Aug. 27, 1963 E. ZELTNER 3,101,935

METHOD AND KILN FOR BURNING CEMENT, LIME, DOLOMITE AND THE LIKE

Filed Nov. 28, 1960 6 Sheets-Sheet 1

Fig.1

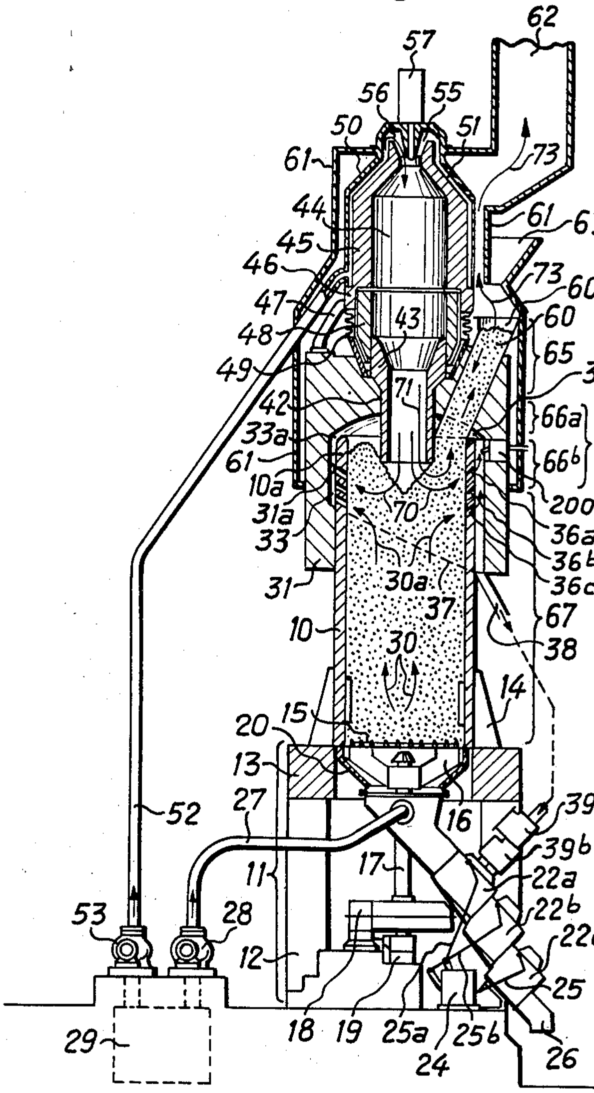

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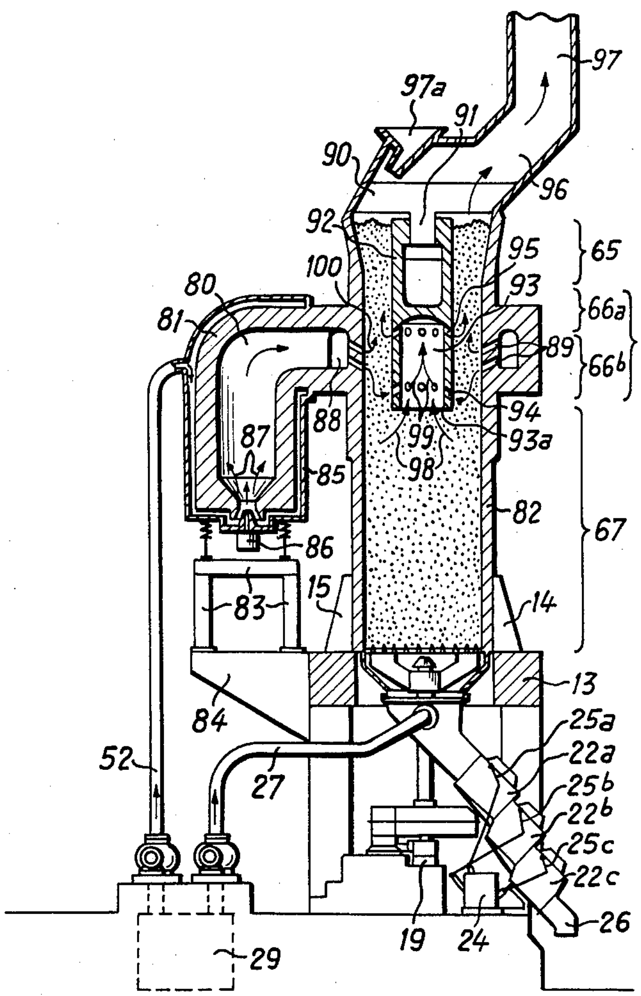
Fig. 2



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METHOD AND KILN FOR BURNING CEMENT, LIME, DOLOMITE AND THE LIKE

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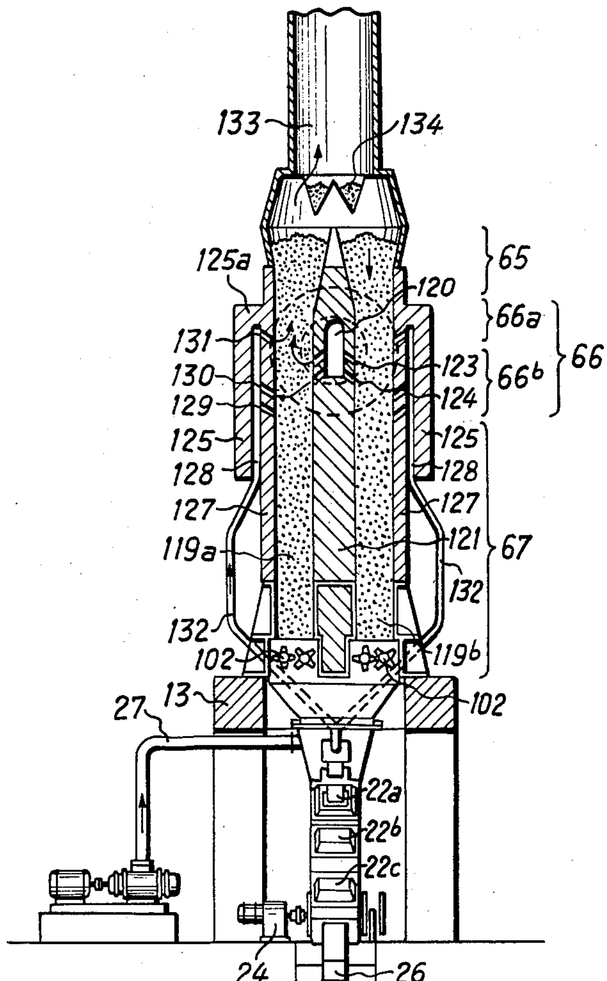
Fig. 3



