

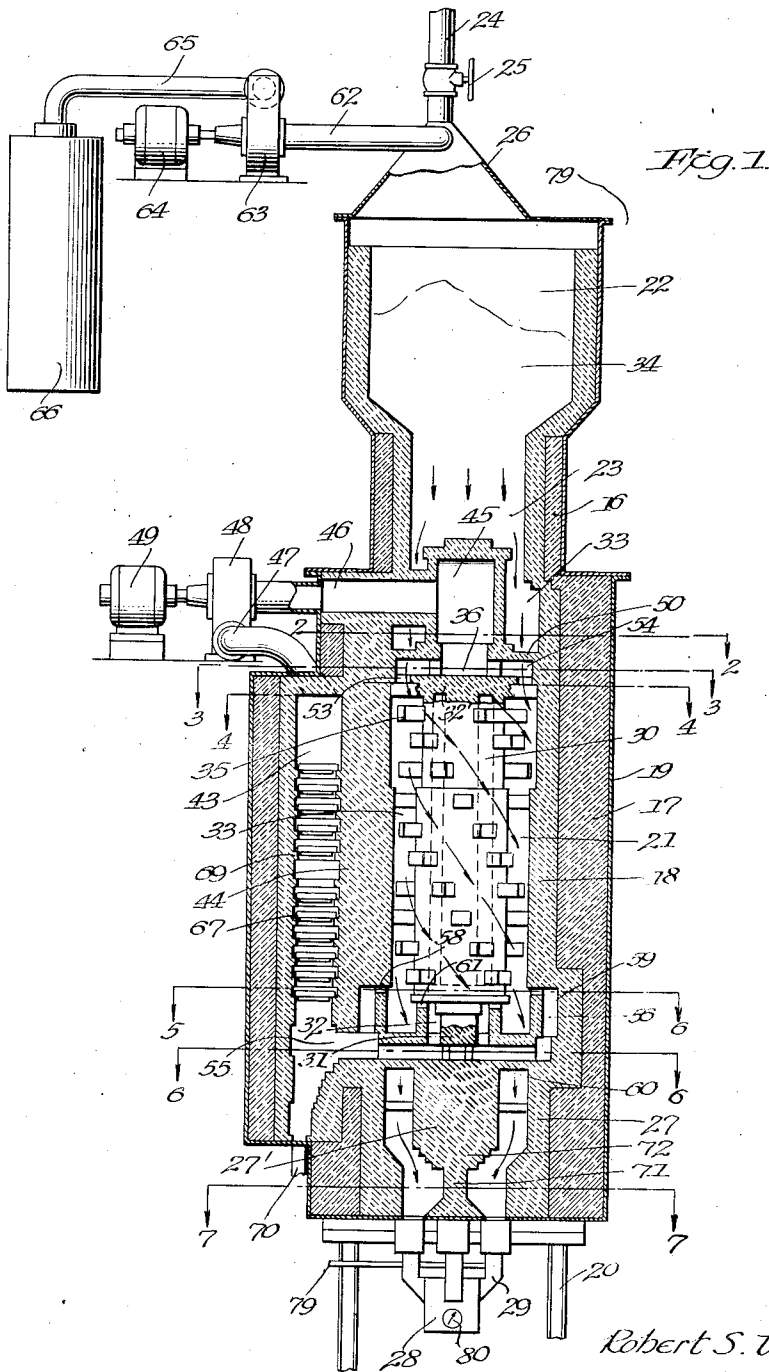
April 5, 1938.

R. S. WALKER

2,113,522

METHOD FOR TREATING CARBONACEOUS MATERIAL

Original Filed Nov. 8, 1934 5 Sheets-Sheet 1



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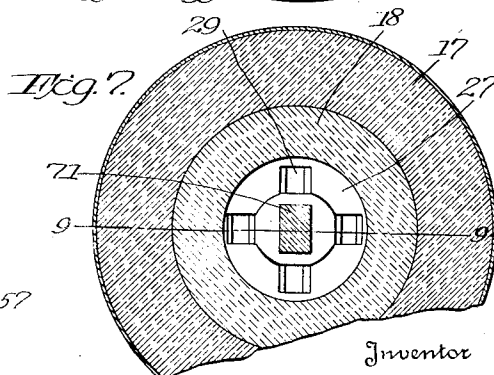
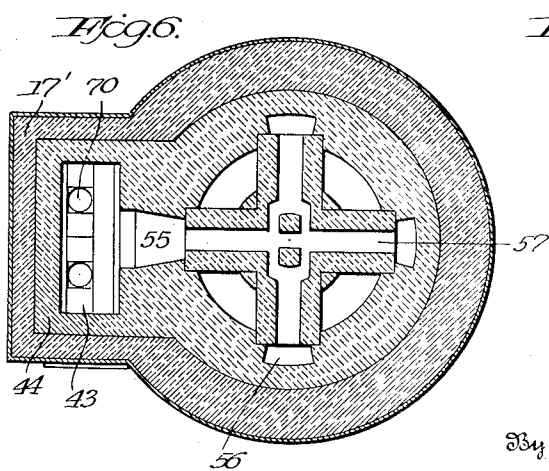
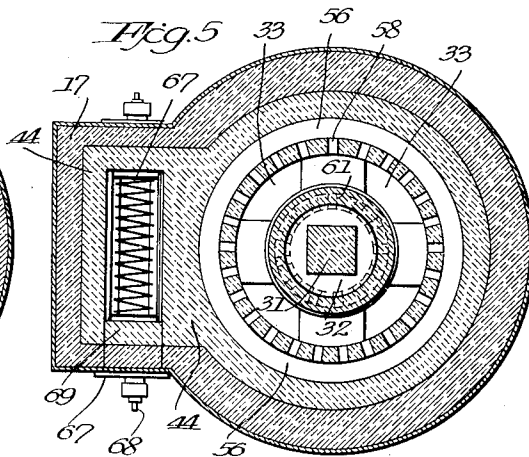
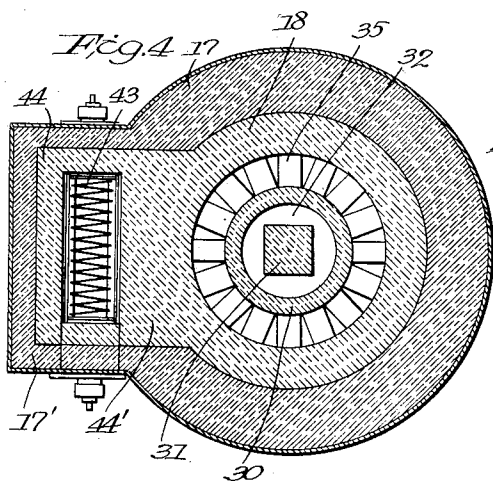
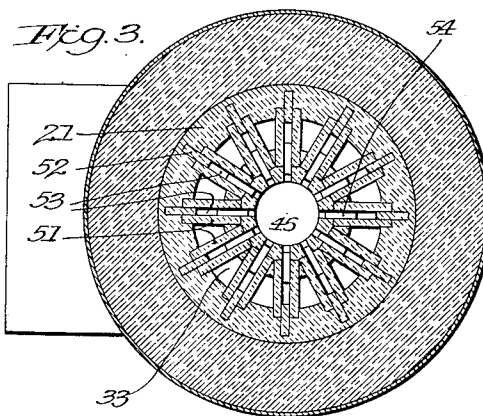
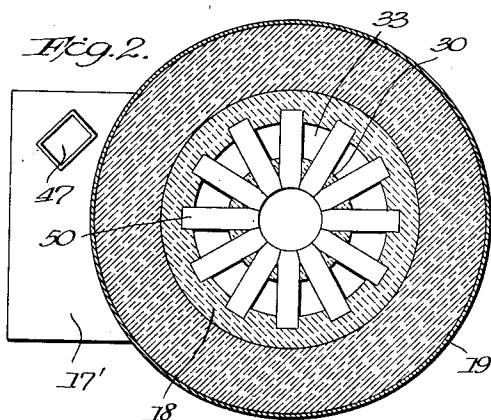
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METHOD FOR TREATING CARBONACEOUS MATERIAL

