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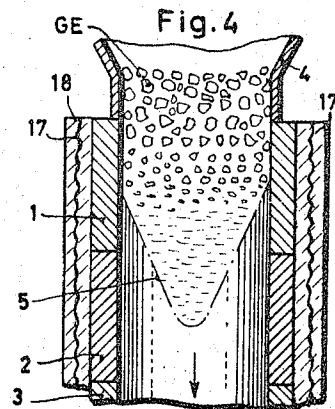
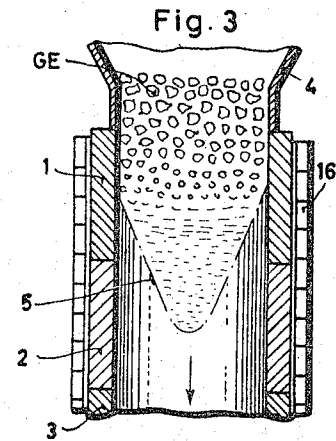
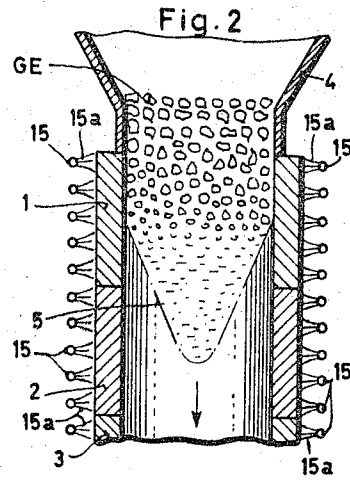
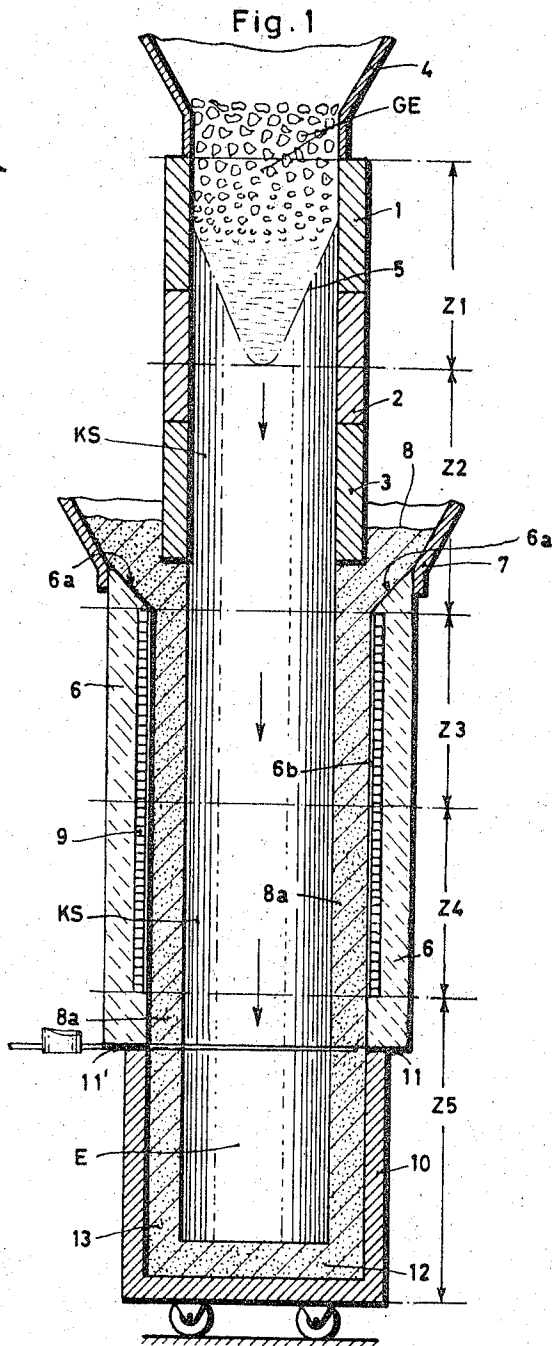
B. MARINCEK

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FURNACE FOR PRODUCING GRAPHITE ELECTRODES

Filed Oct. 8, 1964

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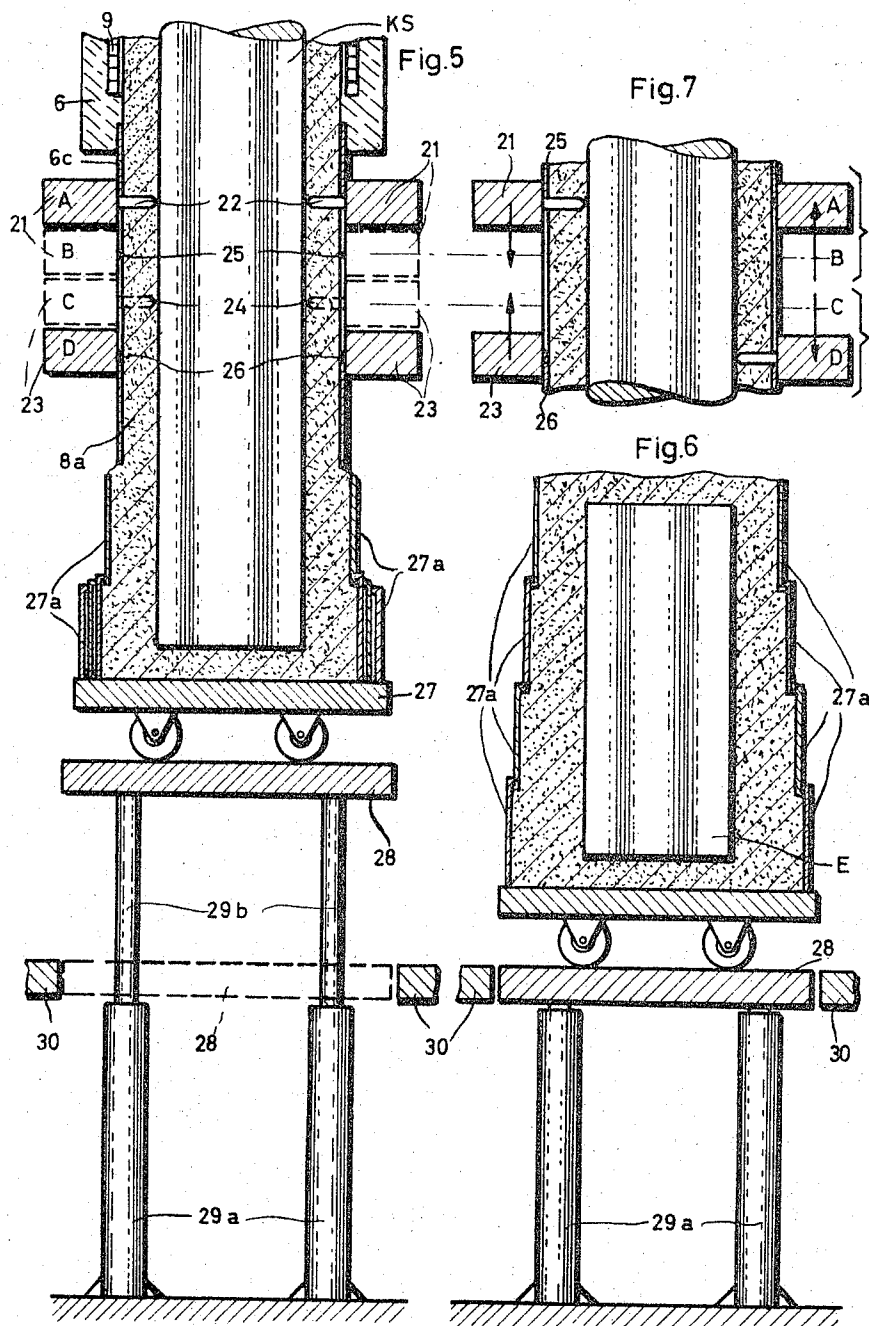
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Fig.8

