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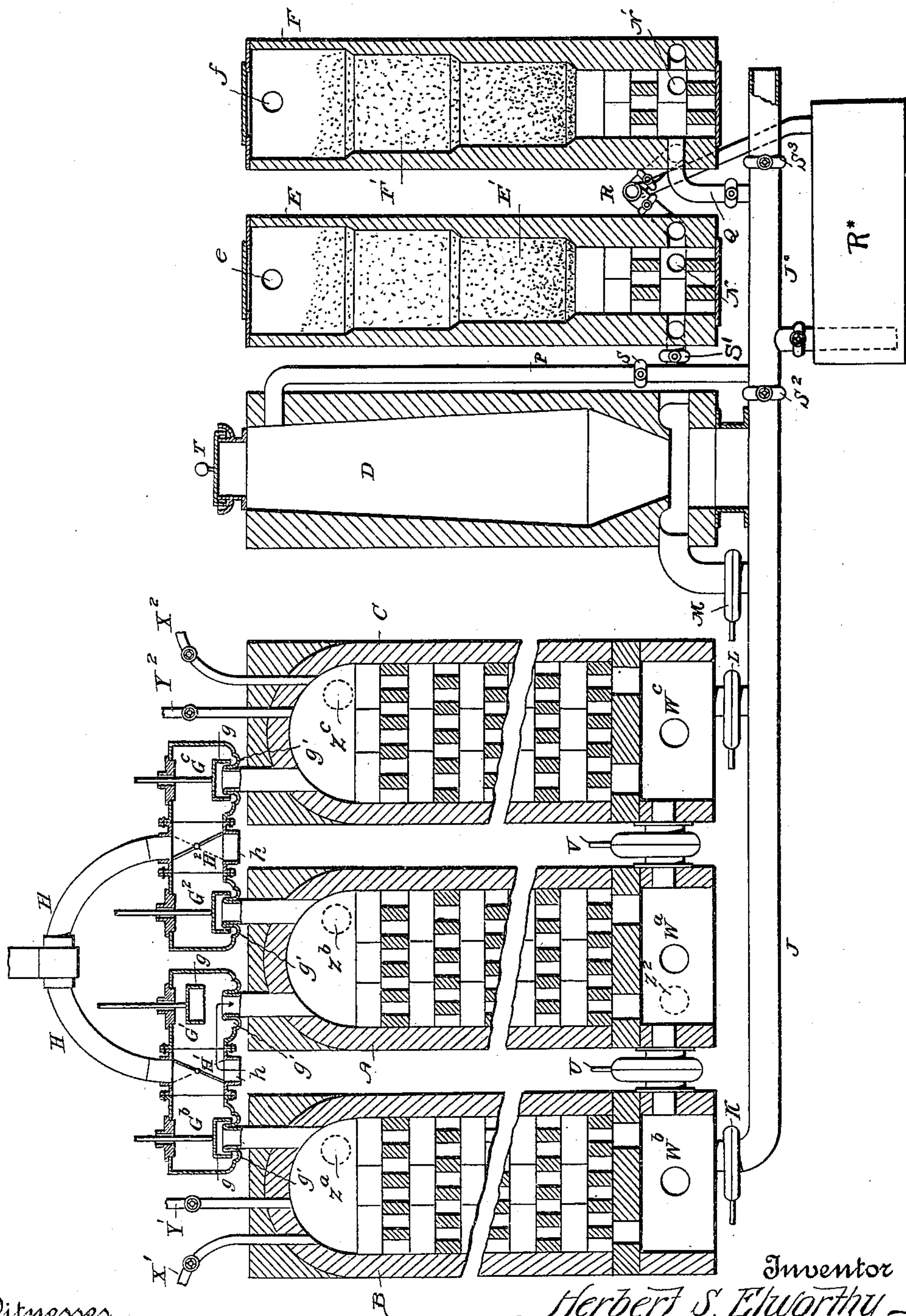
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H. S. ELWORTHY.

PROCESS OF MAKING PURE CARBONIC ACID.

(Application filed Dec. 22, 1897.)

(No Model.)



Witnesses

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UNITED STATES PATENT OFFICE.

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PROCESS OF MAKING PURE CARBONIC ACID.

SPECIFICATION forming part of Letters Patent No. 658,626, dated September 25, 1900.

Application filed December 22, 1897. Serial No. 663,049. (No specimens.)