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METHOD AND KILN FOR BURNING CEMENT, LIME, DOLOMITE AND THE LIKE

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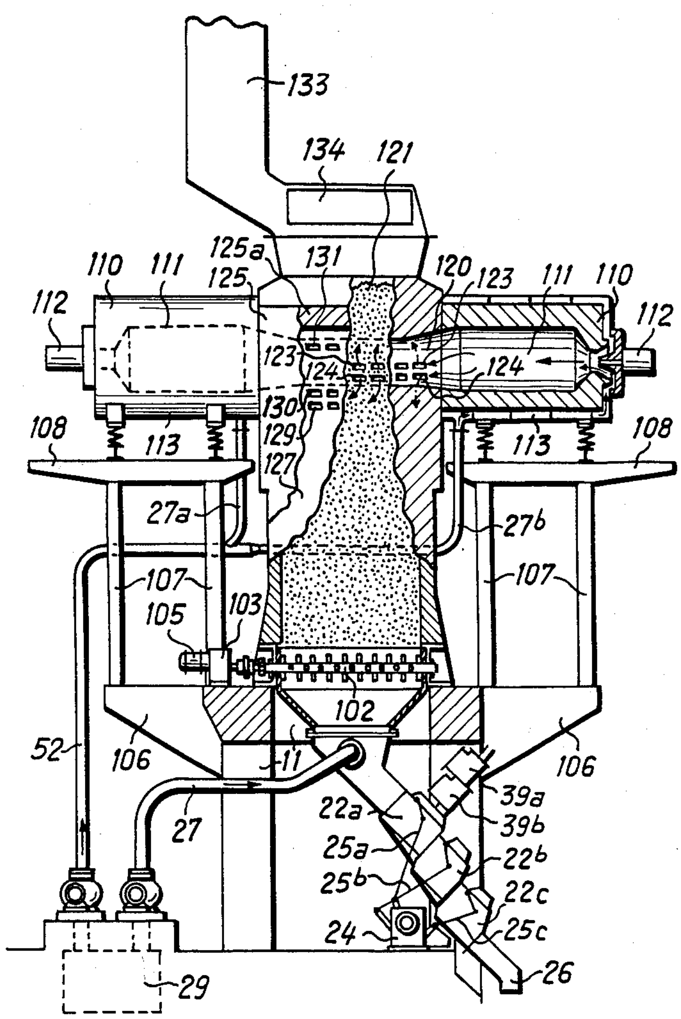
Fig.4



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METHOD AND KILN FOR BURNING CEMENT, LIME, DOLOMITE AND THE LIKE

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Fig. 5

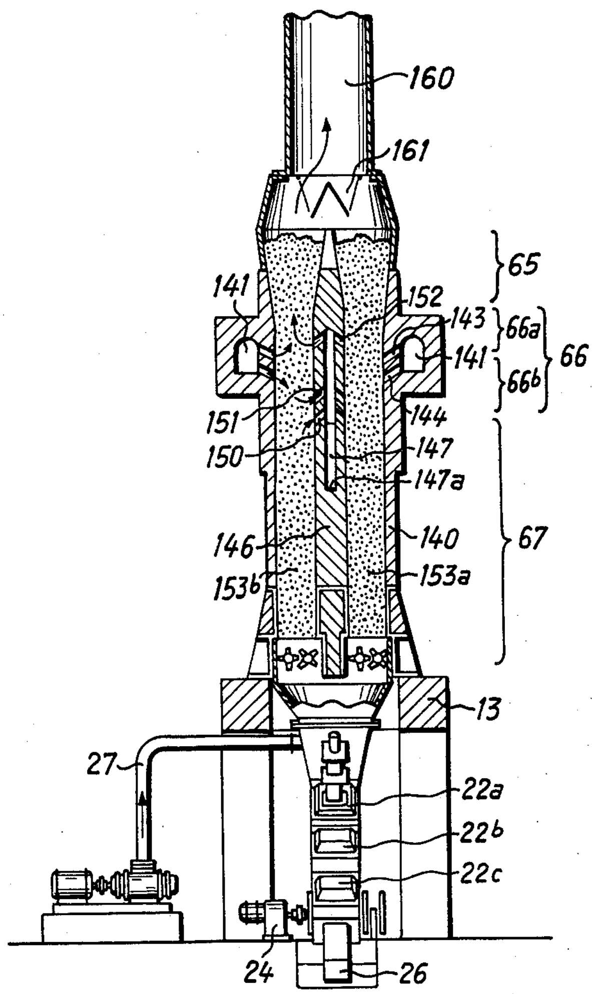

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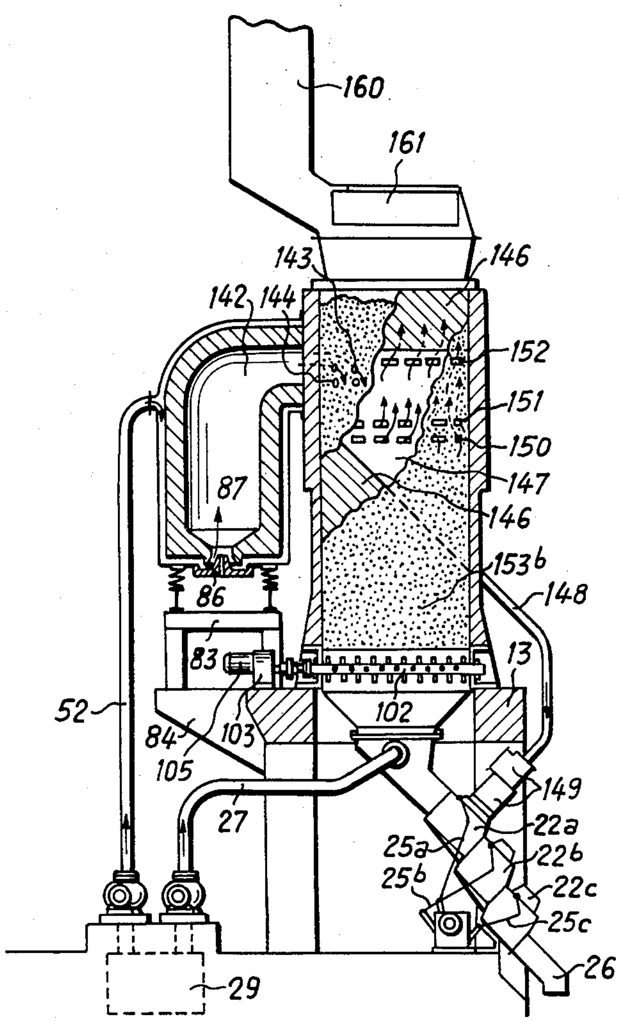
Fig.6



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METHOD AND KILN FOR BURNING CEMENT, LIME, DOLOMITE AND THE LIKE

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Claims priority, application Switzerland Dec. 3, 1959
21 Claims. (Cl. 263—29)

The present invention relates to a novel method and apparatus for burning a fluent charge and, more specifically, to a novel method of and shaft kiln for continuously burning cement, lime, dolomite and similar substances. The term "firing" as employed hereinafter is contemplated to encompass the burning, heating, annealing or sintering of the charge and generally designates a process wherein a charge is heated to a relatively high temperature with or without a corresponding change in its chemical structure.

In a shaft kiln of the type described, noncombustible hot gases are produced by burning a suitable fuel such as coal, oil or gas in one or several combustion chambers. These hot gases are then fed to the material or charge to be burned or sintered which is thereby heated to the requisite firing temperature. The hot gases are the sole source of heat for the sintering or firing process and the kiln charge is largely protected against the direct action of the flames and the heat of radiation, respectively.

A shaft kiln designed to burn or sinter a charge taken from the groups hereinabove mentioned generally comprises a vertical column such as a cylinder which in turn is provided with a preheating zone, a firing or heating zone and a cooling zone. The charge or material to be sintered is supplied from the side or from above and in the firing or heating zone it is subjected to the action of the hot gases which are separately supplied to this firing or heating zone.

Arranged underneath the heating zone is a cooling zone, the fired and cooled material being removed from the lower end of the vertical cylinder. In the cooling zone, the fired material is cooled by means of a supply of cold fresh air supplied from below. In a firing process of the type described, it is necessary, in order to achieve a good thermal efficiency, to utilize the heat obtained after the actual firing process is completed. For this purpose, the air which is heated during the cooling of the heated or fired material is either used to preheat a supply of air by means of which the hot gases are obtained, or else this heated air is supplied directly to the combustion chamber for the generation of the hot gases. Such a method as heretofore employed provides for direct utilization of the thermal energy of the heated cooling air so that the overall efficiency of the firing process is very good. In the known processes, the hot gases which issue from the heating zone are further employed to preheat the material or charge subsequently to be treated.