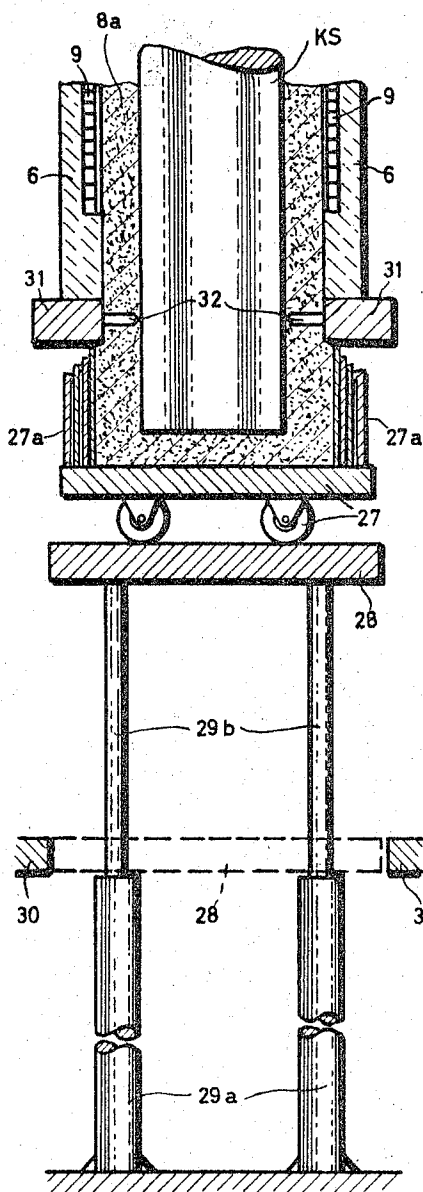
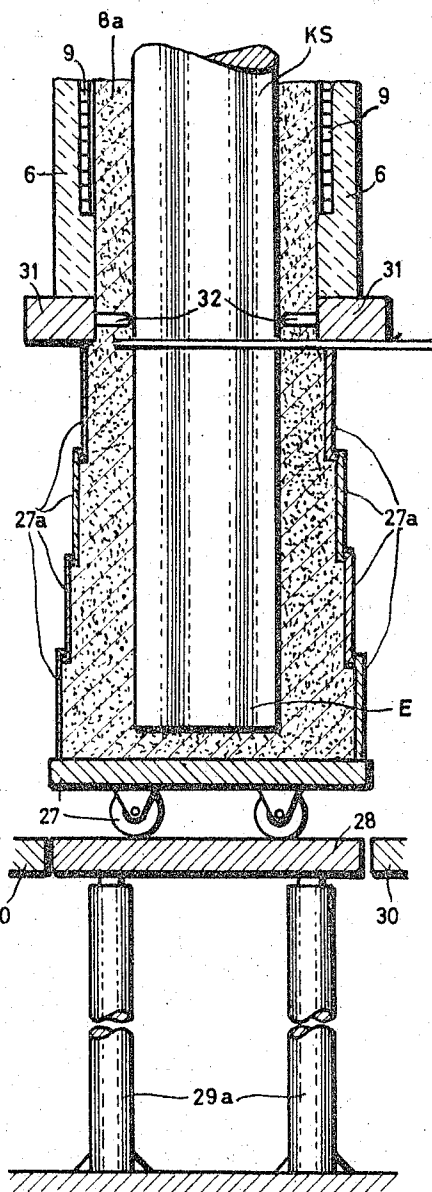


