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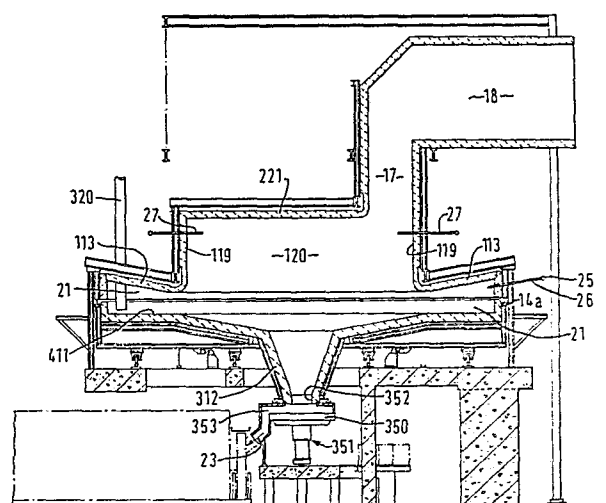
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54 **Process and apparatus for the production of high quality calcined coke.**

57 A process and apparatus for the production of high quality calcined coke are described. The coke feed (e.g. green coke from a delayed coker) is heated at a bulk temperature of from 650 to 850°C under conditions such that the coke heating rate is no more than 100°C/minute until from 50 to 90 weight percent of the volatile matter content is removed, whereafter the heated coke is calcined at a bulk temperature of from 1350 to 1470°C for at least 10 minutes to produce a relatively hard and non-friable calcined coke. Preferably the calcined coke is produced in a rotary hearth furnace divided by an annular radiation shield into a central high temperature calcining zone and a surrounding devolatilizing zone, the radiation shield defining with the hearth an uninterrupted gap of sufficient width for coke to pass from the devolatilizing zone to the central zone but sufficiently narrow to prevent coke in the devolatilizing zone being substantially affected by heat generated in the central zone.



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PROCESS AND APPARATUS FOR THE PRODUCTION OF
HIGH QUALITY CALCINED COKE

TECHNICAL FIELD OF THE INVENTION

The present invention relates to a process and apparatus for the production of high quality calcined coke, and more particularly (but not exclusively) to such a process and apparatus for the
5 production of calcined needle coke of high particle strength.

Coke which is intended for use in the production of certain metals from raw materials by electrolysis of melts containing compounds of the metals or which is intended for the production of graphitic carbon for ultra-high power electrodes in electric arc
10 furnaces must be substantially free of volatile materials, e.g. hydrocarbons. Accordingly, raw coke (the so-called "green coke" in the case of petroleum and similar raw cokes) for such purposes is calcined at temperatures which are suitably high to produce a
volatiles-free coke calcinate. In the case of petroleum coke derived
15 by coking hydrocarbon materials of petroleum origin, calcination is performed at temperatures of about 1300 to 1500°C and higher, e.g. about 1400°C. Similar or different calcination temperatures may be used to devolatilize coke obtained from other sources (e.g. coal, coal tar, lignite, etc).

20 The present invention will be more particularly described below with reference to petroleum coke, but it is to be understood that it applies equally to coke derived from other sources such as coal, lignite and other carbonaceous and hydrocarbonaceous materials.

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Coke which is to be used for the aforesaid purposes is preferably not only substantially free of volatile material (e.g. the residual hydrogen content is preferably not greater than 0.01 to 0.03 wt. %), but preferably also meets other stringent quality specifications, including high particle strength, a specified range of particle size distribution and/or a specified range of absolute density. High particle strength is of particular importance for the production of graphite electrodes of high mechanical strength which are used under high and varying temperatures.

10 PRIOR ART

Processes and apparatuses for the production of calcined cokes are well-documented and, generally speaking, fall into two categories, namely, those employing rotary kiln furnaces and those employing rotary hearth furnaces.

15 In broad terms, the rotary kiln process comprises supplying a suitable feed material to the upper end of a downwardly-inclined rotating cylinder in which the feed material is exposed to heat to expel volatile materials therefrom so that the product material recovered from the bottom end of the cylinder is a coked material
20 of low volatiles content. The heat required to expel the volatile material is furnished by burning a fuel with a combustion-supporting gas (usually air) either in a flame which extends partially up the cylinder or in a separate combustion chamber from which the hot combustion gases are conducted into the cylinder so that the coke
25 and hot gases pass counter-currently to each other while passing through the cylinder. In some instances, the expelled volatile material is burned, e.g. within the cylinder, in order to generate some of the heat required for the conversion of the feed material to calcined coked material.

30 In general terms, the rotary hearth process comprises supplying the feed material to the outer periphery of a flat or saucer-shaped hearth which is rotated about a central vertical axis. The hearth has a central hole for the discharge of calcined coked

material and stationary rabbles or plows cause the feed material to follow a generally spiral path from the outer periphery to the central hole. The hearth is spaced beneath a stationary roof, and fuel is burned with a combustion-supporting gas (usually air) in the space between the roof and the hearth to heat the feed material as it passes across the hearth. Volatile material expelled from the feed material is also burned in this space and thereby augments the supply of heat. The calcined coked material is discharged from the hearth via the central hole therein and is received in a cylindrical or downwardly-tapering container and allowed to heat-soak at temperatures approximating the maximum temperatures attained in order to provide additional time for the escape of volatilizable matter.

The hearth may be substantially flat or it may slope downwardly towards the central hole either from the outer rim or from a location between the rim and the central hole. A detailed description of a rotary hearth furnace is given in U.S. Patent 3,475,286 (Klemmerer et al).

Rotary kiln calcined coke is generally of acceptable quality for many purposes, but as compared with rotary hearth calcined coke, yields of calcined coke are lower (typically 4 to 6 weight percent lower), and the investment for a rotary kiln installation is higher as is the operating cost. The foregoing disadvantages are reflected in the higher cost of rotary kiln calcined cokes.

Rotary hearth calcined coke is generally acceptable for most purposes but a notable drawback is its friability and low particle strength. The premium and high quality calcined cokes required for ultra-high-power electrodes for electric arc furnaces must meet stringent quality specifications, including specifications for size distribution. Such electrode coke should include a certain minimum proportion of coarse calcined coke of good particle strength, and heretofore, it has not been possible to meet the quality specifications consistently.

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BACKGROUND OF THE INVENTION

The inventors have discovered that when a selected range of raw feed materials is heated in two stages with no treatment with hydrogen and with no intermediate cooling, and with the maximum heating rate in the first stage maintained no greater than a specified heating rate and the temperatures in both stages closely controlled, a calcined coke of high particle strength meeting the quality specifications for premium and high quality coke can be produced substantially consistently, provided a specifically limited proportion of the volatile matter content of the raw feed material is expelled in the first stage. Moreover, the inventors have discovered that a rotary hearth furnace, with all its attendant advantages over a rotary kiln, can be employed for the production of premium and high quality coke, provided the furnace is constructed in a particular way, which is specified and described hereinafter, and also operated in a particular manner, as specified and described hereinafter.

