Sept. 25, 1973 H. VON HIPPEL 3,761,359

METHOD AND APPARATUS FOR HEAT-TREATING MATERIALS

Filed July 13, 1971 5 Sheets-Sheet 1

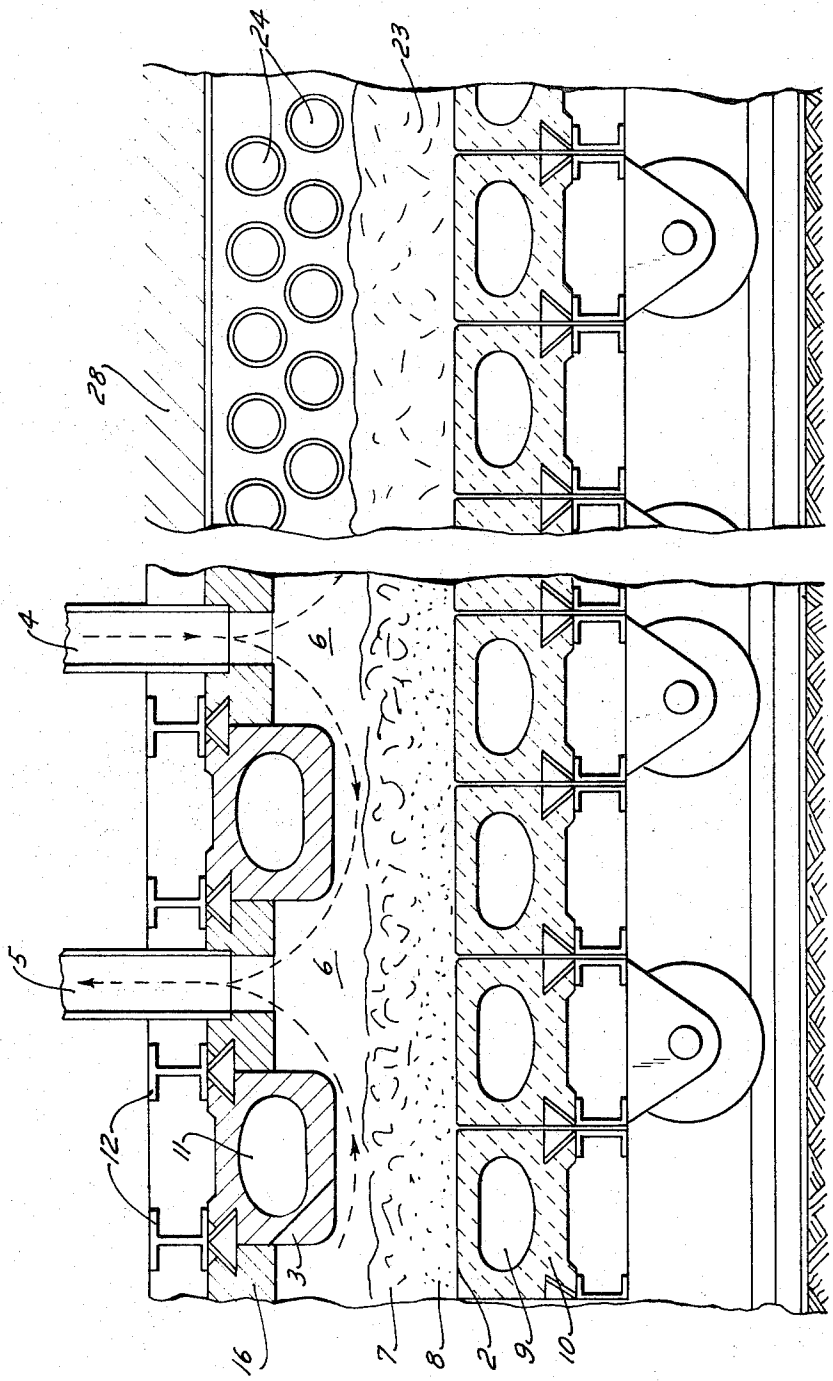


FIG. 1

INVENTOR.
HANS JOACHIM VON HIPPEL
BY Michael S. Striker
Attorney

METHOD AND APPARATUS FOR HEAT-TREATING MATERIALS

Filed July 13, 1971 5 Sheets-Sheet 2

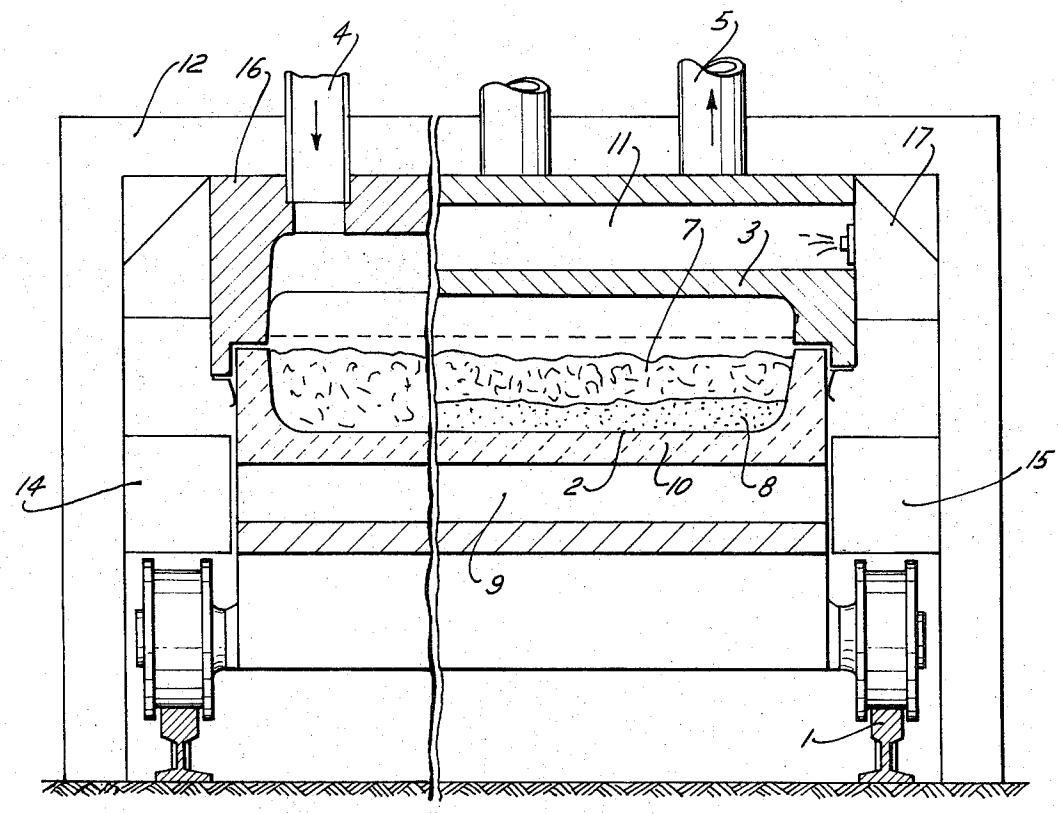


FIG. 2

INVENTOR.
HANS JOACHIM VON HIPPEL
BY Michael P. Strider
Attorney

METHOD AND APPARATUS FOR HEAT-TREATING MATERIALS

Filed July 13, 1971 5 Sheets-Sheet 3

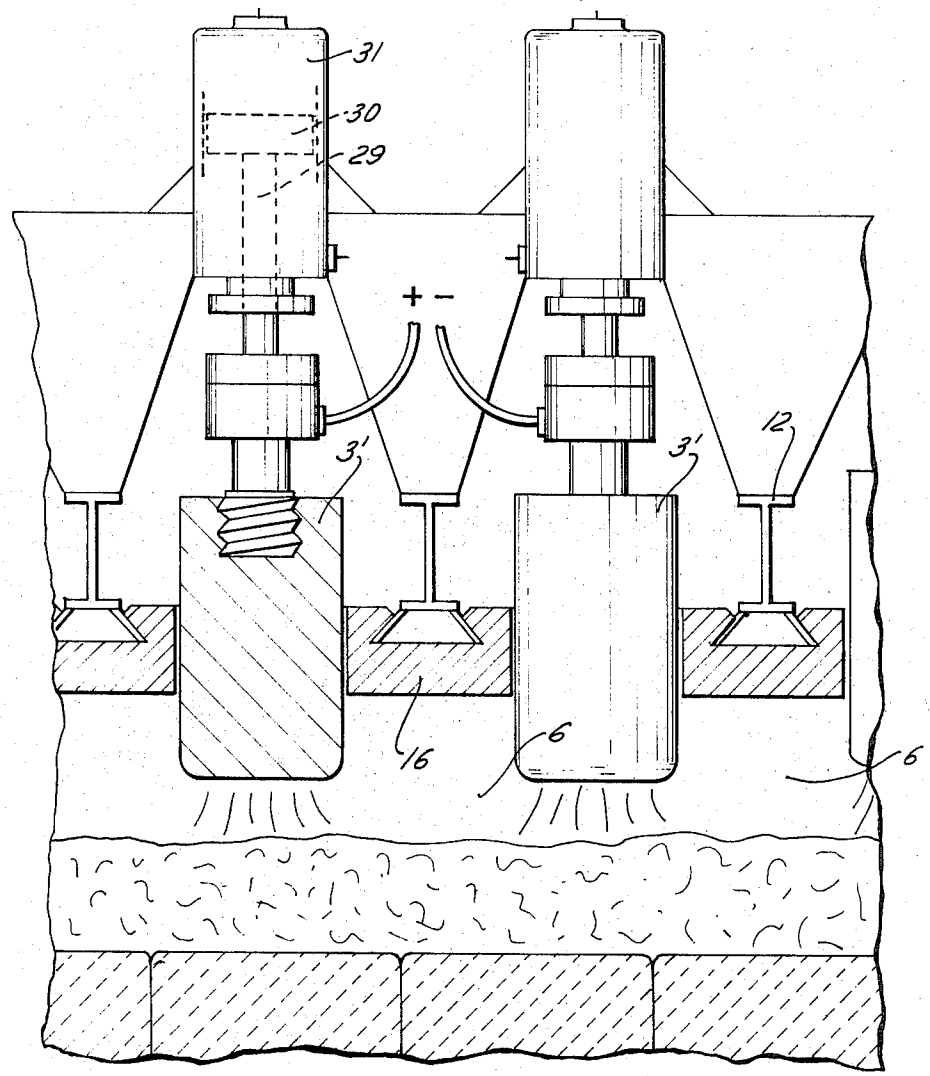


FIG. 3

INVENTOR.
HANS JOACHIM VON HIPPEL
BY Michael S. Striker
Attorney

METHOD AND APPARATUS FOR HEAT-TREATING MATERIALS

Filed July 13, 1971 5 Sheets-Sheet 4

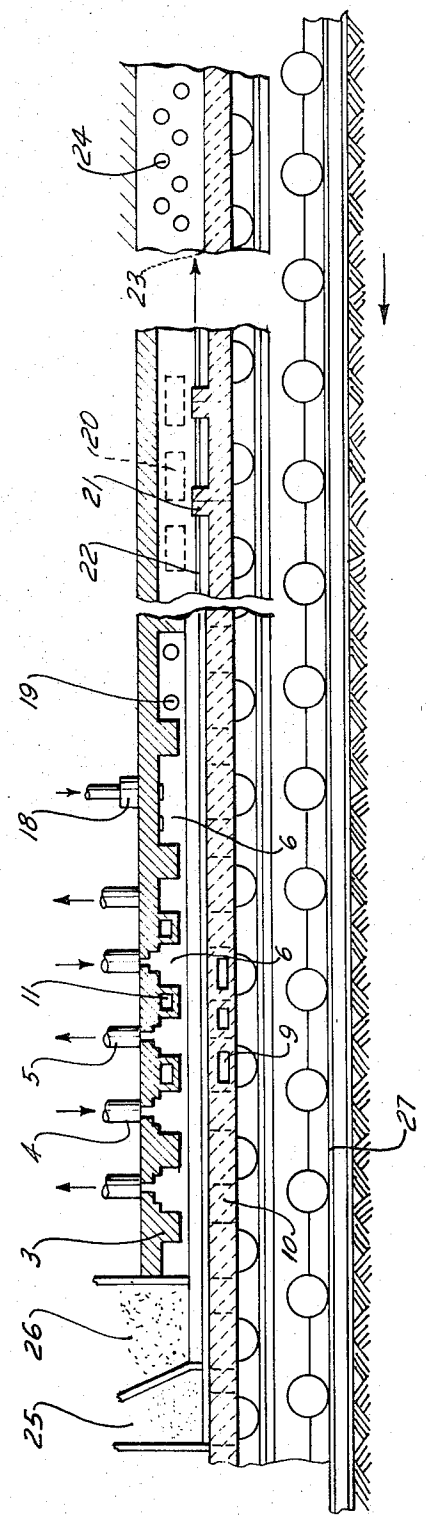


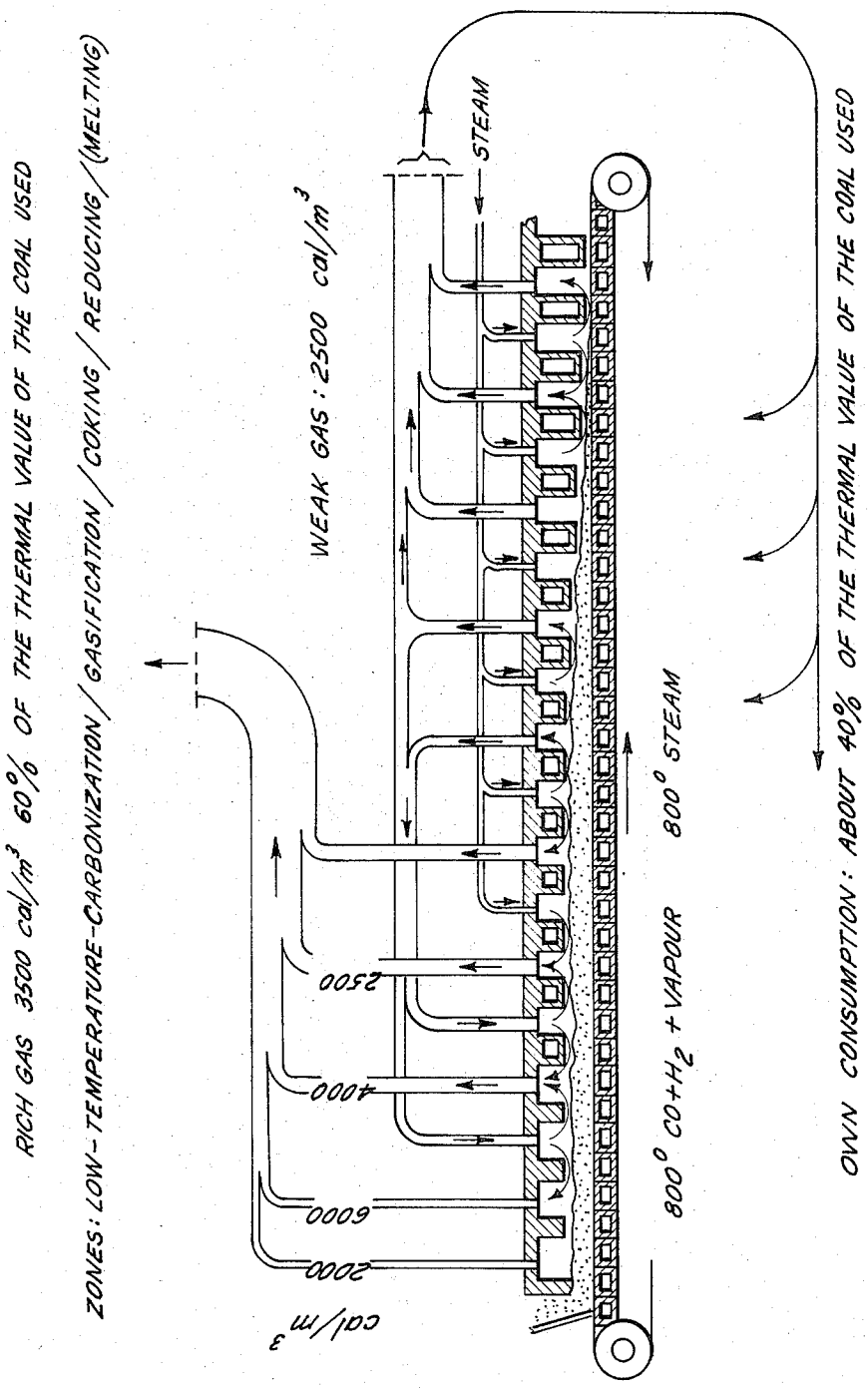
FIG. 4

INVENTOR.
HANS JOACHIM VON HIPPEL
BY Michael P. Shiller
Attorney

METHOD AND APPARATUS FOR HEAT-TREATING MATERIALS

Filed July 13, 1971 5 Sheets-Sheet 5

FIG. 5



INVENTOR.
HANS JOACHIM V. HIPPEL
BY Michael P. Shiler
Attorney

United States Patent Office 3,761,359
Patented Sept. 25, 1973

3,761,359