Original Filed Nov. 8, 1934 5 Sheets-Sheet 2



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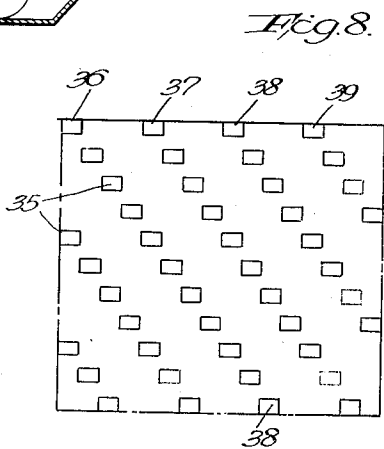
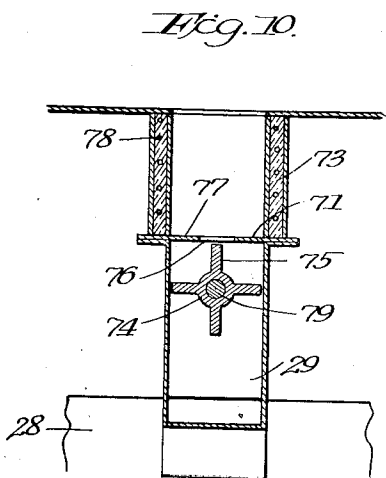
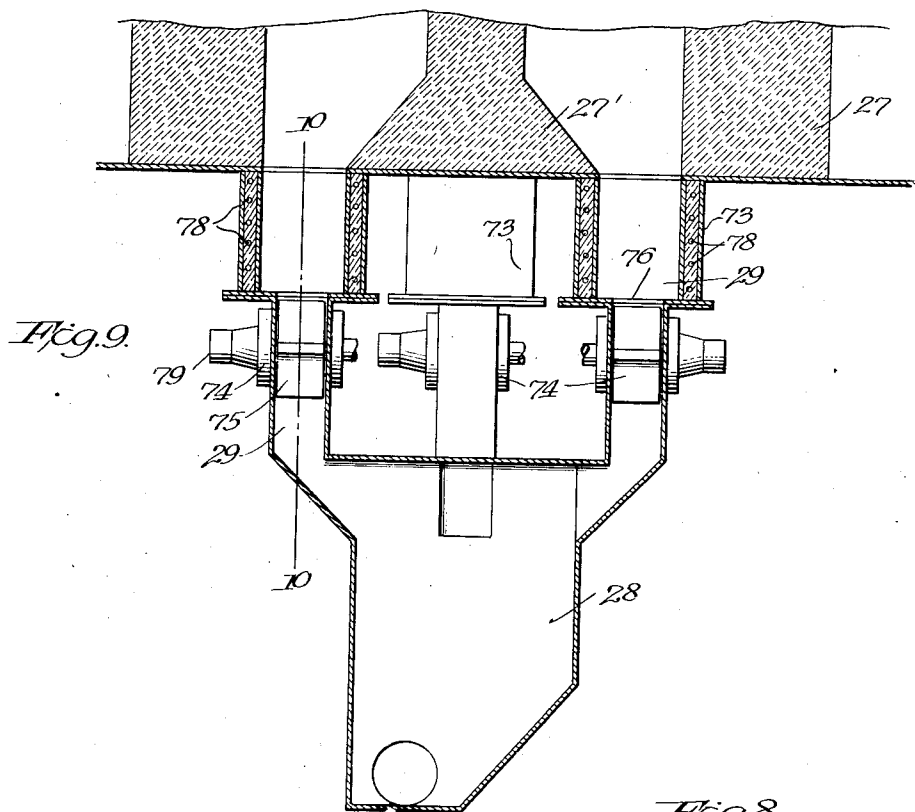
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2,113,522

METHOD FOR TREATING CARBONACEOUS MATERIAL

Original Filed Nov. 8, 1934 5 Sheets-Sheet 3



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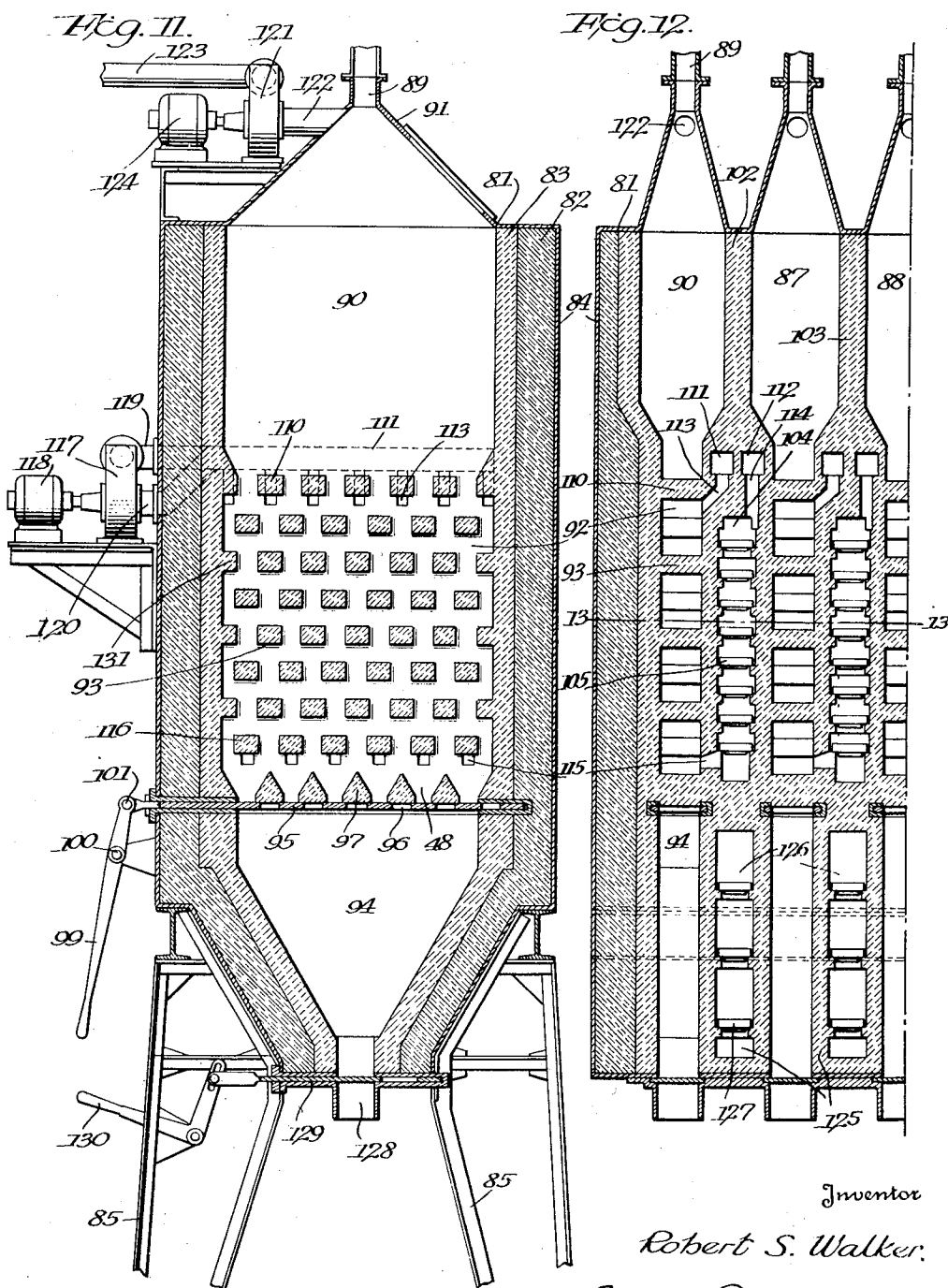
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METHOD FOR TREATING CARBONACEOUS MATERIAL