The above mentioned methods give rise, however, to considerable disadvantages despite superior utilization of heat. These disadvantages mainly arise from the use of the heated cooling air for obtaining the hot gases. In the aforesaid processes the heated cooling air is removed from the border area between the cooling and the heating zones by means of the suction created by a hot-air blower. Since the heated air carries dust, it must first be passed through a dust separator, by way of example a cyclone, so that such dust can be removed. The preheated air from which the dust has been removed subsequently passes into a blower which supplies it to the combustion chamber for the production of the hot gases. The removal of dust, however, entails significant disadvantages since the cyclones are eroded by dust and require frequent replacement. Since cyclones cannot separate very small dust particles, i.e. particles smaller than 5–10μ in size, erosion effects will still occur at the hot air blower.

In all firing or heating processes of the type described, efficient penetration of the material ot be heated or fired by the hot gas is a decisive factor for the throughout rate, the quality of the fired material and the thermal efficiency of the system. In the processes heretofore known, the hot gases flow directly into the preheating zone owing to the pressure gradient so that areas exist in the heating zone which have been insufficiently penetrated by the hot gases. A further disadvantage of the known heating processes resides in the fact that the heated cooling air is mixed with the hot gases at least locally, and thus adversely limits the heating temperature for a given hot-air temperature. Accordingly, the temperature of the hot air must therefore be raised a considerable extent to achieve a desired sintering or heating temperature in order to compensate for heat transfer losses to the cooling air.

In accordance with the present invention there is provided a novel method of continuously burning cement, lime, dolomite and the like in a shaft kiln, the material to be fired or sintered being heated to firing temperature by hot gases which are no longer combustible and which are supplied to the high-temperature area of the heating or firing zone. The present invention is characterized by the fact that fresh-air streams are employed for both cooling the treated material and for the combustion process for generating the hot gases.

The cooling air which is raised in temperature by the burnt material is passed through a shunt duct and bypassed around the high-temperature portion of the heating zone prior to reaching said heating zone. The flow resistance of this shunt duct is smaller than the flow resistance of the high-temperature zone of the shaft. A first portion of the hot gases employed in the process is passed through the shunt duct in order that the material to be fired or heated in the high-temperature portion of the heating zone may be uniformly penetrated. The warmed cooling air and the first portion of the hot gases will mix or combine with the remaining hot gases in the low-temperature portion of the heating zone, and are then collectively employed to preheat the incoming charge which subsequently undergoes a heat-treatment.

It may thus readily be appreciated that the warmed cooling air is used, not as combustion air for the generation of the hot gases as in most known methods, but for preheating the material to be burnt. Accordingly, fresh air may be used as the air for the combustion process for generating the hot gases employed in the sintering operation so that no erosion effects will take place in the fresh-air duct. Removal by suction of the heated cooling air from the shaft before it reaches the heating zone will create a comparatively low pressure region in this heating zone so that the used hot gases will also partially be passed into the shunt duct. The shunt duct will, therefore, influence the uniform distribution of the hot gases in the heating zone. As a result, the heating zone is uniformly penetrated by the hot gases so that the material is evenly burnt and with correspondingly good thermal efficiency. At the end of the shunt duct the warmed cooling air and the first hot-gas portion passed into this duct will combine with the second or remaining hot gas portion so that the collective fluid stream is now used to preheat the material in the preheating zone of the kiln.

Accordingly, the kiln of the present invention is provided with a vertical shaft in which the hot gases originating from a combustion chamber are supplied to the upper half thereof. The shaft kiln is characterized by the fact that a shunt duct is provided which is connected with the shaft by means of slots or ducts the lowermost of which are located below the point of supply for the hot gases, while the upper slots are located above said supply point. Since the chargeless shunt duct provides a smaller flow resistance than the shaft filled with the material to be burnt and with the treated material, respectively, the heated cooling air flows into the shunt duct through the lowermost slots. This air is therefore passed around the heating zone proper. This has the desirable effect that the heated cooling air will not reduce the temperature of the emerging hot gases so that the required maximum temperature of these hot gases may be kept comparatively low. A lower pressure appears in the shunt duct than in the heating zone so that a portion of the hot gases are also partially bypassed into this shunt duct due to the suction effect. This results in a good penetration of the material or charge located in the heating zone by the laterally flowing hot gases. The cooling air which is heated and passing through the shunt duct and said bypassed portion of the hot gases will again be supplied to the shaft through the uppermost slots or ducts and will serve, together with the rest of the hot gases, to preheat the newly supplied material which has not yet undergone a heat treatment.

Accordingly, it is an important object of the present invention to provide a novel method of and a kiln for burning a charge, such as cement, lime, dolomite and the like, exhibiting superior thermal efficiency and improved firing results.

A further object of the present invention is to provide a novel method of burning a charge, particularly suitable for firing cement, lime, dolomite and the like wherein the produced thermal energy is efficiently employed and which obviates the aforementioned disadvantages.

Still another object of the present invention is the provision of a novel method of and kiln for burning a charge wherein the hot gases employed for heating the charge to its firing or sintering temperature is caused to efficiently and uniformly penetrate the charge.

Yet another object of the present invention is the provision of a method of and apparatus for heating or firing lime, cement, dolomite and the like by creating such pressure conditions in the heating zone that the hot gases will uniformly and effectively penetrate the charge located in said heating zone.

It is a further object of the present invention to provide a novel method of and kiln for firing a charge and the like wherein the blowers and conduits for handling the air for combustion are not subjected to erosion effects, and wherein cold, fresh air can be used for generating the hot gases whilst maintaining an excellent overall efficiency for the process.

These and still further objects of the present invention and the entire scope of applicability thereof will become apparent from the detailed description given hereinafter; it should be understood, however, that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

In the drawings wherein like reference numerals denote similar elements:

FIGURE 1 is a vertical section of a circular shaft provided with a combustion chamber arranged above the heating zone in the axial direction and a shunt duct embracing the high-temperature portion of the heating zone;

FIGURE 2 is a vertical section of a circular shaft provided with a combustion chamber arranged outside the shaft and a core member containing the shunt duct arranged inside the shaft;

FIGURE 3 is a vertical section of a shaft which is rectangular in cross-section and wherein the combustion

chambers are arranged outside the shaft and provided with a core member for the supply of hot gas;

FIGURE 4 is a vertical section of a side view of the shaft according to FIGURE 3 turned by 90° relative thereto;

FIGURE 5 is a vertical section of a shaft kiln of rectangular cross-section with a core member which contains the shunt duct; and

FIGURE 6 is a vertical section of a side view of the shaft kiln according to FIGURE 5 turned by 90° relative thereto.

Referring now to the drawings and, more particularly to FIGURE 1, the cylindrical shaft **10** of the kiln rests on a base member **11**. The kiln base **11** may be formed, by way of example, of four columns **12** anchored to the floor, two of which are visible in the drawing. The columns **12** support a frame member **13** which is preferably square and on which the lower end of the shaft **10** rests. Attachment of the shaft **10** to the frame **13** may be effected by means of suitable supports **14**. The lower end of the shaft **10** is closed by a revolving grate **15** which is connected through the intermediary of a yoke **16** with a rotatable shaft **17**. The rotatable shaft **17** is connected to a reduction gear train **18** driven by a motor **19**. The material or charge treated by the action of the heat and located in the hollow shaft **10** is therefore broken by the revolving grate **15** and passes into a hopper **20** disposed therebelow. The material emerging from the hollow shaft **10** thus passes into the hopper **20** and subsequently to three serially arranged valves **22*a***, **22*b*** and **22*c***. The valves **22*a***, **22*b***, **22*c*** are consecutively opened by means of a linkage system **25*a***, **25*b*** and **25*c***, in turn actuated by a control unit **24** so that the burnt or fired material located in the hopper **20** will be intermittently supplied to an outlet tube **26**. The valves **22*a***, **22*b*** and **22*c*** are designed so as to remove the material without permitting the cooling air supplied to the shaft **10** to escape.