SUMMARY OF THE INVENTION

The present invention provides, in a first aspect, a process for the production of high quality calcined petroleum coke from green coke, comprising the steps of:

- (a) feeding green coke having a volatile matter content not exceeding 14 weight % (based on the dry weight of the green coke) into a first heating stage;
- (b) exposing the green coke in the first heating stage to a heated environment maintained substantially solely by the combustion of fuel and any volatile matter released from the coke with a combustion-supporting gas at a regulated rate and in the absence of added

hydrogen to give a coke-heating rate not exceeding 100°C/minute until from 50 to 90 weight % of the volatile matter content of the green coke is removed and the bulk temperature of the coke is in the range of from 650 to 850°C;

5 (c) causing the heated coke produced by step (b) to pass to a subsequent calcining step at a bulk temperature in the range of from 650 to 850°C without any intermediate treating or cooling step;

10 (d) exposing the heated coke in the subsequent calcining step to a heated environment sustained solely by burning fuel and combustible matter released from the coke with a combustion-supporting gas so as to raise and maintain the temperature of the coke to a bulk temperature in the range of from 1350 to 1470°C for an average time period of at least 10 minutes; and

15 (e) recovering high quality coke from the subsequent calcining step (d).

The invention also provides, in a second aspect, a rotary hearth furnace for the production of high quality petroleum coke from green petroleum coke comprising a circular rotary hearth defining a central
20 circular hole, means mounting the hearth for rotation about its central vertical axis, a stationary roof spaced above the hearth, an annular wall to prevent the outward escape of hot gas from the interior of the furnace, an annular radiation shield depending downwardly from the stationary roof to define the outer periphery of a
25 central calcining zone outwardly of the central hole and the inner periphery of an annular pre-heating zone bounded by the annular wall, the radiation shield defining with the hearth a vertical gap of sufficient width to permit coke particles to pass from the pre-heating zone to the calcining zone but sufficiently narrow to
30 substantially prevent the radiation of heat from the central calcining zone to the annular pre-heating zone, burner means for

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burning fuel and any volatile matter released from the coke with
a combustion-supporting gas above the hearth in the calcining
zone to generate temperatures in the range of from 1350 to 1600°C
to heat coke in the calcining zone to temperatures in the range of
5 from 1350 to 1470°C, burner means for burning fuel and any volatile
material released from the coke with a combustion-supporting gas
above the hearth in the annular pre-heating zone and serving as
substantially the sole source of heat in the pre-heating zone to
generate temperatures in the range of from 650 to 900°C to heat coke
10 in the pre-heating zone to temperatures in the range of from 650 to
850°C, means for adding particles of green petroleum coke to an outer
region of the hearth of the annular pre-heating zone, means to
rotate the hearth about the central vertical axis, rabble means for
causing coke particles to be moved from the outer region of the
15 annular pre-heating zone through the vertical gap between the radia-
tion shield and the hearth and into the central calcining zone,
rabble means for causing coke to be moved from the outer periphery
of the central calcining zone to the central hole, and coke-recovery
means beneath the central hole for recovering coke from the central
20 hole.

With reference to the first aspect of the invention, it has
already been proposed to calcine a petroleum coke feed material in
discrete stages.

U.K. Patent Specification No. 1 603 924 (Koa Oil Company)
25 describes and claims a process for calcining green coke containing
water and combustible volatile matter obtained by a delayed coking
process in three or more stages of heating furnaces which are
connected in series and in which the control of the temperature
and the adjustment of the atmosphere in each furnace can be
30 independently carried out, which process comprises carrying out,
in respective furnaces in the order indicated, the steps of:

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(a) evaporating the water contained in the green coke and pre-heating the coke;

(b) distilling off and burning the volatile matter from the dried coke; and

5 (c) heating and calcining the coke from step (b)

In the illustrated embodiments, each one of the three independent furnaces is a rotary kiln furnace but the document refers to the possibility that other types of furnace (e.g. rotary hearth furnaces) can be used in place of each rotary kiln furnace.

10 Obviously, the drawbacks associated with rotary kiln furnaces apply to each such furnace, and where three rotary kilns or other types of furnace are employed in pursuance of the patented process, the investment cost is very high. Moreover, in the transfer of coke from one furnace to a subsequent furnace, there will inevitably be a
15 certain amount of cooling of the coke and the risk or fact of contact with molecular oxygen. The inventors have determined that in order to produce a final calcined coke of high or highest quality, it is critical that not less than 50 wt % and not more than 90 wt % of the volatile matter contained in the green coke must be removed in the
20 first heating stage and, preferably, the amount of volatile matter removal should be in the range of from 55 to 85 wt %, e.g. from 60 to 80 wt %. The data in the Table in U.K. 1603924 show that about 91 wt % of volatile material is removed in the second of the three furnaces and it is reasonable to suppose that additional quantities of
25 volatile material are evolved in the first of the three furnaces where the green coke is exposed to counter-currently flowing gas at initial temperatures within the range of from 1100 to 1300°C.

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A similar proposal to that of U.K. 1603924 is described and claimed in Koa Oil Company's U.K. Patent Application GB 2043676 with the additional step of cooling the partially devolatilized and dried coke from the second furnace before it is passed into the
5 third furnace.

U.K. Patent Application GB 2093061A describes and claims a three-stage process for producing calcined petroleum coke having a sulfur content in the range of 1.5 to 2.5 wt % and a vibrated bulk density of at least 78 g/100 cc from raw petroleum coke having a
10 sulfur content greater than 2.5 wt % and a volatile content of at least 7 wt % which comprises:

(a) heating the coke at a temperature in the range of 250°C to 450°C in an oxidizing atmosphere for a period no less than 0.5 hour;

15 (b) heating the oxidized coke at a temperature in the range of 600°C to 800°C in an atmosphere containing added hydrogen for a period of time sufficient to reduce the sulfur content of said coke to a level such that no more than 1.5 wt % of sulfur is required to be removed in the final stage; and

20 (c) heating the partially desulfurized coke at a temperature in the range of 1350°C to 1600°C in the absence of added hydrogen for a period of time sufficient to reduce the sulfur content of the coke to within the range of 1.5 to 2.5 wt %.

For comparison, GB 2093061A refers to a two-stage calcining
25 process described in U.S. Patent 4160814 (Hardin et al) in which the first stage is effected at 490 to 850°C to remove no more than 70 wt % of the volatile matter of the green coke, and thereafter heating the partially devolatilized coke at a temperature of at least 1500°C for 30 to 70 minutes to calcine and desulfurize the coke.
30 GB 2093061A also describes, for comparative purposes, a two-stage calcination process in which a green coke having a sulfur content of 4.4 wt % and a volatiles content of 10.5 wt % is calcined for 1 hour at 650°C and then for a further hour at 1400°C. The final calcinate

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has a sulfur content of 1.9 wt % (i.e. a sulfur loss of 56.8 wt %) and in addition a low bulk density (vibrated bulk density, VBD), the latter being indicative of a calcinate of poor particle strength. The inventors of the present invention have established that a high

5 quality calcined coke, that is to say, a calcined coke of relatively high particle strength and low friability, can be obtained from a green coke only when the calcination process is conducted in such a manner that the sulfur content of the green coke is not significantly diminished, e.g. diminished by not more than 10 weight %, preferably