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METHOD FOR TREATING CARBONACEOUS MATERIAL

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Fig. 13.

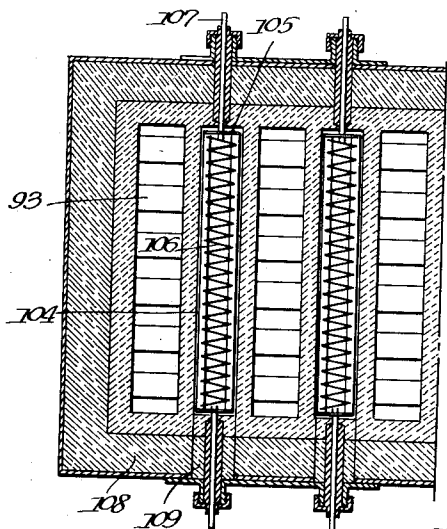


Fig. 14.

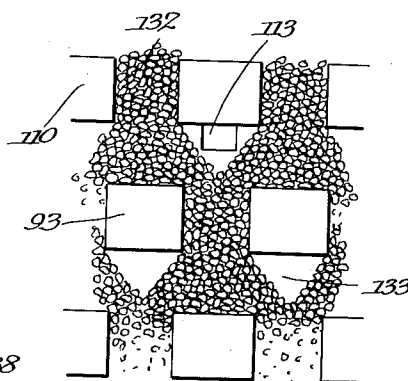
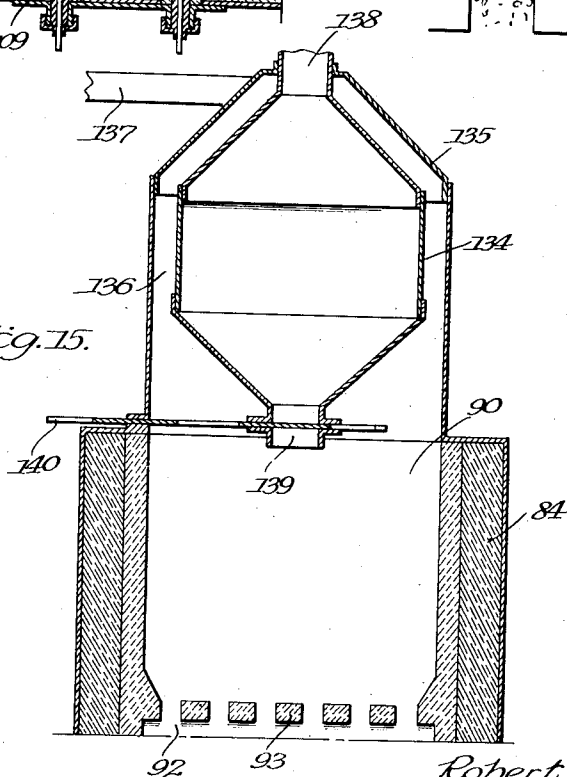


Fig. 15.



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UNITED STATES PATENT OFFICE

2,113,522

METHOD FOR TREATING CARBONACEOUS MATERIAL

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Application November 8, 1934, Serial No. 752,174
Renewed September 7, 1937

4 Claims. (Cl. 263—53)

The present invention is an improved method and apparatus for treating carbonaceous material, and is an improvement upon the method and apparatus disclosed in my copending applications, Serial No. 553,583, Method for treating limestone, filed July 28, 1931, and Serial No. 691,898, Apparatus for treating limestone, filed October 2, 1933.

In my former applications, I have disclosed a method wherein the material is caused to flow or gravitate in a stream, and, at the same time, is directly subjected to heat in an atmosphere inert to the gas, for example, heat produced by an electrical heating medium, in a chamber from which air is excluded and wherein a sub-atmospheric pressure is maintained. This method permits continuous operation in an economical and efficient manner, and the production of substantially pure carbon dioxide. I have discovered that when carbonaceous material is calcined at atmospheric pressure in a carbon dioxide atmosphere, the carbon dioxide tends to cling about the limestone, thereby retarding liberation of further gas and tending to cause re-absorption of the carbon dioxide. I have further discovered that when the treatment is carried on at sub-atmospheric pressure this difficulty is overcome, since the specific gravity of the gas is reduced and it tends to move quickly away from the materials and reduce partial pressure. When the air is excluded and an inert atmosphere maintained, as can be done with an electrical heating means, it is possible to produce a very pure carbon dioxide in an economical manner. By "inert atmosphere", I mean one that does not affect the purity of the carbon dioxide.

The present invention employs these highly valuable features of my process in a somewhat different manner. I have now discovered that it is possible to reduce the carbonaceous material without directly subjecting the same to the electrical heating medium provided the material is caused to gravitate or flow in relatively thin streams, and is thoroughly subjected to a heating medium in an inert atmosphere, such as the released heated carbon dioxide which is circulated through streams of material. In other words, if the material, through at least a part of the calcining chamber, is maintained under sub-atmospheric pressure and is subjected to a countercurrent of highly heated carbon dioxide gas free of impurity while air is excluded, the process is more efficient. That is to say, while the material is caused to flow or gravitate in a thin stream or streams, a countercurrent of highly heated car-

bon dioxide is caused to travel therethrough and impart its heat to the material which liberates more carbon dioxide. This heated carbon dioxide in its circulation is caused to travel through a heating chamber in direct contact with an electrical heating medium which is inert to the gas and does not tend to impart impurities thereto. I have discovered that, in this manner, the gas may be raised to a temperature, for example 2000° F., sufficient to reduce or calcinate the stream or streams of carbonaceous material as it travels therethrough. I find it highly desirable to maintain the pressure in the calcining chamber where the gas contacts with the material below atmospheric, at least throughout a substantial part of the chamber, and to maintain the chamber closed so that air is excluded. It is essential that a thorough distribution of the gas throughout the streams of carbonaceous material be obtained in order to make full use of the heat imparted to the gas in the heating chamber. In some parts of the chamber pressure above atmospheric may be produced without materially affecting the efficiency of the process.