METHOD AND APPARATUS FOR HEAT-TREATING MATERIALS

Hansjoachim von Hippel, 7771 Oberstenweiler, Germany

Filed July 13, 1971, Ser. No. 162,033
Claims priority, application Germany, Nov. 23, 1970, P 20 57 493.0
Int. Cl. C10b 49/06
U.S. Cl. 201—32 21 Claims

ABSTRACT OF THE DISCLOSURE

A tunnel furnace has an elongated furnace chamber along whose bottom a support travels in longitudinal direction. From the roof transverse partitions extend downwardly towards the support and subdivide the space above the same into a plurality of individual treating compartments. Material to be heat-treated is deposited on the support as a relatively thin layer which is advanced through the chamber so that each increment of the layer becomes exposed to the respective compartment. The compartments are provided with inlets and outlets for gas so that different atmospheres of different composition and/or different thermal values can be maintained in the respective compartments for contact with the layer.

BACKGROUND OF THE INVENTION

The present invention relates generally to the heat treatment of materials, and more particularly to a novel method and apparatus for effecting such heat treatment.

There is a world-wide continuous increase in the demand for gas as a fuel, resulting not only from population increases and the greater demand occasioned thereby, but also from an increasing popularity of gas as a relatively "clean" and low-polluting fuel. Generally speaking, gas for these purposes is available in two forms, either as so-called natural gas or as so-called manufactured or industrial gas. The availability of natural gas is, however, strictly limited and only a few countries can draw on supplies of such natural gas. In consequence, the need for manufactured or industrial gas is becoming greater.

However, the methods and apparatuses known heretofore for the production of high-grade gas by the gasification of solid fuels have not been entirely satisfactory. In fact, the methods known heretofore are still rather inefficient. When coal is to be gasified, the production of a high-grade gas in satisfactory volume necessitates complete volatilization and a complete and efficient suppression of the production of gases which are merely waste or ballast. Thus, volatilization must be exclusively performed with the addition of steam or carbon dioxide, but the thermal balance of the known processes is negative.

The known processes cannot be performed in, say, gas producers of for instance the rotary-grate type without the addition of oxygen to the steam, an expedient which is rather expensive. Furthermore, and quite apart from the question of oxygen availability and expense, the known processes are difficult to control because it is necessary at all costs to avoid overheating or undercooling. Even if oxygen is added to the steam, irrespective of the additional expenses involved, the addition of oxygen will tend to change the composition of the gas in favor of carbon

dioxide, that is creating the admixture with the high-grade gas of an undesirable ballast gas. Also, to bring about complete volatilization and avoid the production of ballast gas, the prior-art processes must be continuously observed, monitored and controlled throughout the period of gas evolution. This, incidentally, is also true if the prior-art process is analogously used for reduction and smelting.

