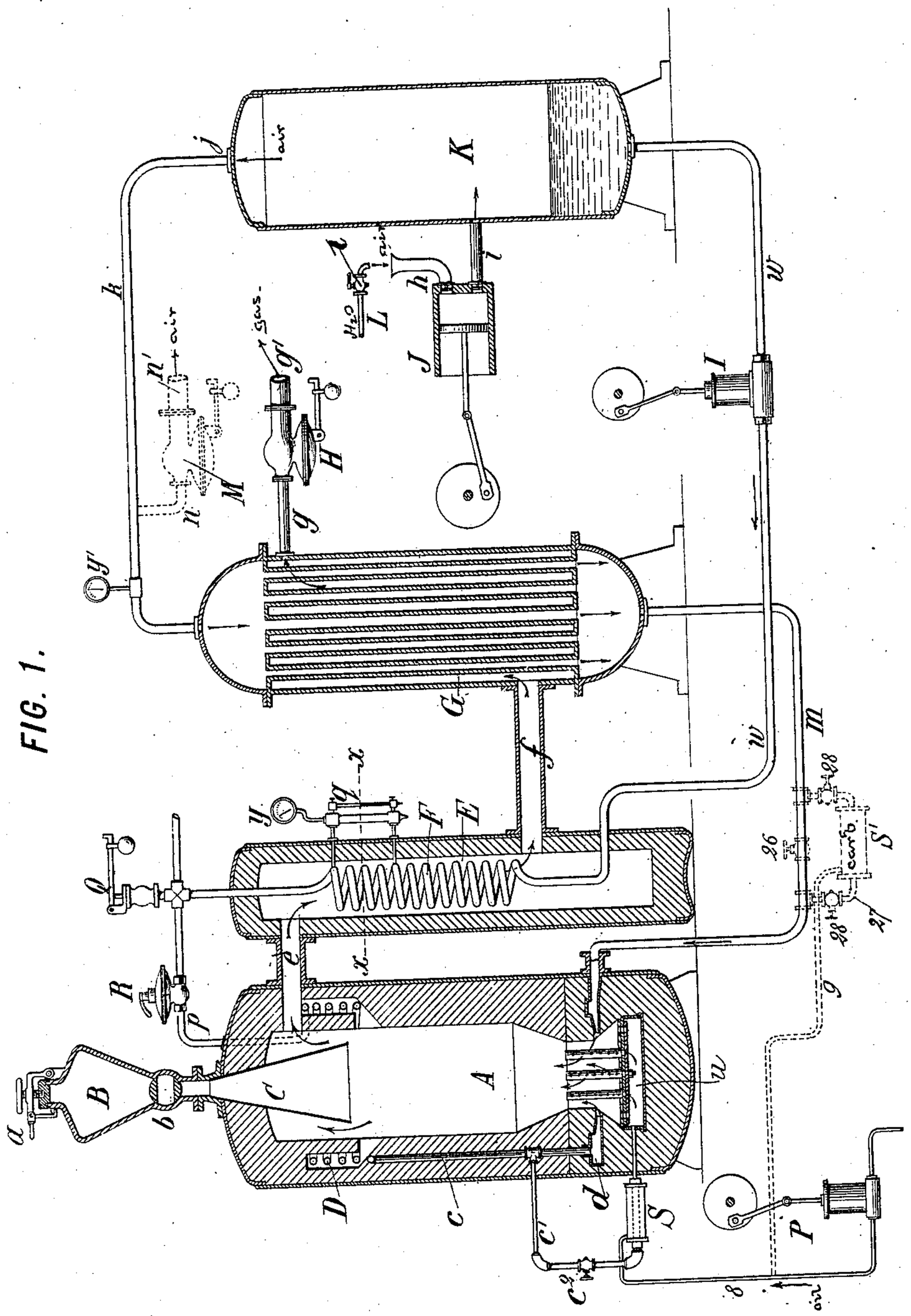
(No Model.) 4 Sheets—Sheet 1.

F. G. BATES.

PROCESS OF AND APPARATUS FOR MANUFACTURING GAS.

No. 576,801. Patented Feb. 9, 1897.

FIG. 1.



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INVENTOR:
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By his Attorneys,
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(No Model.) 4 Sheets—Sheet 2.

F. G. BATES.

PROCESS OF AND APPARATUS FOR MANUFACTURING GAS.

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FIG. 3.