The use of an electrical heating medium to impart heat indirectly to the material, e. g., through a circulation of gas, has been found preferable in some instances to a direct electrical heating of the material as described in my former applications.

I am aware that it has heretofore been proposed in the manufacture of carbonic acid gas by a contact process in which heated gas is circulated through the carbonaceous material, and such a process is disclosed, for example, in the patent to Luhman, No. 706,972, August 12, 1902 and in the patent to Knox, No. 768,230, August 23, 1904. But so far as I am aware, such processes have never been found practicable, for the reason that the gas in its circulation becomes impure, for example, by reason of exposure to the products of combustion or contact with air. Moreover, in such processes where the gas is not subjected to direct contact with products of combustion, it has not been found possible to raise the gas to temperatures sufficiently high to calcinate the material. For these and other reasons, such processes have not been employed commercially.

I utilize the essential features of my original process, namely, (a) the use of an electrical heating medium, (b) the travelling of the material in a stream or streams in a closed chamber, (c) an atmosphere inert to the gas, and (d) a sub-atmospheric pressure in at least a portion of the

chamber. But I have found it possible to dispense with the direct application of the electrical heat and to apply heat to the material from an electrical heating medium by employing the circulating gas as a heating agent.

5 An object of the invention is to provide a simple, efficient and economical method and apparatus for treating carbonaceous material, in which a portion of the gas evolved during calcination is withdrawn in pure condition from the calcining chamber, electrically heated and returned to the calcining chamber in the same pure condition to constitute heat circulating means for effecting calcination of the material.

10 Another object of the invention is to provide a new and improved method and apparatus for recovering pure carbon dioxide gas directly from the reduction of limestone into lime.

A further object is to provide a method for thoroughly subjecting the material to the heat in a closed calcining chamber by interrupting and dividing the material into a stream or streams as it passes through the calcining chamber, thereby insuring substantially uniform distribution of the heat throughout the material and calcining chamber.

A further object comprehends the provision of a calcining apparatus including interrupting or retarding means for separating the material into thin streams, such means comprising spaced rows of horizontally and vertically offset refractory members, each member of the rows being staggered or offset relative to the adjacent upper and lower member, so that the material, as it passes through the calcining chamber, will be continuously and progressively divided into thin streams to insure thorough calcination.

Another object is to insure the uniform distribution of the heated gas as it passes through the chamber, thus preventing the material in certain areas of the chamber being subjected to a degree of heat differing from the heat applied to material in other areas.

A characteristic feature of the apparatus is a closed calcining chamber and a communicating heating chamber, the calcining chamber being provided with means for allowing a portion of the evolved gas as it circulates through the chamber to be confined within the calcining chamber without contacting with the material, and also with means which permits another portion of the heated gas to contact with the material. These two separate portions of the heated gas thus constitute direct and indirect means for insuring the complete calcination of the material as it passes through the calcining chamber. Additionally, the calcining chamber has interrupting means therein for dividing the charge into thin streams that are fed in substantially spiral or sinuous paths through the calcining chamber.

Another feature of the invention consists in associating a soaking pit with the calcining chamber and providing the soaking pit with heating means to insure the thorough calcination of the material before it is discharged from the apparatus and prevent a drop in temperature from radiation losses.

A still further feature of the invention is a construction adapted to provide a battery of furnaces for treating carbonaceous material which may be increased or reduced in number as conditions warrant. Each furnace may comprise a calcining chamber which communicates adjacent its opposed ends with a heating chamber so as to provide a circulating passage for withdrawing

the evolved gas and conducting it to the heating chamber where it is heated to the desired temperature prior to being returned to the calcining chamber to treat the material therein.

Other objects and advantages of the invention will become apparent from the following description when taken in conjunction with the accompanying claims and drawings.

Referring to the drawings which disclose several preferred embodiments of the invention,

Figure 1 is a vertical sectional view of my apparatus for treating carbonaceous material with parts in side elevation.

Figure 2 is a sectional view taken substantially along the line 2—2 of Figure 1.

Figure 3 is a sectional view taken substantially along the line 3—3 of Figure 1.

Figure 4 is a sectional view taken substantially along the line 4—4 of Figure 1.

Figure 5 is a sectional view taken substantially along the line 5—5 of Figure 1.

Figure 6 is a sectional view taken substantially along the line 6—6 of Figure 1.

Figure 7 is a sectional view taken substantially along the line 7—7 of Figure 1.

Figure 8 is a developed view showing the arrangement of the interrupting members in the material passage.

Figure 9 is an enlarged sectional view of the apparatus taken substantially along the line 9—9 of Figure 7.

Figure 10 is a sectional view taken substantially along the line 10—10 of Figure 9.

Figure 11 is a vertical sectional view of a modified form of the apparatus.

Figure 12 is a sectional view taken substantially at right angles to Figure 11.

Figure 13 is a sectional view taken along the line 13—13 of Figure 12.

Figure 14 is a fragmentary view of the interrupting means shown in Figure 11, and

Figure 15 is a sectional view of a modified form of receiving tank and closure member which may be substituted for the corresponding parts shown in Figure 11.

The methods heretofore employed in treating carbonaceous material to recover the evolved pure gas have not been commercially feasible due to the fact that these methods are either unsatisfactory or so expensive as to render them prohibitive. It has been customary in most of the prior methods to heat the carbonaceous material by direct contact with the products of combustion of coal or gas so that the evolved carbon dioxide gas mixes with the air and products of combustion, thus necessitating the separating of the impure gases from the carbon dioxide gas before the latter can be recovered in pure condition. Moreover, in view of the large quantity of fuel consumed in heating the carbonaceous material to the desired temperature to effect calcination, and also because of the expense in constructing a furnace capable of withstanding the high degree of heat to which the material must be subjected, these methods have not been found commercially successful or economical.

The electric heating of carbonaceous material to obtain the evolved gas in pure form has not been given serious consideration because the cost of electric heating has been regarded as too expensive to produce the pure gas on a scale that would be commercially profitable. One serious objection to the electric heating of carbonaceous material is that for this method to be efficient the charge should be brought into intimate con-

tact with the electrical heating means. If the heating means is composed of material that produces a gas which contaminates or dilutes the carbon dioxide gas when mixed therewith, the impure gas has to be removed before the carbon dioxide gas can be recovered in pure form. Another objection to the electric heating method is that due to the high temperature required to calcinate the material, it is difficult to heat the charge uniformly so that portions of the material are either insufficiently burned or overburned.

