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[54] **MONITORING AND CONTROLLING KILN OPERATION IN CALCINATION OF COKE**

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[51] **Int. Cl.** **F27b 7/20**

[58] **Field of Search** 432/19, 26, 36, 45, 54, 432/103

[56] **References Cited**

UNITED STATES PATENTS

2,292,243	8/1942	Schwartz	432/45
3,647,195	3/1972	Drewry	432/45

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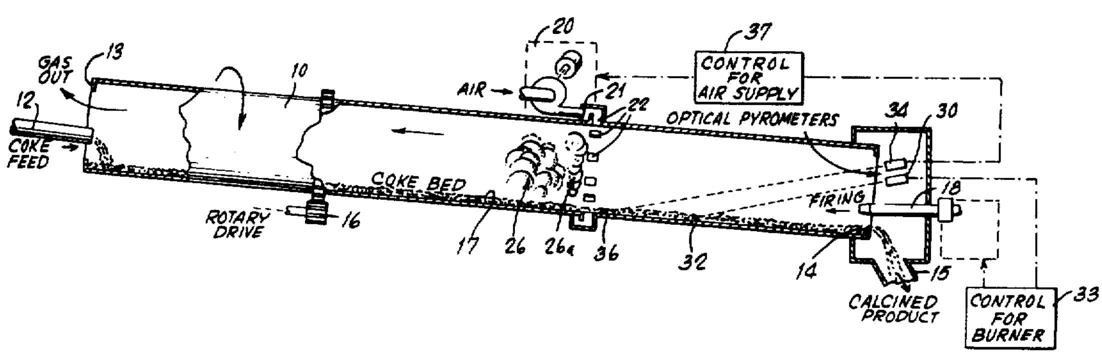
[57] **ABSTRACT**

Calcination of petroleum coke in a rotary kiln is monitored by optical pyrometer inspection, inward from the coke discharge end, at a plurality of places spaced longitudinally inside the kiln, with the improved result of enabling the kiln to be controlled so that desired readings at one of the places, e.g., nearest the coke discharge end, are not impeded or falsified by flame and smoke conditions caused by burning of volatiles. Since pyrometer readings are found to produce a special signal due to flame or smoke, the use of the plural inspections permits detecting the location of such conditions and controlling the kiln to keep the flame and smoke from reaching the place of desired readings.

13 Claims, 2 Drawing Figures



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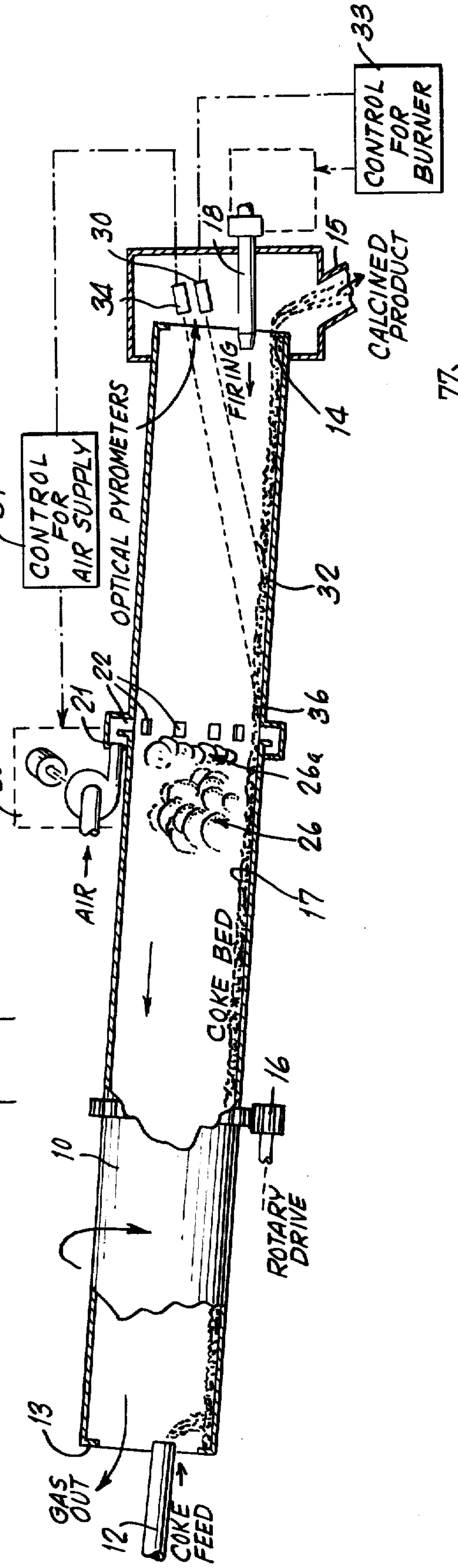

Fig. 1.