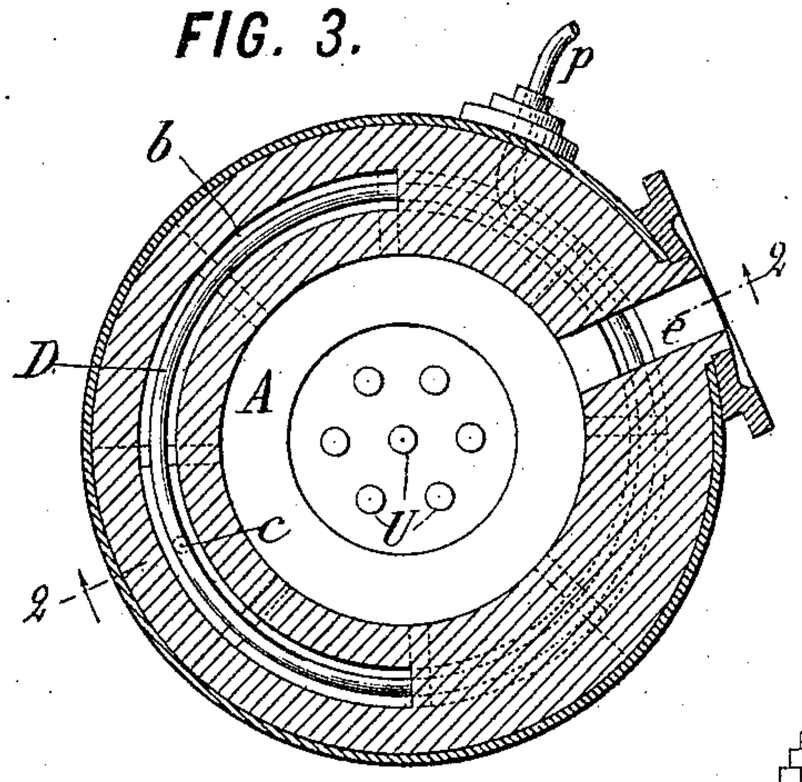


FIG. 2.