In order to overcome the defects heretofore found to be inherent in the electric heating of carbonaceous material to recover the evolved gas in substantially pure form, I have provided a new and improved method in which the evolved pure gas is utilized as the medium for transferring the electrically generated heat to the charge during the calcining operation. This is effected by feeding the carbonaceous material in a thin stream or streams through a closed zone heated by the evolved gas liberated from the material. (The air in the heated zone is first removed so that the material is treated under sub-atmospheric or negative pressure.) The pure carbon dioxide gas as it is evolved is circulated through a heated chamber or passage preferably having an electrical heating unit or units therein. Each heating unit is composed of a suitable resistance which is inert with respect to the evolved carbon dioxide gas so as not to have any deleterious effect on the evolved gas as the latter is brought into intimate contact with the heating unit. In other words, when the carbon dioxide gas contacts with the heating unit no harmful chemical reaction will take place and there will be no formation of a gaseous mixture which would require the separation of the carbon dioxide gas therefrom before the latter can be removed in pure condition. As the evolved gas passes through the heated chamber or passage its temperature is raised by the heating unit and the heated gas is returned to the heating zone. The pure heated gas then passes through the heated zone in a direction counter to the flow of the stream or streams of the carbonaceous material and at a sufficiently high temperature to produce rapid calcination of the material as the latter is brought into intimate contact with the heated gas.

It will, therefore, be seen that by reason of my improved method, the evolved pure gas is efficiently and economically recovered and may be utilized at sub-atmospheric pressure as the means for transferring heat to the carbonaceous material without in any way affecting its purity or requiring further treatment before it is removed from the closed heated zone.

It will be understood, therefore, that the method has certain definite preferred characteristics, which may be briefly summarized as follows:

(a) The maintenance of a condition within the calcining chamber which will overcome the tendency of the gas to cling to the material, which tendency exists at normal or atmospheric pressure. I prefer a sub-atmospheric pressure throughout a substantial portion of the chamber, although in some instances a pressure substantially higher than atmospheric has been found to accomplish the desired results, provided some medium which will reduce the partial pressure is admitted into the chamber. Air is objectionable, because of the difficulty in separating the same from the carbon-dioxide, but, as is well known, other media not open to this

objection are available and may be used. As has been explained, there is a tendency under atmospheric or super-atmospheric pressure for the liberated carbon dioxide to adhere to or cling about the stone. The maintenance of a condition which will counteract this tendency, is, therefore, highly desirable. The sub-atmospheric pressure tends to stretch or rarefy the gas and in this way contributes to overcoming the tendency of the gas to cling about the stone. The degree of vacuum maintained may be materially reduced if the process is carried out by using other media which assists in carrying the gas from the stone, but, in such cases, the media employed must be of a character which will be readily separable from the gas and substantially non-miscible therewith. In certain chemical processes where a mixture of air with carbon dioxide is not objectionable, it may be used, and, in such instances, the pressure may be raised or the degree of vacuum reduced.

(b) Causing the material to flow in a relatively thin stream or streams while continuously subjecting the same to a countercurrent of highly heated pure gas.

(c) An electrical heating medium inert to the gas is used to apply heat, preferably in an indirect manner, by recirculating the gas and causing it to pass in direct contact with the electrical heating medium.

These essential characteristics of the method enable the same to be practiced in a continuous manner and permit the production of pure carbon dioxide.

A suitable apparatus for practicing my method comprises a unitary kiln or shaft furnace built up or constructed so as to include an outer wall of suitable heat resisting material, such as silocel or red brick, and an inner brick wall or lining of refractory material which has a high thermal conductivity, such as fire brick or the like. The apparatus is enclosed within a steel casing or jacket and may be supported in any suitable manner, as by the frame or uprights.

The intermediate portion of the apparatus constitutes a calcining or reducing chamber (Fig. 1) which communicates at its upper end with a material receiving compartment or tank through a reduced portion. The charge is delivered to the compartment through a supply pipe or spout controlled by the valve. The top of the compartment is closed by a hood or cover which communicates with the supply pipe. The lower end of the calcining chamber communicates with a soaking pit which in turn discharges into a tank through the spaced passages or pipes. The calcining chamber, compartment, and soaking pit constitute a vertical passage through which the material passes in a plurality of streams, and these parts are enclosed within the refractory wall which in turn is insulated against loss of heat by the insulated wall. The apparatus may be of any desired size and shape and when of a twenty-five ton capacity, it has been found that desirable results are obtained by having the internal diameter of the calcining chamber approximately eight feet with a material receiving area of approximately fifty square feet.

Extending upwardly within the soaking pit and spaced from the lining is a column of refractory material. Above the column and in substantially vertical alignment therewith is a tubular or hollow member having therein an axially disposed post or pier which

preferably extends the length of the calcining chamber 21 within the tubular member 30. The space between the tubular member 30 and the post 31 constitutes an annular heating chamber 32 which is closed at the upper end of the calcining chamber as by a cap 32'.

The tubular member 30 is also spaced from the inner wall of the calcining chamber 21 to form a passage 33 through which the charge 34 from the compartment or tank 22 passes to be calcinated by the heated gas which passes upwardly through the same passing in a direction counter to the flow of the material.

To insure the thorough calcination of the material as it gravitates through the passage 33, means is provided for progressively interrupting and retarding the flow of the charge and dividing the same into thin streams. This means comprises spaced refractory members or blocks 35 that are built into the apparatus and extend radially from the tubular member 30 to the inner wall 18 of the calcining chamber (Fig. 4). As illustrated in the developed view shown in Figure 8, the members 35 are arranged in uniformly spaced stepped relation in four spiral rows 36, 37, 38 and 39, each brick being vertically offset, staggered or stepped relative to the adjacent upper brick so as to be in the path of the material as it falls from the upper brick. By reason of this arrangement the material is progressively interrupted and subdivided into thin streams throughout its passage through the calcining chamber. Additionally, the interrupting members serve to distribute the heat uniformly throughout the calcining chamber to insure thorough and complete calcination of the charge.

Within the apparatus, and preferably positioned to one side of the calcining chamber 21, is a heating chamber or passage 43 arranged to be heated by suitable means which will be subsequently described. The heating chamber 43 is preferably formed in a lateral offset portion 44 of the inner wall 18 and is spaced from the calcining chamber 21 by the refractory wall 44' through which heat may be conducted to the chamber 21. The outer wall 17 has an offset portion 17' which encloses the portion 44 and the chamber 43 in the manner as shown in Fig. 4.

At the upper end of the chamber is a gas reservoir or collector 45 having a port 46 which communicates with the upper portion of the heated chamber 43 through a pipe 47 in which is positioned a suction fan 48 operated by a motor 49. The reservoir 45 is connected to the inner wall of the calcining chamber by the radially disposed webs or bricks 50 (Fig. 2) which are suitably spaced to allow the charge to fall freely from the compartment 22 to the calcining chamber 21. In order that a portion of the evolved gas in the calcining chamber 21 may be circulated through the apparatus to heat the material, the passage 33 is arranged to communicate with the reservoir 45 in any suitable manner, and as shown in Figure 3, this may be effected by positioning beneath the webs 50 blocks 51 separated by the spacer blocks 52 so as to form a series of vertical passages 53 and horizontal passages 54 which establish communication between the chamber 33 and reservoir 45 adjacent the upper end of the tubular member 30 (Fig. 1).