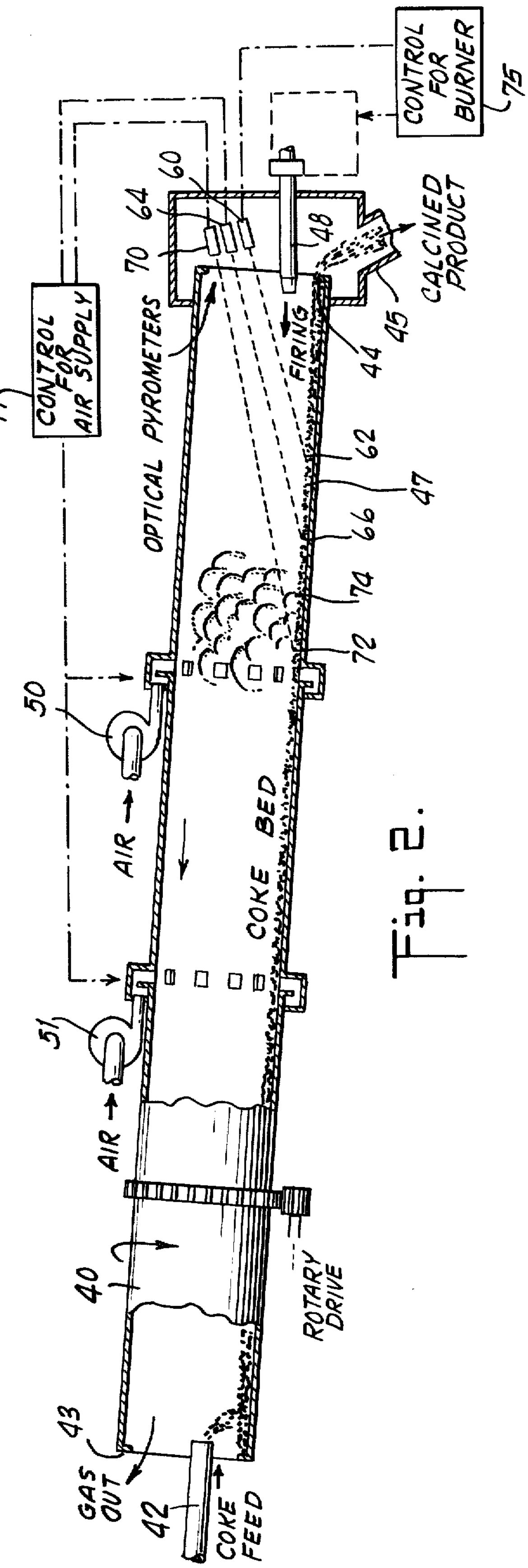

Fig. 2.

MONITORING AND CONTROLLING KILN OPERATION IN CALCINATION OF COKE

BACKGROUND OF THE INVENTION

This invention relates to the calcination of coke, particularly petroleum coke such as intended to provide carbon for making electrodes or the like. Calcining operations of this sort are commonly performed in a rotary kiln into which the green petroleum coke in suitable particulate form is fed at one end, for delivery of treated product at the other end. In the kiln, the coke is calcined at high temperature, to drive off the volatiles and shrink the coke to a predetermined, desired density. The calcined product is useful for carbon elements and structures, notably for various situations of electrical function, such as in high temperature electrochemical operations, and most particularly for anodes and lining compositions in aluminum reduction cells.

The calcining process is endothermic, and desired results require adequate heating but very preferably without appreciable combustion of the carbon itself. A prime indicator of desired operation is found to be the temperature of the calcined or nearly-calcined material, for example as it approaches the end of the kiln. A considerable amount of heat is obtained by burning the released volatiles, i.e., ordinarily a substantial proportion of them. The excess of volatiles is carried off in the countercurrent flow of all gases including combustion products, out the gas discharge, which is the feed end of the kiln, and such excess of volatiles can be recovered or otherwise made available for external utilization.

A common past practice, for maintaining temperature control, has been to provide separate heat, as needed, by combustion of supplemental fuel, for example employing a gas or oil burner at the product discharge end of the kiln, to project the hot products of combustion, e.g., flame and burned gas, into the kiln. It has been proposed to measure the temperature of the travelling coke, for instance at a locality 25 feet within the kiln from the discharge end, by focusing an optical pyrometer on a suitable section at such place that can function as representing a black body state, being either the coke bed or adjacent interior kiln surface. In a broad sense, this temperature serves as an indicator of kiln operation, particularly in that failure to reach a desired value, for instance 1,250°C, indicates incomplete calcining, to be corrected by use or increased use of the supplemental burner.

In recognized instances, the effect of variations in feed or nature of the green coke can be controlled by changing the feed rate or changing the time of passage through the kiln, i.e., by altering rotation speed. To a considerable extent, however, changes in calcining effect revealed by unsatisfactory temperature in the discharge section of the kiln may be corrected by altering the amount of heat, as for instance with increase of the amount of air supplied into the kiln for burning volatiles, and most usually with addition or increase of supplemental fuel-fired heat.

Thus one practice is to read the coke temperature as above, on a continuous or like basis. Considering the supplemental heat to be inoperative unless required, departure of the temperature below a predetermined value (such as 1,250°C) signals the need for more heat, whereupon manually or automatically the burner is brought into operation, using the ancillary fuel. When the desired temperature is exceeded in the coke that approaches the discharge, the burner cuts out. At the same time, if possible there must also be appropriate attention to the amount of air that is advantageously supplied to the interior of the kiln at an intermediate region or regions, for the desired combustion of the volatiles, the object being to obtain a substantial quantity of heat without having so much air that oxidizing conditions prevail in the sense of promoting combustion of the carbon itself.