10 by not more than 5 weight %, more preferably by not more than 3.5 weight %, and most preferably by 3.0 weight % or less. Although the reasons for this are by no means fully understood, it is hypothesized that the conditions which lead to a significant loss of sulfur also produce minute pores and fractures in the coke particles and thereby

15 adversely affect their strength and friability. Factors which are thought to cause a reduction in the sulfur content of the coke particles include the following: (i) an excessively high rate of heating of the green coke; (ii) an excessive loss of the volatile content of the green coke during the initial devolatilization thereof; and

20 (iii) exposure of the coke to desulfurizing conditions for a time sufficient to cause significant desulfurization. Factors (i) and (ii) depend on the time and temperature during which the initial devolatilization of the green coke is effected. According to the present invention, the maximum bulk coke temperature in the first

25 stage is 850°C, the average coke-heating rate is no more than 100°C/minute and the amount of devolatilization in the first stage is in the range from 50 to 90 weight % of the total volatile material in the green coke. With regard to factor (iii), the maximum bulk coke temperature in the second stage is no more than 1470°C. Tem-

30 peratures in excess of 1470°C are found to have an adverse effect on the particle size and friability of the calcined coke product, particularly when the coke has a bulk temperature above 1470°C for sufficient time for sulfur to be lost.

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In the practice of the process of the present invention, the bulk temperature of the coke in the final calcination stage is in the range of from 1350 to 1470°C, and as a generality, it is found that good quality calcined coke is obtained when the time during which the coke
5 is subjected to the final calcination stage is longer at bulk temperatures towards the lower end of the range 1350 to 1470°C and shorter at bulk temperatures towards the upper end of the range.

U.K. Patent Application GB 2016512A, which is the U.K. counterpart of the above-quoted U.S. Patent 4160814, describes and claims
10 a two-stage calcination process starting from green cokes of high sulfur content (about 4 wt % S) in which the first-stage calcination

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is performed in a rotary kiln to heat the coke to temperatures of from 490 to 850°C and the second-stage calcination is performed in a rotary kiln to heat the coke to temperatures in excess of 1500°C and to remove a major proportion of the remaining sulfur. Although
5 the process as described purports to achieve its objective of achieving a low sulfur calcinate (about 0.5 wt % S), the high temperature of the coke in the second calcination stage causes a loss of sulfur from the coke and a corresponding reduction in its particle strength.

10 U.K. Patent Application GB 2078775A describes and claims a process for producing calcined petroleum coke having a sulfur content in the range of 1.8 to 2.5 wt % and a vibrated bulk density of at least 78 g/100 cc from raw petroleum coke having a sulfur content of at least 3.5 wt % and a volatile content of at
15 least 7 wt % which comprises:

(a) heating the coke at a temperature in the range of 600°C to 800°C in the absence of added hydrogen for a time sufficient to reduce the volatile content of the coke to a value in a range of 3 to 6 wt %.

20 (b) heating the partially devolatilized coke at a temperature in the range of 600°C to 800°C in an atmosphere containing added hydrogen for a period of time sufficient to reduce the sulfur content of said coke to a level in the range of 2.8 to 3.3 wt %; and

(c) heating the partially desulfurized coke at a temperature
25 in the range of 1350°C to 1600°C in the absence of added hydrogen for a period of time sufficient to reduce the sulfur content of the coke to within the range of 1.8 to 2.5 wt %.

This process is similar to that of GB 2016512A except that between the first and last calcination stages, there is interposed
30 a hydrogen-desulfurization step. The high loss of sulfur content

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during the process results in a coke calcinate of low particle strength. Moreover, the use of hydrogen in the additional step adds greatly to the operating cost and is reflected in the cost of the calcined coke product. GB 2078775A also describes, for comparison, 5 other staged calcinations of high sulfur coke, e.g. at 700°C for 1 hour in the first stage and 1500°C for 25 minutes in the second stage. It is not clear whether hydrogen is employed to desulfurize the coke in either of the stages, but the high temperature in the second stage undoubtedly reduces the particle strength of the calcinate product, as reflected in its excessively high loss of sulfur 10 content (50 wt %). GB 2078775A further describes other two-stage calcination processes which start from green coke having a sulfur content of 4.8 wt % and finish with a calcinate having a sulfur content of 1.9 wt % (60.4 wt % loss of sulfur) and other properties 15 which also are indicative of a calcined coke of low particle strength and high friability.

U.K. Patent Specification No. 1219322 and corresponding U.S. 3448012 describe and claim a rotary hearth furnace or oven comprising a heated chamber, hearth located in the chamber, a 20 material outlet at the centre of the hearth, means for delivering material to the hearth adjacent the outer periphery thereof to form a bed of material on the hearth, spaced rabblies disposed above the hearth and disposed to move material on the hearth progressively inwardly toward the material outlet upon relative 25 movement between the hearth and rabblies, at least one partition means dividing the chamber into at least one inner zone and at least one outer zone, the partition means having upper and lower edges, the upper edge of the partition means being connected to the wall enclosing the chamber so as to form a seal substantially

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impervious to gases and mechanically fixed to the chamber wall,
the partition means extending downwardly toward the hearth and
terminating in a lower edge substantially parallel to and disposed
close to the top of the bed, to form a substantially gas-tight seal
5 at the lower edge, and wherein an exhaust exit for gases is provided
from at least one inner zone, and conduit means connects the exhaust
means to an inlet in at least one outer zone so that exhaust gases
from the inner zone or gases heated by the exhaust gases flow through
at least a portion of the outer zone, whereby material on the hearth
10 moves progressively inwardly passing substantially under the partition
means and whereby only minor flow of gases between the inner and outer
chambers occurs between the top of the bed and the lower edge of the
partition means.

The purpose of the partition means is to divide the interior
15 of the furnace into zones of different temperatures and to provide a
seal preventing the passage of gas from one zone to the other zone.
In the preferred embodiment, the outer zone is heated by hot flue gas
derived from the combustion of fuel and volatiles evolved from the
coke in the inner zone. U.K. 1219322 states (page 2, lines 94 to
20 102):

"The temperatures within the zones may be controlled by the auto-
genous process of reducing volatiles and oxidizing them within
each of the zones at a rate sufficient to give the temperature
desired in each particular zone. Alternatively, burners or cooling
25 means such as cold air blowers can be provided to control the
temperatures within the various zones", and there is further
reference to the use of respective burners in the inner and outer
zones at page 4, lines 28 to 30.

However, it is clearly apparent from page 4, lines 43 to 62,
30 that the outer of the two chambers is solely for the purpose of
drying green coke at temperatures below 500°F (260°C) to avoid de-
volatilization of the coke therein, the latter step being effected in

the inner chamber at a temperature of e.g. above 2000°F (1093°C). This is quite different to the purpose and operation of the rotary hearth furnace of the invention wherein the raw coke is dried and devolatilized within the specified limits in the outer zone, and
5 subjected to a final calcination within the inner zone. These differences are reflected in the construction of the furnace of the invention.