The lower portion of the heating chamber 43 has a laterally disposed port 55 (Fig. 6) which communicates with an annular chamber or passage 56, which in turn communicates with four radial passages 57. The passages 57 lead to

the interior of tubular member 30 to conduct a portion of the heated gas from the lower end of the chamber 43 into the tubular member where it is confined due to the fact that the upper end of the member is closed. The heat of the gas is imparted to the material in chamber 21 through the wall of the tubular member. The remaining portion of the heated gas traveling through port 55 is delivered to the lower end of the calcining chamber 21 through the radial ports 58 (Fig. 5) in the wall 59 which separates the passage 56 from the calcining chamber.

It will be seen that the heated gas as it issues from the chamber 43 through the port 55 is divided into two streams, one of which is conducted by the ports 57 to the interior of tubular member 30 which is closed at its upper end. The lower end of the chamber 32 communicates with the chamber 33 through the ports 61 formed in the tubular member. The remaining portion of the heated gas passes from the chamber 56 through the openings 58 (Fig. 5) into the calcining chamber and passes upwardly through the material at a sufficiently high temperature to effect rapid calcination. A portion of the gas in the passage 33 is delivered to the reservoir 45 through the passages 53 and 54 where it is drawn by the suction of the fan 48 through the pipe 46 and forced through the heating chamber 43. The remaining portion of the evolved gas passes upwardly through the charge 34 to preheat the same, and is withdrawn from the tank 22 through a pipe 62 by a fan 63 operated by the motor 64. From the pipe 62 the gas is conducted by a pipe 65 to a storage or receiving tank 66. The confined gas in the annular opening or closed passage 32 is allowed to escape slowly through the ports 61 to the passage 33 due to the suction created in the calcining chamber by the fans 48 and 63, so that a constant flow of heated gas from the chamber 43 is delivered to the interior of the tubular member 30 to maintain the same at a uniform temperature.

While any suitable electrical heating means may be employed for heating the circulating gas as it passes through the chamber 43, I prefer to use an electrical heating unit that will be inert to the circulating gas brought into contact therewith; a heating or resistance unit of nichrome metal will serve this purpose. These units may be composed of a series of vertically disposed electric resistance members 67, each of which consists of a grid 67' extending transversely of the chamber 43 (Fig. 5). Leads 68 connect each of the grids 67' to any suitable source of current or control apparatus so that the temperature in the heating chamber may be varied to heat the material. The grids 67' are separated from the calcining chamber by the wall 44' which serves to protect the heating units 67 and which also prevents the material from passing into the upper portion of the heating chamber 43. The resistance units 67 are capable of producing a temperature of 2000° F. in the chamber 43 which is sufficient to disassociate completely the gas from the material during the calcination operation. Preferably one of the side walls 69 of the chamber 43 is removable so that the heating units 67 may be readily inserted or withdrawn from the heating chamber. In order to facilitate this movement, the inner wall of the chamber 43 is formed with spaced vertically disposed ledges 69 for slidably receiving each of the heating units 67.

Dust or other foreign matter that may ac-

accumulate within the chamber 43 during the operation of the apparatus may be withdrawn through the discharge pipes 70 which lead from the lower end of the heating chamber 43 to a dust collector or the like (not shown).

The base of the column 27' extends upwardly in the soaking pit 27 and is provided with a reduced portion 71 to increase the area of the soaking pit. Extending outwardly from the reduced portion 71 are a series of stepped portions 72 that act to increase the heating surface of the column and assist in calcinating the material in the soaking pit. Means is provided for heating the material in the soaking pit; this may be effected by enclosing the upper end portions of each of the discharge pipes or passages 29 (Fig. 9) within a thin refractory wall 73 which may be heated in any suitable fashion, as by the electrical resistance coils 78 embedded in the wall 73. The maintenance of the material in heated condition in the soaking pit prevents re-absorption of the gas.

In order to insure the withdrawal of the treated material or lime from the apparatus at predetermined intervals so that each charge will be uniformly treated, each of the pipes 29 is provided with a rotatable feeder 74 having spaced blades 75 of substantially the same width as the interior of the pipe. The feeders 74 are positioned beneath elongated openings 76 in the plates 77 to receive the treated charge or lime and conduct it to the tank 28. A drive shaft 79 connected to a motor, not shown, is keyed or otherwise secured to each of the feeders 74 to discharge the material in the pipes 29 to the tank 28 at predetermined intervals during the operation of the apparatus. Each of the blades 75 is associated with the opening 76 so that when the blades are rotated to withdraw the material from the pipes 29, each succeeding blade will be moved to a position medially of the opening 76 (Fig. 10) and will coact with the blade which is being moved away from the opening to prevent any material from escaping between the ends of these blades and the adjacent wall of the pipe.

In operation, the carbonaceous material to be treated, such as limestone, is introduced into the receiving compartment 22 through the spout 24, controlled by the valve 25, and is fed downwardly through the reduced portion 23 into the calcining chamber 21. As the charge passes the spaced webs 50 it is separated and impinges on the upper horizontal row of blocks 36 from where the separate streams successively fall on the lower adjacent offset blocks so as to be continuously subdivided into thin streams, thus insuring the particles being brought into intimate contact with the heated gas passing upwardly through the apparatus. The relative location of the interrupting members 35 causes the material to pass through the calcining chamber in tortuous or spiral paths, as indicated by the arrows in Fig. 1. The heat confined within the passage 32 serves to heat the tubular member 30 which, in turn, heats the material in the passage 33. During this operation, a portion of the evolved gas is drawn by the suction of the fan 48 through the openings 53 and 54 into the reservoir 45 where its temperature is reduced to about 1200° F. due to the fact that it has given up some of its heat in treating the material in the calcining chamber. This gas is then conducted by the pipes 46 and 47 into the heating chamber 43 where it contacts with the heating units 67 so that its temperature is raised to approximately 2000° F. This heated

gas is then forced through the port 55 where it is divided so that a portion thereof is carried by the passages 57 to the annular opening 32 while the remainder of the heated gas is delivered through the ports 58 into the passage 33 and as it passes upwardly, due to the suction created by the fans 48 and 63, it is brought into intimate contact with the thin streams of material to thoroughly heat the same.

As the tubular member is closed at its upper end, the heated gas confined therein will tend to maintain the tubular member 30 sufficiently heated so that this radiant heat will combine with the heat directly applied by the gas in the calcining chamber 21 to insure thorough calcination of the material. A portion of the evolved pure gas in the chamber 33 is delivered as previously described through the openings 53 and 54 to the reservoir 45 so as to be conducted to the heating chamber 43 and utilized as the medium for transferring the heat to the calcining chamber. The remaining portion of the pure gas in the passage 33 is drawn up by the fan 63 through the compartment 22 to preheat the charge therein and then is conducted by the pipes 62 and 65 to the storage tank 66.