To all whom it may concern:

Be it known that I, HERBERT SAMUEL ELWORTHY, a subject of the Queen of Great Britain, residing at London, in the county of Middlesex, England, have invented certain new and useful Improvements in Processes of Making Pure Carbonic Acid; and I do declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same.

This invention has reference more particularly to the manufacture by combustion of carbonic acid free from permanent gases, such as nitrogen, for the preparation of liquefied or solid carbonic acid for the charging of beverages with or without previous liquefaction and for other purposes to which such pure carbonic acid may be adapted; but each of the improvements constituting the invention is intended to be secured for all the uses to which it may be applicable.

The combustion of carbon in carbonaceous bodies of all kinds yields carbonic acid, as is well known, when the combustion is effected with a sufficient quantity of oxygen; but when such combustion is effected by means of air the resultant gases consist, mainly, of nitrogen. Such a gaseous mixture is wholly unsuited to many uses to which carbonic acid is applied, and even a small proportion—say five per cent., for example—of a non-condensable gas will interfere with its uses for many purposes. Thus if it be desired to liquefy the carbonic acid by compression it is found that it is necessary to employ much higher pressure (at a given temperature) if even five per cent. of a non-condensable gas is present. Again, if the liquefied carbonic acid is to be used in refrigerating-machines the presence of the non-condensable gas (which may be dissolved in the liquefied carbonic acid) is apt to interfere with the working of the machine by necessitating higher pressure in compression, and thereby impeding the action of the pumps. Further, if water is charged with impure carbonic acid the non-condensable gas dissolves also to a sufficient extent to impair the comestible value of the carbonated water, as the so charged waters lose their sparkle and sharp taste quickly after opening. Moreover, for certain chemical reactions carbonic acid will

not answer if it contain a certain proportion of inert gas. In each of the cases mentioned the same objection would be encountered whether the impurity consists of air, nitrogen, hydrogen, or other neutral gas non-condensable as compared with carbonic-acid gas.

In accordance with the present invention carbon (in the form of coke, charcoal, petroleum, or other carbonaceous substance or substances, herein termed the "fuel" for convenience of reference) is burned without air by converting the said carbon, first, by steam or carbonic acid or a mixture thereof into carbonic oxid (CO) free from non-combustible non-condensable gas, and, second, oxidizing completely this carbonic oxid and any accompanying combustible non-condensable gas by means of a metallic oxid, which is formed again after reduction, so that the same charge can be repeatedly utilized.

In order to convert carbon into carbonic oxid by means of steam or carbonic acid or mixture thereof, it is necessary to supply heat from an outside source, and to do so in the most advantageous manner recourse is had in the present invention to contact with the surfaces of fire-brick or other suitable inert bodies previously raised to a sufficiently high temperature. According to one mode the steam or carbonic acid or mixture thereof is superheated by contact with such highly-heated surfaces before it is brought into contact with the carbonaceous substance. According to another mode the steam or carbonic acid or mixture thereof and the fuel are passed together over the highly-heated inert surfaces. These two modes can be combined by admitting part of the fuel to pass with the steam or carbonic acid or mixture thereof over the highly-heated inert surfaces in such manner that the escaping products are so highly superheated that on contact with a further portion of fuel a further amount of carbonic oxid is formed. In either or any mode the inert surfaces must supply heat enough to compensate for that which is rendered latent by the decomposition of the steam or carbonic acid, or both, and the conversion of carbon into carbonic oxid. In other words, the formation of the carbonic oxid develops a certain quantity of heat; but the decomposition of the steam or carbonic

acid, or both, (the "oxidizing-gas," as it may be shortly expressed,) renders latent a larger amount of heat than is thus developed. The excess is supplied by contact of the oxidizing-gas or of the oxidizing-gas and fuel with the highly-heated surfaces. The fuel when superheated steam or carbonic acid is brought in contact therewith may and, indeed, should itself be at a high temperature.

10 In many places and perhaps under most conditions it may be advisable to use coke or charcoal or other solid fuel massed in a stack or cupola, as customary in the making of water-gas. At the beginning such coke
15 or other solid fuel may be brought to incandescence by an air-blast; but by suitably superheating the steam or carbonic acid or mixture thereof the formation of carbonic oxid can afterward be made continuous without requiring the charge to be blown with
20 air at short intervals. Such periodic blowing with air would be very objectionable, because after each application of an air-blast the carbonic oxid obtained would be mixed
25 with the non-condensable non-combustible nitrogen for a considerable time until, in fact, the nitrogen which would remain in the fuel when the air-blast is stopped should have been all removed. These losses are avoided
30 by supplying the heat by means of inert bodies. If the temperature of the latter fall, they can readily be raised again to a proper temperature, and if in the heating the nitrogen is left between them it can readily be
35 swept out by a blast free from non-condensable non-combustible gas, as of steam or carbonic acid, for example.

