as rapidly and as widely as required by the combustion process.

A small portion of the air required for combustion (15 to 20% in current installations) is used to transport the coal to the burner. This is known as primary air. In the direct-firing system, primary air is also used to dry the coal in the pulverizer. The remainder of the combustion air (80 to 85%) is introduced at the burner and is known as secondary air.

All coals, when exposed to air, undergo oxidation even at room temperature. This tendency varies with coal ——————————

type: anthracite and semi-anthracite, for example, are little affected whereas many bituminous coals are particularly liable to absorb and combine with oxygen. The process of oxidation continues with increasing rapidity as the temperature rises. Heat is generated which, if allowed to accumulate, could result in thermal decomposition and ignition of the coal. Volatile components of the coal, such as methane and related compounds, are released during the decomposition. Accumulation of these gaseous materials may be ignited at fairly low temperatures and rapidly propagate fire or explosion.

Spontaneous combustion of coal is dependent on a sufficient supply of oxygen to maintain the reaction and on the surface area exposed. Coals with a high surface area, due to small particle size, as in pulverized coal fuel, are particularly liable to self heating. This problem is of special significance to the safe operation and performance of industrial coal pulverizers. Spontaneous combustion may result in deterioration in the quality of the coal, in damage to the power plant, and in certain cases, for example, where critical concentrations of coal dust are involved, may provide the ignition source for an explosion.

Present systems for fire detection in industrial coal pulverizers use either thermocouples to measure the rise in outlet temperature of the pulverizing mill or infrared gas analyzers to detect the buildup of CO produced in the mill.

Thermocouples or resistance temperature devices (RTD's) are normally part of the control system for mill operation. However, they are a relatively insensitive means for detecting pulverizer fires. At best, they warn of impending trouble only a few minutes before it actually occurs, and in some cases, do not even detect a significant temperature rise before a fire or explosion is evident. The ineffectiveness of thermocouples and RTD's in this application is due, in part, to the shielding used to protect them from the corrosive coal particles. Shields reduce heat conduction, slowing response time.

Actual CO measurements are also used for fire detection in coal pulverizers since that CO buildup is related directly to the oxidation rate of coal. Infrared gas analyzers are used to compare the CO content of the incoming and outgoing mill air and in effect, the amount of CO produced in the mill. Currently available infrared gas analyzers require extensive filtering and dehydration of the gas sample extracted from the mill, to prevent interference by water vapor and particulate matter. Due to the high cost and maintenance requirements of infrared absorption analyzers, it is the usual practice to use one analyzer for several measurement points. Continuous measurement of each mill is not provided, thus, slowing response time. Nevertheless, this provides an improvement over the thermocuple and RTD method described. Additional problems occur, at some power plants, where appreciable concentrations of CO can be found in the air supply to the mill. Since in such plants CO in the boiler flue gases is transferred to the combustion air via the regenerative air heater and it thus becomes necessary to provide an analysis of the air entering the mill.

Thus, it is seen that an accurate and reliable safety system was required for coal pulverizers which would provide an early warning of impending safety problems in coal pulverizers.

According to the invention there is provided a safety system for a coal pulverizer, the safety system comprising:

means for measuring the actual net oxygen level in the coal pulverizer and establishing a signal indicative thereof;

means for comparing the signal from the net oxygen measuring means with a predetermined setpoint signal indicative of a potentially hazardous net oxygen level and establishing a control signal therefrom; and

alarm means responsive to the control signal to indicate an alarm condition indicative of a potentially hazardous condition in the coal pulverizer.

The invention also provides a safety system for a coal pulverizer, the safety system comprising:

means for determining the actual rate of carbon monoxide level change in the coal pulverizer and establishing a signal indicative thereof;

means for comparing the signal from the determining means with a predetermined setpoint signal indicative of a potentially hazardous rate of carbon monoxide level change in the coal pulverizer and establishing a control signal therefrom; and

alarm means responsive to the control signal for indicating a potentially hazardous condition in the coal pulverizer.

Further, the invention provides a safety system for a coal pulverizer, the safety system comprising:

means for measuring the actual net oxygen level in the coal pulverizer and establishing a signal indicative thereof;

means for measuring the rate of change of carbon monoxide level in the coal pulverizer and establishing a signal indicative thereof;

comparing means for comparing the signals established by the net oxygen measuring means and the rate of carbon monoxide change measuring means with predetermined setpoints for establishing respectively independent control signals whenever the predetermined setpoints are exceeded; and

alarm means responsive to either of the control signals for indicating a potentially hazardous condition in the coal pulverizer.