Connected to the hopper **20** is a supply line **27** for feeding a supply of cooling air. The free end of the line **27** is connetced with a rotary compressor **28**, the suction side of which is connected with a filter diagrammatically shown at **29**. The rotary compressor **28** therefore sucks air through the filter **29** and supplies it, via the supply line **27** and the hopper **20** to the lower end of the shaft **10** under a small overpressure. This air stream, which is hereinafter referred to as cooling air, flows through the hollow shaft **10** in an upward direction, i.e. in the direction indicated by the arrows **30** and cools the heated material flowing through the shaft **10** in the downward direction. Owing to the arrangement of the valves **22*a***, **22*b*** and **22*c***, the cooling air under pressure cannot escape through the delivery tube **26**. The upper portion of the shaft **10**, which is preferably cylindrical, is enclosed at a predetermined distance from its base by a jacket or sleeve **31**. The outer wall **10*a*** of the shaft **10** and the inner wall **31*a*** of said sleeve **31** are spaced from one another to define an annular chamber **33**. Owing to the function which this space is called upon to perform it will hereinafter be referred to as a shunt or bypass duct. Arranged in the upper portion of the hollow shaft **10** are three rows of slots or openings, **36*a***, **36*b*** and **36*c*** which connect the interior of the upper portion of the shaft **10** with the shunt duct **33**. The upper portion of the sleeve **31** is spaced from the upper edge **33*a*** of the shaft **10** to define an opening **33*b***. The function of these slots or channels will be described in greater detail hereinafter in conjunction with the operation of the kiln.

The lower extremity or confine of the shunt duct or annular chamber **33** is inclined as indicated by dotted line **37**. The lowermost point of the shunt duct **33** is connected with a dust return conduit **38** which connects said shunt duct with two dust gates **39*a*** and **39*b***. The conduit **38** and the dust gates **39*a*** and **39*b*** therefore enable dust which collects at the lower end of the shunt duct 33 to pass to the valve 22*a*. The jacket or sleeve **31** is provided with a central vertical bore **42** which accommodates a tubular core or sleeve insert **43**. Arranged above the core or sleeve insert **43** is the combustion chamber **44** for the generation of the hot gases. The combustion chamber **44** is formed by an upper wall or casing member **45** which rests on a support ring **46**. This support ring **46** is retained in a desired position by a number of supporting members **47** attached to the upper surface of sleeve member **31**. In FIGURE 1 a single one of these supports **47** is illustrated. The ring **46** further carries an intermediate body member **48** which embraces the outside of the core or sleeve insert **43** so as to conduct the hot gases generated in the combustion chamber **44** into the shaft **10**. The hot air duct is therefore formed by the annular members **43**, **45** and **48**. The tripartite design of the combustion region is necessary in order to prevent the hot air duct or passageway from being destroyed due to thermal expansion. A sealing jacket **49** which is at least partially elastic is provided between the intermediate member **48** and the core or sleeve insert **43**.

The annular casing **45** forming the combustion chamber **44** is enclosed by a jacket **50** spaced from said annular casing **45**. The air for the combustion process and for the generation of the hot gases is supplied to this space designated at **51** by a feed pipe or line **52**. The other end of the line **52** is connected with a rotary compressor **53**, the suction side of which is provided with the air filter **29**. The air for combustion therefore flows through the line **52** and into the space **51** under pressure and thence passes, via an annular opening **55**, into the combustion chamber **44** as indicated by the arrow **56**. Arranged above the combustion chamber **44** is an oil burner diagrammatically indicated by reference numeral **57**. The oil burns in the combustion chamber **44** when air is supplied and generates hot gases which flow into the upper portion of the shaft **10** through the central core **43**. The hot gases completely burn in the combustion chamber **44** so that no combustion occurs in the interior of the shaft **10** itself. The material or charge located in the shaft **10** is therefore heated to burning or firing temperature solely by the hot gases and not by a combustion process.

Inserted in the jacket or sleeve **31** enclosing the upper shaft end **10***a* are several preheating tubes **60** for the supply and preheating of the charge to be fired. Only one such preheating tube **60** is shown in FIG. 1. The upper portion of the jacket **31** and the jacket **50** are enclosed by an outer jacket **61** which opens into a discharge pipe **62**. The outer jacket **61** is provided with an opening at one point and is connected with a charging or stoking device as indicated at **63**. The material to be fired is supplied to the charging device and is then passed into a preheating tube **60**. The hot gases previously used in the firing operation and the used cooling air flow upwardly from an upper end **60***a* of the preheating tube and are passed into the discharge pipe **62** between the jacket **50** and the outer jacket **61**. This discharge pipe **62** is connected, by way of example, with a conventional flue known in the art.

In explaining the operation of the furnace, the kiln may be regarded as being composed of three zones, i.e. a preheating zone **65**, a heating or firing zone **66** and a cooling zone **67**. The heating zone **66** comprises a low temperature portion **66***a* and a high-temperature portion **66***b*. The material to be burnt or fired, by way of example lime, is preheated in a portion of the preheating tube **60**. The warmed material or charge subsequently first passes into the low-temperature portion **66***a* owing to its continuous downward movement and then into the high-temperature portion **66***b* of the heating zone **66**. The charge then finally moves into the cooling zone **67** which is formed by about the lower two-thirds of the shaft **10**.

In the cooling zone **67** the material heated in the heating zone is cooled by a stream of cooling air compressed by the rotary compressor **28** and supplied to the lower end of the shaft **10** via the line or pipe **27** and the hopper unit **20**. The cooling air then flows upward internally of the shaft **10** as indicated by the arrows **30**. The cooling zone **67** ends at the lowest row of slots or channels **36***c*. It is readily to be appreciated that the resistance to flow exhibited by the shunt duct **33** is substantially smaller than the flow resistance set up by the high temperature portion **66***b* of the heating zone **66** in the shaft **10** charged with the material to be treated. The heated cooling air will therefore not flow through the heating zone of the shaft **10** but is bypassed through the slots **36***c* into the shunt duct **33** as indicated by the arrows **30***a*. This clearly indicates that the heated cooling air does not pass into the high temperature portion of the heating zone but flows around or bypasses this zone by means of the shunt duct **33**. A substantial advantage thus obtained resides in the fact that the heated cooling air cannot reduce the temperature of the hot gases flowing out of the combustion chamber **44**. In the kiln disclosed, it will therefore be sufficient if the temperature of the hot gases is only about 50° C. higher than the required maximum temperature since heat losses between the hot gases and cooling air are minimized. Mention is here made of the fact that the temperature of the hot gases in those shaft kilns in which the heated cooling air mixes with the hot gases must be above the desired heat treating temperature at an extent substantially exceeding 100° C.