SUMMARY OF THE INVENTION

It is, accordingly, an object of the present invention to avoid the disadvantages of the prior art.

More particularly it is an object of the present invention to provide an improved method of the type and for the purposes discussed above, and an improved apparatus for carrying out the method.

In pursuance of the above objects, and of others which will become apparent hereafter, one feature of the invention resides in a method of the type under discussion, particularly suitable for the gasifying or coking of solid fuels or of oleiferous sands or for the smelting of ores. This method comprises, briefly stated, the provision of a tunnel furnace having an elongated furnace chamber which is formed with a longitudinally travelling support, has a roof upwardly spaced from this support, and is provided with partitions which extend downwardly from the roof and subdivide the space above the support into a plurality of individual treating compartments. The material to be treated is deposited on the support in the form of a wide relatively thin layer which is advanced on and with the support through the chamber so that successive longitudinal increments of the layer become successively exposed to each of the compartments. In the respective compartments different atmospheres and temperatures are established to which each of the aforementioned longitudinal increments becomes exposed.

According to the invention each of the compartments is provided with inlet or outlet openings for gases, which are preferably so disposed that the inlet and outlet openings are located in alternate compartments so that gases of different compositions, different enthalpy and different temperatures can be separately introduced or abstracted from the respective compartments. The volumes of gas, which are large in relation to the bulk of solid fuel which can be volatilized, are in contact with the solid fuel for only brief periods of time. In the normal gas generation process, carbon dioxide is first formed and only subsequently reduced in the cooler zones to monoxide, with the result that in the methods utilized heretofore any gas produced inevitably contains a significant quantity of carbon dioxide which constitutes mere ballast, that is which is useless for the intended purposes.

By contrast, the method according to the present invention makes it possible to control the temperature from compartment to compartment by heating the partitions, by introducing specially selected gases such as superheated steam or combustible hydrogen-containing gases, and by thus optimizing the volatilization processes. Owing to the disposition of gas outlets in the separate compartments the quality of gas produced in the respective compartments can be individually and immediately monitored. During coking, that is during the gasification of coke, large volumes of gas evolve and the invention proposes to perform the process in a plurality of steps each of which involves one or more chambers and in each of

which only a fraction of the total quantity of gas is liberated.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments of the invention when read in connection with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a longitudinal section through an apparatus for carrying out the present invention, with portions omitted for the sake of clarity;

FIG. 2 is a cross-section in vertical direction through the apparatus shown in FIG. 1;

FIG. 3 is a view similar to FIG. 2, but on an enlarged scale and of a different embodiment of the invention;

FIG. 4 is a diagrammatic fragmentary vertical longitudinal section through an apparatus according to the invention; and

FIG. 5 is a view analogous to FIG. 4 but illustrating the gas flow in operation of the apparatus.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Discussing firstly the embodiment illustrated in FIGS. 1 and 2 it will be seen that reference numeral **1** identifies rails on which a support for material to be treated travels through the diagrammatically illustrated furnace chamber of a non-illustrated tunnel furnace. The support is here in form of a plurality of closely adjacent coupled carriages which carry respective refractory pallets **10** having upper exposed surfaces **2**.

Deposited on the pallet surfaces **2** is a dual-layer bed of volatilizable material, namely a layer of coarse-grained material **7** and beneath it a layer of fine-grained material **8**. The pallets **10** are provided with preferably transversely extending conduits **9** which—at points along the length of the furnace chamber at which it is desired to heat the pallets **10**—move into registry with lateral burner heads **14** and exhaust gas chambers **15** so that the pallets can be heated sectionally in accordance with given requirements.

The chamber also has a roof formed by bricks which are suspended from girders **12** and are identified with reference numeral **16**. Additionally there are provided partitions—which may also be in form of bricks—identified with reference numeral **3** and projecting downwardly from the roof of the chamber towards but short of the pallet surfaces **2**. This subdivides the space between the pallet surfaces **2** and the roof defined and composed of the bricks **16** into a plurality of working compartments or treating compartments **6**. Preferably the partitions **3** can be adjusted in their elevation (not shown in FIG. 1) so that they can be raised and lowered with respect to the pallet surfaces **2**. This makes it possible to have their lower edges approach the surfaces **2** sufficiently to provide an adequately tight seal between neighboring ones of the compartments **6** so that different phases of the process can be performed in each chamber, with one chamber containing for instance a reducing atmosphere and the adjacent one an oxidizing atmosphere.

As the drawing shows, especially in FIG. 1, the partitions **3** are also provided with internal conduits **11** and can be heated by the admission thereinto of combustion gases from burners **17** (see FIG. 2). Thus, heat required for performing any particular phase of the process can be supplied via the partitions **3**. Gas inlet or burner openings **4** and gas outlet openings **5** are provided in the roof bricks **16**, and gas admitted at the openings **4** is forced downwardly into contact with the surface of the bed **7**, **8** by the presence of the partitions **3**.