A preferred embodiment of the invention decribed in detail hereinbelow overcomes or at least alleviates the above-stated problems of prior art safety systems and provides an improvement over the existing art. It is not dependent on the measurement of pulverizer or pulverizing mill outlet temperature, the removal of moisture and all particulate matter from the sample extracted from the mill or multi-point sampling. The preferred system incorporates the use of a standard single point oxygen and CO analyzer directly mounted to the coal pulverizing mill or pulverizer and providing a continuous percent by volume measurement of oxygen content and a continuous measurement of CO gas concentration of the mill atmosphere. The O_2 portion of the analyzer uses a sensor operating at a temperature where any combustible volatile material will combine with O_2 in the sample. The sensor will then respond to the free or uncombined O_2 remaining. The resulting measurement, denoted net or residual, O_2, can be correlated with the amount of combustible volatiles within the mill. An additional significant indicator of a potentially hazardous condition is, thus, provided, augmenting the CO measurement. The combined measurement of CO and net O_2 concentration in the mill atmosphere is used to indicate and alarm both the onset and progress of spontaneous combustion within the mill.

Thus, according to respective aspects of the present invention, the preferred system provides the following advantageous features. It provides an automated system capable of being integrated into a plant's pulverizer management and combustion control system designed to monitor the performance of and detect impending fires and explosions in industrial coal pulverizers and alarm such conditions. It provides an automated alarm system based on a net oxygen measurement in the coal pulverizer. It provides an automated alarm system based on a predetermined carbon monoxide rise per time. It provides an automated inerting control of the coal pulverizer upon detection of either a predetermined net oxygen level or an absolute carbon monoxide level.

The invention will now be further described, by way of illustrative and non-limiting example, with reference to the accompanying drawings, in which:

Figure 1 is a schematic drawing of a safety control system embodying the present invention for a coal pulverizer; and

Figure 2 is a schematic drawing of monitoring and control logic of the Figure 1 safety control system.

The drawings depict a reliable, relatively low-cost automated safety system 8 capable of being integrated into a plant's computer control system designed to monitor the performance of and detect impending fires and explosions in electric-utility and industrial coal pulverizers by monitoring the level of carbon monoxide (CO) and net oxygen (O_2) concentration in a pulverized coal mill atmosphere. The combined measurement of CO and O_2 concentration in the mill atmosphere is used to indicate the oxidation rate of the coal to preclude spontaneous combustion. Additionally, the measurement of net O_2 concentration, when combined with other measurements, may provide the basis for overall mill performance calculations and the quality of the pulverized coal.

As shown in Figure 1, a CO/O_2 sample probe 10 is typically placed in a coal pulverizer 12 classifier outlet zone. A sample of gas is drawn through the probe 10 which has a porous high temperature filter 14. The filter 14 is required to maintain trouble-free operation by minimizing the amount of particulate matter drawn into the analyzer. A suitable filter 14 for this application is of a type described in U.S. Patent No. 4,286,472.

The air sample drawn from the coal pulverizer 12 is then analyzed for percent by volume of oxygen (O_2) content and CO gas concentration in ppm (parts per million) via a known oxygen and CO gas analyzer 16 designed to operate in a harsh power plant environment and having autocalibration capabilities. A suitable analyzer for this application is one manufactured by the Bailey Controls Company of Babcock and Wilcox and is known as the Type OL Oxygen and CO Analyzer. This analyzer 16 has a CO range of 0-1000 ppm and an O_2 range of 0.1-25%. Electrical signals corresponding to carbon monoxide and oxygen concentrations are respectively transmitted to a monitoring system control 18 located in the central control room along lines 20 and 22. CO and O_2 concentrations are displayed and/or recorded on a strip-chart recorder 24. During normal pulverizer 12 operation, net O_2 levels represent typically 16% O_2 and normal CO levels range between 40 and 80 ppm. If the net O_2 concentration falls below a certain predetermined level, typically 15%, and/or the amount of CO produced exceeds a predetermined rise level considered cause for concern, typically a 50 ppm/minute sudden rise, the system 8 activates audible and visible alarms 26, 28 to alert the operator who in turn may manually take corrective action to inert the pulverizer 12 or permit the automatic monitoring system 8 to continue until it initiates an automatic inert to bring the pulverizer 12 operating parameters under control.