Another aspect of the furnace of the present invention which is not described or suggested in U.K. 1219322 is that the bottom
10 of the radiation shield forms a complete circle or annulus with no gaps in it, whereas in U.K. 1219322, the partition or curtain wall 62 is formed with a gap, notch or wicket 68 or is in the form of a number of arcs with gaps between their adjacent pairs of ends, whereby coke is caused to pass from the outer to the inner chamber
15 substantially solely through the gap or gaps. Thus, the area of the gap(s) limits the throughput of coke through the furnace. By contrast, the arrangement in the furnace of the present invention is such that coke passes from the outer zone to the inner calcining zone via the gap between the radiation shield and the hearth without
20 the capacity of the furnace being limited by the presence of the radiation shield.

In one embodiment of the present invention, the roof of the outer zone slopes inwardly and downwardly to the base of the annular radiation shield, the latter bounding the sides of a high
25 temperature region above the inner zone whereby, during operation, substantially no radiant heat can be directly received in the outer zone from the high temperature region.

Preferably, the high temperature region has a roof which is shaped to reflect radiant heat downwards towards the hearth of the
30 inner zone so as to heat coke on the hearth in the inner zone at least partly by radiation.

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The said volatiles-containing green coke contains less than 14 wt % of volatile material, preferably less than 10 wt %, still more preferably less than 8.5 wt %. In preferred embodiments, the volatiles content is in the range of from 5 to 8 wt %, e.g. about 5 7 wt. %.

With reference to the process aspects of the present invention, it is preferred that the first heating stage and the subsequent calcining step are effected in a single furnace. Preferably, the single furnace is a rotary hearth furnace.

10 Preferably, the coke recovered from the calcining step is maintained at an average temperature of at least 1275°C for at least 10 minutes and more preferably for a period of from 15 to 30 minutes. This period of temperature maintenance or heat-soaking improves the quality of the coke product from the point of view of its residual 15 hydrogen and other volatiles content and in other ways.

The particle size of the green coke feed may be nominally up to 100 mms, which in practice would include a proportion (e.g. up to 15%) of particles of size up to 150 mms. Preferably, however, the particle size of the green coke is a nominal 50 mms maximum, and in practice, 20 this will usually provide a feed having a small proportion (e.g. up to 15%) of particles having somewhat larger sizes (e.g. up to 80 mms maximum, as a general, but not rigid, rule).

Preferably, the bulk temperature of the coke passing from the first heating stage to the calcining step is in the range of from 25 730 to 780°C, e.g. from 740 to 760°C.

The average temperature of the atmosphere in the first heating stage is preferably regulated to be in the range of from 800 to 900°C, more preferably 830 to 870°C, and the average residence time of coke material in the first stage may be in the range of from 0.2 30 to 2.0 hours, preferably from 0.25 to 1.5 hours, e.g. from 0.3 to 1.0 hours. The most preferred residence or hold-up time in the first heating stage will depend on temperature and throughput. For a temperature of about 850°C, the residence time may vary from 0.5 hours at high throughputs to 1 hour at low throughputs.

The temperatures and residence times in the first heating stage are selected to heat the coke at a rate not exceeding 100°C per minute, more preferably at a rate up to 60°C/minute, e.g. in the range 35 to 45°C/minute and to expel or remove from the green coke
5 feed from 50 to 90 weight % of its volatile matter content in the first heating stage. Preferably, the volatile matter loss in the first heating stage is in the range 55 to 85 wt %, more preferably from 60 to 80 wt % and most preferably from 65 to 75 wt %.

An important result of the process of the invention is that
10 the sulfur content of the calcined coke product is hardly different to that of the raw coke feed. The maintenance of the sulfur content at approximately a constant level has been found to impart a high degree of stability and hardness to the calcined coke so that it meets the quality specifications for higher and premium quality
15 calcined cokes. There is some sulfur loss during the conversion of the green coke to calcined coke, but the sulfur loss is preferably less than 8 wt % of the weight of sulfur in the green coke, more preferably less than 4 wt % loss, and still more preferably less than 2.5 wt % loss. Such beneficial low losses of the sulfur
20 of the original green coke result from the temperatures and residence times in the two heating stages of the process of the invention, and it is believed that the greater part of any sulfur loss occurs in the second heating stage and therefore careful control of the maximum temperatures to which the coke is exposed in the second
25 heating stage is important. In the practice of the present invention for the production of the calcined cokes of the higher and premium grades for use in the manufacturing of electrodes used in electric arc furnaces for steel production, the sulfur content of the green coke should be no more than 1.33 weight % (based on the weight of
30 dry coke) and is preferably no more than 1.0 wt %, more preferably less than 0.85 wt %. For most purposes, a commercially-acceptable calcinate can be made economically by the process of the present

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invention starting from a green coke having a sulfur content of 0.2 wt % or more, e.g. 0.4 wt % sulfur, such as 0.5 wt % sulfur (or more), based on the dry weight of the green coke.

In the calcining stage, the coke is heated to a temperature in the range of from 1350 to 1470°C, preferably 1400 to 1460°C, more preferably from 1415 to 1445°C in order to convert the partially devolatilized coke from the first heating stage into a hard calcined coke product having a very low residual content of volatilizable material (e.g. not more than 0.05 wt % hydrogen, preferably not more than 0.035 wt % hydrogen, most preferably 0.030 wt %, or less, of hydrogen). The average residence time of the coke in the calcining stage is at least 10 minutes and may be as high as 2 hours (depending on the temperature in the calcining stage and the rate of coke throughput), and is preferably in the range of from 0.3 to 1.5 hours, e.g. 0.5 to 1.2 hours. In many instances, an average residence or hold-up time of from 30 to 60 minutes will usually be adequate to calcine the coke. Careful control of the temperature of the atmosphere to which the coke is exposed in the calcining stage is important to ensure that the coke is not subjected to excessively high temperatures. The inventors believe that temperatures of the coke above 1470, e.g. 1490°C, rapidly cause adverse changes in the factors which lead to low particle density and thus to low particle strength, and that optimum particle properties are obtained in the temperature range 1350 to 1470°C, with more preferred ranges as stated hereinabove. The temperature of the atmosphere to which the coke is exposed is preferably in the range of from 1380 to 1565°C, and depends on the efficiency of heat transfer to the coke by radiation and convection and also on the residence time. For most applications, the temperature of the atmosphere may be in the range 1480 to 1560°C, more preferably from 1490 to 1555°C. At high coke throughputs (i.e. at, or approximating to the design throughput of the apparatus for performing the process of the invention), temperatures towards the higher end of the temperature range are preferred, and at lower coke throughputs, correspondingly lower temperatures will give calcined coke of high or premium quality.

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The calcined coke from the calcining step is recovered in a so-called heat-soaking pit where it is "aged" at high temperatures in order to provide a further period during which the calcined coke can assume the properties associated with higher and premium quality cokes, in particular, a very low content of volatile materials, preferably a high real density (e.g. in the range 2.10 to 2.18, preferably 2.12 to 2.15), and a range of size distribution of particles including relatively coarse particles (e.g. 30 to 50 mm), which particles are hard and relatively non-friable. The calcined coke may be retained in the heat-soaking pit for an average time of from 10 to 40 minutes, preferably from 15 to 30 minutes, at average temperatures which may be in the range of from 1200 to 1470°C, preferably from 1300 to 1450°C.