The above description clearly points out that the pressure in the annular shunt duct **33** is substantially the pressure set up in the interior of the high temperature portion **66***b* of the shaft **10**. One of the effects thereof is that the hot gases flowing downward from the central tube **43** at least partially tends to pass into the annular shunt duct **33** by virtue of the pressure gradient. The rows of slots **36***a* and **36***b* are provided for the hot gases. The hot gases therefore flow radially outward from the lower end of the central core or sleeve insert **43** and enter the annular shunt duct **33** through the rows of slots **36***a* and **36***b*. This results in the feature that the material to be heated or burnt in the high-temperature zone **66***b* of the heating zone **66** will be uniformly penetrated as indicated by the arrows **70**. The upper end of the shunt duct **33** is provided with an annular slot **33***a* through which the heated cooling air and the portion of the hot gas which has passed into the shunt duct **33** through the slots **36***a* and **36***b* are again supplied to the low temperature portion **66***a* of the burning zone **66**. There the air and the gas originating from the shunt duct **33** will mix with the hot gas which has passed into the low-temperature portion **66***a* of the burning zone **66** directly from the high-temperature portion **66***b*, as indicated by the arrow **71**. All the gas and all the heated cooling air forming a collective heated fluid mixture will then flow through the preheating tube **60** in the upward direction and pass into the flue **62** as indicated by the arrows **73**. When passing through the preheating tube **60** the gases and the heated cooling air, respectively, transfer their heat to the material to be burnt located in the respective preheating tube **60**. The air-gas mixture or heated fluid mixture formed above the annular slot **33***a* generally will still have a temperature somewhat above the minimum burning temperature of the charge so that a burning or heating process will already be performed to a limited extent in the lower portion of the respective preheating tube **60**. The drawing shows that the low-temperature portion **66***a* of the heating or burning zone **66** extends as far as the lower end of the preheating tube **60**. The gases leaving the upper end **60***a* of the respective preheating tube **60** have transferred practically their entire heat to the incoming material to be burnt which has been newly supplied so that the kiln will operate under very good conditions of thermal efficiency.

The burnt material passes, as has already been outlined, continuously downward in the shaft 10 and it is disintegrated into individual pieces by the revolving grate 15 disposed at the lower end of said shaft 10. Subsequently, the cooled material passes through the valves 22*a*, 22*b* and 22*c* to the outlet or delivery tube 26. It will be seen that the shaft kiln disclosed combines a number of substantial advantages. In the first place, fresh air is employed for the combustion process for the generation of the hot gases so that it will not be necessary to purify the warmed cooling air. The use of fresh air for the combustion process will eliminate all erosion effects in the compressor 53 and in the fresh air conduit or line 52. A particular noteworthy advantage is secured by employing the shunt duct 33. This shunt duct 33 has, on the one hand, the effect that the heated cooling air will not pass into the high-temperature portion 66*b* of the burning zone 66 and, on the other, that the hot gases will uniformly penetrate the material located in the heating or burning zone 66 owing to the resulting pressure gradient. This uniform penetration increases the quality of the material, the throughput rate, and consequently the thermal efficiency. In addition, the shaft kiln disclosed enables the heat to be practically completely utilized since the gas-air mixture obtained will almost entirely transfer its heat to the incoming material not yet burnt which is newly supplied.

The shaft kiln shown in FIG. 2 differs from the shaft kiln according to FIG. 1 in that the hot gases are radially supplied from the outside of the shaft while the shunt duct is located centrally in the upper shaft portion. The kiln base, the revolving grate, the arrangement of valves and the rotary compressors in this embodiment according to FIG. 2 are similar to those members in FIG. 1, like reference numerals generally indicating similar structure, so that for the sake of clarity a further description may be dispensed with.

The combustion chamber here designated at 80 is formed by a casing 81 rigidly connected with the shaft 82. The casing member 81 of L-shaped cross-section has its lower end resting on a supporting structure 83 which in turn rests on a projection or table portion 84 of the kiln base. The casing 81 forming the combustion chamber 80 is again enclosed by a jacket member 85 connected with an air supply line 52. The oil burner supplying the fuel for the combustion process and diagrammatically indicated at 86 is located at the lower end of the combustion chamber 80. The combustion air circulating within the jacket 85 flows into the combustion chamber 80 in the region of the burner opening, as indicated by the arrows 87. The combustion chamber 80 opens into a sleeve member or the like providing an annular chamber 88 enclosing the shaft 82, said chamber 88 communicating with the interior of the shaft via slots or ducts 89. In the present embodiment the hot gases emanating from the combustion chamber 80 therefore pass radially into the interior of the shaft 82 from externally thereof.

Arranged across the upper end of the shaft 82 is a support 90 carrying a sleeve or core insert 92 by means of a suspension bar 91, the sleeve insert 92 is located at the center of the shaft 82 and terminates somewhat short of the middle of said shaft 82. The lower end of the hollow sleeve insert 92 is open and is provided with an opening designated by the reference numeral 93 forming the shunt duct. The shunt duct 93 is connected with the interior of the shaft 82 by a lower row of slots 94 arranged below the hot gas inlet slots or channels 89 and by a second row of slots or channels 95 located above the hot gas slots 89. Arranged above the shaft 82 is a hood member 96 which conducts the gases issuing from the shaft 82 into a flue 97. The hood member 96 further supports a charging device for the material to be burnt as indicated at 97*a*.

The kiln according to FIG. 2 may be subdivided into separate zones in a manner similar to the kiln shown in FIG. 1. The different zones being designated by the same reference numerals as in FIG. 1, to wit, the preheating zone is indicated at 65, the burning zone at 66 and the cooling zone at 67, said burning zone again comprising a high-temperature region 66*b* and a low-temperature region 66*a*. Cooling air flows into the shaft 82 through the cool air conduit again designated by reference numeral 27 and cools the burnt material located in the lower portion of the shaft 82. As indicated by the arrows 98, the cooling air passes into the shunt duct 93 through the lower opening and the slot 93*a* since said shunt duct 93 presents a region of less flow resistance than the shaft 82 filled with the material to be burnt. In the same manner as in the embodiment according to FIG. 1, the preheated cooling air cannot establish contact with the hot gases entering the shaft 82 through the hot-gas inlet openings 89. The pressure set up in the shunt duct 93 is therefore lower than that appearing in the shaft 82 at the corresponding elevation. One of the consequences of this pressure gradient is that a portion of the hot gases entering through the openings 89 passes into the shunt duct 93 through the slots 94 as illustrated by the arrows 99. One effect thereof is that the hot gas uniformly penetrates the high-temperature portion 66*b* of the heating zone 66 resulting in the advantages recited in conjunction with the description of FIG. 1. The cooling air-gas mixture supplied to the shunt duct 93 emerges from this duct through the row of slots 95 and again passes into the low-temperature portion 66*a* of the shaft 82. The air-gas mixture there mixes with the remaining portion of the hot gases which have not passed into the shunt duct 93, the direction of flow of which is indicated by the arrows 100. The entire air-gas mixture or fluid stream then flows through the low-temperature portion 66*a* into the preheating zone 65 and heats the incoming material to be burnt.

The shaft kiln according to FIG. 2 operates in the same manner as that shown in FIG. 1 and combines the same advantages. The essential difference between the two embodiments, as previously stated, consists in that the shunt duct of the shaft kiln according to FIG. 1 is located on the outside and the burning chamber coaxially with the axis of the kiln, while the shunt duct in the embodiment according to FIG. 2 is located inside of the shaft and the burning chamber laterally thereof.

FIGS. 3 and 4 show a further kiln arrangement which is of rectangular cross-section in distinction to the kilns shown in FIGS. 1 and 2, the hot gases of combustion again flowing from the inside to the outside as explained in conjunction with FIG. 1. FIG. 3 is a longitudinal section of the smaller cross-sectional area, and FIG. 4 is a view, partly in section of the kiln seen from its larger side. The kiln base, the air compressors and the arrangement of valves are again identical with the corresponding members illustrated in FIG. 1 so that repetition of the description is herein dispensed with, like reference numerals generally indicating similar structure.

In the kiln according to FIGS. 3 and 4, the revolving grate of FIGURE 1 is replaced by a cylinder grate 102. The individual cylinders of said grate 102 are driven by a motor 105 via gearing means 103. The function of the grate 102 is the same as that of the revolving grate illustrated in the preceding embodiments. As may clearly be seen from FIG. 4, two opposite or diametrically opposed supports 106 are arranged on the kiln base 11, each of which carries a platform or table 108 via the struts 107. The platforms in turn carrying a casing member 110 provided with a combustion chamber or compartment 111. The oil burners 112 are arranged at the outer ends of the casing members 110. The casing members 110 are each encircled by a jacket 113, the air for combustion being supplied to the space formed by the jacket 113 and the associated casing 110 via line 52 and branch lines 27*a* and 27*b*. The combustion air combines with the oil supplied from the oil burners 112 and provides the necessary hot air required for the combustion process taking place in the respective combustion compartments 111.