Referring now to Fig. 2, it will be seen that the monitoring and control logic assembly 18 utilizes both a net oxygen measurement provided by the analyzer 16 along line 20 as well as a carbon monoxide measurement provided along line 22 from analyzer 16, to, on the one hand, actuate alarms 26 and 28 at predetermined levels of net oxygen and predetermined rise times of carbon monoxide concentration. Also, when the net oxygen levels and the absolute carbon monoxide levels exceed certain critical limits, automatic inerting of the pulverizer 12 is accomplished by controllably opening a valve 30 which allows some inerting media such as carbon dioxide for steam to flow along a line 32 into the pulverizer 12.

Turning first to the alarm functions, it will be seen that the net oxygen measurement from line 20 is transmitted along a line 34 to a difference station 36 having a setpoint set at a predetermined net oxygen control point transmitted along line 38. The difference station 36 compares the actual net oxygen measurement provided by the analyzer 16 representing the net oxygen level in the pulverizer 12 and compares it with the setpoint oxygen level which, in the present situation, is set at 15%. The present setpoint of 15% is based on the assumption that the typical atmosphere in the pulverizer representative of normal conditions is approximately 16% and the initial alarm condition is desired to be a warning indicative of potential problem areas.

The difference station 36 thus compares the two signals and provides an error signal along line 40 which is one input of an AND gate 42. The other input of the AND gate 42 is provided by a constant negative signal from a predetermined source along line 44. Thus, as long as the net oxygen level provided to the difference station 36 along line 34 is greater than the 15% setpoint, a positive level error signal will be transmitted along line 40 to the AND gate 42 which then will fail to provide any control signal along line 46, failing to actuate the alarm 26. As soon as the net oxygen level falls below the 15% setpoint, the output along line 40 becomes negative and, in combination with the constant negative signal along line 44, will result in a conduction of the AND gate 42, causing a control signal to be transmitted along line 46 to the alarm 26 to thus actuate it and provide an indication of potential problems in the pulverizer 12 atmosphere.

Alternatively, the measured carbon monoxide signal transmitted along line 22 may also provide an actuation of the alternate alarm 28. The measured carbon monoxide signal is transmitted to a derivative action controller 48 which will be sensitive to any variations in the carbon monoxide level and will effectively provide an output signal along line 50 indicative of the slope or rate of change of the carbon monoxide level in the pulverizing mill 12. The output of the derivative action controller 48 is transmitted to a difference station 52 having a predetermined setpoint along line 54 indicative of a rate of carbon monoxide change which would indicate coal ignition in the pulverizer 12. Such a rate of change is typically taken to be a 50 ppm/minute rate of carbon monoxide change. The output of the difference station 52 is transmitted along the line 56 to an AND gate 58 having a second input of a constant negative value provided along line 60. In operation, the rate of carbon monoxide change normally stays below the 50 ppm/-minute setpoint resulting in a negative output signal from the difference station 52. Whenever the actual rate of carbon monoxide change exceeds the setpoint of line 54, the signal transmitted along line 56 turns positive, causing the AND gate 58 to start conducting a control signal along line 62 to the alarm 28 actuating the alarm 28 to indicate a potentially hazardous atmosphere in the pulverizer 12.

These individual alarms, when actuated, warn the operator of potentially hazardous conditions in the pulverizer. This should indicate to the operator that close monitoring of the pulverizer is required and typically one alarm will be actuated, possibly followed by the second alarm. Since the inerting of a pulverizer may shock the pulverizer, such inerting is left to the discretion of the operator and his supervisor. However, there are certain conditions beyond which inerting of the pulverizer 12 is mandatory and should be automatically initiated. To provide for such automatic inerting, the control system 8, again, utilizes both the net oxygen measurements and the carbon monoxide measurements provided by lines 20 and 22, respectively.