A serious difficulty in operations of this sort has now been noted, particularly in relation to efforts to achieve the controlled, high product temperature while promoting good utilization of the burning of volatiles and corresponding effectiveness in the calcining operation. Thus it has been observed that the volatiles distilling from the coke, as they burn, can be described as smoky, with the effect of producing a combustion disturbance visible as extending across the kiln interior at the locality of the coke path where the combustion occurs, specifically the place furthest downstream in the direction of coke travel where volatile burning begins although such burning may presumably extend through localities further up the kiln, i.e., toward the coke feed end to which the burning or burned gases flow. This optically detectable disturbance, being the beginning of the volatile burning operation in the path of travel of air and gas toward the feed end, can be variously described as a wall of flame or a smoke curtain, and may have an appearance of mingled flame and smoke extending substantially across the kiln, so as to obscure or confuse an attempted inspection of interior regions of the kiln at and beyond the curtain.

With changing conditions, this combustion disturbance tends to move lengthwise of the kiln, and particularly when the air supply is low, may move down the coke path, toward the discharge end, to and beyond the locality where temperature is measured by the optical pyrometer. When this happens, the signals of the pyrometer become abnormal, being characterized by a rapid, substantial fluctuation. This represents a false or meaningless reading of temperature and may correspondingly produce a false control of the supplemental burner, for example to bring it into operation when it would not be needed, thereby drawing in more fuel to compete for the already inadequate oxygen in the kiln. Since insufficient oxygen or air is often responsible for the downward travel of the smoky curtain, the unwanted operation of the burner can lead to a worsening of conditions, reducing the actual combustion of volatiles and impairing rather than improving the kiln operation.

In all cases, regardless of the use of the temperature signals from the pyrometer — i.e., whether they control the burner or indicate the need for it or whether they are employed for some different function or aid in kiln control — the unwanted movement of the combustion disturbance obscuring the locality of the primary temperature reading is seriously objectionable, since there is then no proper temperature detection. As will be understood, the present invention is designed to obviate these difficulties and to provide a superior way of monitoring, i.e., controlling kiln operation, by the use of temperature readings.

SUMMARY OF THE INVENTION

For the improvement of the operation of calcining petroleum coke in a rotary kiln, performed as described above, the invention embraces a process wherein radiant energy inspection, i.e., by optical pyrometer means, is maintained at a plurality of successive localities along the kiln, notably in that portion of the kiln which can be considered the downstream region of the coke path, and advantageously in a portion which approaches the downstream end, the optical inspection procedure being so aimed and utilized as to provide for continued maintenance of the significant kiln temperature readings, without interference by the combustion disturbance as it may undesirably tend to travel along the interior of the kiln and thus occupy an unwanted locality.

Specifically, in its basic concept, the invention provides for monitoring the operation of a kiln by optical pyrometer inspection, e.g., from the discharge end. This operation comprises effecting such inspection of a first kiln locality suitable for temperature reading significant of kiln operation, e.g., in the last half, and indeed preferably in the last quarter, of the kiln, the locality being downstream of a place where the volatile combustion is desired to occur, or at least downstream of the place below which such combustion and its disturbance should not move. The procedure also includes effecting such inspection at another kiln locality, upstream in the coke path, from the first locality of inspection but downstream also of the permitted place of disturbance. As explained, it will be understood that each optical pyrometer inspection is such that if the wall of smoke and flame embraces the inspected locality or comes downstream of it, the temperature signal will have a characteristic instability which is distinctive of the local occurrence of the combustion disturbance.

In accordance with the invention, the temperature readings of the second, more upstream pyrometer are observed, by the attendant or automatically, and if they are characterized by an abnormal condition, the operation to maintain monitoring is brought into play, as by altering the calcining conditions of the kiln so that the volatile combustion zone is caused to move upstream and to depart from a location where it obscures the second or higher locality of optical pyrometer inspection. An unusually effective adjustment for such purpose, manually or automatically, is to increase the supply of air to the interior of the kiln for enhanced burning of volatiles. This may be effected by adjusting the blower arrangements conventionally attached to the side of the kiln for introducing air at intermediate localities. With this or other suitable adjustment, the obscuring combustion disturbance is caused to move back up the kiln (toward the feed end) so as to serve the primary purpose of preventing such disturbance from ever reaching the first locality of pyrometer inspection; the temperature readings from the latter are thus kept accurate for their desired function of indicating the operating condition of the kiln. At the same time the adjustment in itself usually serves corrective functions, e.g., in restoring the locality of volatile combustion to a desired place and restoring the extent of such combustion to a desired value.