In order to effect the complete combustion of the carbonic oxid into carbonic acid by a
40 metallic oxid or oxids, the latter may be arranged in various ways. What is considered the best way, itself forming a special improvement, is to combine the oxid with fragments of an inactive or less active substance to constitute a carrier for the oxid.
45

The invention also comprises certain other features and certain improvements in apparatus, as hereinafter set forth.

The accompanying drawing, which forms
50 part of the specification, is a diagram of apparatus which can be used to carry out the process improvements of the present invention and which embodies the improvements in apparatus the subject-matter of a patent
55 of even date on my divisional application, filed March 31, 1900, Serial No. 10,915.

The furnace D, which constitutes a generator of carbonic oxid and which is shown in the form of a cupola, although other forms
60 may be used, is supplied with coke or other solid fuel, or, according to another mode of working, it may be filled with brick or other inert refractory material, or it may be cut out or disused entirely. It is shown as connected on the one side by the flue J with the
65 hot-blast stoves B and C and on the other by the flue P J with the two oxidizing-furnaces

E F, charged with a body E' F' of an oxidizing or oxidizable metal, which most advantageously is distributed over the fragments
70 of an inactive or less active refractory substance as a carrier. This carrier is particularly useful in connection with an active substance like copper oxid, which is fusible. Between each of the hot-blast stoves and the
75 flue J is a valve K L, respectively, so that either stove can be connected with the flue J while the other is cut off, the object being to use the stoves alternately. This is necessary
80 with the regenerating type of stove, since such a stove has to be shut off while it is being reheated. Each stove consists of a chamber filled with the open brickwork usual in
85 regenerating-furnaces and provided with the valved inlet X' or X² for the admission and valved outlet K or L for the escape of the steam or carbonic acid, or mixture thereof,
90 and also with a valved inlet W^b or W^c for the admission of the reheating-gas, the valved air-pipe U or V for the admission of air for burning the reheating-gas, and a valved passage G^b or G^c for the escape of the products
95 of combustion. The valved air-pipes lead from a hot-blast stove A, which, as shown, is also of the regenerating type and consists of a chamber filled with the usual brickwork
100 and provided, in addition to the valved air-pipes U and V for delivering the hot-air blast to the chamber B and C, with the valved inlet W^a for the gas to reheat chamber A, a valved passage G' or G² for the escape of the products
105 of combustion, and means for admitting air at top or bottom of the chamber, as may be desired. These means most advantageously are constituted by four-way reversing-valves
110 H' H², provided each with an air-inlet h and an outlet H for the products of combustion and interposed one between the tops of the chambers A and B, the other between the tops of chamber A and C. Between each of
115 these valves and the tops of the corresponding chambers are additional valves, each in the form of an inverted cup g, whose edges are sealed by dipping into a gutter g', which is filled with melted lead or other suitable
120 metal. If the inverted cups g in the passages G^b and G' are raised and the valve H' is in the position shown in full lines, air can enter the top of the chamber A, and by turning the valve H' to the position shown in dotted lines
125 air from the inlet h can enter the top of chamber B and will enter the bottom of the chamber A by the passage U after passing through the brickwork of chamber B. Similarly if the inverted cups in the passage G² G^c are raised, those in the passages G' G^b being shut
130 down, air can enter the top of chamber A from the inlet h and passage G² when valve H² is in the position shown. By turning the said valve to the position shown in dotted lines the air from the inlet h will first enter the top of chamber C, and after it has passed through the brickwork in this chamber it will enter the bottom of chamber A by the passage

V. With this arrangement the dotted openings Z^a Z^b Z^c Z^2 would be unnecessary; but, if desired, the four-way valves could be omitted, and valved passages opening at Z^b and Z^2 , respectively, might serve to admit air to the top and bottom, respectively, or the air could be admitted to the top of the chamber A by an opening at Z^a and to the bottom of said chamber by the passage U or V, the air in this case first entering the chamber B or C at Z^a or Z^c and descending through the brickwork therein before it goes through the passage U or V into the bottom of chamber A.