FIG. 4 shows, incidentally, that the compartments **6** may be of different width and it will be understood that they can be heated by burners disposed in side walls **19** or in the roof **18** as may be desired or reruired (see FIG. 4). Heating may be effected alternately from opposite sides, with the combustion gases leaving through openings **20** and being fed in conventional manner to a recuperator.

If the method and apparatus are utilized not for volatilizing solid fuels but instead for smelting ores, for instance for making steel, a possibility which will be discussed in more detail later, the pallets **10** will be configurated as troughs, tubs or the like **21** mounted on the carriages as shown, with the carriages and troughs **21** forming an endless chain or train. This is also more clearly shown in FIG. 4.

For the recovery of waste heat in the production of coke the roof above the coke **23** is equipped with a conduit or tube system **24** forming part of a steam or hot water system **28**. The conduits **9** may also be used as recuperating channels for heating wind blown therethrough. Reference numeral **25** in FIG. 4 shows a supply hopper from which for instance the fine-grained material for the layer **8** may be supplied, and reference numeral **26** shows a supply hopper from which the coarse-grain material for the layer **7** may be supplied. Reference numeral **27** is utilized for illustrating diagrammatically in FIG. 4 the returning part or run of the train or chain of cars with their pallets or troughs.

The raising and lowering of the partitions is more clearly ilustrated in FIG. 3, where the partitions are identified with reference numeral **3'** and where each of them is shown to be associated with a hydraulic cylinder **31**, a piston **30** and a piston rod **29** which connects the respective piston with the associated partition **3'**. It is advantageous, according to an embodiment of the invention, to generate high temperatures by means of electric arc heating. As shown in the embodiment of FIG. 3 this can be effected in a simple manner by constructing some or all of the partitions **3'** as arc heating electrodes which are preferably so arranged that a second or counter-electrode is located a short distance downwardly of the arc heating electrode, with electric current flowing from the arc heating electrode into the bed of material to be heated (which is rendered electrically conductive by the presence of the coke) and entering from there into the counter-electrode.

FIG. 5 shows the gas flow in an apparatus according to the invention, for instance as shown in FIG. 4, and the legends applied to FIG. 5, in conjunction with the arrows indicating gas flow and the indicated thermal value in degrees centigrade, are self-explanatory.

The heating of the partitions, as discussed above, permits volatilization to be performed with pure steam or carbon dioxide, or with a mixture thereof, because the missing process heat can be supplied via the heated partitions.

According to the invention the proportion of the total gas volume needed for volatilization is always introduced into one chamber in superheated state, and exhausted from a neighboring chamber or chambers, with the gas thus being forced to flow from chamber to chamber, and each time being forced downwardly into contact with the surface of the bed of material, as indicated by the broken-line arrows in FIG. 1. As a result, and this refers of course to coking or gasification of solid fuels, a gas having a high hydrogen and carbon monoxide content and a minimum content of carbon dioxide is obtained because the flowing gas is repeatedly contacted with the bed of coke at high temperature.

This high-calorie gas contains up to 45% of hydrogen, 45% of carbon monoxide and just about 10% of heavier hydrocarbons. The reason for this relatively high content of heavier hydrocarbons is the fact that the gasification process according to the present invention can be

performed in the presence of steam or of hydrogen-containing gases, which makes it possible to achieve a higher yield of the heavier hydrocarbons than could be achieved before. Moreover, the sulfur content can be reduced if volatilization is performed in an atmosphere which contains no oxygen, and if lime is added the retention of sulfur in the ash is further facilitated.

Gas having the lowest heating value (as compared to quantities of gas having higher heating values) is obtained at the end of the volatilization of gasification process, and this gas is advantageously used for supplying the amount of heat missing for carrying out the process. About one third of the heat content of the fuel that is volatilized is just used for maintaining the process, but the heat so used is theoretically recovered in the gas which is produced.

To prevent any part of the fuel during execution of the process from becoming entrained by the gas stream which moves in contact with the fuel bed, the invention proposes to deposit the fuel on the support in the earlier-described two separate layers, namely with the finer grain forming a lower layer which is covered by the upper layer of coarser grain, it being evident that the coarser grain will resist entrainment more than the finer grain could do.

Furthermore, it is also possible and intended according to one concept of the invention to mix the feed (that is the incoming material which is being deposited on the support) with one or more binding agents of a type capable of preventing the evolution of dust and entrainment of fine particles. Such binding agents may be tar or tar oils and/or lime or milk of lime, or any combination of these.