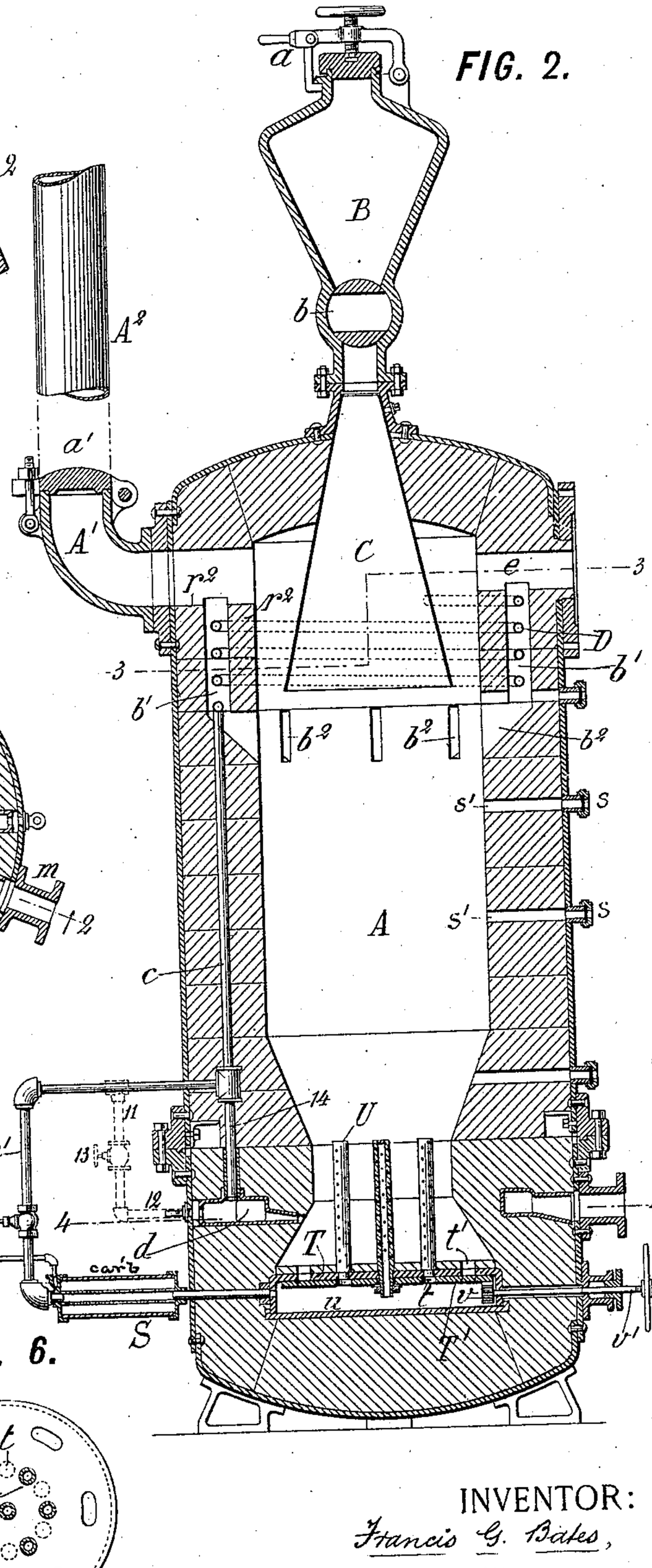


FIG. 4.

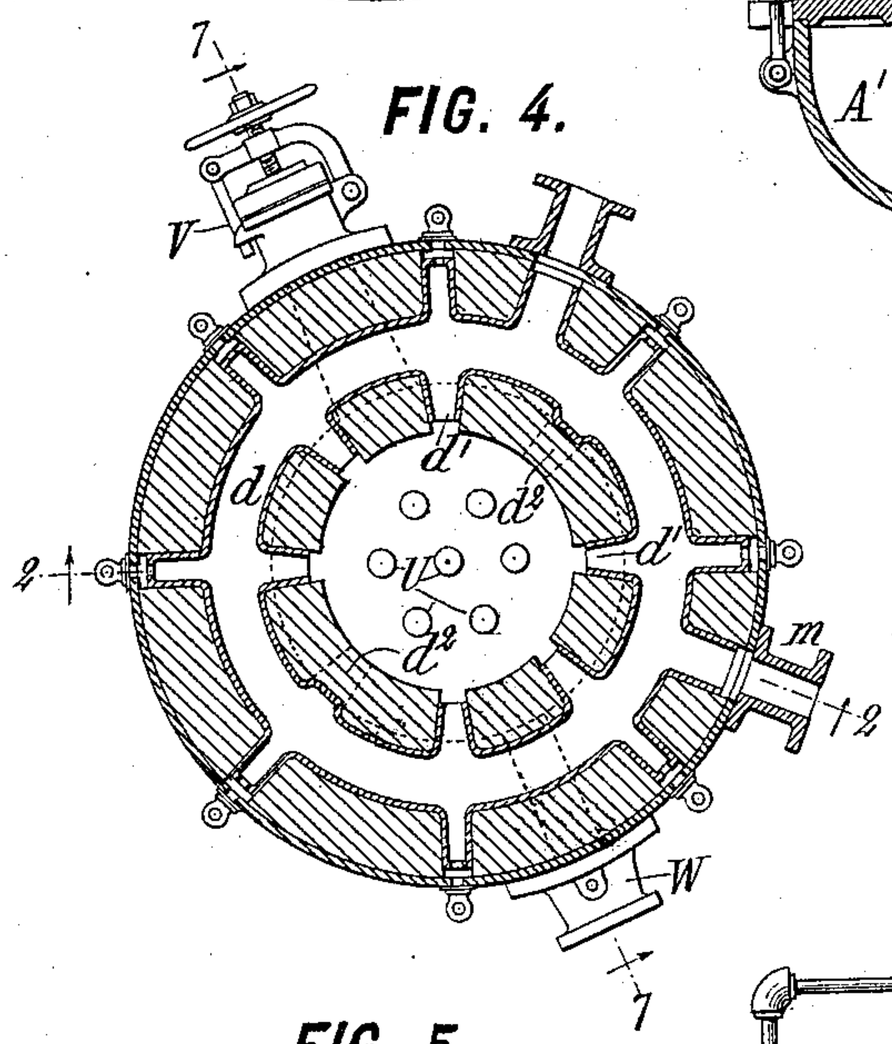


FIG. 5.

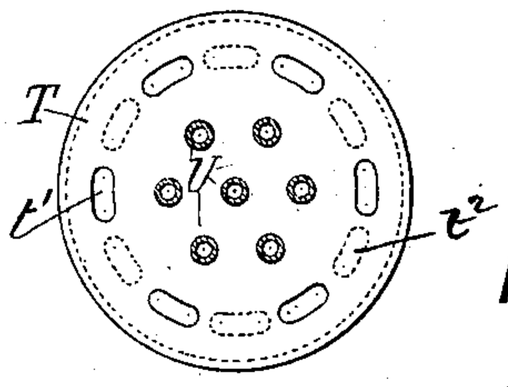
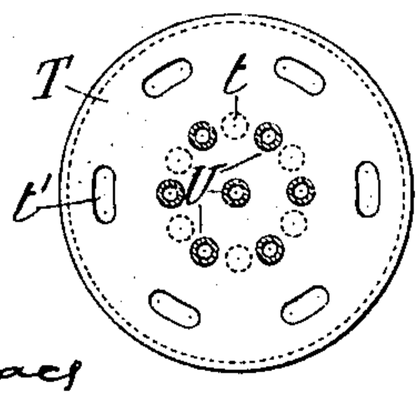


FIG. 6.