The two combustion chambers 111 are interconnected by a hot-gas channel or passageway 120 which is located in an internally arranged sleeve insert or core piece 121. This sleeve or core piece 121 extends, as clearly shown by FIG. 3, through the kiln in the longitudinal direction and separates the interior of the shaft into two sections conveniently designated by reference numerals 119*a* and 119*b*. The interconnecting channel 120 is connected with the interior of the shaft 127 by two rows or banks of slots or channels 123 and 124. The hot gases flowing from the combustion chambers 111 into the hot-air channel 120 from opposite sides thus reach the interior of the shaft through the upper and lower slots 123 and 124.

As can further clearly be seen in FIG. 3, two substantially flat jacket or sleeve members 125 are arranged at the larger side surfaces of the shaft and are located at a predetermined distance from the side walls 127 of the shaft and each form an intermediate space or duct 128. The jacket members or sleeves 125 are connected with the shaft body and, respectively, the side walls 127 by means of yokes 125*a* arranged at the upper ends. The two intermediate spaces 128 each constitute a shunt duct. The two shunt ducts 128 communicate with the interior of the kiln via three rows of slots or channels 129, 130 and 131. The two lower rows of the slots or channels 129 and 130 are located below the inlet openings 123 and 124 for the hot gases while the upper row of slots 131 is arranged above said inlet openings for the hot gases.

The two lower ends of the shunt ducts 128 are connected with a dust gate via conduit lines 132, which dust gate is identically designed similar to the dust gate 39*a*, 39*b* of the shaft kiln shown in FIG. 1. In FIG. 4 part of the jacket or sleeve member 125, the kiln wall 127 and part of the core member 121 have been shown so that the rows of slots 129, 130 and 131, and a portion of the inside of the hot-gas channel 120 are clearly visible. The upper end of the shaft is closed by a flue 133 which also contains a charging device 134 as best seen in FIGS. 3 and 4.

In operation, a quantity of cooling air is supplied from the lower end of the shaft via conduit 27. This cooling air flows into the shunt ducts 128 through the slots 129. In a manner similar to that of the two embodiments previously described, the lowest row of slots defines the upper region of the cooling zone 67. At the same time, the underpressure in the shunt ducts 128 draws the hot gas emerging preferably from the lower hot-gas openings 124 into the shunt ducts 128 so that the material to be heated or fired is fully penetrated by the hot gas in the high-temperature portion 66*b* of the heating zone 66. A portion of the hot gases flow into the shunt ducts 128 through the intermediate row of slots 130. The gas-air mixture located in the shunt ducts 128 returns back into the shaft through the upper row of slots 131. The temperature of the thus formed fluid mixture is still above the burning temperature of the material, so that it causes a heating process to occur in the low-temperature portion 66*a* of the heating zone 66. On the discharge side of the slots 131 the gas-air mixture coming from the shunt ducts 128 mixes with the remaining hot-air portion which has not reached the shunt ducts 128 mainly emerging from the upper row of hot gas openings 123. The fluid mixture of hot gases and cooling air then rises upwards in the shaft and permeates, as previously stated, the low-temperature portion 66*a* of the heating zone 66 and then the preheating zone 65.

It may be seen that the shaft kiln according to FIGS. 3 and 4 achieves the same advantages as obtained by the shaft kilns previously described with respect to the other embodiments. What is remarkable in the shaft kiln according to FIGS. 3 and 4 is the rectangular cross-section of the shaft and the supply of hot gases through the core member 121. The hot-gas channel in the core member 121 is provided, as already described, with two rows of slots 123 and 124. The gas emerging from the row of slots 124 flowing mainly into the shunt ducts 128 while the gas issuing from the row of slots 123 remains largely in the interior of the shaft. The cross-section described requires the presence of two shunt ducts which, however, perform the same function as the individual shunt ducts in the shaft kilns according to FIGS. 1 and 2.

FIGS. 5 and 6 show a further embodiment of a shaft kiln having a rectangular cross-section. In FIG. 5 there is shown a longitudinal section of the smaller cross-sectional area and FIG. 6 a view of a larger side surface of the shaft partly in section. The design and arrangement of the kiln base, the valves and the compressors is the same as in the embodiment according to FIGS. 3 and 4 while the burner is designed similarly to that in the shaft kiln according to FIG. 2 like reference numerals again denoting similar structure. Provided at the larger side walls 140 of the rectangular shaft are sleeve means or the like providing two hot-gas channels 141 which are connected with the combustion chamber 142. The two channels 141 are connected with the interior of the shaft via two rows of openings or slots 143 and 144 through which the hot gases enter the interior of said shaft. Arranged parallel with the side walls 140 of the shaft and internally thereof is a sleeve insert or core piece 146 provided with an extended slotted opening 147. This opening 147 constitutes the shunt duct. As best seen in FIG. 6, the lower boundary surface 147*a* of the shunt duct is inclined. This lower surface 147*a* communicates with a dust return line 148 which is connected with a two-stage dust gate 149 similar to the dust gates 39*a*, 39*b* of FIGURE 1. The shunt duct is connected with the two shaft halves separated by the core piece 146 via three rows of slots or openings 150, 151 and 152. The two lower rows of slots 150 and 151 are located below the hot-gas supply openings 143 and 144 while the upper row of slots 152 is arranged above said hot-gas openings. Arranged above the upper shaft end is a hood member 160 which establishes communication with a conventional flue. A charging device 161 is again located within said hood 160.

The shaft kiln according to FIGS. 5 and 6 operates in the same manner as explained in conjunction with the previous embodiments. The cooling air entering from below transverses the cooling zone 67 and passes into the shunt duct 147 through the rows of slots 150. In the same manner, the hot gases of the two rows of lower hot-gas supply openings 144 pass into the shunt duct 147 through the rows of slots 151. This enables the material to be heated to be thoroughly penetrated by the hot gases in the heating zone. The cooling air which has now been raised in temperature and the hot gases appearing in the shunt duct 147 thence flow back through the upper slots 152 into the upper shaft halves 153*a* and 153*b*. Where the slots 152 open, the air-gas mixture appearing in the shunt duct 147 now combines with the remaining hot-gas portion that has not been passed through the shunt duct 147 and which emanates mainly from the upper row of openings 143. The gas-air or fluid mixture will then flow through the low-temperature portion 66*b* of the heating zone 66 in an upward direction and heats the incoming material next to be treated. The shunt duct 147 therefore performs the same function as in the shaft kilns hereinabove described. On the one hand, the heated cooling air is bypassed about at least the high-temperature portion 66*b* of the heating zone 66 so that this heated cooling air cannot reduce the temperature of the hot gases. It is to be appreciated that this feature of the shaft kilns described makes it sufficient for the hot gases to have a temperature which is only 50° C. higher than the desired maximum heating temperature. The shunt duct 147 further causes a pressure gradient in the shaft, which pressure gradient has the advantageous effect that the hot gases uniformly penetrate all of the material to be heat treated. With respect to all the embodiments of the shaft kilns disclosed, it may be said that they provide a high throughput rate, good thermal efficiency with a minimum possibility of breakdown. The shaft kilns thus meet all the requirements necessary for efficient practical operation. A number of modifications of the embodiments shown are possible. In particular, after-burners may be provided in the shunt ducts which will contribute to heating the gases and the heated cooling air, respectively, and may result in a further improvement of the thermal efficiency. In FIGURE 1 such an after-burner or burner means 200 is provided in the region of the shunt duct 33 for introducing a suitable fuel to further heat the bypassed cooling air and gases. It should be understood that a substantially similar arrangement can be provided for the corresponding shunt ducts of the other herein described embodiments. Although the present invention has been described in conjunction with a charge such as cement, lime, dolomite or the like, the same have been given by way of illustration only as other charges may equally well be employed.