Other procedures to move the wall of flame and smoke and to serve the above purposes may be followed, alternatively or additionally, such as reducing the feed rate of coke or slowing the travel of the coke by reducing the rotation of the kiln. In the main, however, and as a particular feature of the invention, the basic control is preferably exercised over the air supply to the kiln, e.g., to increase such air when the combustion disturbance has been detected at the second pyrometer inspection locality. In consequence, the volatile burning zone is caused to move upward of the kiln, away from the second inspection locality, as will be determined by absence of the abnormal or unstable temperature signal. Thus the monitoring procedure basically involves adjusting conditions so that when the abnormal signal appears, it is caused to disappear, and at the same time the process achieves the primary object of preventing the combustion disturbance from ever reaching (by further downstream travel) the first locality of temperature inspection, which is deemed of major importance for primary control of kiln operation.

A further feature of the invention embraces a more elaborate monitoring procedure and system, specifically including provision for inspection by optical pyrometer means at a third kiln locality, further upstream (toward the coke feed end) than the second of the localities described above. This further locality is advantageously chosen as appropriate for combustion of volatiles, or more strictly, as lying within a zone which in desired, normal operation of the kiln would be obscured by the curtain of combustion disturbance, and thus would normally result in the characteristic instability, i.e., fluctuation, of the temperature signals resulting from inspection there.

With the three readings or inspections of the interior of the kiln, e.g. each at the coke bed or close to it so that the observed wall temperature in effect measures the coke bed temperature, the operation is as follows: The object, as before, is to maintain unaffected readings from the first locality, so that the desired continuous or frequent measurement of calcined coke temperature is obtained. The control or interpretation from the readings of the other two localities is that if both localities yield the abnormal instability of temperature signal, adjustment is effected, as by increasing supply of combustion air in the kiln by the blowers or by other alteration of kiln conditions, so that the combustion disturbance or curtain moves back up the kiln and the reading of the second locality becomes stable. At the same time, the control is conveniently exercised so that instability is maintained at the third locality, thus placing the burning of volatiles or the front or beginning of such burning at a position upstream (as the coke travels) of the second inspection locality but at or downstream of the third locality.

Indeed, the operation can include response to disappearance of abnormal instability in the signals from the third locality, such that the flow of air is somewhat decreased, or other suitable adjustment made, to cause the combustion curtain to move along the kiln to such locality. That is to say, if all three pyrometer readings become stable, the combustion curtain can be considered to be moved too far up the kiln, and the above or other change of condition can then be desirable to move the combustion region back downstream. It will be understood that this more complete operation and system, involving three pyrometer readings, is believed to be advantageous, for maximum stability of kiln function. Very effective kiln operation and control, however, are attainable with the simpler provision of two inspections, especially in that in many cases unwanted upstream movement of the combustion disturbance does not ordinarily occur or tends to be self-correcting.

As will be appreciated, the described procedures are highly effective for monitoring kiln operation, especially in order to permit true temperature reading near the discharge end, continuously or as frequently as may be desired, for a variety of purposes, whether to control the supply of supplemental heat or indeed to control or record the state of kiln operation regardless of the use of such heat. As will be understood, the present improvements not only embrace the described procedures, but novel apparatus including the combinations of instrumentalities as herein set forth.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagrammatic view, showing a rotary kiln mostly in longitudinal vertical section and illustrating the operations and arrangements of a first form of the invention.

FIG. **2** is a like diagrammatic view of a rotary kiln illustrating a second form of the invention.

DETAILED DESCRIPTION

In the way of specific examples, the invention is illustrated in the above-mentioned figures, wherein with reference first to FIG. **1**, a rotary kiln **10** is shown into which granular petroleum coke is fed through an appropriate duct **12** at one end, and the calcined coke is caused to be discharged at the opposite end **14**, e.g., by gravity down through a suitable outlet **15**. The kiln is arranged with a slope downwards, of suitable small angle, from the feed to discharge ends so that as it is continuously rotated around the longitudinal axis through appropriate drive means such as a pinion and ring gear arrangement illustrated at **16**, the granular coke advances as a continuous bed **17** along the inside bottom of the kiln.

For one type of operation described hereinabove, supplemental heat is directed into the kiln, e.g., from the discharge end **14**, such heat being illustrated by the fuel burner **18** directed to project flaming or otherwise hot gaseous products of combustion into the kiln, upstream of the coke travel, it being understood that air is also supplied, at least as necessary for the combustion of the fuel, and that the path of gases through the kiln is countercurrent to the feed of coke, all such gases being discharged at the feed end **13**.

At least a substantial quantity of the air employed for combustion of the volatile material removed from the coke by calcining is conveniently supplied at intermediate localities of the kiln. In FIG. **1**, although a plurality of air supply means can be used, one arrangement is shown including a fan or blower **20** carried by the shell of the kiln **10** and rotating with it. The blower **20** delivers air into an annular distributor or manifold **21** from which a plurality of openings or tuyeres **22** permit introduction of the air. This sytem is appropriately arranged, as will be known, so that the air is introduced without undue disturbance of the travelling coke bed **24**.

As will now be understood, the normal operation of calcining petroleum coke in a kiln of this sort involves continuous feed of the coke particles, which are caused to travel as a substantial bed in the bottom of the kiln, by reason of the rotation of the latter, so that they eventually discharge over the end **14** of the cylindrical kiln shell. During this time, with heat initially supplied by the burner **18**, and (after the bed is heated up) with at least a very substantial supply of heat derived by combustion of the volatile materials driven off the coke, the travelling coke is effectively calcined, becoming essentially pure carbon with at least nearly all of the material driven off. The quality of the product is also measurable by its density, i.e., so-called real density, which increases substantially by reason of the heating during the calcining process.