The connection of the carbonic-oxid generator D with the oxidizing-furnaces E F may be direct or through gas-purifying apparatus, or both forms of connection may be provided. The flue P J* is shown as opening directly into the bottom of the oxidizing-furnaces E F through the valved branch pipes S' Q; but such direct connection is advisable only in case the fuel in the furnace D is a very pure carbon. Ordinarily the carbonic oxid from the flue J* would be passed through one or more coolers and scrubbers or other purifying apparatus to the pipe R, from which it would pass into whichever of the furnaces E F has its charge E' or F' in an oxidized condition. At R* is indicated such purifying apparatus, which serves to remove any ammonia or other impurity-yielding non-condensable gas by oxidation. After or before passing through the purifying apparatus the carbonic oxid may be stored in gasometers. Blowers can be employed to force the carbonic oxid into the furnaces.

Each of the oxidizing-furnaces has a valved inlet N or N' for admitting air or steam thereinto for oxidizing its metallic charge E' or F', and each of said furnaces also has an outlet e or f for the residual gas and for the carbonic-acid gas. As shown, one opening is represented. This may serve for both gases; but of course the passage leading therefrom would be used one for the residual gas, the other for the carbonic-acid gas.

The charge E' or F' may consist of fragments of brick or other refractory material coated or combined with copper oxid. This is considered the best material; but other oxids and other ways of supporting the oxid can be used so long as aeriform fluids have access to the metallic matter, (oxidized or deoxidized, as the case may be.)

What is considered the best way of coating or combining the copper oxid with the refractory material is to fuse the copper oxid, which can be done in any ordinary glass-furnace—such as a tank-furnace, for instance—and to immerse fragments of fire brick therein. To prevent the oxid of copper being reduced by small amounts of organic matter present in the fire-brick or by the gases of combustion, ammonium or sodium nitrate in small amounts may be added to the bath of fused copper oxid from time to time. By making the ni-

trate adhere to the fragments of fire-brick it can be introduced with the latter.

Having charged the furnace D with coke and the furnaces E F with a material which is capable of being oxidized or deoxidized (preferably fragments of fire-brick coated with copper oxid) the said furnaces and also the chambers A B C are raised to a high temperature. To ignite the charge of solid fuel in the furnace D, a fire is started in the bottom of said furnace, the top T is raised, and air from one of the stoves A B C is blown in until the mass of fuel is at a white heat. At this time the valves S and S² are closed, also the valve L (if the air is taken from the chamber B) and the valve U. The air can be admitted to the chamber B through the valve H' and passage G^b by turning the valve H' to the dotted position and raising the inverted cup g in the passage G^b, or it can be admitted to B by the opening Z^a , if this be used. To heat the furnaces E and F, air may be introduced at N and N' and fuel in the form of carbonic oxid or of other combustible gas through the branches of pipe R. To raise the temperature of chambers A B C, gas—producer gas, for example—from the inlet W^a is burned among the brickwork of the chamber A by air introduced from the chamber B (let us say) or from the passage Z^2 , if this be used. By raising the inverted cups g in the passages G' G^b and turning the valve H' to the dotted position the air may descend through the chamber B and enter the chamber A by the passage U, and the products of combustion can escape to the chimney I through the passage G' and the flue H. After a proper time (half an hour or more or less) by turning the valve H' to the position represented the air will go by the passage G' to the top of the chamber A, while products of combustion from the chamber B can escape to the chimney I by the passage G^b and the flue H. At this time the gas at W^a is cut off and is admitted at W^b into the chamber B. Combustion now takes place among the brickwork of the chamber B. After a proper time the valve H' is reversed and gas from the opening W^a is burned among the brickwork of the chamber A by a hot blast of air from the chamber B. In time after changing the position of the valve H' as often as necessary both chambers are brought to an intense heat. In like manner the chamber C is heated, the chamber A serving to heat the air, which is introduced by the passage V to the bottom of the chamber C and which serves to burn the gas which is introduced at the opening W^c. During this operation the passages G' G^b would be closed and the passages G² G^c would be opened, and the valve H² would be shifted from time to time. Assuming that chamber B is heated to, say, about or above 1500° centigrade and that the passages G^b, W^b, and U are closed, the valve K is opened and also the valves S² S³. Steam or carbonic