As already briefly indicated before, the present method and the apparatus according to the present invention are suitable not only for gasifying or coking of solid fuels or of oleiferous sands or the like, but can also be employed for smelting of ores. When this latter type of operation is to be carried out, the ore is admixed with a solid or liquid fuel and conveyed on the support successively through a gasification zone, a coking zone, a reducing zone and a melting-down zone. In the gasification and coking zones the fuel admixed with the ore is exposed to hot reducing gases or to superheated steam introduced into the various compartments which make up the respective zones. Into the zone for reducing the ore an oxygen-containing gas is introduced in order to support the combustion of surplus coke. However, this latter gas can also be omitted. The melting-down zone, mentioned above and already described with respect to FIG. 4 for example, may be fitted with gas burners which may be supplied with the high-calorific combustible gas which is obtained in the gasification zone during operation of the process and apparatus.

Particularly when the smelting of ore is concerned, the support may be composed of a plurality of carriages or the like which carry not the elements shown in FIG. 1, but carry upwardly open troughs or the like which latter may themselves be so designed that they can be heated (compare for example FIG. 5). Thus, these troughs 21 (FIG. 4) may be provided with heating channels having open ends which move into registry during advancement of the support, with laterally located stationary gas-supplying and gas-venting conduits or openings, as already described earlier. The individual troughs will eventually be filled with molten pig iron or steel and can later be tipped into a mixer at the point where the support—which in this case is at least composed of a continuous chain of such carriages and troughs—moves from its working run into its return run.

It will be appreciated that with such an arrangement installations of extremely high performance characteristics can be provided. For instance, if an apparatus according to the present invention utilizes as the travelling support a train of travelling pallets four meters wide and moving at a rate of speed of 0.1 meter/second, a daily capacity of up to 5,000 tons of coal or output of coke, or of 10,000 tons of steel can be achieved in a completely continuous process free of dust evolution. If the invention is employed in the production of coke and of course the concomitant production of gas, there is the advantage over the presently existing (but still experimental) coking processes that no special heat carrier material such as sand is required, and that the coal to be gasified and coked need not first be briquetted or pelletized. If the invention is used for making steel, and thus for smelting ores and converting the metal obtained into steel, an advantage obtained is that the liquid pig iron in the individual troughs which together make up the travelling support can be selectively treated. By this it is meant that for instance decarburization and the addition of alloying metals can be individually controlled as each trough moves into and out of registry with the successive compartment. It should be remembered in this connection that in a modern high-performance blast furnace the hot air must penetrate up to six meters into the ore and coke mixture in order to reach the ore at the furnace center. Keeping this in mind it will be readily understood that the present invention which is performed on a travelling bed will necessarily be far more efficient because it avoids the penetration requirement of the prior art. Additionally, because volatilization and coking of the fuel surrounding the ore causes a carbon envelope to form around each grain of ore, the latter is always in direct and intimate contact with the carbon needed for reduction purposes, unlike in a blast furnace where the ore is usually reduced by carbon monoxide at lower temperature.

Still speaking with respect to the smelting of ore, it is pointed out that when the process has progressed to the coking stage, the quantity of heat needed for reduction purposes can be produced by blowing air or oxygen into the respective chambers involved, and the ore reduced by the enveloping carbon without being exposed to the oxygen. In this utilization of the present invention it is particularly advantageous if the partitions can be raised and lowered as discussed earlier, to make it possible to cleanly separate the several phases of the smelting process from one another. Since the lime required for the slag has already been added during the preparation of the ore and is therefore already contained in the carbon or coke enveloping the ore grains, the slag binding the sulfur is molten at the same time as reduction takes place, and the molten iron fills the troughs of the travelling support train. Because the iron is no longer in contact with coke it can be directly recovered as steel if the process is properly controlled.

From all of the foregoing it will be understood that the method and apparatus according to the present invention offer significant advantages over what is known. Broadly speaking, these advantages can be summarized in three categories, namely firstly a complete volatilization of fuels for the production of a high-calorific gas, secondly a continuous process of coking with the recovery of the coking heat, and thirdly a process of smelting iron and non-ferrous ores which in the smelting of iron permits the pig iron phase to be eliminated and its cost saved by a special control of the smelting process as pointed out above.

If the feed, that is the incoming material which is to be processed, is prepared with tar or oils, for instance such as are obtained in coking, the evolution of dust will also be either substantially reduced or completely suppressed. Moreover, the process according to the present invention can be readily observed in every phase and each stage can be controlled because of the division of the furnace into a plurality of individual working compartments. The travelling support may also be constituted by a suitable turntable (known per se) which affords the desired features. Of course, the configuration of the furnace cham-

ber must then be appropriately changed to accommodate it to that of the turntable.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of applications differing from the types described above.

While the invention has been illustrated and described as embodied in an apparatus for the heat treatment of certain materials, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be protected by Letters Patent is set forth in the appended claims:

1. A method of the character described, particularly for gasifying or coking solid fuels or oleiferous sands or for smelting ores, comprising the steps of providing a tunnel furnace having an elongated furnace chamber formed with a longitudinally travelling support, a roof upwardly spaced from said support, and partitions at least some of which are hollow extending downwardly from said roof and subdividing the space above said support into a plurality of individual treating compartments; depositing a material to be treated on said support in form of a wide but relatively thin layer; advancing said layer on said support through said chamber so that successive longitudinal increments of said layer become successively exposed to each of said compartments; establishing in the respective compartments different atmospheres and temperatures to which each of said longitudinal increments become exposed; and circulating hot gas through at least some of said hollow partitions.