Fig.9



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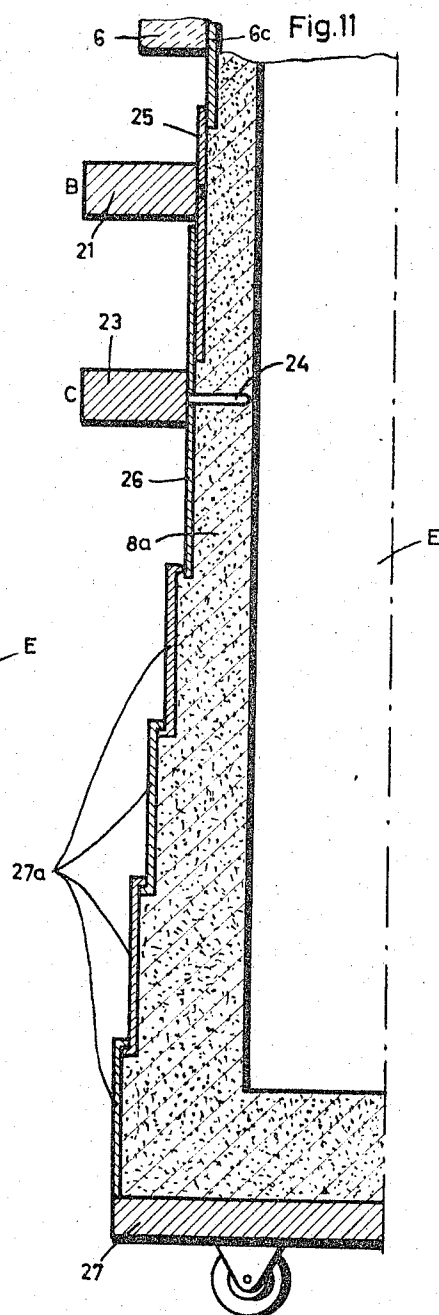
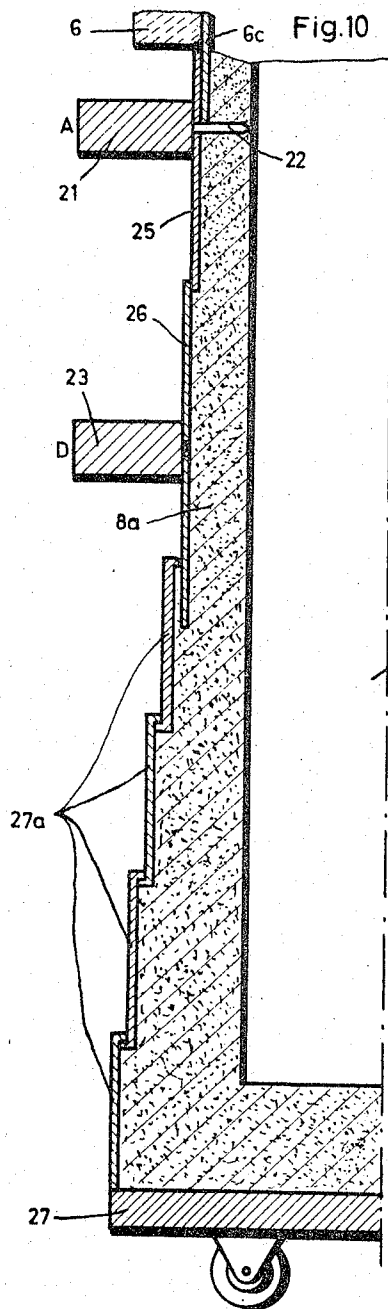
B. MARINCEK

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FURNACE FOR PRODUCING GRAPHITE ELECTRODES

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FURNACE FOR PRODUCING GRAPHITE ELECTRODES

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12 Claims. (Cl. 13—7)

ABSTRACT OF THE DISCLOSURE

Furnace for producing graphite electrodes from a green electrode mass includes a tubular structure having a first portion and an inlet for passing green mass into and through the first portion. The first portion has a cross-sectional shape corresponding to that of the electrodes to be produced, and heating means are provided on the first portion for baking the shaped mass as it passes through the first portion. The furnace structure also has a second portion coaxially adjacent to the first portion, the second portion having high-temperature heating means for graphitizing the baked strand as it passes through the second portion substantially without intermediate cooling.

My invention relates to a method and to a furnace for producing graphite electrodes.

Heretofore, carbon and graphite electrodes have been produced, as a rule, by intimately mixing the raw materials to form a "green" electrode mass and then shaping the mass to electrodes by means of large extrusion presses. Subsequently, the green electrodes have been baked, usually in gas-fired ring-type furnaces. The carbon electrodes thus produced have been graphitized in special electrical furnaces in which the carbon electrodes are electrically connected as resistances and thus heated to a temperature above 2500° C. Such baking and graphitizing of the electrodes requires a period of several weeks.

Also known is a method according to which electrodes for use in an electric furnace are formed or further fabricated from green electrode masses in the furnace itself by having them advance into the furnace chamber, baked by the furnace heat so as to be converted to a firm electrode, and thus simultaneously and immediately thereafter passed to operation as a non-graphitized carbon electrode.

It is an object of my invention to provide a method for the continuous or substantially continuous production of graphitized carbon electrodes for various uses, and to provide furnace equipment for performing such a continuous method.

Further objects of the invention will appear from the following description.

According to the invention, graphite electrodes are produced as follows. The green electrode mass is continuously shaped into a strand whose cross-sectional shape corresponds to that of the graphite electrodes to be produced. As this strand advances it is simultaneously subjected to baking temperature and thus converted to artificial (coked) carbon during continuous travel. Thereafter, and still during the same continuous travel, the baked strand is subjected to graphitizing temperature substantially without intermediate cooling, and the individual electrodes of the desired length are then severed off the graphitized portion of the strand.

According to another feature of my invention, the above-described method is performed in a furnace struc-

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ture which forms a tubular passage and has an inlet for the green electrode mass, the passage being heatable from the outside and having an inner cross-sectional shape corresponding to the cross section of the graphite electrodes to be produced. The tubular furnace is preferably mounted in vertical position, and the green electrode mass is introduced from above. In the above-mentioned passage of the furnace, the mass is shaped into a strand which, as it travels downward, is gradually baked and carbonized or coked, thus assuming a firm and mechanically resistant external shape and increased hardness so that it converts to a self-supporting carbon electrode.

The baking heat is applied through the same furnace wall that imparts the desired shape to the strand and may be effected, for example, by gas or oil burners or by electric induction acting upon the iron structures which form part of the furnace passage. The heating may also be effected by means of shaped bodies, heated to the proper temperature by electric resistance heating.