Having thus described the present invention what is desired to be secured by United States Letters Patent is:

1. A method of heat treating a charge such as cement, lime, dolomite and the like, comprising the steps of mixing a quantity of air with a fuel and burning the same to complete combustion to produce hot gases, directing said hot gases with substantially symmetrical infeed into contact with a charge to be heat treated in a heating section of a kiln, distributing said hot gases into substantially at least two hot gas streams, each of which is operable throughout approximately one-half of the cross-section of said kiln to thus uniformly penetrate and heat treat the charge located therein, bypassing a first portion of said hot gases into a duct which does not contain said charge while the remaining major portion of said hot gases freely circulates through said charge for heat treating thereof, feeding a supply of cooling air through a cooling section of said kiln to contact said charge for heat transfer therewith and toward said hot gases circulating through said charge, then bypassing said cooling air into said duct which does not contain said charge adjacent the upper region of said cooling section at least prior to intimate contact of said cooling air with said hot gases to prevent heat transfer between said cooling air and said hot gases to thereby prevent undesired reduction of the temperature of said hot gases in contact with said charge, said bypassed cooling air and said first portion of said hot gases freely mixing within said duct, then commingling said bypassed cooling air and said first and remaining hot gas portions to produce a fluid mixture of hot gases and air, then causing said fluid mixture to circulate through another portion of a charge in a preheating section of said kiln to raise the temperature of the same in preparedness for a similar heat treating operation.

2. A method of heat treating a charge such as cement, lime, dolomite and the like, comprising the steps of mixing a quantity of air with a fuel and burning the same to complete combustion to a temperature range exceeding the desired heat treating temperature for the charge by approximately 50 degrees to produce hot gases, directing said hot gases with substantially symmetrical infeed into contact with a charge to be heat treated in a heating section of a kiln, distributing said hot gases into substantially at least two gas streams, each of which is operable throughout approximately one-half of the cross-section of said kiln to thus uniformly penetrate and heat treat the charge located therein, bypassing a first portion of said hot gases into a duct which does not contain said charge while the remaining major portion of said hot gases freely circulates through said charge for heat treating thereof, feeding a supply of cooling air through a cooling section of said kiln to contact said charge for heat transfer therewith and toward said hot gases circulating through said charge, then bypassing said cooling air adjacent the upper region of said cooling section into said duct which does not contain said charge immediately prior to intimate contact of said cooling air with said hot gases to prevent heat transfer in said heating section between said cooling air and said hot gases to thereby prevent undesired reduction of the temperature of said hot gases in contact with said charge, said bypassed cooling air and said first portion of said hot gases freely mixing within said duct, then commingling said bypassed cooling air and said first and remaining hot gas portions to produce a fluid mixture of hot gases and air, then causing said fluid mixture to circulate through another portion of a charge located in a preheating section of said kiln to raise the temperature of the charge in preparedness for a similar heat treating operation.

3. A method of heat treating a charge such as cement, lime, dolomite and the like, comprising the steps of mixing a quantity of air with a fuel and burning the same to complete combustion to produce hot gases, directing said hot gases with substantially symmetrical infeed into contact with a charge to be heat treated in a heating section of a kiln, distributing said hot gases into substantially at least two hot gas streams, each of which is operable throughout approximately one-half of the cross-section of said kiln to thus uniformly penetrate and heat treat the charge located therein, bypassing a first portion of said hot gases into a duct which does not contain said charge while the remaining major portion of said hot gases freely circulates through said charge for heat treating thereof, feeding a supply of cooling air through a cooling section of said kiln for contact with said charge for heat transfer therewith and toward said hot gases circulating through said charge, then bypassing said cooling air from adjacent the upper region of said cooling section into said duct which does not contain said charge at least prior to intimate contact of said cooling air with said hot gases to prevent heat transfer between said cooling air and said hot gases in said heating section to thereby prevent undesired reduction of the temperature of said hot gases in contact with said charge, said bypassed cooling air and said first portion of said hot gases freely mixing within said duct, said cooling air when disposed in said duct aiding to produce a pressure differential between said heating section of said kiln and said duct to facilitate bypass of said first portion of said hot gases, then commingling said bypassed cooling air and said first and remaining hot gas portions to produce a fluid mixture of hot gases and air, then causing said fluid mixture to circulate through another portion of a charge disposal in a preheating section of said kiln to raise the temperature of the charge in preparedness for a similar heat treating operation.

4. A method of heat treating a charge such as cement, lime, dolomite and the like in a kiln provided with a shunt duct, said kiln including a heating section, a cooling section and a preheating section; comprising the steps of mixing a quantity of air with a fuel and burning the same to complete combustion to produce hot gases, directing said hot gases with substantially symmetrical infeed into contact with a charge to be heat treated in said heating section of the kiln, distributing said hot gases into substantially at least two hot gas streams, each of which is operable throughout approximately one-half of the cross-section of said kiln to thus uniformly penetrate and heat treat the charge located therein, bypassing a first portion of said hot gases into said shunt duct which does not contain said charge while the remaining major portion of said hot gases freely circulates through said charge for heat treating thereof, feeding a supply of cooling air through the predominant portion of said cooling section of said kiln and said charge for heat transfer therewith and toward said hot gases circulating in said heating section, then bypassing said cooling air into said shunt duct which does not contain said charge prior to intimate contact of said cooling air with said hot gases to prevent heat transfer between said cool-

ing air and said hot gases to thereby prevent undesired reduction of the temperature of said hot gases in contact with said charge, said bypassed cooling air and said first portion of said hot gases freely mixing within said shunt duct, then commingling said bypassed cooling air and said first and remaining hot gas portions to produce a fluid mixture of hot gases and air, and finally causing said fluid mixture to circulate through another portion of a charge located in said preheating section of said kiln to raise the temperature of the same in preparedness for a similar heat treating operation.

5. A method of heat treating a charge according to claim 4, including the step of introducing a fuel into said shunt duct to further heat said bypassed cooling air and said first portion of said hot gases freely mixing within said shunt duct to raise the temperature thereof.

6. A kiln for heat treating a charge, comprising a shaft having a hollow interior defined by side walls, said kiln being successively provided with a preheating section, a heating section and a cooling section with at least said heating section and said cooling section located within said hollow interior of said shaft, charging means cooperable with said shaft for feeding a charge to be heat treated to said hollow interior of said shaft, combustion means in registry with said heating section of said shaft for directing a supply of hot gases thereto for contact with said charge, feed means for supplying a respective quantity of air to said combustion means and said cooling section of said shaft, a member arranged in said hollow interior of said shaft, a member arranged outside of said shaft adjacent the side walls thereof and in the region of said heating section of said kiln, said interiorly arranged member being provided with opening means communicating with said hollow interior of said shaft, said side wall of said heating section of said shaft in the region of said outside arranged member being provided with slot means communicating with said hollow interior of said shaft including said interiorly arranged member, one of said members being in registry with said combustion means with the other of said members defining a shunt duct, thereby permitting bypassing of at least a portion of said hot gases into said shunt duct prior to moving through the predominant portion of said heating section as well as removing said cooling air prior to intimate mixing and circulation thereof with a remaining portion of said hot gases located in said heating section of said kiln.