No heat is added to the coke in the heat-soaking pit except by the addition of freshly-calcined coke from the calcining stage. Aged or heat-soaked coke is removed from the pit and then cooled in any convenient manner, as will be known to those acquainted with the manufacture of calcined coke.

With reference to the apparatus aspects of the present invention, the rotary hearth furnace is provided with burners to maintain the desired respective temperatures in the pre-heating and calcining zones. Associated with the burners for each zone are preferably provided means for regulating the rate of supply of fuel. There may be means responsive to the temperature, or a representative temperature, of each zone to regulate the rate of supply of fuel to the burners. The representative temperature may be, for example, the temperature of flue gas leaving the respective zone or zones.

The furnace preferably is provided with a vessel defining a heat-soaking pit, serving as the said coke-recovery means, to provide a residence period or hold-up time within the range of 10 to 40 minutes, e.g. 10 to 30 minutes, preferably from 15 to 30 minutes. The heat-soaking pit may have discharge means for the discharge of coke from the heat-soaking pit at the end of the residence period. The heat-soaking pit may be of refractory lined steel, and may be integral with the hearth so that it rotates with the heart. A heat-soaking pit which is integral with the hearth of a rotary calcining furnace is described and illustrated in U.K. Patent Specification 1219322 and its counterpart, U.S. Patent 3448012.

The radiation shield of the furnace preferably has no circumferential gap therein. Such a gap, or gaps, is or are provided in the curtain wall of U.K. 1219322 and U.S. 3448012 and constitutes the sole means for the passage of coke from the outer zone, outwardly of the curtain wall, to the inner zone (as is apparent from e.g. Fig. 3 of those patent documents). By contrast, in the furnace of the present invention, all the coke passes from the pre-heating zone to the calcining zone by passing through the vertical gap between the bottom of the radiation shield and the hearth. This permits higher throughputs with reduced attrition of the coke.

Preferably the vertical gap between the bottom of the radiation shield and the hearth has dimensions in the range of from 50 to 100 cms, more preferably from 60 to 90 cms. A gap of these ranges of dimensions is sufficiently small to substantially prevent significant amounts of heat from the calcining zone passing by direct radiation and also by convection into the pre-heating zone, but is sufficiently large to enable access for operatives between the zones for maintenance, inspection and repair. However, it is to be

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appreciated that a range of smaller dimensions would be suitable where it is considered that access through the gap is of no importance. In this instance, the vertical extent of the gap may be in the range of from 40 to 60 cms.

5 In preferred embodiments, the furnace may have a single flue exit in the high temperature zone for the discharge of flue gas from both the preheating zone and the high temperature zone, and the gap between the hearth and the baffle is preferably sufficiently great to permit the passage of flue gas, as well as coke, from the preheating zone
10 to the high temperature zone. However, the preheating zone may, alternatively or in addition, have its own flue for the discharge of flue gases generated in the preheating zone. In the latter instance, the vertical gap between the bottom of the radiation shield or baffle and the hearth may be in the range of from 15 to 45 cms, e.g. from
15 20 to 40 cms which may or will permit the passage of at least some flue gas through the gap from the preheating zone to the central calcining zone.

 In a preferred embodiment of the furnace of the invention, the roof of the pre-heating zone slopes inwardly and downwardly
20 to the base of the annular baffle, the annular baffle bounding the sides of a high temperature region above the hearth of the calcining zone and substantially preventing the receipt in the preheating zone of radiant heat directly from the high temperature zone. In this preferred type of embodiment the high temperature zone is located
25 generally above the average height of the pre-heating zone, and fuel is burned therein to produce temperatures of, preferably, from 1400 to 1600°C, e.g. from 1475 to 1575°C (these temperature ranges would be typical, in most instances, of the temperature ranges with most other configurations of the furnace of the invention, generally speaking).
30 Heat is radiated down to the hearth of the calcining zone directly from the flames of burning fuel and by radiation from the walls and roof of the calcining zone.

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DETAILED DESCRIPTION OF THE DRAWINGS

The invention will now be further described with reference to non-limitative examples thereof and with reference to the accompanying drawings. The drawings show the principal features necessary
5 for an understanding of the invention by those skilled in the art without depicting every detail involved which will be known or obvious to those skilled in the art. The drawings are not intended to be to any particular scale but are to illustrate the general nature of non-limitative embodiments of the invention.

10 Figure 1 is a cross-sectional elevation of one type of rotary hearth coke-calcining furnace;

Figure 2 is a cross-sectional elevation of another type of rotary hearth furnace according to the invention;

Figure 3 is a cross-sectional elevation of yet another type of rotary hearth furnace according to the invention;

Figure 4 is a cross-sectional elevation of a further type of rotary hearth furnace according to the invention.

5 Figure 5 is a cross-sectional elevational view of another rotary hearth furnace according to the invention;

Figure 6 is a cross-sectional plan view of a rotary hearth furnace similar to that shown in Figure 5 showing the hearth, the arrangement of rabbles and other features;

10 Figure 7 is a cross sectional elevation of part of the furnace of Figure 6.

The same reference numeral is used to denote the same or similar features in all of the Figures of the drawings.

In the embodiment of Figure 1, the furnace 10 comprises a
15 rotary table or hearth 11 which inclines downwardly towards a hole at its centre. Beneath the hole is a soaking pit 12 which receives coke material which falls from the hearth 11 and from which calcined coke material may be recovered, as indicated by arrow 23. Above the hearth is a stationary roof member 13. The outer rim of the
20 roof member 13 has a downwardly-extending lateral wall 14 which is sealed (e.g. by means of water seals or sand seals of known type, indicated by reference numeral 14a) against a lateral wall 15 which extends upwardly from the rim of the hearth 11. The hearth 11 is supported on, and rotated by, suitable wheels 16 and/or other
25 means known in the art, such as a rack and pinion driven by an electric motor (not shown). A hole 17 is provided in the roof member 13 for the discharge of flue gas from the interior of the furnace to a flue gas exhaust duct 18. An annular baffle 19 extends downwardly from the roof 13 to define the outer boundary of a central
30 high temperature combustion chamber 20. The bottom of the baffle 19

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is spaced from the upper side of the hearth 11 by sufficient distance (e.g. about 50 cms) to permit the passage of coke and flue gas under the baffle 19 from the radially outer regions of the hearth to the hole at the centre of the hearth while substantially preventing radiation and hot gases from the combustion chamber 20 affecting the region radially outwards of the baffle 19. If it is desired to provide access through the gap between the bottom of the baffle 19 and the upper side of the hearth 11 for maintenance, inspection and/or repair, the dimensions of the gap may be about 80 cms. A conduit 320 supplies raw petroleum coke (e.g. from a delayed coker) to an outer region of the hearth. The green coke is selected to have a volatile matter content not exceeding 14 weight % and, for the production of a higher or premium grade coke calcinate, a sulfur content not exceeding 1.33 wt % (based on the dry weight of coke). Preferably the coke selected has a volatile matter content of about 7 wt % and, for the production of a higher or premium grade calcinate, a sulfur content of about up to 1.0 wt % (e.g. about 0.6 wt %) based on the dry weight of coke. Preferably rabbles 24 which depend from the roof 13 are provided to cause coke deposited on the hearth at the outer rim to execute an inward spiralling movement towards the central hole in the hearth. Preferably other rabbles (not shown) are provided to turn over the coke layer so as to expose substantially all the coke in the coke layer to the atmosphere above the coke layer. The average thickness of the coke layer is preferably maintained at about 15 to 40 cms, preferably from 20 to 30 cms, e.g. about 25 cms.