To avoid sticking of the electrode mass to the heated mold constituted by the furnace passage, the furnace structure or part thereof can be given a vibratory, downwardly jerking motion relative to the electrode strand which continuously travels in the downward direction. This jerking vibration of the molding structure is comparable to that nowadays applied during strand casting of steel. However, sticking of the electrode mass to the heated furnace structure may be also prevented by an intermediate layer of materials which subsequently carbonize during baking (for example paper, corrugated cardboard and the like) or materials which, if desired, remain preserved or which form a smooth outer skin when melting (for example asbestos paper). After thorough coking of the carbon electrode thus obtained, the travelling electrode is further heated, for example by induction heating, without subjecting the electrode strand to intermediate cooling. As a result, the graphitizing temperature, for example 2500° C. or more, is reached within a rather short period of time. This completes the preparation of the shaped graphite strand, although at this stage the strand material is still at a high temperature.

In order to obtain individual graphite electrodes of suitable length from the strand as it continuously travels downwardly, the strand must be cut to the desired length at the high temperature. This is done, for example, by a water-cooled saw or by a rotating Carborundum disc resistant to high temperature. The electrode thus cut off, the strand is then permitted to cool, preferably on a cooling carriage which is provided with a poured bed or lining of granular coke for heat-insulating the hot electrode and protecting it from oxidation.

Since the entire electrode strand moving downwardly has considerable weight, particularly if strand diameter is rather large, it is preferable, according to another feature of my invention, to compensate some or all of the weight by a supporting device which simultaneously and continuously moves downward together with the strand.

In the graphitizing zone, where the strand is heated to a very high temperature, for example by electric induction, it is preferable to surround the electrode strand by a heat-insulating lining of coke granules which separates the strand from the induction heater winding or other heating means. It is further advisable to electrically insulate the induction winding on its inner side for preventing the electric current from being shorted between the turns of the winding.

During downward travel, the graphite electrode entrains more or less of the granular coke in the downward direction. For that reason, the material of the lining is preferably replenished continuously from above. The

quantity of entrained coke granules draining from the bottom outlet of the furnace can be used for covering the cut-off graphite electrodes or for similar protective purposes and, after each use, may again be employed for insulating the graphitizing zone in the above-described manner.

The above-mentioned cooling carriages have an upwardly open receptacle whose shape corresponds to the shape of the graphite electrodes to be received and which are made, for example, of sheet iron or stainless high-temperature-resistant steel. As a rule, the electrodes cool very slowly. After cooling, the electrodes can be subjected to further fabrication, such as turning on a lathe, cutting nipple ends or sockets, and the like.

The above-described and more specific objects, advantages and features of my invention, said features being set forth with particularity in the claims annexed hereto, will be apparent from, and will be described in, the following with reference to the accompanying drawings showing, by way of example, embodiments of furnaces and accessories according to the invention. More particularly:

FIG. 1 shows a furnace in longitudinal section, but without the heating device in the upper furnace portion.

FIG. 2 is a longitudinal section of the upper furnace portion equipped with an embodiment of the appertaining heating device.

FIG. 3 shows the upper furnace portion equipped with a different heating device.

FIG. 4 also shows the upper furnace portion but illustrates still another heating device.

FIG. 5 is a longitudinal section of the lower furnace portion and shows it equipped with a holding and lowering device for the electrode strand together with a carriage for receiving and removing the individual electrodes produced.

FIG. 6 shows in longitudinal section a portion of FIG. 5 in a different position of movable components.

FIG. 7 is an explanatory diagram referring to the operation of the holding and lowering device according to FIGS. 5 and 6.

FIG. 8 is a longitudinal section through the lower furnace portion of another embodiment.

FIG. 9 shows in longitudinal section the same furnace as FIG. 8 with the movable components in a different position.

FIG. 10 illustrates one-half portion of a longitudinal section through part of a modified holding and lowering device generally corresponding to the one shown in FIG. 5.

FIG. 11 corresponds to FIG. 10 but illustrates various parts in a different operating position.

The furnace illustrated in FIG. 1 has an upper portion composed of ring-shaped sections 1, 2 and 3 of refractory material which are coaxially aligned and whose inner cross-sectional shape corresponds to that of the electrode to be produced. Generally, the passage formed by the sections of the upper portion constitutes a cylinder of circular cross section. The upper portion receives the green electrode mass through a funnel 4 and passes it into the lower portion 6 of the furnace.

The green electrode mass generally consists of granular anthracite and granular coke with additions of tar or pitch.

For explaining the method embodied in the performance of the furnace, the furnace space may be thought to comprise several zones Z1 to Z5. In zone 1 the green electrode mass is shaped as it travels downwardly and is simultaneously heated from the outside by devices such as those described hereinafter with reference to FIGS. 2, 3 and 4. Thus the electrode mass is shaped and gradually solidified to a strand whose cross section corresponds to that of the furnace top portion. In zone Z2 and partially already in the lower portion of zone Z1, the resulting carbon strand is baked and carbonized (coked) to convert to artificial carbon material. In the next following zone Z3,

the travelling strand zone coming from the baking zone Z2 is heated to the much higher graphitizing temperature. Thus, the strand is gradually graphitized in zone Z3 and, above all, in the following zone Z4. At the end of zone Z4 the graphitizing process is completed. From then on, commencing with zone Z5, the graphitized strand portion gradually cools.

As mentioned, the furnace top portion 1, 2, 3 constitutes a tubular passage in which the green electrode mass GE, as it advances, is continuously converted to a carbon strand KS of firm consistency and baked constitution. The three tubular sections 1, 2, 3 preferably consist of steel or other metal having a similarly high or a higher melting point. While a circular cross section of the sections is mentioned above, any other desired cross section, for example a quadrangular shape, may be chosen. Preferably the sections 1, 2 and 3 have the same wall thickness. They may be formed for example of pieces cut from a tubular structure of circular cross section. They are supported by a suitable frame structure (not illustrated). This applies at least to the section 3 which may be used for entirely or partly supporting the upper sections 2 and 3.