Automatic inerting of the pulverizer 12 is actuated by a difference station 64 which has a setpoint provided to it along line 66 having a net oxygen level significantly lower than the setpoint level provided to difference station 36. Typically, the difference station 64 has a net oxygen setpoint of 9%. Thus, during normal pulverizer 12 operation, the net oxygen level measured and transmitted to the difference station 64 will exceed the 9% setpoint and the error signal produced by the difference station 64 will be a positive level signal transmitted along line 68 to an AND gate 70. The other input of the AND gate 70 is provided by a constant negative level signal transmitted to the AND gate 70 along line

72. Thus, during normal operation, the inputs to the AND gate 70 will be positive and negative, providing no control signal from the output of the AND gate along line 74. Whenever the oxygen level of the pulverizer 12 falls below the 9% setpoint level, the output of the difference station 64 turns negative, providing two negative inputs to the AND gate 70 and resulting in a control signal along line 74 being transmitted to a switching circuit 76. The switching circuit 76 is a normally open circuit, preventing the signal transmitted from a controller 78 from reaching the control valve 30. When the control signal from line 74 is present, the switching circuit 76 changes to a closed-circuit condition, turning over control of the valve 30 to the controller 78.

The controller 78 has an input signal indicative of the actual net oxygen level in the pulverizer 12 which is provided by a parallel line 80, paralleling the net oxygen signal in line 20. The setpoint of the controller is provided along line 82 from some predetermined setpoint station and is typically set at a 12% level. Thus, when the switching circuit 76 is actuated by a control signal from the AND gate 70, the controller 78 will open valve 30, causing an inerting atmosphere, such as carbon dioxide, to be delivered to the pulverizer 12 until a somewhat normal ambient is reached close to the setpoint level of 12%. The reason for keeping the setpoint of the controller 78 at a somewhat lower than typically normal atmosphere is to minimize the shock to the pulverizer 12 due to the inerting process. The switching circuit is then switched back to its normally open condition by a reset signal provided along line 84 from either a manual source or an automatic source which can be tied to some parameter indicative of the reestablishment of normal ambient conditions in the pulverizer 12.

The actuation of the automatic inerting means is also alternatively done upon the sensing of a predetermined absolute level of carbon monoxide in the pulverizer 12. The carbon monoxide signal normally provided along line 22 is tapped by a line 86 to provide one input of a difference station 88. The setpoint of the difference station 88 is provided along line 90 from a predetermined setpoint station typically set at an absolute carbon monoxide level of 200 ppm. Thus, as long as the carbon monoxide level stays below a 200 ppm value indicative of normal operation, a positive error signal will be transmitted by the difference station 88 along line 92 to an AND gate 94. The other input to AND gate 94 is provided by a line 96 connected to a constant negative level source. Thus, during normal pulverizer 12 operation, opposite polarity signals are provided to the AND gate 94, preventing the establishment of any control signal along line 98 from the AND gate 94. Whenever the absolute carbon monoxide level exceeds the predetermined setpoint of 200 ppm, the error signal transmitted to the AND gate 94 turns negative, causing the conduction of the AND gate 94 and the establishment of a control signal along line 98 to the switching circuit 76. As was described earlier, with reference to the net oxygen level control, this causes the switching circuit 76 to become conductive, turning control of the valve 30 over to the controller 78. Again, automatic inerting of the pulverizer 12 occurs until a reset signal is established along line 84, causing the switching circuit 76 to again become non-conductive and causing the valve 30 to switch its normally closed position.

CLAIMS

1. A safety system for a coal pulverizer (12), the safety system (8) comprising:

means (10, 16) for measuring the actual net oxygen level in the coal pulverizer (12) and establishing a signal (20) indicative thereof;

means (36) for comparing the signal (20) from the net oxygen measuring means (10, 16) with a predetermined setpoint signal (38) indicative of a potentially hazardous net oxygen level and establishing a control signal (46) therefrom; and

alarm means (26) responsive to the control signal (46) to indicate an alarm condition indicative of a potentially hazardous condition in the coal pulverizer (12).

2. A safety system according to claim 1, including:

means (48) for determining the actual rate of carbon monoxide level change in the coal pulverizer (12) and establishing a signal (50) indicative thereof; and

means (52) for comparing the signal (50) from the determining means (48) with a predetermined setpoint signal (54) indicative of a potentially hazardous rate of carbon monoxide level change in the coal pulverizer (12) and establishing a control signal (62) therefrom, the alarm means (28) being responsive also to the control signal (62) established by the comparing means (52).

3. A safety system according to claim 1 or claim 2, including:

means (64) for comparing the signal (20) from the net oxygen measuring means (10, 16) with a second predetermined oxygen level setpoint signal (66) lower than the first-mentioned predetermined oxygen level setpoint signal (38) and establishing a control signal (74) therefrom; and

inerting means responsive to the control signal (74) established by the comparing means (64) for inerting the coal pulverizer (12).