Rabbles for propelling the coke particles along a helical path towards the central hole in the hearth and for turning over the coke in the coke layer are well-known. Such rabbles and their arrangements are described in detail in U.S. 3859172; U.K. 1272880 (and corresponding U.S. 3652404); U.K. 1345845 (and U.S. 3470184) and U.K. 1440833 (and U.S. 3,788,800); and will

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not therefore be further described herein. Fuel gas and air are supplied from respective manifolds 25 to burners 26 for combustion at a regulated rate in the annular space 21 between the outer face of the baffle 19 and the inner faces of the lateral walls 14, 15 to
5 maintain a temperature therein in the range of from 650 to 850°C, preferably from 700 to 800°C, more preferably about 750°C so that the raw coke is preheated, while passing via space 21, at a bulk heating rate preferably of up to 100°C/minute, more preferably up to 60°C/minute (e.g. most preferably at about 40°C per minute). The coke may
10 have a residence time in space 21 of from 0.25 to 1.5 hours, preferably 0.3 to 1.3 hours (e.g. 0.4 to 1.25 hours), and passes under the baffle 19 at a bulk temperature which may be in the range of from 600 to 850°C, preferably 700 to 850°C, e.g. about 750°C, when initially exposed to the conditions of the high temperature combustion
15 chamber 20. In the preferred embodiments described herein, the annular preheating space or zone 21 has no separate flue for the discharge of flue gas or combustion gas therefrom, and the gap between the bottom of the baffle and the hearth is about 80 cms to permit the passage of coke and flue gas from the preheating zone 21 to the
20 calcining zone, but substantially preventing coke in the preheating zone 21 receiving heat from the calcining zone. The chamber 20 has burners 27 extending downwardly through the roof 13 which are supplied with suitably regulated amounts of air and fuel to maintain a temperature of at least 1375°C, preferably 1450 to 1560°C, e.g. about 1500 to
25 1550°C in the chamber 20. The turning and propelling action of the rabbles 24 ensures that coke is exposed to the radiation and other high temperature effects from the chamber 20 so that the volatile-matter-content of the coke is reduced to very low levels. The coke on the hearth beneath combustion chamber 20 is heated to, and maintained
30 at, about 1470°C by the combustion and radiation effects and thereby

calcined. Calcined coke, at a temperature of about 1460 to 1480°C (e.g. about 1470°C) is received in the soaking pit 12 from where the last residues of labile volatile material may escape. The calcined coke is heat-soaked in the soaking pit at an average temperature of
5 about 1400°C for an average time of about 20 minutes. The calcined coke ("calciate") withdrawn via line 23 from the soaking pit 12 has a very low content of residual volatile material (e.g. 0.01 to 0.03 wt % hydrogen), a good size distribution and high size stability which meet the standards for the higher and premium grades of calcined coke (e.g.
10 needle coke).

Preferably, the operating conditions in the annular space 21 are such that no more than 90 wt %, but preferably at least 50 wt % (more preferably 55 to 85 wt %, e.g. 60 to 80% and most preferably about 70 wt %) of the volatile material content of the green coke feed is removed in the first heating stage which is constituted by the preheat section in space 21, the remainder being removed in the subsequent heating stage constituted by the section including the high temperature combustion chamber 20, and a small amount in addition escaping during the heat-soak in the heat-soaking pit 12.

As shown in Figure 1, air may be passed into the flue gas leaving the combustion chamber 20 from line 28 in order to combust any combustible materials remaining in the flue gas.

The manner of construction of the furnace of Figure 1 may take any convenient form suitable to accommodate its duties. In preferred embodiments, the hearth may be of refractory material supported on structural steel members as shown in any of the patent documents hereinabove quoted, e.g. similar to the hearth of U.K. 1055857; U.K. 1219322 (and counterpart U.S. 3448012), inter alia. There may be a mild steel "floor" of thin (e.g. 2 to 4 mm) steel sheet between the structural steel members and the refractory hearth for greater structural stability of the refractory hearth. The rotation of the hearth is effected by the engagement of a pinion driven by an electric motor attached to the structure steel-work to a circular rack attached to the underside of the hearth. The pinion, electric motor and rack are not shown because they are conventional in this art and are well-known to practitioners, as will be noted from U.K. 1219322, page 3, lines 1 to 4. The mode of construction of other parts of the furnace of the invention may also be similar to the corresponding parts, where they are present, in the herein quoted patent documents. The heat soak pit is preferably integral with the hearth so that it rotates therewith about the central vertical axis of the hearth. However, it may alternatively be separate from the hearth and non-rotatory, e.g. in the type of manner described and shown in U.K. 1345106 and counterpart U.S. 3763011.

The hearth slopes towards the central hole at a relatively small angle to the horizontal which is preferably well below the angle of repose of the coke. The angle may be from 8 to 12°, e.g. about 10°.

5 Reference is now made to Figure 2 which is largely the same as Figure 1 except for the arrangement of the roof and annular baffle. Items which are common to Figures 1 and 2 have the same reference numerals. In the interests of clarity of illustration, the rabbles 24 have not been depicted in full. As will be seen,
10 the fixed roof 113 is circular and slopes downwardly and inwardly towards a central aperture 114 in much the same way as the rotary hearth 11 slopes towards the central hole at its juncture with the soaking pit 12. The roof 113 and hearth 11 may be downwardly inclined at the same or slightly different angles. Preferably, the
15 angles are the same, and they may be from 8° to 12°, e.g. about 10°. An annular baffle 119 extends upwardly from the edge of the aperture 114 to form the lateral boundary of a high temperature combustion section 120, the top of which is closed by a cap member 121 having a central hole 17 for the escape of flue gas to the flue duct 18.

20 Fuel gas and air are supplied at regulated rates to the spaces 21 and 120 from respective feed lines 26 and 27 to respective burners in amounts sufficient to maintain the temperatures of the spaces 21, 120 within the ranges suitable to heat the coke to the preferred temperatures (as herein specified) in each part of the furnace, e.g.
25 800 to 900°C and 1380 to 1565°C respectively. It will be appreciated that the configuration of the furnace of Figure 2 is such that coke in the preheat section 21 is shielded from radiation and other high temperature effects from the combustion chamber 120 until it approaches the notional downward geometric projection of the baffle 119.

30 In order to enhance the shielding of coke in the pre-heat section 21 from radiation and other high temperature effects from the combustion chamber 120, there may be provided a downwardly-extending annular baffle 122 (shown in broken lines) of refractory material reducing the gap for the passage of coke and gases between

the preheat section 21 and the high temperature section 120. The gap between the bottom of the baffle 122 and the hearth 11 may be about 80 cms if it is desired to provide access for maintenance, inspection and/or repair operatives to pass between the sections 21
5 and 120. On the other hand, if no such access is required, the baffle 122 may extend downwardly nearer to the hearth 11 to form a gap of about 15 to 25 cms, which, during operation, will be approximately the depth of the layer of coke on the hearth 11. In Figure 2, the gap depicted is the wider gap of about 80 cms.