2. A method as defined in claim **1**, wherein the advancing layer yields into the respective compartments liberated gases which have different calorific and compositional parameters; and further comprising the step of abstracting said gases from said chambers separated according to at least one of said parameters.

3. A method as defined in claim **2**; further comprising admitting extraneous gases to said layer for assisting volatilization; and wherein the step of abstracting said liberated gases comprises simultaneously withdrawing said extraneous gases.

4. A method as defined in claim **1**; further comprising the steps of admitting streams of superheated volatilizing gas into alternate ones of said compartments for contact with said layer and passage beyond the respective partition into an adjacent compartment; and withdrawing such gas from the respectively adjacent compartment.

5. A method as defined in claim **1**, wherein said material is a solid fuel to be coked; and further comprising the steps of admitting flue gases into contact with said material during coking thereof for cooling purposes; and utilizing the weak gas produced for heating respective coking zones of said chamber.

6. A method as defined in claim **1**, wherein said material is a solid fuel to be coked, and wherein said chamber has a bottom wall provided with channels which communicate with said chamber; and further comprising the step of blowing cold air through said channels with the latter functioning as recuperators.

7. A method as defined in claim **1**, wherein said material is a solid fuel to be coked, and wherein said chamber comprises conduits provided in said roof; and further comprising the step of cooling said material by passing a cooling medium through said conduits.

8. A method as defined in claim **1**, wherein said material is an ore; further comprising the steps of admixing said ore with a combustible fuel prior to advancement of said layer through said chamber; and conducting the thus-obtained mixture successively through a volatilization and coking zone for the fuel and thereupon through a reducing zone for the ore, all of said zones being defined by said compartments.

9. A method as defined in claim **8**; and further comprising the step of advancing said ore from said reducing zone directly into a melting zone.

10. A method as defined in claim **8**, wherein the step of admixing said ore with said fuel comprises breaking the ore, providing ground additives, and admixing said ore with said additives and fuel to form a flowable mass; and further comprising the step of depositing a continuous at least substantially uniform layer of said mass on said support.

11. A method as defined in claim **10**, wherein said ore is broken to a grain size smaller than that of said additives.

12. An apparatus of the character described, particularly for gasifying or coking solid fuels or oleiferous sands or for smelting ores, comprising a tunnel furnace having an elongated furnace chamber provided with a floor and a roof; a travelling support in the region of said floor and adapted to travel longitudinally of said chamber; a plurality of partitions extending from said roof downwardly towards said support for subdividing the space above the latter into a plurality of individual treating compartments, at least some of said partitions being hollow; gas inlet and outlet openings arranged in alternate ones of said compartments so that gas admitted into one of said compartments must pass beneath a respective partition into the adjacent compartment for access to the outlet opening herein; and means for circulating hot gas through said hollow partitions.

13. An apparatus as defined in claim **12**, wherein said partitions extend transversely of the direction of travel of said support.

14. An apparatus as defined in claim **12**; and further comprising heating means for heating said partitions.

15. An apparatus as defined in claim **12**; and further comprising control means for raising and lowering said partitions with reference to said travelling support.

16. An apparatus as defined in claim **12**, wherein at least some of said partitions are constructed as arc-heating electrodes; and further comprising counter-electrodes for cooperation with and located downstream of the respective arc-heating electrodes, and a source of electric energy connectable with said electrodes.

17. An apparatus as defined in claim **1**, wherein at least some of said partitions are constructed as arc-heating electrodes; and further comprising a source of electric energy connectable with said electrodes.

18. An apparatus as defined in claim **1**, said support comprising a continuous chain of individual but connected receptacles composed of refractory material.

19. An apparatus as defined in claim **1**, wherein said support comprises a plurality of hollow components which are adapted to be heated.

20. An apparatus as defined in claim **1**, said material comprising finer and coarser particles; and further comprising depositing means for separately depositing first said finer and atop the same said coarse particles on said support.

21. An apparatus as defined in claim **1**, wherein said support comprises a turntable.

References Cited

UNITED STATES PATENTS

1,814,463	7/1931	Trent	202—117
3,464,892	9/1969	Bennett	202—98

(Other references on following page)

9

UNITED STATES PATENTS

1,952,363	3/1934	Bunce et al.	202—117
1,493,758	5/1924	Lamie	202—103
3,594,286	7/1971	Kemmerer	201—40
1,906,755	5/1933	Karrick	201—40 X
2,208,705	7/1940	Soubbotin et al.	201—98

FOREIGN PATENTS

104,066	1916	Great Britain	201—19
1,177,062	1964	Germany	202—98

10

540,021	1955	Belgium	202—98

NORMAN YUDKOFF, Primary Examiner

D. EDWARDS, Assistant Examiner

U.S. Cl. X.R.

201—38; 202—98, 117; 48—197 R, 202, 99; 266—20; 208—11