In the initial operation of the apparatus, the compartment 22 is filled with calcium carbonate or the like, and the valve 25 is cut off so as to completely close the apparatus and the air is withdrawn by the suction of the fan 63. The amount of time required and the duration the material is exposed to the heat varies with the character of the material being treated. When Bellefonte limestone, known as Trenton Ledge, is being treated, and it is desirable to liberate the evolved carbon dioxide gas in substantially pure form, the electrical heating units 67 in the heating chamber 43 will produce a temperature of approximately 2000° F., which is sufficient to effect complete calcination of the material, especially under sub-atmospheric pressure. The evolved gas drawn into the reservoir 45 gives up a portion of its heat by reason of its contact with the raw material or limestone, and is discharged into the heating chamber 43 through the pipes 46 and 47 at a temperature below 1200° F. and 1400° F. As the gas circulates downwardly through the heating chamber 43 and past the heating units 67, its temperature is raised to approximately 2000° F., and at this temperature it is introduced into the calcining chamber in the manner as previously described. As the heating units 67 are formed of suitable material inert to the gas, they have no deleterious effect on the evolved pure gas passing through the passage 43 and allow the heated gas to be returned to the calcining chamber in its pure form.

The exhaustion of the air from the apparatus is ascertained by testing the carbon dioxide passing through the pipe 65 and after the air has been completely withdrawn, the carbon dioxide gas in substantially pure form is delivered to the tank 66 and constitutes a very valuable by-product to be used in the manufacture of solid carbon dioxide more commonly known as "dry ice" in making chalk and for other suitable purposes. When starting the apparatus the fan 63 is preferably operated before the fan 48, to insure the air being withdrawn prior to the circulating of the evolved gas through the calcining and heating chamber.

By maintaining the apparatus constantly at a slight vacuum or under sub-atmospheric pressure, the gas evolved during calcination is im-

mediately withdrawn so as to avoid re-carbonization and is allowed to either circulate through the heating chamber 43 and be returned to the calcining chamber to thoroughly heat the material therein or is withdrawn from the calcining chamber to preheat the charge in the tank 22 prior to it being delivered to the storage tank 66 by the fan 63. The discharge feeders 74 in the passages 29 are timed to operate at the proper speed to withdraw the lime or treated material from the apparatus as fast as complete calcination takes place.

The method of treating the carbonaceous material is continuous and one charge of the material in the tank 22 may be operated for twenty-four hours without re-charging the same or the discharging of the treated material from the tank 28. When discharged at the end of the treated period, the fan 63 is cut off. Immediately a carbon dioxide pressure is generated within the apparatus brought about by continued calcination of the material. As soon as this pressure is disclosed at the gauges 79 and 80, the tank 22 is re-charged and the tank 28 is emptied. The carbon dioxide pressure within the apparatus prevents air from entering the system. This entire operation requires between five to ten minutes. Therefore, very little time is lost due to re-charging the apparatus and discharging the lime or treated material therefrom.

It has been found that when limestone is calcined at atmospheric pressure in a carbon dioxide atmosphere, the evolved carbon dioxide gas has a tendency to cling about the limestone and its natural pressure, due to its weight, not only retards liberation of further gas, but the lime is at such a temperature that it will absorb the carbon dioxide and re-carbonate. It will therefore be seen that by initially withdrawing the air from the apparatus and treating the material at a negative or sub-atmospheric pressure through at least a part of the calcining chamber, these difficulties are eliminated, since the evolved gas is allowed to escape immediately.

In the modified form of the invention shown in Figs. 11 and 12, the apparatus is preferably formed so that sections may be added to or removed from the apparatus in order that batches of material of varying quality or size may be simultaneously and separately treated at the same temperature or at different temperatures, as conditions may warrant. The apparatus comprises a shaft furnace 81 having an insulated outer wall 82 and a refractory inner wall or lining 83. The outer wall is enclosed within a steel jacket 84 and may be supported on the ground or on a suitable base by a frame 85.

For the purpose of illustrating the arrangement of the shaft furnaces constituting the apparatus, I have shown three of such furnaces 81, 87 and 88. It will be understood, of course, that any number of these furnaces may be employed so as to form a battery of devices for simultaneously treating the material in separate batches. As each furnace is identical in construction and operation, only one will be described.

The material to be treated is delivered by the spout 89 to the receiving compartment or tank 90 which, as shown, is of elongated shape and is closed by a hood or cover 91. The calcining or reducing chamber 92 is positioned beneath the tank 90 and has spaced interrupting members or blocks 93 of suitable refractory material which extend transversely across the inner wall

of the calcining chamber to interrupt the flow of the material as it falls therethrough. These blocks are uniformly spaced in longitudinally and vertically disposed rows, the blocks of each horizontal row being offset relative to its adjacent upper and lower brick so as to continuously interrupt and divide the material into thin streams as it passes through the calcining chamber 92. A soaking pit 94 receives the treated material as it issues from the calcining chamber. The flow of the material to the soaking pit may be controlled by a slidable gate valve 95 having spaced openings 96 arranged to be moved from beneath the grids or blocks 97 to register with the openings 98 between the grids 97 to permit the material to flow freely into the soaking pit 94. Suitable operating means, either automatic or manual, is provided to actuate the valve; for example, a manually operable handle 99 pivoted to the apparatus as at 100, is connected to the outer end of the valve as at 101 to move the openings 96 into and out of registration with the complementary openings 98 in the bottom of the calcining chamber. The furnace 81 is spaced from the adjacent furnace 87 by a refractory wall 102 and the furnace 87 is spaced from the furnace 88 by a similarly formed wall 103. Each of these walls extends the length and width of the apparatus so as to constitute one side of the receiving compartment 90, the calcining chamber 92 and the soaking pit 94. The wall 102 adjacent the calcining chamber has a heating passage 104 in which are positioned electric heating units 105. Each of these units consists of a resistance grid 106 (Fig. 13) connected by the leads 107 to any suitable source of current or control apparatus so as to vary the temperature in the heating chamber. One of the end walls, such as 108, has a removable portion or block 109 to permit the ready removal or insertion of the units 105 into the heating chamber 104.

Formed in each of the walls 102 and 103 adjacent the upper horizontal row 110 of the interrupting members 93 are a pair of spaced passages or conduits 111 and 112 (Fig. 12). The passage 111 communicates with the calcining chamber 92 through a series of inclined ports 113 that extend from beneath each of the interrupting members of the upper horizontal row 110. A suction fan 117 operated by a motor 118 communicates through the pipe 119 with the passage 111 and through the pipe 120 with the passage 112 so that upon the operation of the fan, a portion of the evolved gas in the calcining chamber 92 is drawn through each of the passages 113 to the passage 111 and is carried by the pipe 119 through the fan and discharged by the pipe 120 into the passage 112. From the passage 112 the gas is forced downwardly into the heating chamber 104 through the passage 114 so as to be brought into intimate contact with the heating units 105. The heated gas is withdrawn from the bottom of the chamber 104, through the ports 115 and delivered into the lower portion of the calcining chamber 92, at a sufficiently high temperature, e. g. 2000° F., to produce rapid calcination of the material, as the latter gravitates downwardly and sub-divided into thin streams by the interrupting members 93.