10 The absolute and relative amounts of volatilizable material removed in the preheat section 21 and the high temperature section are arranged to be about the same for the Figure 2 embodiment as for the Figure 1 embodiment by expedients which will be readily apparent to those skilled in the art.

15 Reference is now made to Figure 3 of the drawings. It will be seen that Figure 3 is largely similar to that of Figure 1 except that the rotary hearth 211 of Figure 3 is substantially flat (instead of downwardly sloping towards the central hole as in Figure 1). The passage of coke across the rotating hearth 211 from the outer region
20 where the coke enters the furnace from the feed duct 320 to the central hole above the soaking pit 12 is promoted by the rabbles 24. Additional rabbles (not shown) are preferably furnished to turn over the coke layer so that all the coke in the coke layer is exposed to the conditions in the furnace.

25 With reference to Figure 4, it will be seen that the furnace which is depicted is largely similar to that of Figure 2, except that the rotary hearth 311 is substantially flat and resembles the hearth 211 of Figure 3 in this respect. The embodiment of Figure 4 also depicts, in broken lines, the optional additional refractory
30 baffle 122, previously described with reference to Figure 2, to reduce the gap at the juncture of the inner and outer chambers in order to further reduce the amounts of radiation and hot gases which

can pass from the inner section to the outer section. As previously explained, the gap between the bottom of the baffle 122 and the hearth may be (as shown in Figure 4) adequate for operatives to pass between the sections for inspection, maintenance and/or
5 repair (a gap of about 80 cms would be provided in this instance) or where no such access is designed for, the gap may be just sufficient for the passage therethrough of coke and flue gas from the preheat zone 21 to the high temperature zone, in which case a gap of about 60 cms or slightly less (e.g. 45 to 55 cms) may be adequate. As in
10 the Figure 3 embodiment, rabbles 24 are provided to promote the passage of coke across the hearth from the outer region to the central hole, and preferably, additional rabbles (not shown) e.g. of the types described for this purpose in U.K. 1272880 and U.S. 3652404, U.K. 1345845 and U.S. 3740184, U.K. 1440833 and U.S. 3788800, inter
15 alia, are provided to turn over the coke layer in order to expose all the coke to the conditions in the combustion chamber, to reduce the rate of heating of coke by reducing the time during which each coke particle is exposed directly to the high temperature conditions in the combustion chamber, and to heat coke particles in the coke
20 layer by conduction from hotter particles of coke. It will be appreciated that the foregoing all tend to make the temperatures of the coke particles in the bed relatively uniform at each location and to avoid major changes in the temperature of each coke particle on passing from one location on the hearth to another location thereon.
25 As depicted, the soaking pit 312 is frusto-conical and downwardly tapering and differs in this respect from the cylindrical soaking pits illustrated in Figures 1 to 3. The roof 221 of the central high temperature combustion chamber 120 is similar to the roof 121 of the furnace of Figure 2 except that the flue opening 217 and the flue
30 duct 218 are eccentrically located with respect to the vertical axis

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of the chamber 120 whereas in Figure 2 they are concentric with respect to the vertical axis of the chamber 120.

Reference is now made to the embodiment illustrated in Figure 5. The furnace of Figure 5 is generally similar to that of Figure 4,
5 and also similar to that of Figure 2, but is different in the following respects: the hearth 411 beneath the downsloping annular roof 113 (i.e. the radially-outer part of the hearth in the pre-heating section 12) is substantially horizontal, so that the vertical distance between the roof 113 and the outer part of the hearth

progressively diminishes when passing radially inwardly from the periphery thereof to the radially inner part of the roof 113 where the latter joins the annular baffle 119 which extends upwardly from the inner edge of the roof 113 to form the peripheral or lateral
5 boundary of the high temperature combustion section 120. Radially inwardly from the positions beneath the inner part of the roof 113, the hearth 411 slopes downwardly and inwardly towards the central hole forming the entrance to the heat-soaking pit 312. The angle of downward inclination of the inner part of the hearth is less
10 than the angle of repose of coke, and may be from 8 to 12°, suitably about 10°. Rabblers (not shown) are provided to cause coke deposited from the green coke feed pipe 312 on the outer horizontal part of the hearth 411 to pass along a generally helically-inward path across the hearth 411 and into the heat
15 soaking pit 312. The rabblers may be of the type already adverted to, and previously described in the herein-cited documents. In addition to the rabblers for causing coke to pass from the peripheral regions of the hearth 411 to the hole in the radially inner part of the hearth at the entrance to the heat soaking pit 312, other
20 rabblers (not shown) are provided to effect a raking-over action on the coke in order that coke particles which are initially at the bottom of the coke layer on the hearth 411 are exposed to the heating conditions in the furnace, so that all the coke fed to the furnace is exposed to the pre-heating conditions in the pre-heating
25 section 21 and thereafter to the calcining conditions when passing along the hearth beneath the high temperature combustion section. It will be understood that rabblers for raking over, and thereby exposing all the coke in this manner, are preferably provided in all the other embodiments of the furnace of this invention.

30 From Figure 5, a means for regulating the discharge of coke from the heat soaking pit 312 will be apparent. In broad terms, the said means comprises a delivery table 350 mounted for rotation about the central axis of the furnace on a mounting system 351.

Coke from the discharge hole 352 of the heat-soaking pit 312 is received on the rotating delivery table 350 and delivered to exit conduit 353 so as to discharge to a coke cooling unit (not shown) as indicated by arrow 23. Suitable rabbles (not shown)
5 of any of the types well-known in the art for the purpose may be provided to assist the discharge of coke from the discharge hole 352 to the exit conduit 353.

Figure 6 shows in plan view some of the features of a furnace largely similar to that of Figure 5, including a hearth 411 having
10 a central discharge hole to the heat-soaking pit 312 and three sets of rabbles 24 arranged about 120° apart. The sets of rabbles are each generally indicated by reference 124 in Figure 6.

Figure 7, in the side elevation taken on line A-A of Figure 6, shows the outer flat part of the hearth 411 and the downsloping
15 roof 113. It will be seen that the roof slopes downwardly and inwardly at a relatively shallow angle (e.g. about 11°) from the periphery of the furnace, and then from the locus (i.e. the circle) of point 113a, slopes downwardly and inwardly at a greater angle (e.g. about 30°, on average) as far as locus 113b, whereafter the
20 roof is horizontal until locus 113c where it joins the lower end of the baffle 119 which bounds the high temperature section 120.

It is to be appreciated that features and/or items of equipment which are illustrated in connection with one embodiment may be employed in feasible and practical combinations with features
25 and/or items of equipment shown in connection with other embodiments. Moreover, although the embodiments described each have a single uninterrupted annular baffle to separate the higher and lower temperature zones, it is contemplated that more than one baffle may be provided so as to separate the interior of the furnace into more than
30 two heating stages.

By the practice of the invention, it is surprisingly found that a calcined coke of high particle strength can be obtained in equipment which operates or can be operated so as to subject the coke to relatively rapid heat-up rates.