The green electrode mass GE may be subjected from above to pressure, for example by means of compressed air, which will then act in addition to the gravity of the strand for securing a continuous downward travel. When applying air pressure, an air lock is provided for introducing the green electrode mass into the lock chamber of which the funnel 4 forms part. The lock structure is not illustrated because such structures are generally known, for example for ventilating shafts in mines.

As the green electrode mass GE travels through the passage formed by sections 1, 2 and 3, the low-melting constituents become liquid or doughy, for example at a temperature of about 120° C. This takes place within approximate limits usually constituting a downwardly pointing conical shape having a rounded tip as schematically indicated by a dot-and-dash curve 5. The resulting coherent and continuously advancing strand KS encounters a gradually increasing temperature as it approaches the lower end of the passage formed by the sections 1, 2 and 3. This temperature amounts to about 1300 to 1500° C. at the lower end of section 3. During this forward travel the strand becomes firm, and is baked and carbonized to a further extent as the strand leaves the passage 1 to 3. That is, the coking and baking may continue throughout the entire extent of the zone Z2.

Since the portion of the carbon strand last considered now has a solid and firm shape and retains this shape, with the exception of any slight and negligible changes in diameter, the next following portion of the furnace need not have a shape-imparting effect upon the strand. It serves only for graphitizing the travelling strand portion by heating it up to the high graphitizing temperature of about 2500 to 3000° C. For this purpose, the lower furnace portion 6 consists of a tubular jacket of refractory material, for example ceramic material such as fire brick. The jacket 6 has an inner cross-sectional shape which generally corresponds to the shape of the graphite electrodes being produced but is sufficiently wider to permit inserting around the strand KS a poured lining of granular coke. The upper end 6a of the jacket 6 is funnel-shaped and is continued upwardly into a funnel 7. Granular coke 8 is supplied and replenished through the funnel 7 in such quantities as to form the intermediate granular coke lining 8a about the strand KS and is continuously preserved or replenished, independently of the further operations described hereinafter. In the graphitizing and outlet zone of the furnace, the granular lining 8a heat-insulates the strand and simultaneously protects the strand and the furnace jacket 6 from oxidation.

The inner wall of the furnace jacket 6 has a recess 6b completely surrounding the furnace space and extending over most of the jacket length. An electrical helical induction winding 9 is mounted in a recess 6b and is rated

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for heating the jacket space to the graphitizing temperature of 2500 to 3000° C. In the illustrated embodiment, the induction winding 9 does not extend over the lowermost portion of the furnace jacket 6 so that this lowermost jacket portion already constitutes part of the cooling zone Z5.

Located directly beneath the furnace jacket 6 is a carriage 10 for receiving and removing the individual electrodes. Each individual electrode, as it sufficiently protrudes downwardly out of the furnace jacket 6, is severed from the graphitized strand KS, for example by means of a gas- or liquid-cooled severing disc of Carborundum 11' which rotates at high speed and can be swung from the outside toward and into the strand. Any other suitable severing means such as a liquid-cooled saw may be used in a similar manner. The severing device 11' enters into a gap 11 between the upper edge of the carriage 10 and the lower edge of the furnace jacket 6.

The carriage 10 is provided with a bed 12 of granular coke for supporting the electrode to be received. The inner diameter or cross section of the carriage 10 is so dimensioned that a lining 13 of granular carbon will form around the graphite electrode in the same manner as within the furnace jacket 6. For this purpose, the granular coke mass 8a, which becomes replenished through the funnel 7, is permitted to issue from the furnace jacket 6 into the carriage 10.

This can be achieved in different ways. For example, the granular coke mass 8a may first be retained in the furnace jacket by means of a diametrically subdivided slider whose two parts jointly have an annular shape and are normally located in the gap 11. After the strand KS moves downwardly through the annular slider and out of the jacket 6 a distance corresponding to the desired length of the electrode, taking into consideration the loss of material subsequently encountered by cutting the strand, the carriage 10 is lifted from below by a platform toward the protruding portion of the graphite electrode, the bottom of the carriage being already lined with the bed 12 of granular carbon. When the carriage 10 has reached the position shown in FIG. 1, the two-part or otherwise subdivided annular slider is removed or opened, so that granular coke will now drain into the carriage and form the intermediate lining 13 in the carriage 10. Thereafter, the portion of the strand KS now located in the carriage 10 is severed in the gap 11 as described above, whereupon the carriage 10 is moved laterally away. Preferably, the top of the electrode on the carriage is covered with carbon granules to prevent oxidation. The electrode is then permitted to cool or is available for any desired preliminary treatment or use, for example for utilization of the heat quantity still contained in the electrode. The next following electrodes are severed and removed in the same manner.

A sufficient number of carriages 10 are provided for each individual furnace and are successively placed in operation and, after use, are individually returned to the furnace after the individual electrode, sufficiently cooled, is taken from the carriage.

The granular coke material removed from the carriages 10 may be used again, preferably after cooling. For example, the coke material may be returned to the funnel 7.

As mentioned above, the shaping passage formed by sections 1, 2 and 3 is heated from the outside for baking the green electrode mass as it is being shaped to a strand. Several ways of providing for such heating are schematically exemplified in FIGS. 2 to 4.

According to FIG. 2, the passage formed by sections 1, 2 and 3 is heated from the outside by gas or oil burners 15. The flames directed from the burners toward the sections 1 to 3 are schematically shown at 15a.

In the embodiment of FIG. 3, an electrical induction heater coil is arranged about the passage formed by the sections 1, 2 and 3. High-frequency current is supplied to the coil for correspondingly heating the electrode mass

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within the top portion of the furnace as described above.

In the embodiment according to FIG. 4, the passage formed by sections 1, 2 and 3 is surrounded by electrical resistance heater elements 17 which are embedded in a ceramic mass 18.

Relative to the design and arrangement of the heating devices for the sections 1 to 3 as well as for the furnace jacket 6, there are various other possibilities which, however, are not further described herein because they are not essential to the present invention proper and readily available to those skilled in the art.