The remaining portion of the evolved gas liberated in the calcining chamber 92 is drawn upwardly through the charge in the receiving compartment 90 by the suction of the fan 121 which communicates with the receiving compartment

90 through the pipe 122. As the evolved gas passes through the material, it gives up its heat to initiate calcination of the charge in the compartment 90. The pure gas from the pipe 122 is delivered to a suitable storage tank, not shown, by the pipe 123. The fan 121 may be operated in any suitable manner, such as by the motor 124.

The lower portion 125 of the wall 102 adjacent the soaking pit 94 is preferably provided with an auxiliary heating chamber 126 (Fig. 12) in which are positioned electrical heating units 127 that act to maintain the soaking pit 94 at a sufficiently high temperature to prevent re-absorption of the gas. After the material has been thoroughly treated, it is withdrawn from the soaking pit 94 through a spout 128 which is controlled by a slidable valve 129 operable by the handle 130.

In order to insure the uniform circulation of the heated gas through the calcining chamber 92 and thus prevent certain areas being subjected to different temperature than others during the calcining operation, the lining 93 of the calcining chamber has a series of vertically disposed uniformly spaced projections 131 between which are alternately positioned horizontal rows of the interrupting members 93. These projections coact with the adjacent interrupting members 93 to deflect the heated gas and insure its uniform distribution throughout the calcining chamber 92, thus precluding any appreciable varying of the temperature of the heated gas at certain points in the calcining chamber which would cause particles of the material to be either overburned or underburned and impair the efficiency of the apparatus.

As diagrammatically illustrated in Fig. 14, the interrupting members 93 of each horizontal row are horizontally offset relative to the members immediately above and below the same so that as the material 132 (Fig. 14) passes between the members of each horizontal row, it will pile up on the interrupting members immediately below and be divided into streams that extend from opposite sides of each of the lower interrupting members. In other words, the spaces between adjacent horizontal rows of the interrupting members 93 are filled by substantially triangular-form heaps of material between which the heated gas circulates so as to be brought into intermediate contact with the material during the calcining operation. As the material builds up in a pyramidal heap on each block 93, it forms gas pockets 133 (Fig. 14) of pyramidal form beneath each of the interrupting members or blocks. The formation of these pockets tends to insure the thorough heating of the material and also permits the ready removal of a portion of the evolved pure gas through the passages 113 in the upper horizontal row 110, so that this gas may be circulated through the heating chamber 104 and be returned to the calcining chamber 92 at a sufficiently high temperature to effect rapid calcination of the material.

As shown in Fig. 15, the raw material or limestone prior to its introduction into the receiving compartment or tank 90 may be preheated by the evolved gas, which is withdrawn from the calcining chamber 92, by positioning a hopper 134 within the hood or cover 135. The hopper 134 is suitably spaced from the hood 135 to provide a passage 136 which communicates the receiving compartment 90 with the discharge pipe 137, so that the evolved pure gas, which is withdrawn from the apparatus and conducted through

the pipe 137 to a storage tank, in the manner previously described, may be utilized to pre-heat the charge in the hopper 134 prior to the latter's introduction into the receiving compartment 90. The material to be treated is initially introduced into the hopper 134 through a spout 138 and after the treated material has been withdrawn from the apparatus, the pre-heated material in the hopper 134 is delivered to the receiving compartment 90 through a spout 139, which is controlled by a slidable gate valve 140. The operation of the device is otherwise substantially similar to the apparatus shown in Fig. 11. By reason of this arrangement, the evolved gas is utilized to heat and initiate calcination of the material in the hopper 134 as the heated gas is drawn through the passage 136 on its way to the storage tank through the pipe 137, thereby reducing the time and expense involved in calcinating the charge.

It will be observed that in all the forms of the invention disclosed, the evolved gas liberated during calcination, is utilized as the medium for transmitting the heat to the material, and that very little, if any of this heat is dissipated. Moreover, the means provided for continuously and progressively interrupting and retarding the flow of the material and which divides the charge into streams as it gravitates through the calcining chamber, insures the particles of material being brought into intimate contact with the heated circulated gas so as to effect rapid and thorough calcination of the charge at a minimum of current consumption.

It will be understood that the method and forms of the invention shown for recovering the gas in pure condition from carbonaceous material are merely illustrative of preferred embodiments, and that such changes may be made as fall within the purview of one skilled in the art without departing from the spirit of the invention and the scope of the appended claims.

I claim:

1. The method of treating alkali earth carbonate material to obtain the evolved gas in substantially pure form, which consists in passing the material in a substantially continuously moving stream through a closed heated zone maintained under sub-atmospheric pressure, separating the material as it passes through the heated zone into thin streams by progressively interrupting and retarding its flow, withdrawing the evolved gas, heating the liberated gas by passing the same through an electrically heated passage and into direct contact with an electrical heating medium in said passage, and returning the heated gas to the heated zone at a temperature sufficient to produce rapid calcination of the material and in a direction counter to the flow of the material whereby the heated gas intimately contacts with the particles of material at all points in the heated zone to insure a thorough and uniform heating thereof.

2. The method of treating alkali earth carbonate material to obtain the evolved gas in substantially pure form, which consists in passing the material in a substantially continuously moving stream through a closed heated zone maintained under sub-atmospheric pressure, separating the material as it passes through the heated zone into thin streams by progressively interrupting and retarding its flow, so as to move the sub-divided streams downwardly in an irregular path through the heated zone, withdrawing the evolved gas, heating the liberated gas by

passing the same through an electrically heated passage and into direct contact with the electrical heating medium in said passage, and returning the heated gas to the heated zone at a temperature sufficient to produce rapid calcination of the material and in an irregular path counter to the flow of the material whereby the heated gas directly contacts with the particles of material at all points in the heated zone to insure thorough and uniform heating thereof.

3. The method of treating alkali earth carbonate material to obtain the evolved gas in substantially pure form, which consists in passing the material in a substantially continuously moving stream through a closed heated zone maintained under sub-atmospheric pressure, separating the material as it passes through the heated zone into thin streams by progressively interrupting and retarding its flow, withdrawing the evolved gas, heating the liberated gas by passing the same through an electrically heated passage and into direct contact with an electrical heating medium in said passage, and returning the heated gas to the heated zone at a temperature sufficient to produce rapid calcination of the material whereby the heated gas intimately contacts with the particles of material at all points in the heated zone to insure a thorough and uniform heating thereof, passing the calcined material into a soaking pit, and electrically heating

the calcined material in the soaking pit to prevent the reabsorption of the evolved gas by the material.

4. The method of treating alkali earth carbonate material to obtain the evolved gas in substantially pure form, which consists in passing the material in a substantially continuously moving stream through a closed heated zone maintained under sub-atmospheric pressure, separating the material as it passes through the heated zone into thin streams by progressively interrupting and retarding its flow, withdrawing the evolved gas, heating the liberated gas by passing the same through an electrically heated passage and into direct contact with an electrical heating medium in said passage, returning the heated gas to the heated zone at a temperature sufficient to produce rapid calcination of the material and dividing the heated gas so as to cause it to directly and indirectly heat the material, a portion of the heated gas being conducted upwardly through the material in a direction counter to the flow of the material so as to intimately contact with the particles thereof at all points in the heated zone, and conducting another portion of the heated gas indirectly into heat exchange relation with the material to insure a thorough and uniform heating of the same.

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