4. A safety system according to claim 3, wherein the inerting means includes:

a source of carbon dioxide for providing an inerting atmosphere to the coal pulverizer (12);

valve means (30) for controlling the source of carbon dioxide; and

controller means (78) responsive to the signal (20) from the measuring means (10, 16) for controlling the valve means (30).

5. A safety system according to claim 4, including switching means (76) mounted between the controller means (78) and the valve means (30) and responsive to the control signal (74) established by the comparing means (64) to allow control of the valve means by the controller means.

6. A safety system for a coal pulverizer (12), the safety system (8) comprising:

means for determining the actual rate of carbon monoxide level change in the coal pulverizer (12) and establishing a signal (50) indicative thereof;

means (52) for comparing the signal (50) from the determining means with a predetermined setpoint signal (54) indicative of a potentially hazardous rate of carbon monoxide level change in the coal pulverizer and establishing a control signal (62) therefrom; and

alarm means (28) responsive to the control signal (62) for indicating a potentially hazardous condition in the coal pulverizer (12).

7. A safety system according to claim 6, wherein the determining means includes:

means (10, 16) for measuring the actual carbon monoxide level in the coal pulverizer (12); and

a derivative action controller (48) connected to the measuring means (10, 16) for providing the output signal (50) indicative of the rate of actual carbon monoxide level change in the coal pulverizer (12).

8. A safety system according to claim 7, including:

means (88) for comparing a signal (22) from the measuring means (10, 16) with a predetermined setpoint signal (90) indicative of a hazardous carbon monoxide level in the coal pulverizer (12) and establishing a control signal (98) therefrom; and inerting means responsive to the control signal for inerting the coal pulverizer (12).

9. A safety system according to claim 8, including:

means (10, 16) for measuring the actual net oxygen level in the coal pulverizer (12) and establishing a signal (20) indicative thereof; and

means (36) for comparing the signal (20) from the net oxygen measuring means (10, 16) with a predetermined setpoint signal (38) indicative of a potentially hazardous net oxygen level and establishing a control signal (46) for actuating the alarm means (26).

10. A safety system according to claim 9, including:

means (64) for comparing the signal from the net oxygen measuring means (10, 16) with a second predetermined oxygen level setpoint signal (66) lower than the first-mentioned predetermined oxygen level setpoint signal (38) and establishing a control signal (74) therefrom for actuating the inerting means.

11. A safety system according to claim 10, wherein the inerting means includes:

a source of inerting atmosphere for inerting the coal pulverizer (12);

valve means (30) for controlling the source of inerting atmosphere; and

controller means (78) responsive to the signal (20) from the means (10, 16) for measuring the net oxygen level in the coal pulverizer (12) for controlling the valve means (30).

12. A safety system according to claim 11, including switching means (76) mounted between the controller means (78) and the valve means (30) and responsive either to the control signal (98) from the comparing means (88) comparing the absolute carbon monoxide level in the coal pulverizer (12) with the predetermined setpoint signal (90) or the control signal (74) from the comparing means (64) comparing the net oxygen level in the coal pulverizer (12) with the second predetermined oxygen level setpoint signal (66) for allowing control of the valve means (30) by the controller means (78).

13. A safety system for a coal pulverizer (12), the safety system (8) comprising:

means (10, 16) for measuring the actual net oxygen level in the coal pulverizer (12) and establishing a signal (20) indicative thereof;

means (10, 16, 48) for measuring the rate of change of carbon monoxide level in the coal pulverizer (12) and establishing a signal (50) indicative thereof;

comparing means (36, 52) for comparing the signals (20, 50) established by the net oxygen measuring means (10, 16) and the rate of carbon monoxide change measuring means (10, 16, 48) with predetermined setpoints (38, 54) for establishing respectively independent control signals (46, 62) whenever the predetermined setpoints are exceeded; and

alarm means (26, 28) responsive to either of the control signals (46, 62) for indicating a potentially hazardous condition in the coal pulverizer (12).

14. A safety system according to claim 13, including:

comparing means (64) for comparing the signal (20) indicative of the actually measured net oxygen level in the coal pulverizer (12) with a setpoint (66) indicative of a hazardous condition in the coal pulverizer and establishing an inerting signal (74) whenever the actual net oxygen level in the coal pulverizer exceeds this setpoint (66); and

automatic inerting means (76, 78, 30) responsive to the inerting signal (74) for providing an inerting atmosphere to the coal pulverizer (12).