7. A kiln for heat treating a charge, comprising a shaft having a hollow interior defined by side walls, said kiln being successively provided with a preheating section, a heating section and a cooling section with at least said heating section and said cooling section located within said hollow interior of said shaft, charging means cooperable with said shaft for feeding a charge to be heat treated to said hollow interior of said shaft, combustion means in registry with said heating section of said shaft for directing a supply of hot gases thereto for contact with said charge, feed means for supplying a respective quantity of air to said combustion means and said cooling section of said shaft, and a hollow sleeve member disposed adjacent one end of said shaft at least in the region of said heating section and spaced from the outer wall of said side wall to define therewith a shunt duct, said side wall of said shaft opposite said hollow sleeve member being provided with slot means communicating said heating section of said hollow interior of said shaft with said shunt duct, to thereby permit bypassing of at least a portion of said hot gases into said shunt duct prior to moving throughout said heating section as well as removing said cooling air into said shunt duct prior to intimate mixing and circulation thereof with a remaining portion of said hot gases located in said heating section of said kiln.

8. A kiln for heat treating a charge according to claim 7, further including a sleeve insert mounted internally of said shaft in a longitudinal direction to divide said hollow interior into two separate compartments, said sleeve insert being provided with channel means in registry with said combustion means, said combustion means including a pair of separate diametrically opposed combustion chambers cooperating with said separate compartments.

9. A kiln for heating treating a charge, comprising a shaft provided with a hollow interior defined by side walls and having a longitudinal axis, said kiln being successively provided with a preheating section, a heating section and a cooling section with at least said heating section and said cooling section located within said hollow interior of said shaft, charging means cooperable with said shaft for feeding a charge to be heat treated to said hollow interior of said shaft, combustion means coaxially arranged with respect to said longitudinal axis of said shaft in registry with said heating section of said shaft for directing a supply of hot gases with symmetrical infeed thereto for contact with said charge, feed means for supplying a respective quantity of air to said combustion means and said cooling section of said shaft, and a hollow sleeve member disposed adjacent one end of said shaft at least in the region of said heating section and spaced from the outer wall of said side wall to define a shunt duct, said side wall of said shaft opposite said hollow sleeve member being provided with slot means communicating said hollow interior of said shaft in the region of said heating section with said shunt duct, to thereby permit bypassing of at least a portion of said hot gases into said shunt duct prior to moving throughout said heating section as well as removing said cooling air into said shunt duct prior to intimate mixing and circulation thereof with a remaining portion of said hot gases located in said heating section of said kiln.

10. A method of treating a charge such as cement, lime, dolomite and the like, comprising the steps of mixing a quantity of air with a fuel and burning the same to produce hot gases, directing said hot gases into contact with a charge to be heat treated in a heating section of a kiln, distributing said hot gases through said heating section of said kiln into at least two hot gas streams, each of which is effectively operative throughout approximately one-half the cross-sectional area of said heating section of said kiln, forming a pressure gradient between said heating section and a region devoid of said charge, with said charge devoid region defining a shunt duct possessing a flow resistance which is smaller than that of said charge-containing heating section, said formed pressure gradient causing bypass of a portion of said hot gases into said shunt duct while the remaining major portion of said hot gases passes through said charge located in said heating section, feeding a supply of cooling air through said charge disposed in a cooling section of said kiln for heat transfer therewith and toward said hot gases in contact with said charge and flowing through said heating section, then bypassing said cooling air into said shunt duct which does not contain said charge prior to intimate contact of said cooling air with said hot gases in contact with said charge, to prevent heat transfer between said cooling air and said hot gases in said heating section in contact with said charge, thereby preventing an undesired reduction of the temperature of said hot gases in contact with said charge.

11. A method of treating a charge such as cement, lime, dolomite and the like, comprising the steps of mixing a quantity of air with a fuel and burning the same to produce hot gases, directing said hot gases into a charge to be heat treated in a heating section of a kiln having a vertical axis by forcing said gases to flow symmetrically about said axis through said charge between infeed and outfeed locations, one of said locations being the periphery of the charge and the other of said locations originating at least substantially centrally within said charge, forming a pressure gradient between said heating section and a region devoid of said charge, with said charge devoid region defining a shunt duct which possesses a

smaller flow resistance than that of said charge-containing heating section of said kiln, said pressure gradient causing bypass of a portion of said hot gases into said shunt duct while the remaining major portion of said hot gases pass through said charge within said heating section, feeding a supply of cooling air through said charge disposed in a cooling section of said kiln for heat transfer therewith and toward said hot gases flowing through said heating section in contact with said charge, then bypassing said cooling air from adjacent the upper region of said cooling section into said shunt duct immediately prior to intimate contact of said cooling air with said hot gases in contact with said charge to prevent heat transfer between said cooling air and said hot gases in said heating section, thereby preventing an undesired reduction of the temperature of said hot gases in contact with said charge.

12. A kiln for heat treating a charge according to claim 7, wherein said hollow sleeve member is spaced from an upper edge of said shaft to define an opening permitting communication of said shunt duct with said preheating section of said kiln, said preheating section being defined by at least one preheating tube supported by said hollow sleeve member and extending toward said opening.

13. A kiln for heat treating a charge according to claim 7, wherein said side walls of said shaft define a circular cross-section, and said shunt duct is annular.

14. A kiln for heat treating a charge according to claim 13, wherein dust removal means are provided which cooperate with the lower extremity of said shunt duct to remove impurities contained therein.

15. A kiln for heat treating a charge, comprising a vertical shaft having a hollow interior defined by wall portions and adapted to receive a charge therein, sleeve means supported by an upper portion of said vertical shaft and disposed adjacent the outer surface thereof and spaced therefrom to define a shunt duct, said kiln being successively provided with a preheating section, a heating section and a cooling section with at least said heating section and said cooling section being located within said hollow interior of said vertical shaft, charging means cooperable with said vertical shaft for feeding a charge to be heat treated to said hollow interior of said vertical shaft, combustion means adjacent said upper portion of said vertical shaft in registry with said heating section and coaxially arranged with respect to the longitudinal axis of said shaft for directing a supply of hot gases into contact with said charge, feed means for supplying a respective quantity of air to said combustion means and said cooling section of said vertical shaft, said wall portion of said vertical shaft being provided with openings in the region of said heating section permitting bypass of at least a portion of said hot gases into said shunt duct prior to moving throughout said heating section as well as removing said cooling air into said shunt duct to prevent intimate mixing and circulation of said cooling air with a remaining portion of said hot gases located in said heating section of said kiln.

16. A kiln for heat treating a charge according to claim 6; wherein said other member defining a shunt duct is said interiorly arranged member and comprises a sleeve insert which is disposed in said hollow interior of said shaft at least in the region of said heating section.

17. A kiln according to claim 16; wherein said sleeve insert is supported by an upper portion of said shaft.

18. A kiln for heat treating a charge according to claim 16; wherein said sleeve insert is mounted internally of said shaft and extended in a longitudinal direction to divide said hollow interior into two separate compartments.

19. A kiln for heat treating a charge according to claim 18; wherein said combustion means communicates with said two separate compartments to supply hot gases thereto.

20. A kiln for heat treating a charge according to claim 16; wherein at least one portion of said opening means of said internally arranged sleeve insert is arranged adjacent the lower extremity of said heating section and at least one other portion of said opening means being arranged adjacent the upper extremity of said heating section to permit bypass of at least a portion of said hot gases and said cooling air around said heating section of said kiln.

21. A kiln for heat treating a charge according to claim 6; wherein said other member defining a shunt duct is said outside arranged member and comprises sleeve means supported by an upper portion of said shaft in spaced relation from said side walls to provide said shunt duct, said one member which is in registry with said combustion means being an insert member located in said shaft to divide the latter into separate compartments.

References Cited in the file of this patent

UNITED STATES PATENTS

1,895,284	Hay	Jan. 24, 1933
2,744,743	Beggs et al.	May 8, 1956
2,788,961	Pooley et al.	Apr. 16, 1957
2,960,323	Ludin	Nov. 15, 1960
2,996,292	Graf et al.	Aug. 15, 1961