acid or mixture thereof is then introduced through the pipe X' to drive out the non-condensable and non-combustible nitrogen from the chamber B. It passes off to a waste-flue or to any desired receiver. When all of the nitrogen has been expelled, the valve S² is closed, and the valves M and S opened, the top T being shut down. The steam or carbonic acid or mixture thereof now passes into the incandescent fuel in the furnace D and is decomposed, the products of decomposition passing out by the flue P J* and valve S³ to any suitable receiver. When the nitrogen left by the air-blast in the interstices of the fuel in the furnace D has been carried off, the products of decomposition will consist of carbonic oxid free from non-condensable and non-combustible gas, the only other gases being hydrogen (from the steam, if this is used) and ammoniacal sulfur and hydrocarbon compounds, (from the solid fuel in the furnace D, if this is not sufficiently pure). These bodies are either combustible or condensable, and therefore removable at once or after combustion in the oxidizing-furnace. Hence they are not open to the objection which arises from the presence of a non-combustible non-condensable gas like nitrogen.

In order that the decomposition in the carbonic-oxid generator D may take place as near as may be without loss of temperature, the steam or carbonic acid or mixture thereof is heated by contact with the inert surfaces of the fire-brick in the stove B so much above the temperature necessary for the decomposition in the carbonic-oxid generator that it carries with it from said stove B enough heat energy to compensate for that which is rendered latent by said decomposition without lowering the temperature below the decomposing-point. After a time, however, the temperature of stove B (when of the regenerating type, as shown) becomes insufficient properly to superheat the steam or carbonic acid or mixture thereof. When this occurs, the valve K is closed, and the brickwork of the stove C being at the highest temperature used the valve L and pipe X² are opened, so that this stove now supplies the superheated blast of steam or carbonic acid or mixture thereof to the carbonic-oxid generator. Before, however, this steam or carbonic acid or mixture thereof is admitted to the furnace D it is allowed (the valve M being temporarily closed) to blow off through the flue J J* and valves S² S³ until the nitrogen is displaced from chamber C and flue J J*. The valve M is now opened, the valve S² is closed, and the superheated steam or carbonic acid or mixture thereof from the chamber or regenerating-stove C is admitted to the furnace D. While using the stove C the brickwork of stove B is reheated by the combustion of gas from opening W^b by means of a hot blast from the stove A. In this reheating the valve H' is shifted once or oftener in the manner before explained. Thus the chambers B and C serve alternately

as hot-blast stoves for superheating the steam or carbonic acid or mixture thereof, which is supplied to the furnace D, while the chamber A serves as a hot-blast stove for supplying hot air alternately to the stoves B and C for reheating the same. The carbonic oxid from the generator D, free from non-condensable non-combustible gas, is passed through whichever of furnaces E F that is ready to receive it, the said carbonic oxid being, when desired, first passed through one or more coolers and scrubbers or other purifying apparatus, or when this is not desired and the carbonic oxid is sufficiently pure being admitted directly to the oxidizing-furnace. Assuming that the furnace E is ready, the valve S and the passage S' may be opened for a direct admission, or the passage S' being closed the carbonic oxid, passing away by the flue J* and valve S³, may be passed through appropriate purifying apparatus R* and afterward be introduced through the pipe R and its left-hand branch. The carbonic oxid or carbonic oxid and other combustible gas in the products of decomposition from the furnace D in passing through the furnace come in contact with the metallic oxid therein and combine with oxygen of said oxid to form carbonic acid or carbonic acid and water. The contact with the said oxid should be sufficient completely to burn all the combustible gas, the resulting product being simply carbonic acid or carbonic acid and vapor of water free from non-condensable gas. After a time the furnace F is utilized, the charge E' in furnace E being reoxidized by passage of air or steam from the inlet N through the said charge. If air is used, the operation is completed by a current of steam, so that no nitrogen is left in said furnace. When the charge in the furnace F has been sufficiently deoxidized, the delivery of carbonic oxid thereto is stopped, and the charge is reoxidized either by air or steam or mixture thereof, and the furnace E is utilized while this is being done.

The carbonic-acid gas from the oxidizing-furnace is passed through coolers for lowering its temperature and removing therefrom the vapor of water which it may contain, and, being free from any non-condensable gas, it is then ready for liquefying by compression, for charging beverages, or for use in the gaseous state.