In the above operation, it has been sought to determine the success of calcining, not only by examination and analysis of the product from time to time, but also by some reading of the temperature of the coke as it approaches the discharge end. Considering the supplemental burner **18** as being normally inoperative while heat is continuously supplied by burning the combustible volatile material as at region **26** and upstream thereof toward the feed end **13**, the temperature has been found to have a relation to the product quality. If the temperature near the discharge end of the kiln is below a given value, that is found to be indicative of less than optimum calcination, and the burner **18** is then brought into operation, providing additional heat. When the temperature reaches a desirable value again, the burner is cut out and reliance is placed solely on combustion of volatiles by air supplied through the means **20, 21, 22,** plus any further air that may be introduced at the discharge end **14.**

As will be appreciated, adjustment of the air supply through the fan **20** is also feasible, the desired conditions being to maintain as much burning as possible and optimum utilization of heat without introducing so much air as to create oxidizing conditions which would unduly burn up the carbon itself. At the same time, insufficient air represents inefficiency and indeed precludes optimum heating for calcination.

For purposes of determining the kiln temperature, and controlling the operation as above or in any other desired way, an optical pyrometer **30** may be aimed, i.e., focused, to a portion of the kiln wall some distance in from the kiln end **14**, so that this pyrometer, viewing such locality **32** of the coke bed or adjacent wall through the kiln end, provides signals which represent the temperature at the locality. It will be understood that optical pyrometers of suitable nature are well known and that they are preferably used, in suitable focus, for optically reading the radiating condition (e.g., in visible and infrared light radiation) of the observed locality, the latter being deemed to constitute a so-called black body. The response of the pyrometer, of course, is read out as signals having values, as temperature, corresponding to the optical radiation of the inspected place.

While in the situation of the calcining procedure, such pyrometers may be focused on the coke bed itself, as indicated for simplicity in the drawings, it is ordinarily preferable to make inspection of some immediately adjacent portion of the interior kiln wall, e.g., where it has just left the coke bed, for more even determination, which can be taken as substantially equal to the coke temperature, or differing from it by a small, constant amount for which allowance is made. It will be understood that the pyrometer **30** may be connected to suitable control instrumentalities **33** which in turn govern the operation of the burner **18**, as by initiating burning when the temperature falls below a given value and interrupting burning when it substantially exceeds such value.

As has been explained, the burning of volatile materials which are driven off the coke as a desired purpose of calcination, creates what may be defined as a combustion disturbance, which can be considered to occur at **26** and to have a front **26***a* optically detectable, even visible, from the discharge end of the kiln. That is to say, this combustion disturbance is represented by a wall or curtain of smoke or flame, indeed usually a mixture of both, across the kiln. So long as this combustion disturbance remains upstream (relative to coke travel) of the temperature-inspection locality **32**, the kiln operation is readily controlled, but it has a tendency to move longitudinally of the kiln, particularly in the downstream direction, toward the discharge end **14**. If the disturbance comes down to the locality **32**, it has been found that the reading of the pyrometer **30** becomes abnormal, especially in having a rapid instability or fluctuation. In consequence, the burner **18**, because of a false reading, ay be brought into operation when such is not desired, or alternatively if there is a false high reading, there may be a failure of the burner to be started. In either case, the desired control of process conditions is greatly impaired. Particularly if the burner is fired when it is unneeded (as most usually occurs when the smoke **26***a* reaches **32**), the result is to bring in more fuel, which competes for the already inadequate oxygen within the kiln, and instead of reducing the smoky curtain or moving it back, there is a worsening of kiln conditions. In such case, of course, the kiln conditions really did not require more heat, and to say the least, the firing of the burner represented inefficiency without useful effect.

In accordance with the present invention, the system of FIG. **1** includes a second optical pyrometer **34**, also inspecting the interior of the kiln from the discharge end **14**, but focused upon a locality **36** further upstream than the locality **32**. As in the case of pyrometer **30**, this may be a suitable locality of the coke bed **24** or advantageously an adjacent locality of the rotating kiln wall, i.e., a place just traversed by the coke. This pyrometer yields signals which, if obscured by the combustion disturbance **26***a*, have the characteristic rapid fluctuation described above, i.e., abnormal instability, which is readily recognized. Normally, it is desired that the combustion disturbance remain upstream, i.e., closer to the coke feed and gas removal end **13**. In consequence, normal reading of the pyrometer **34** is a relatively steady temperature. However, when the signals of this second pyrometer indicate, by their abnormal conditon, that the wall of flame and smoke **26***a* has advanced to the locality **36**, down the kiln, suitable adjustment operation of kiln conditions can be made, as by increasing the air supply through the tuyeres **22**, so as to cause the combustion region **26** to move up the kiln toward the feed end. This frees the kiln interior from being obscured at the locality **36** and restores the signals of the pyrometer **34** to normal, level, nonfluctuating condition. Most importantly, this monitoring procedure insures that the disturbance is always kept well upstream of the chief temperature-sensing locality **32**, whereby the desired control of the kiln operation, including specifically the stated control of the burner **18**, is made possible without false action. That is to say, the detection of the disturbance at the locality **34**, and the described corrective action can always be effected well before the disturbance might move all the way down to the region **32**.