As mentioned, the downwardly traveling strand KS has considerable weight, particularly if electrodes of large diameter are being produced. It is then preferable or necessary to provide the furnace with a holding and/or lowering device for the electrode strand. It is particularly simple to mount such a device at a locality where the strand is already graphitized.

The holding and lowering device according to FIGS. 5, 6 and 7 is located directly beneath the furnace jacket 6 according to FIG. 1. The insulating lining 8a of granular coke in the modified embodiment of FIG. 5, however, is downwardly longer than in the embodiment of FIG. 1.

The main components of the holding and lowering device are constituted by two rings 21 and 23 with respective gripper teeth 22 and 24 which can be moved from within each ring radially inwardly toward and against the carbon strand KS, thus clamping the strand to the individual ring and releasing the strand when the teeth are run back into the ring. The clamping and releasing motion is controlled in any suitable manner, for example electrically, hydraulically, or by compressed air. The first ring 21 is axially displaceable between positions A and B (FIGS. 5 and 7). The second ring 23 with teeth 24 is displaceable between positions C and D. The two rings 21 and 23 operate in an alternating cycle. Assume that ring 21 is in position A (FIGS. 5 and 7) and that its teeth 21 have just gripped the strand KS. From this moment on, the ring 21, with its teeth remaining in engagement with the strand, is moved downwardly to the position B at the speed required by the data of the furnace (length and heating of the individual zones) and the data of the starting material for the baking and the subsequent graphitizing of the strand KS. As a rule, the drive means for moving the ring 21 do not have the purpose to impart traveling motion to the strand but serves essentially as an escapement mechanism for regulating the speed of the travel caused by the weight of the strand KS.

As the ring 21, with its teeth 22 in clamping engagement with the strand KS, moves from position A to the lower position B, the second ring 23, having the same design but having at this stage its teeth withdrawn into the ring, moves from the lower position D back to the upper position C, being actuated by a drive or escapement mechanism corresponding to, or forming part of, the one which acts upon the ring 21 and which, as mentioned, may be electrical, hydraulic or pneumatic. The two rings simultaneously arrive at the respective positions B and C. At this moment, the teeth 24 of ring 23 move out of the ring and engage the strand KS so that now ring 24 supports the weight of the strand KS. Simultaneously or slightly later, the teeth 22 of ring 21 are withdrawn from the strand. Immediately thereafter, the two rings 21 and 23 move the above-mentioned speed toward the respective positions A and D. Now ring 23 guides the strand KS downwardly at the prescribed speed, whereas ring 21 returns to its starting position to be prepared for the next active stroke. The idle return stroke of each ring may be effected at a faster speed, and the ring may then remain in waiting position until its next working stroke commences. The working cycle described above is continually repeated with the result that the strand KS is permitted to continuously travel downwardly at a properly restrained travel speed.

It will be understood from the foregoing that the strand KS is continuously replenished at the top, but is shortened at the bottom intermittently to remove from time to time a single graphite electrode of the desired length.

As a rule, each of rings 21 and 23 has three or more teeth preferably distributed uniformly over the periphery. The rings and/or their teeth may be cooled, for example by circulation of water. It should be understood that the "teeth" may consist of serrated or waffle-shaped structures forming an arcuate gripper surface along part of the cylindrical surface of the strand for minimizing any injury to the strand surface.

If desired, automatic control means may be provided for controlling the displacement travel of the two rings 21, 23 and the inward and outward movement of their respective teeth 22 and 24 in the above-mentioned time relation.

While reference is made in the foregoing to continuous travel of the carbon strand KS, it will be understood that, aside from a strictly continuous travel, the process may also be performed in a somewhat modified manner. That is, depending upon the type of the furnace, the type of heating, the starting materials, the strand diameter, the desired penetrating depth of the baking process and graphitizing effect, it may be desirable in some cases to interpose travel pauses during which the carbon strand KS remains temporarily at standstill and/or changes its advancing speed, for example, between two or more speed values.

At the holding and lowering device the strand KS is already graphitized and consequently very hot. In order to heat-insulate this hot strand and to protect it from oxidation, the lining 8a of granular coke envelops the strand also in the region of the rings 21 and 23. The rings 21 and 23 are connected with a multi-part cylinder 25, 26 of sheet metal whose parts are in telescopic engagement with each other. This is shown schematically in FIGS. 5 and 7 but will be more fully described below with reference to FIGS. 10 and 11.

As explained, the two rings 21 and 23 (FIGS. 5, 7) only control the lowering of the strand KS but do not impart lifting action upon the strand. After the bottom end of the strand has protruded sufficiently far out of the lower furnace portion 6, this end, already graphitized and therefore relatively soft, is severed in the manner described above, for example by a water-cooled circular saw. At this time, or already at an earlier stage, the resulting electrode is received in a carriage 27 whose lateral walls are constituted by telescopic sheet-metal cylinders 27a. The outermost sheet-metal cylinder is fastened to the bottom of the carriage 27, whereas the others can be pulled upwardly. The expansible sheet-metal cylinder serves to catch the insulating layer of granular coke which is to extend into the carriage. Before lifting the carriage beneath the electrode into contact with the protruding front of the strand KS, the bottom of the carriage is provided with a bed of granular coke. The travel and lifting of the carriage, the subsequent lowering of the carriage still to be described, and the axial extension of its telescopic lateral wall, may be effected by suitable drive means mounted on the carriage itself or in the vicinity and may be also controlled automatically, for example by the same means which control the operation of the above-described holding and lowering rings 21, 23.

The carriage 27 is moved toward and beneath the furnace when the protruding length of strand is still short and still growing toward the full electrode length desired. Consequently, it is necessary to first lift the carriage 27 toward the furnace. This is done by means of a platform 28 which can be lifted and lowered, for example by hydraulic or pneumatic cylinders 29a and pistons 29b designed and operating in the conventional manner. During lowering of the strand KS, the previously lifted carriage 27 must participate in the downward motion. This is apparent from comparing the earlier stage shown in FIG. 5

with the later stage shown in FIG. 6. As this movement proceeds, the lateral telescopic wall portions 27 and of the carriage 27 are pulled out. After the carriage 27 has reached the height of a fixed working platform 30, the protruding portion of the strand is cut off as described, and the carriage is then moved laterally away, after the top of the electrode is covered with granular coke to prevent oxidation. Thereafter, the graphite electrode E is permitted to cool down to normal room temperature.