If it be desired to fill the cupola D with inert refractory material instead of with solid fuel, the fuel for decomposing the steam or carbonic acid or mixture thereof may be introduced into the superheated steam or carbonic acid or mixture thereof on its way to the furnace D, the superheating in the chamber B or C being sufficient to supply the heat for effecting decomposition without lowering the temperature of the furnace D. Instead of bringing the fuel into contact with the steam or carbonic acid or mixture thereof after superheating the latter they may be passed to-

gether over the highly-heated inert surfaces, which supply the heat rendered latent by the decomposition. In the drawings the pipes Y' Y² are for introducing liquid vaporized or gaseous hydrocarbon of any suitable description—petroleum, for example. Solid fuel in powder could also be introduced alone or in connection with other forms. It might be injected by the blast of steam or carbonic acid or mixture thereof. The furnace D need not be used, and it could either be dispensed with entirely or be simply shut off by closing the valves M and S.

The furnace D, filled with solid fuel, may be used in conjunction with the delivery of fuel into the hot-blast stove, the decomposition of the steam or carbonic acid or mixture thereof being effected partly in the stove and partly in the furnace D. After the decomposition has been carried on in the stove B the brickwork therein loses its temperature until it falls below the decomposition temperature. Just before this point is reached the supply of fuel and of steam or carbonic acid or mixture thereof is transferred to the stove C, the chamber B being now reheated by producer or other suitable gas from the opening W^b and a blast of hot air from the stove A in the manner hereinbefore explained. The carbonic oxid free from non-condensable non-combustible gas which is generated in the chambers B and C is passed through the oxidizing-furnaces E F in such a manner that all the combustible gases are completely consumed, leaving only carbonic acid free from non-condensable gas. The carbonic oxid unless sufficiently pure should, and it in any case may be, passed through purifying apparatus before it is passed through the oxidizing-furnace. The principal impurity (as is also the case when the steam or carbonic acid or mixture thereof is decomposed by the solid fuel in the furnace D) would be ammonia, which would be decomposed in the oxidizing-furnace with the elimination of nitrogen. Washing the carbonic oxid with water or dilute acid would remove the ammonia.

Although the pipe J is for convenience shown exposed and unlined, this is preferably made of large diameter and internally lined with refractory material and may also be coated outside with some non-conducting composition. The valves exposed to a high temperature are of the hot-blast type, in which a water-current is caused to circulate through the valve and also through the seat to prevent fusion.

It is believed to be of the highest industrial importance to generate the carbonic oxid free from non-condensable non-combustible gas and to effect a complete combustion by the metallic oxid in the oxidizing-furnaces, so that the carbonic acid thus obtained shall be free from non-condensable gas. In the working of the apparatus described with solid fuel in the furnace D some carbonic oxid is produced (at the beginning of an operation)

which is mingled with nitrogen, and it may sometimes happen that by carelessness of the attendant a complete combustion is not effected and more or less carbonic acid is obtained which is mingled with hydrogen or carbonic oxid, both of which are non-condensable. Such impure carbonic oxid and carbonic acid may be used as fuel; but it may in some cases be preferred to prepare pure carbonic acid therefrom. For this purpose carbonic oxid can be passed through an oxidizing-furnace, and the carbonic acid thus generated can then be separated from the non-condensable gas by any known or suitable means, such as solution in water under pressure and evaporation therefrom. In the case of the impure carbonic acid a like separation can be effected, or the impure carbonic acid, when the non-condensable impurity or impurities are combustible, may be passed again over metallic oxid to effect a complete combustion.

Heretofore it has been proposed to separate carbonic acid from non-condensable gas in admixture therewith; but so far as I am aware this step was never used in combination with the two operations of, first, decomposing steam or carbonic acid or mixture thereof and, second, effecting a combustion of the carbonic oxid by metallic oxid. The resulting gaseous mixture consists mainly of carbonic acid, and thus differs essentially from ordinary products of combustion which are mainly composed of nitrogen. When carbonic acid predominates, it is much easier to effect a separation of the same than where it is mixed with an excess of nitrogen. When the step of separating the carbonic acid from non-condensable gas in admixture therewith is used in the combination just mentioned, some air might be admitted during the decomposing operation into the stove A or B or into the furnace D, whether this contain solid fuel or be filled with inert refractory material, and some air might be admitted into the furnace E or F during the oxidation of the carbonic oxid to carbonic acid; but this is not recommended. For some uses where carbonic acid above a certain degree (which is always more than half carbonic acid) is required the carbonic acid may be obtained in admixture with the (for such purposes immaterial or comparatively unimportant) amount of non-condensable gas. The generation of carbonic oxid and the oxidation with metallic oxid may be employed without any separation of the carbonic acid from the smaller volume of non-condensable gas mingled therewith.