Although the adjustment of kiln conditions in response to appearance of the combustion disturbance as viewed by the pyrometer **34**, is readily accomplished by manual attention of an operator, FIG. **1** shows connections of the pyrometer to a control device **37** (having appropriate electronic or other means to discriminate between abnormal, fluctuating signals and normal, level signals), whereby the fan or other air supply means **20** is adjusted, for example to increase the air supply when the pyrometer signals from **36** are abnormal and to maintain such increased air flow as long as necessary, and preferably at least until the signals have remained at a restored, level state for a considerable time.

Another form of the invention is shown in FIG. **2**, including an additional step or feature in the monitoring operation which is of advantage in a number of situations. Here, as in FIG. **1**, there is a rotary kiln **40**, having coke feed **42** at one end **43** which also discharges gases, so arranged as before that by rotation of the downward sloping kiln **40** with means such as shown in FIG. **1** but not here, the coke bed is advanced to the discharge end **44** for removal in a duct **45**. Supplemental heat for calcining the coke in the bed **47** is provided by a burner **48**, it being understood that principal heat is derived by burning the released volatile materials with the aid of air supply instrumentalities such as shown at **50** and **51**, at successive localities lengthwise of the kiln.

The system is provided with a first optical pyrometer **60** functioning to inspect a locality **62** to read the desired coke temperature that is of primary significance for control of kiln operation. There is also a second pyrometer **64** which senses a locality **66**, upstream in the coke path from the first locality **62**. Finally, there is a third pyrometer **70** which senses the temperature of the coke bed at a third locality **72** still further upstream from the second locality **66**. All of these localities of sensing, where the pyrometers may actually be focused on adjacent portions of the wall, are disposed in a portion of the kiln well within the second half (toward the discharge end **44**) and indeed usually well within 40 or 50 feet of such end.

In preferred operation, the kiln is controlled so that the wall of flame or smoke, i.e., the combustion disturbance **74**, is maintained at a place between the localities **72** and **66**, considered lengthwise of the kiln. Under these circumstances, an abnormal, fluctuating signal is continuously received from the locality **72**, while level or even signals are produced by inspection of localities **66** and **62**. In the procedure of FIG. **2**, this situation is intended to persist, i.e., to represent desired operating conditions.

If the wall of smoke and flame moves down the kiln toward the discharge end **44**, i.e., far enough to obscure the locality **66**, an abnormal signal is produced by the pyrometer **64**, indicating that corrective action is needed to avoid further movement of the combustion disturbance toward the primary sensing locality **62**. Accordingly, adjustment of kiln operation, as explained in connection with the process of FIG. **1**, is effected, manually or automatically, so as to cause the locality of volatile combustion and the corresponding disturbance to move upstream of coke travel toward the feed end. Advantageously this may involve increase in air supply to the intermediate regions of the kiln, as by adjusting the blower instrumentalities **50** and **51**. When such adjustment has moved the combustion disturbance back away from the locality **66**, the control of the monitoring operation is returned to normal.

If the combustion disturbance should for any reason move upward, i.e., toward the feed end to a point where the locality **72** is no longer obscured and the signals of the third pyrometer **70** become level and non-fluctuating, the arrangement in FIG. **2** contemplates a corrective action to restore the combustion disturbance to its intended place at or just downstream of locality **72.** This can be by appropriate adjustment of kiln operation in one or another of the ways indicated above, e.g., to speed up the passage of coke or most advantageously by decreasing the air supply at the intermediate localities. When the combustion disturbance has moved back down so that the so-called abnormal signals, i.e., fluctuating temperature signals, are produced by the pyrometer **70,** the corrective action is interrupted and the system is deemed to be restored to intended, normal condition.

Stated in another way, the operation of the procedure of FIG. **2** involves sensing the localities **66** and **72** with pyrometers **64** and **70.** If both pyrometers show an abnormal, fluctuating signal, adjustment of the air supply can be made to move the combustion disturbance upstream toward the feed end until only the locality **72** yields a fluctuating signal at the pyrometer **70.** If neither of the pyrometers **64** and **70** show an abnormal signal, this situation calls for reverse corrective action, for example by decreasing the air supply to the interior of the kiln, so that the combustion disturbance will move downstream of the coke bed travel (toward the discharge end) and again obscure the locality **72,** restoring the readings of the pyrometers **70** and **64** to their intended state. As will be seen, the process of FIG. **2** serves to insure uninterrupted, accurate reading of the kiln temperature conditions, desired from locality **62,** and also coacts to keep the combustion disburbance from moving too far down the kiln, thus directly achieving a desired improvement in kiln operating conditions, all as explained in connection with FIG. **1.**

The reading from the locality of FIG. **2** by pyrometer **60** can be employed for general kiln control, as for example in bringing the burner **48** into and out of operation according as the temperature falls below or rises above a desired value (which may, in all cases, be a single temperature, or sometines a range) — this being achieved automatically via the control **75** if desired. The process in FIG. **2,** however, fulfills a further, effective function in relation to the control of the combustion of volatiles, in that the position of the combustion front can be maintained at a desired place, against movement in either direction lengthwise of the kiln. As will be understood, this control can be exercised manually, or automatically by means similar to that described above for FIG. **1,** e.g., including a control system **77** which is sensitive to the nature of signals in the readouts from the pyrometers **64** and **70,** for effecting increase or decrease of air through the fans **50, 51,** or in monitoring no change, as has been explained above.