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(No Model.) 4 Sheets—Sheet 3.

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PROCESS OF AND APPARATUS FOR MANUFACTURING GAS.

No. 576,801. Patented Feb. 9, 1897.

FIG. 7.

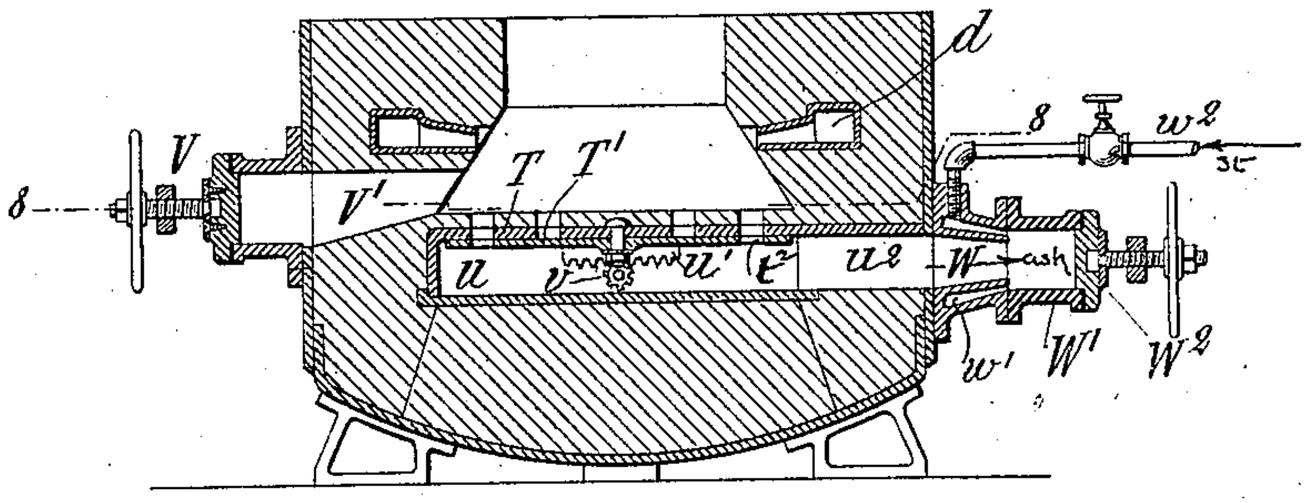


FIG. 8.