It will be understood that in referring to carbon in the claims following it is intended to include coke, charcoal, anthracite coal, bituminous coal, crude petroleum, petroleum-tar, other petroleum products, coal-tar, wood-tar, asphaltum, bitumens, natural or artificial gas containing carbon compounds, and any other suitable form of carbon, combined

or uncombined, in a form which yields carbonic acid on oxidation.

If it should be desired, the carbonic acid free from non-condensable gas can of course be subjected to a treatment calculated to effect a separation of the carbonic acid from non-condensable gas mixed therewith. Such a treatment would be a solution in water and evaporation from such solution, and it might perhaps be useful in some cases for a more assured state of absolute purity to use such treatment, notwithstanding that the carbonic acid may be free from non-condensable gas, or practically so, for purposes of liquefaction.

Certain hydrocarbon gases—such, for instance, as natural gas—may be sent through the regenerative stoves B or C and thence into the oxidizing-furnaces E or F without admixture with steam or carbonic acid; but it is preferable to mix a certain proportion of one or other of the two latter gases with the hydrocarbon. The hydrocarbon gas might also be sent direct into the oxidizing-furnaces without first passing through the regenerative stoves; but in this case again it would be preferable to mix it with a certain proportion of carbonic acid or steam, more especially the latter. Where the hydrocarbon is sent direct into the oxidizing-furnaces, it is a difficult matter to get entirely rid of the odor, and this may unfit the gas for commercial use for the manufacture of aerated beverages or ice.

Where the production of carbonic acid free from non-condensable gas is desired as the direct result of the oxidation, a complete combustion must be effected by the metallic oxid and the gas or vapor which is passed into the oxidizing-furnace must be free from non-condensable non-combustible gas. If, however, the product after leaving the oxidizing-furnace is to be subjected to a treatment calculated to separate the carbonic acid from condensable gas or if the carbonic acid would be suited to the use intended, notwithstanding the presence of a non-condensable gas which would unfit it for liquefaction, the freedom from non-condensable non-combustible gas of the gas or vapor which is supplied to the oxidizing-furnace and a complete combustion of said gas or vapor by metallic oxid are not essential, the content of carbonic acid in any case exceeding the content of non-condensable gas of the gaseous product which results from the oxidation with metallic oxid.

I claim as my invention or discovery—

1. The process of making carbonic acid by so highly superheating the specified oxidizing-gas above the temperature of decomposition that it can compensate for the heat rendered latent in such decomposition, such superheating being effected by the intermittent passage of the said oxidizing-gas over inert surfaces rendered highly incandescent in the intervals of such passage by direct contact with the

products of a combustion by the aid of intensely-heated air, bringing the so-highly-superheated oxidizing-gas and carbon in contact with each other to effect the decomposition of said oxidizing-gas and the oxidation of the carbon to carbonic oxid, and passing the products of such decomposition over metallic oxid to effect a complete combustion, substantially as described.

2. The process of making carbonic acid by so highly superheating the specified oxidizing-gas above the temperature of decomposition that it can compensate for the heat rendered latent in such decomposition, such superheating being effected by the intermittent passage of the said oxidizing-gas over inert surfaces rendered highly incandescent in the intervals of such passage by direct contact with the products of a combustion by the aid of intensely-heated air, bringing the so-highly-superheated oxidizing-gas and carbon in contact with each other to effect the decomposition of said oxidizing-gas and the oxidation of the carbon to carbonic oxid, treating the products of such decomposition to remove ammonia or other condensable gas, and then passing the decomposition products so deprived of condensable gas over metallic oxid to effect a complete combustion, substantially as described.

3. The process of making carbonic acid by so highly superheating the specified oxidizing-gas above the temperature of decomposition that it can compensate for the heat rendered latent in such decomposition, such superheating being effected by the intermittent passage of the said oxidizing-gas over inert surfaces rendered highly incandescent in the intervals of such passage by direct contact with the products of a combustion by the aid of intensely-heated air, bringing the so-highly-superheated oxidizing-gas and carbon in contact with each other to effect the decomposition of said oxidizing-gas and the oxidation of the carbon to carbonic oxid, passing the products of such decomposition over metallic oxid to effect a complete combustion, and separating carbonic acid from the products of such combustion by absorption of said carbonic acid in water from which it is afterward recovered, substantially as described.