As will be understood, various instrumentalities such as the optical pyrometers, fuel burner, air supply means, and other parts of the kiln, are shown diagrammatically, and being well known instrumentalities, need no further details. Although other modes of optical pyrometer inspection can be employed, as for example by employing a single pyrometer device which is arranged to scan the required two or three localities (in FIG. **1** or FIG. **2**), so as to obtain selectable periodic readings which can function in somewhat similar fashion to continuous readings, unusually effective operation is achieved with separate pyrometer means for each locality of inspection, as illustrated.

Rotary kilns of suitable type for calcining petroleum coke may range in length, for example, from 100 to 200 feet and may preferably have a slope of approximately one fourth to 1 inch (for example, one half inch) per linear foot, or more or less as may suit requirements. In one operation according to FIG. **1,** the main pyrometer **18,** for sensing the primary control temperature of kiln operation, was focused on a place (identified at **32**) 25 feet inside the kiln, from the discharge end, at the interface between the coke bed and the brick lining of the kiln. The second pyrometer **30** for determining the location of the combustion disturbance, was focused at a locality **36** about 40 feet inward from the discharge end, actually on the kiln lining structure, next to the coke bed, at the region of the air-supply tuyere **22** nearest to the discharge end.

The specific kiln in which the process was so used in FIG. **1** was 127 feet long and had two air supply fans, respectively supplying air to the interior through ducting to respective groups of inlets (note FIG. **2**), the inlets in each group being spread helically along the kiln. One group of inlets was spread between 46 and 52 feet from the feed end **13,** and the second group of six inlets was spaced approximately 4 feet apart, with the last inlet being 87 feet from the feed end. The process was practiced effectively, and adjustment of the amount of air supply by the fans was effective to keep the wall of flame or smoke **26***a* well away from the primary point **32** of temperature observation and indeed, as desired, upstream of the second locality **36** of pyrometer inspection. This enabled the kiln operation to be effectively controlled by the burner at a desired temperature of 1,250°C for locality **32,** in the manner which has been described.

An arrangement for utilizing the process of FIG. **2** involves locating the successive places of inspection, **62,** 66, and **72,** respectively, for example, at distances of 20 feet, 30 feet, and 40 feet from the discharge end **44** of the kiln. With operation as described, the function is to keep the combustion disturbance generally between the locality **72** and **66,** and in any event to restore it to such place, all before it can get far away and with complete assurance that it never reaches a primary place of temperature oobservation, i.e. locality **62.** Again, a desired temperature, e.g. 1,250°C, may be maintained there, as by control of the burner **48** or other kiln conditions.

The invention affords an effective mode of monitoring kiln operation for calcining petroleum coke, permitting efficient control of the kiln atmosphere, so as to accomplish the desired calcining job, yielding a high density product with minimum of residual volatile, while economically using the available heat and avoiding significant combustion of the carbon itself.

It is to be understood that the invention is not limited to the specific steps and elements herein described, but may be carried out in other ways without departure from its spirit.

I claim:

1. In a method of calcining coke wherein the coke is advanced from feed end to discharge end in a rotary kiln countercurrent to gas flow and wherein by causing heat to traverse the kiln, combustible volatiles are removed from the traveling coke and are caused to burn continuously in an intermediate region of the kiln and thereby to produce heat used in continuing removal of volatiles, said burning creating a condition of flame and/or smoke constituting a combustion disturbance across the kiln that is observable from the discharge end, and the place of said burning being indicated by the place of said observable disturbance and being movable, with accompaniment by corresponding movement of said observable disturbance, lengthwise of the kiln in accordance with operating conditions:

the procedure of monitoring kiln operation by optical pyrometer inspection of the interior of the kiln from the discharge end, such inspection of said combustion disturbance yielding a distinctive instability of temperature signals that is detectable as such but is meaningless as a reading of kiln temperature; said procedure comprising

a. effecting said inspection of a first kiln locality downstream in the coke path from a desired place for said combustion disturbance, to obtain temperature signals significant to the effectiveness of the calcining operation,

b. effecting said inspection of a second kiln locality spaced upstream in said path from the first locality but also downstream of said desired place, to determine, by appearance of temperature signals having or lacking said instability, whether said disturbance is or is not occurring at said second locality, and

c. when said inspection of said second locality indicates occurrence of said disturbance, adjusting the kiln operation as to condition, to cause said volatile burning and disturbance to move upstream toward the desired place, away from the second locality, for keeping said disturbance away from said first locality.