- 5 The following comparative simulations illustrate the benefits afforded by the practice of the invention.

Test 1

- 10 A sample of a typical green petroleum coke having a volatile matter content of less than 14 wt % and a sulfur content below 1.33 wt % (based on dry green coke) at room temperature was exposed in a kiln to a temperature of about 1000°C for about 20 minutes to simulate the conditions in a conventional rotary hearth furnace. After 20 minutes, the sample had attained a temperature of about 1000°C. It was removed from the kiln and the particles of calcined coke
15 were found to be severely cracked and highly friable.

Test 2

- 20 Test 1 was repeated with another sample of the same green coke but with the kiln temperature at about 1100°C. The calcined coke was found to be somewhat inferior in quality to the calcined coke product of Test 1.

Tests 3 and 4

- 25 Samples of the same green coke used in test 1 were exposed in a series of different test runs first to a relatively lower temperature in a first heating stage and cooled to room temperature (about 20°C) before being exposed to a temperature of about 1100°C in a second heating stage. In each heating stage, the sample was exposed for sufficiently long to attain approximately the temperature to which it was exposed. The results are given in Table 1.

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TABLE I

<u>Run No.</u>	<u>Stage No.1 Temperature °C</u>	<u>Product Quality</u>	<u>Stage No.2 Temperature °C</u>	<u>Product Quality</u>
1	900	Friable	1100	High friability
2	800	Hard	1100	Low friability
5 3	700	Hard	1100	Low friability
4	600	Hard	1100	Increased "

Runs 2 and 3 simulate the process of the invention, particularly in the treatment of the coke in what is considered to be the critical period immediately up to the exposure of the coke to the high temperatures of stage 2. Heretofore, there have been considerable problems in converting a raw petroleum coke to a hard, low friable calcined coke. The process and apparatus of the present invention enable hard coke of low friability to be produced consistently and in a relatively simple manner. Those skilled in the art will appreciate that the low-friability calcined cokes of runs 2 and 3 will not meet quality specifications for premium grade coke because the final calcination temperature is too low. The inventors have confirmed that calcination for a time in the range of from 10 minutes to 2 hours at a temperature in the range of from 1350 to 1470°C of a coke which immediately previously has been heated to a temperature in the range of from 650 to 850°C gives a coke of premium quality with a hard crystalline structure of low friability suitable for use in the manufacture of ultra high-power electrodes for electric arc furnaces.

CLAIMS:

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1. A process for the production of high quality calcined petroleum coke from green coke, comprising the steps of:

5 (a) feeding green coke having a volatile matter content not exceeding 14 weight % (based on the dry weight of the green coke) into a first heating stage;

10 (b) exposing the green coke in the first heating stage to a heated environment maintained substantially solely by the combustion of fuel and any volatile matter released from the coke with a combustion-supporting gas at a regulated rate and in the absence of added hydrogen to give a coke-heating rate not exceeding 100°C/minute until from 50 to 90 weight % of the volatile matter content of the green coke is removed and the bulk temperature of the coke is in the range of from 650 to 850°C;

15 (c) causing the heated coke produced by step (b) to pass to a subsequent calcining step at a bulk temperature in the range of from 650 to 850°C without any intermediate treating or cooling step;

20 (d) exposing the heated coke in the subsequent calcining step to a heated environment sustained solely by burning fuel and combustible matter released from the coke with a combustion-supporting gas so as to raise and maintain the temperature of the coke to a bulk temperature in the range of from 1350 to 1470°C for an average time period of at least 10 minutes; and

25 (e) recovering high quality coke from the subsequent calcining step (d).

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2. A process as in claim 1 in which the first heating stage and the subsequent calcining step are effected in a single furnace.

3. A process as in claim 1 or in claim 2 in which the said single furnace is a rotary hearth furnace.

4. A process as in any one of claims 1 to 3 in which the coke recovered in step (e) is maintained at a temperature of at least 1275°C for at least 10 minutes.

5. A process as in any one of claims 1 to 4 in which the particle size of the green coke feed in step (a) is nominally up to 100 mm, preferably up to 50 mm.

6. A process as in any one of claims 1 to 5 in which the bulk temperature of the coke in step (c) is in the range of from 730 to 780°C.

7. A process as in any one of claims 1 to 6 in which in step (d), the bulk temperature of the coke is raised to, and maintained at, a temperature in the range of from 1410 to 1450°C.

8. A process as in any one of claims 1 to 7 in which the coke is maintained at the said bulk temperature for a time period within the range of from 15 minutes to 30 minutes.

9. A process as in any one of claims 1 to 8 comprising the step(s) of monitoring the temperature in at least one of the heated environments of steps (b) and (d) and regulating the rate of supply of fuel thereto in order to maintain the temperature therein within a respective selected range of temperatures.

10. A rotary hearth furnace for the production of high quality petroleum coke from green petroleum coke comprising a circular rotary hearth defining a central circular hole, means mounting the hearth for rotation about its central vertical axis, 5 a stationary roof spaced above the hearth, an annular wall to prevent the outward escape of hot gas from the interior of the furnace, an annular radiation shield depending downwardly from the stationary roof to define the outer periphery of a central calcining zone outwardly of the central hole and the inner periphery of an annular pre-heating zone bounded by the annular wall, 10 the radiation shield defining with the hearth a vertical gap of sufficient width to permit coke particles to pass from the pre-heating zone to the calcining zone but sufficiently narrow to substantially prevent the radiation of heat from the central calcining zone to the annular pre-heating zone, burner means for 15 burning fuel and any volatile matter released from the coke with a combustion-supporting gas above the hearth in the calcining zone to generate temperatures in the range of from 1350 to 1600°C, burner means for burning fuel and any volatile material released from the coke with a combustion-supporting gas above the hearth 20 in the annular pre-heating zone and serving as substantially the sole source of heat in the pre-heating zone to generate temperatures in the range of from 650 to 850°C, means for adding particles of green petroleum coke to an outer region of the hearth of the annular pre-heating zone, means to rotate the hearth about the 25 central vertical axis, rabble means for causing coke particles to be moved from the outer region of the annular pre-heating zone through the vertical gap between the radiation shield and the hearth and into the central calcining zone, rabble means for causing coke to be moved from the outer periphery of the central 30 calcining zone to the central hole, and coke-recovery means beneath the central hole for recovering coke from the central hole.

11. A furnace as in claim 10 comprising means for monitoring the temperature in one or both of the said zones, and means for regulating the rate of supply of fuel to both zones to maintain the temperatures therein within respective temperature ranges.

5 12. A furnace as in claim 10 or claim 11 in which said coke-recovery means comprises a vessel defining a heat-soaking pit to provide a residence period within the range of from 10 to 30 minutes for hot coke received or recovered from the central hole in the calcining zone, and discharge means for the discharge of coke from
10 the heat-soaking pit at the end of the residence period.

13. A furnace as in any one of claims 10 to 12 in which the roof of the pre-heating zone slopes inwardly and downwardly to the base of the annular baffle, the latter bounding the sides of a high temperature region above the hearth of the calcining zone and
15 substantially preventing the receipt in the preheating zone of radiant heat directly from the high temperature region.