4. The process of making carbonic acid by so highly superheating the specified oxidizing-gas above the temperature of decomposition that it can compensate for the heat rendered latent in such decomposition, such superheating being effected by the intermittent passage of the said oxidizing-gas over inert surfaces rendered highly incandescent in the intervals of such passage by direct contact with the products of a combustion by the aid of intensely-heated air, bringing the so-highly-superheated oxidizing-gas and carbon in contact with each other to effect the decomposition of said oxidizing-gas and the oxidation of the carbon to carbonic oxid, treating the products of such decomposition to remove

ammonia or other condensable gas, passing the decomposition products so deprived of condensable gas over metallic oxid to effect a complete combustion, and separating carbonic acid from the products of such combustion by absorption of said carbonic acid in water from which it is afterward recovered, substantially as described.

5. The process of making liquefied carbonic acid by decomposing the specified oxidizing-gas and carbon with the aid of heat derived from inert surfaces which have been heated by direct contact therewith of the products of a combustion with intensely-heated air and with avoidance of any contact of air with the carbon for decomposing the said oxidizing-gas, effecting a complete combustion of the products of such decomposition by passage over metallic oxid, and liquefying the resulting carbonic acid which is practically free from non-condensable gas, substantially as described.

6. The method of coating refractory material with metallic oxid, by flushing the same and immersing the refractory matter therein, substantially as described.

7. The process of making carbonic acid, by so highly superheating the specified oxidizing-gas in the form in which carbonic acid is an essential constituent thereof so highly above the temperature of decomposition as to compensate for the heat rendered latent in such decomposition, such superheating being effected by the intermittent passage of the said oxidizing-gas over inert surfaces rendered highly incandescent in the intervals of such passage by direct contact with the products of a combustion by the aid of intensely-heated air, bringing the so-highly-superheated oxidizing-gas and carbon in contact with each other to effect the decomposition of said oxidizing-gas and the oxidation of the carbon to carbonic oxid, and passing the products of such decomposition over metallic oxid to effect a complete combustion, substantially as described.

8. The process of making carbonic acid, by so highly superheating the specified oxidizing-gas above the temperature of decomposition that it can compensate for the heat rendered latent in such decomposition, such superheating being effected by the intermittent passage of the said oxidizing-gas over inert surfaces rendered highly incandescent in the intervals of such passage by direct contact with the products of a combustion by the aid of intensely-heated air, bringing the so-highly-superheated oxidizing-gas and a finely-divided diffused form of carbon in contact with each other to effect the decomposition of such oxidizing-gas and the oxidation of the

carbon to carbonic oxid, and passing the products of such decomposition over metallic oxid to effect a complete combustion, substantially as described.

9. The process of making carbonic oxid by so highly superheating the specified oxidizing-gas above the temperature of decomposition that it can compensate for the heat rendered latent in such decomposition, such superheating being effected by the intermittent passage of the said oxidizing-gas over inert surfaces rendered highly incandescent in the intervals of such passage by direct contact with the products of a combustion by the aid of intensely-heated air, and bringing the so-highly-superheated oxidizing-gas and carbon in contact with each other to effect the decomposition of said oxidizing-gas and the oxidation of the carbon to carbonic oxid, substantially as described.

10. The process of making carbonic oxid, which process consists in heating two masses of inert material by combustion of gas in contact with each of said masses alternately by the aid of air heated by passage over the other until said masses have been brought to so high a temperature as to superheat the specified oxidizing-gas sufficiently for it to supply the heat rendered latent in the decomposition thereof with carbon, so superheating the specified oxidizing-gas by passage over one of said so-heated masses of inert material, and bringing the said so-superheated oxidizing-gas into contact with carbon to generate carbonic oxid, substantially as described.

11. The process of making carbonic acid, which process consists in heating two masses of inert material by combustion of gas in contact with each of said masses alternately by the aid of air heated by passage over the other until said masses have been brought to so high a temperature as to superheat the specified oxidizing-gas sufficiently for it to supply the heat rendered latent in the decomposition thereof with carbon, so superheating the specified oxidizing-gas by passage over one of said so-heated masses of inert material, bringing the said so-superheated oxidizing-gas into contact with carbon to generate carbonic oxid, and passing the so-generated carbonic oxid over metallic oxid to convert the said carbonic oxid into carbonic acid, substantially as described.

In testimony whereof I hereunto affix my signature in presence of two witnesses.

HERBERT SAMUEL ELWORTHY.

Witnesses:

BENJ. G. COWL,
A. B. SIUT.