2. A method as defined in claim **1** which includes

d. effecting said optical pyrometer inspection of a third kiln locality which is upstream of the second locality and is representative of the desired place for said burning and disturbance,

e. said adjustment is condition of kiln operation being effected to maintain instability of temperature signals in said third locality inspection and to prevent or remove said instability as to said second locality inspection, whereby to tend to keep said combustion disturbance upstream of the second locality but not upstream of the third locality.

3. A method as defined in claim **2** in which air is adjustably supplied at one or more intermediate locations of the kiln, for use in said burning of volatiles, said step of adjusting the condition of kiln operation comprising adjusting said air supply, including increasing said supply to cause the place of said burning and combustion to move in a direction upstream of the coke path.

4. A method as defined in claim **1** in which air is adjustably supplied at one or more intermediate locations of the kiln, for use in said burning of volatiles, said step of adjusting the condition of kiln operation comprising adjusting said air supply, including increasing said supply to cause the place of said burning and combustion to move in a direction upstream of the coke path.

5. A method as defined in claim **1** in which said adjustment to cause the volatile burning and disturbance to move upstream along the coke path comprises one or more of: adjusting the rotation of the kiln to a lower rate; increasing supply of air into the kiln said burning; adjusting feed of coke into the kiln to a lower rate.

6. A method as defined in claim **1** which includes providing a controllable supply of heat by combustion of fuel, directed into the discharge end of the kiln for coaction with the heat of said burning of volatiles in calcining the coke, and controlling said discharge end supply of heat in accordance with said inspection of said first kiln locality, to maintain the temperature at said locality substantially at a predetermined value.

7. A method as defined in claim **6** in which air is supplied at one or more intermediate locations of the kiln, for use in said burning of volatiles, and in which said discharge end supply of heat comprises directing hot gases of combustion into the kiln and said control of said heat supply comprises initiating same when the temperature at the first locality falls below said predetermined value and interrupting same when said temperature rises above said value.

8. A method as defined in claim **7** in which the intermediate supply of air is adjustable and in which the step of adjusting the condition of kiln operaticn to control said combustion disturbance comprises adjusting said air supply, including increasing said supply to cause the place of said burning and combustion to move in a direction upstream of the coke path.

9. A method as defined in claim **6** which includes

d. effecting said optical pyrometer inspection of a third kiln locality which is upstream of the second locality and is representative of the desired place for said burning and disturbance,

e. said adjustment in condition of kiln operation being effected to maintain instability of temperature signals in said third locality inspection and to prevent or remove said instability as to said second locality inspection, whereby to tend to keep said combustion disturbance upstream of the second locality but not upstream of the third locality.

10. A method as defined in claim **9** in which

f. air is adjustably supplied at one or more intermediate locations of the kiln, for use in said burning of volatiles, and said discharge-end supplying of heat comprises directing hot gases of combustion into the kiln,

g. said control of said heat supply comprising initiating same when the temperature at the first locality falls below said predetermined value and interrupting same when said temperature rises above said value, and

h. said step of adjusting the condition of kiln operation to control said combustion disturbance comprises adjusting said air supply, including increasing said supply to cause the place of said burning and combustion to move in a direction upstream of the coke path.

11. A method as defined in claim **5** which includes furnishing heat when desired by burning a stream of fuel and directing same into the discharge end, and controlling said furnished heat to maintain the temperature as detected at the first locality substantially at a predetermined value, by respectively initiating and interrupting said burning when the detected temperature falls below and rises above said value.

12. Apparatus for calcining coke comprising

a. a rotary kiln having a coke feed end and a coke discharge end and arranged for travel of gases countercurrent to the travel of coke,

b. adjustable means for supplying air at least at one locality intermediate the ends of the kiln, for use in burning volatiles removed from the coke, the place of said burning being observable by combustion disturbance of said burning,

c. optical pyrometer means for inspecting the interior of the kiln from the discharge end at a plurality of localities to yield temperature signals, said pyrometer means yielding a distinctive instability of temperature signals when inspecting a locality at or upstream of such combustion disturbance, said pyrometer means comprising

d. first means for inspecting the kiln interior at a first locality closer to the discharge end than the feed end, to produce temperature signals indicative of the effectiveness of calcining, and

e. second means for inspecting the kiln interior at a second locality upstream of the first locality, to produce temperature signals indicative of presence or absence of combustion disturbance at said locality, and

f. means controlled by said pyrometer means and responsive to such distinctive instability of temperature signals from the second means, for adjusting the air supply means to increase the air supplied thereby for causing the burning of volatiles to be displaced upstream of said second locality.

13. Apparatus as defined in claim **12** in which

g. said pyrometer means also includes third means for inspecting the kiln interior at a third locality upstream of the second locality, to produce temperature signals indicative of presence or absence of combustion disturbance at said locality, and

h. said means controlled by said pyrometer means is also responsive to presence or absence of such distinctive instability of temperature signals from the third means, for so adjusting the air supply means as to maintain the said instability of signals from the third means, for keeping the combustion disturbance at a position which, while upstream of the second locality, is not upstream of the third locality.

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