Instead of using any drive means for extending the lateral telescopic wall portions 27a, the top portion may be temporarily attached to the furnace so that the lowering of the carriage automatically causes the telescopic wall to be extended in the above-described manner.

In the embodiment according to FIGS. 8 and 9, which in many respects is essentially a modification of the one described with reference to FIGS. 5 to 7, the lowering of the strand KS is controlled with the aid of the carriage 27, the platform 28 and the drive and guiding means 29a, 29b. The ring 31 with the inwardly and outwardly movable holding teeth 32 is fixed to the furnace jacket 6 and is so controlled that, when the protruding electrode length is located in carriage 27 and the graphite electrode E can be cut off, the ring 31, 32 takes care of holding the strand KS. In contrast to the embodiment described with reference to FIGS. 5 to 7, the ring 31 does not move downwardly but remains immovable. Consequently, in this embodiment, the strand KS is stopped during the interval of time in which the electrode E is being cut off, and thus the downward travel is temporarily interrupted.

After the graphite electrode E is cut off and the carriage 7 with the electrode is moved away from the furnace, the next carriage is run beneath the strand KS to the position shown in FIG. 8. The new carriage and the platform 28 then take up the entire weight of the strand KS after the teeth 32 of the ring 31 are loosened from the strand to release its further downward travel. From now on, the strand KS is retardingly supported by the hydraulic drive means 29a, 29b only, and is lowered at the speed determined by the operation of these drive means as described with reference to the preceding embodiments.

The sheet-metal cylinders for shielding and confining the lining of granular coke within the rings 21 and 23 of the holding and lowering device according to FIGS. 5 to 7, are given such an axial length and diameter relative to each other that they do not interfere with the operation of the other components and continuously hold the granular coke together, thus thermally shielding the mass of coke toward the outside. Details of such shielding cylinders are more fully shown in FIGS. 10 and 12 in two different positions of the respective rings 21 and 23.

The uppermost sheet-metal cylinder 25 fastened to the ring 21, overlaps with a fixed sheet-metal cylinder 6a coaxially secured to the bottom portion of the furnace jacket 6. A comparison of FIGS. 10 and 11 will readily reveal the coaction of the sheet-metal cylinders. In positions B and C the respective rings 21 and 23 have a larger distance from each other as in FIGS. 5 to 7, and the mutual position of respective rings 21 and 23 is somewhat different from the embodiment of FIGS. 5 to 7. It will be noted that according to FIGS. 10 and 11 the cylinders 25 and 26 are provided with openings or slots for the passage of the ring teeth 22 and 24. These openings or slots may be equipped with sliders which cover the openings when the teeth are withdrawn. As a rule, however, the teeth themselves will prevent ingress of granular coke into the interior of the rings 21, 23.

Instead of providing telescopically extendable sheet-metal cylinders to form lateral walls on the carriage 10 or 27, or in addition to such carriage walls, similar telescopically extendable walls may be provided directly adjoining the furnace jacket 6. Such telescopic walls may then be supported by the furnace structure or by the frame structure on which the furnace is mounted and surround the lower end of the strand KS as it grows down-

wardly beyond the lower end of the furnace jacket 6, so that the lining of granular coke around the graphitized zone of the strand is held together by the gradually extending telescopic structure. If desired, automatic control means may be used for extending the telescopic walls, but they may also be extended simply by mechanical engagement with the downwardly protruding strand.

Whenever the furnace is started up, the carbon strand must be newly formed by gradually growing downwardly at a rate corresponding to the operational data of the furnace and depending upon the starting material. There are various ways of then causing the holding and lowering device or the carriage and lifting platform, as the case may be, to perform the necessary travel controlling operation.

One way of starting the furnace is to feed a finished electrode into the furnace and to let the carbon strand KS be formed from the green electrode mass on top of the finished electrode. The finished electrode then operates together with the holding and lowering device as well as with the carriage, until the newly formed strand has sufficiently grown downwardly and the finished electrode has left the furnace.

Another way of starting the furnace is to provide a plate-shaped partition supported on top of a rod which is placed into the furnace and controlled at the proper advancing rate to move downwardly through the furnace. The holding and lowering device is then placed into operation only when the newly formed carbon strand, located above the partition, has entered into the action range of the holding device.

Still another way is to fill the furnace with granular coke upon which the green electrode mass is deposited. The granular mass of coke is then permitted to slowly drain from the furnace at the proper advancing rate. In this case, too, the holding and lowering device is placed in operation only after the newly formed carbon strand KS has entered into the action range of the device.

The entire process of graphite electrode production proceeds as follows. When the green electrode mass, supplied from above, touches the hot inner furnace wall, the mass is shaped and slowly heated. This converts the electrode mass to a doughy consistency. During further heating of the electrode mass through the furnace wall, there occurs a phenomenon known as baking or coking. In its course, the material passes through several stages or changes in constitution and thermal dissociation in the individual layers or zones of the mass. During one of these stages, for example, the outer zone is already baked and coked, the inner zone is liquid, and both zones issue gaseous dissociation products which become thermally dissociated and form segregated carbon or which condense in the upper, colder zones. Thus the mass converts more and more to a solid and firm carbonized (coke) electrode as the mass travels downwardly through the furnace. This takes place in a temperature range of about 500 to 600° C. and results in solidifying and mechanically strengthening the carbon strand with vigorous development of gaseous dissociation products. These reactions taper off during further heating. The baking stage, in most cases, is terminated at temperatures in the neighborhood of 1300° up to 1500° C. In this temperature range, the electrode exhibits qualities corresponding to those of conventional electrode carbon.

In order to convert this carbon electrode into a graphite electrode, the hot carbon strand described above is further heated to the graphitizing temperature of about 2500 to 3000° C., for example, by induction heating. In this stage, the carbon recrystallizes. The small crystallites of the hard amorphous carbon convert to the large crystals of graphite, this being a prerequisite for the known properties of graphite electrodes, such as low hardness and high electrical conductance.