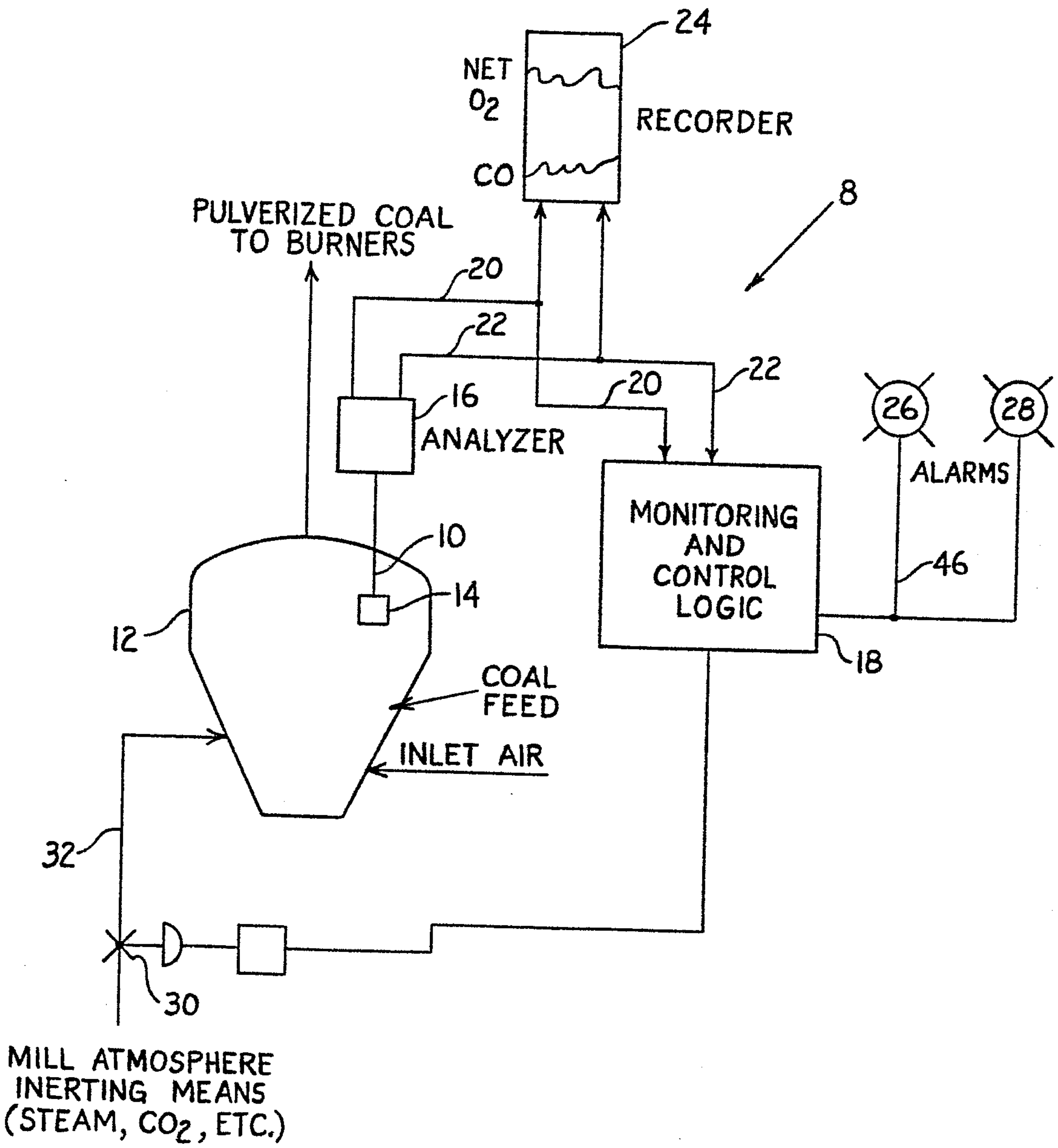
24
NET
O_2
RECORDER
CO
8
PULVERIZED COAL
TO BURNERS
20
22
22
20
16
ANALYZER
26
28
ALARMS
MONITORING
AND
CONTROL
LOGIC
10
14
46
12
18
COAL
FEED
INLET AIR
32
30
MILL ATMOSPHERE
INERTING MEANS
(STEAM, CO_2, ETC.)