The heating in the baking and graphitizing phases must be adapted to the travel of the electrode strand.

This must be taken into account when dimensioning and operating the heating elements and the induction heating devices. The process of the invention has another advantage in comparison with the heretofore conventional production of graphite electrodes. That is, since the baking zone is subjected to the pressure of the liquid electrode mass located above the baking zone, the evolving gases can readily escape. This promotes the re-carbonization (coking) of these gases, and consequently the deposition of carbon in any still existing pores. The result is a graphite electrode of higher density than obtained with the conventional manufacturing processes.

A further densification of the electrode is obtainable by applying gas pressure upon the liquid electrode mass or by applying a direct pressure, for example by imposing hydraulic pressure upon the hot doughy electrode mass in the uppermost portion of the strand.

The above-described process and furnaces according to the invention may also be used for continuously producing artificial (non-graphitized or amorphous) carbon electrodes from the green electrode mass. For this purpose, the process and furnace is used in the manner described in the foregoing, except that the graphitizing operation is omitted. One way of doing this is to shorten the furnace by eliminating the graphitizing stage, for example, the zone Z4 in FIG. 1, and also omitting all or part of zone Z3. Another way is to use any of the furnaces described above, but to either omit the high-temperature heating device, such as the induction winding 9 in FIG. 1, or to simply switch off the induction heater electrically so that it remains inactive. Under such conditions, the carbon strand KS travelling downwardly through the furnace is baked to a hard carbon electrode but is not graphitized so that the individual electrodes cut from the strand consist of amorphous carbon rather than graphite electrodes. Consequently, one and the same furnace can be used selectively for either producing amorphous carbon electrodes or graphite electrodes, depending upon whether the graphitizing heater, such as the induction winding 9 in FIG. 1, is switched off or on during furnace operation.

To those skilled in the art, it will be obvious from a study of this disclosure that processes and furnaces according to my invention can be modified in various respects for achieving the same or equivalent results and hence can be given embodiments other than those particularly illustrated and described herein, without departing from the essential features of my invention and within the scope of the claims annexed hereto.

I claim:

1. A furnace for producing graphite electrodes from a green electrode mass, comprising a tubular structure having a first portion and having an inlet for passing green mass into and through said first portion, said first furnace portion having a cross-sectional shape corresponding to that of the electrodes to be produced, heating means on said first portion for baking the shaped mass as it passes through said first portion, said furnace structure having a second portion coaxially adjacent to said first portion, said second portion having high-temperature heating means for graphitizing the baked strand as it passes through said second portion substantially without intermediate cooling.

2. In a furnace for producing graphite electrodes according to claim 1, said second furnace portion having an open outlet end for issuance of the advancing graphitized strand, whereby the strand portion protruding beyond said end can be cut off to obtain individual graphite electrodes.

3. In a furnace for producing graphite electrodes according to claim 2, said second furnace portion having an outlet end for issuing the graphitized strand, and cutting means at said outlet end for severing the issued strand portion from the strand to obtain each time an individual graphite electrode.

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4. A furnace for producing graphite electrodes from a green electrode mass, comprising a tubular structure having a first portion and having an inlet for passing green mass into and through said first portion, said first furnace portion having a cross-sectional shape corresponding to that of the electrodes to be produced, heating means on said first portion for baking the shaped mass as it passes through said first portion, said furnace structure having a second portion coaxially adjacent to said first portion, said second portion having high-temperature heating means for graphitizing the baked strand as it passes through said second portion substantially without intermediate cooling, said second furnace portion having an inner width larger than that of said first portion so as to form an interspace around the strand advancing through said second portion, a lining of granular coke filling said interspace when the furnace is in operation, and inlet means communicating with said interspace for filling it with said granular coke.

5. A furnace for producing graphite electrodes from a green electrode mass comprising a tubular structure having a vertical axis and having an axially elongated top portion and an elongated lower portion adjacent to said top portion, a feeder funnel on said top portion for supplying green electrode mass from above into said top portion, said top portion having an inner cross-section corresponding to that of the electrodes to be produced, external heating means on said top portion for progressively baking the electrode mass as it is being shaped during its passage through said top portion, said lower portion having an inner width larger than said top portion to form an interspace around the strand advancing through said lower portion, a lining of granular coke filling said interspace when the furnace is in operation, and inlet means communicating with said interspace for filling it with said granular coke, said lower portion having high-temperature heating means for graphitizing the baked strand as it passes through said lower portion, and said lower portion having an open bottom end through which the graphitized strand issues, whereby the strand portion protruding beyond said end can be cut off to obtain individual graphite electrodes.

6. A furnace for producing graphite electrodes according to claim 5, comprising a carriage movable to a position beneath said lower furnace portion and forming an upwardly open chamber for receiving the strand portion

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issued from said bottom opening and removing the cut-off electrode to be cooled.

7. A furnace for producing graphite electrodes according to claim 6, comprising envelope means on said carriage, said envelope means surrounding said chamber having a lining of granular coke for enveloping the electrode.

8. In a furnace for producing graphite electrodes according to claim 5, said top portion having a slightly larger inner cross section than the electrodes to be produced so as to permit insertion of substances which promote the downward gliding movement of the electrode mass.

9. In a furnace for producing graphite electrodes according to claim 5, said heating means of said lower portion comprising an induction heater winding mounted on said lower portion and extending coaxially about the axis and axially along said lower portion.

10. A furnace for producing graphite electrodes according to claim 6, comprising a holding device mounted on said lower portion of the furnace and temporarily engageable with the strand for arresting it when said carriage is removed.

11. A furnace for producing graphite electrodes according to claim 6, comprising a platform beneath said lower portion for supporting said carriage, said platform being vertically displaceable for lifting and lowering said carriage into and out of proximity to said bottom end of said lower portion.

12. A furnace for producing graphite electrodes according to claim 5, comprising a holding and lowering device mounted on said lower portion and engageable with the strand for controlling its downward travel.

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