FIG. 1

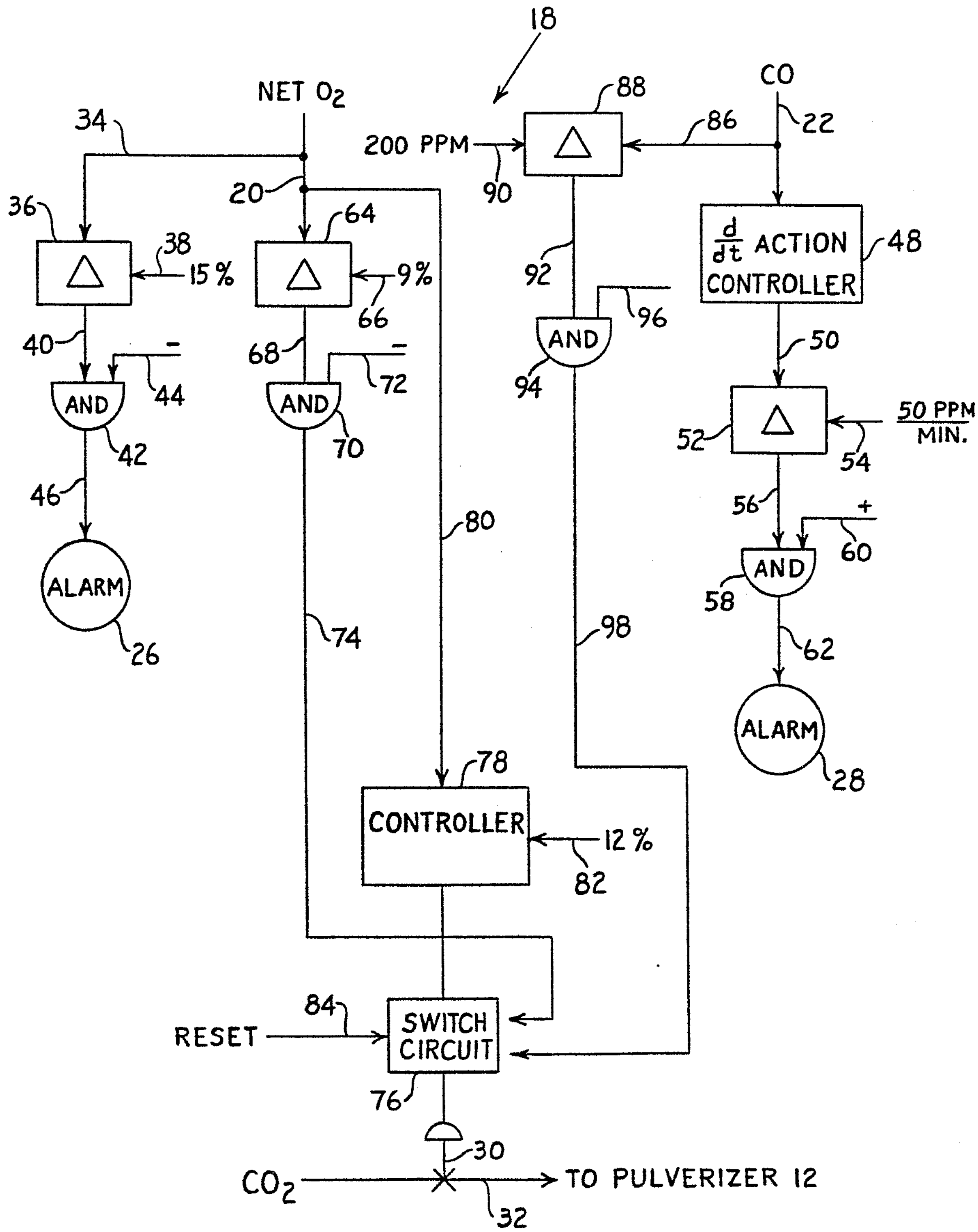
18
NET O_2
CO
34
20
22
86
88
200 PPM
90
36
38
15 %
64
9 %
66
48
$\frac{d}{dt}$ ACTION CONTROLLER
92
96
AND
94
40
-
44
AND
42
68
-
72
AND
70
50
52
54
50 PPM / MIN.
56
+
60
AND
58
46
ALARM
26
80
74
98
62
ALARM
28
78
CONTROLLER
12 %
82
RESET
84
SWITCH CIRCUIT
76
30
CO_2
TO PULVERIZER 12
32

FIG. 2