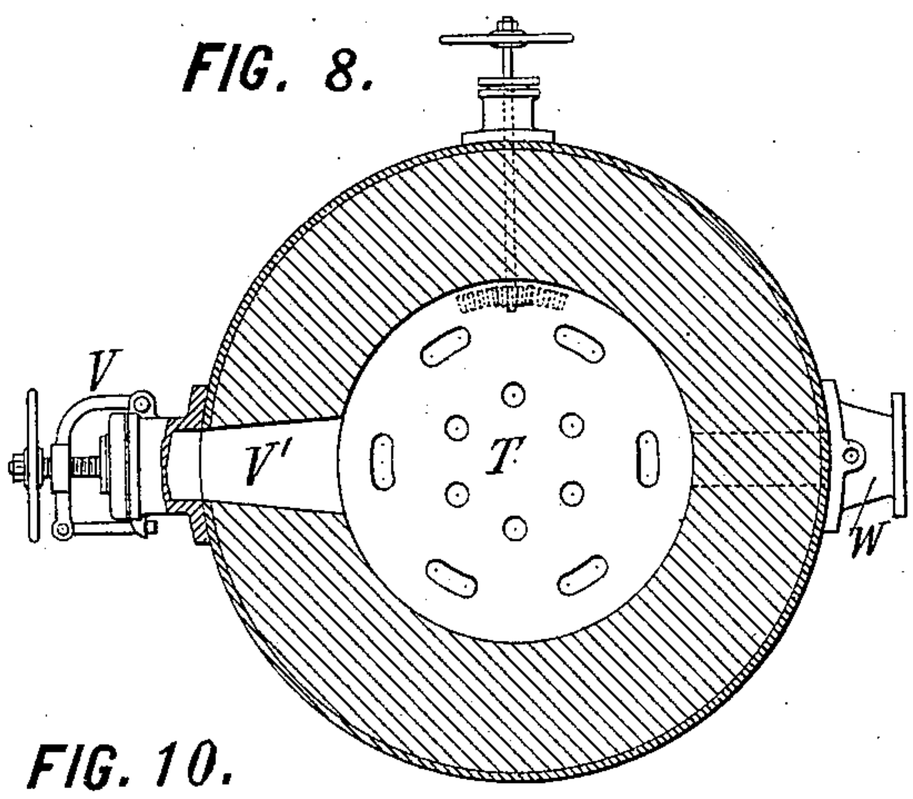


FIG. 9

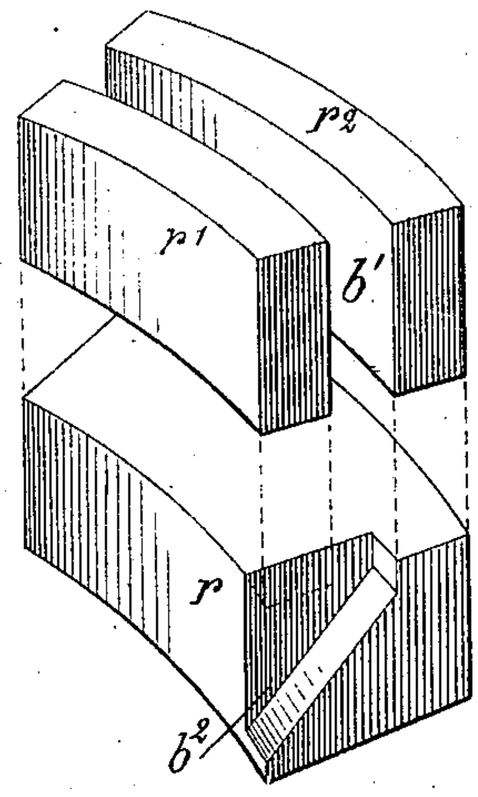


FIG. 10.

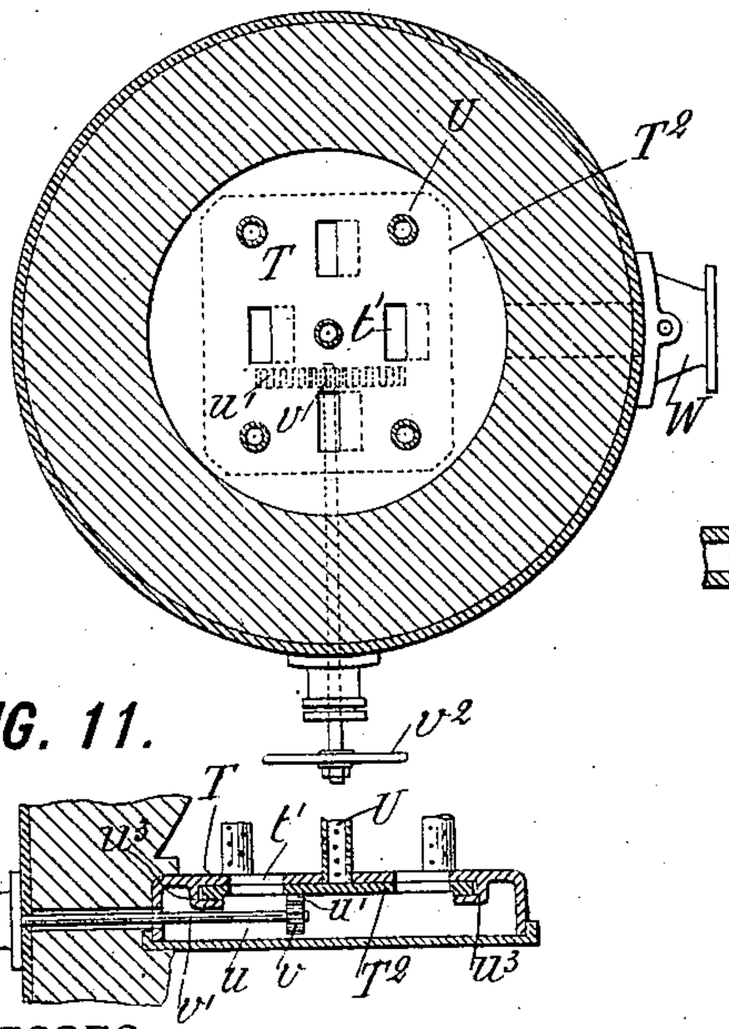
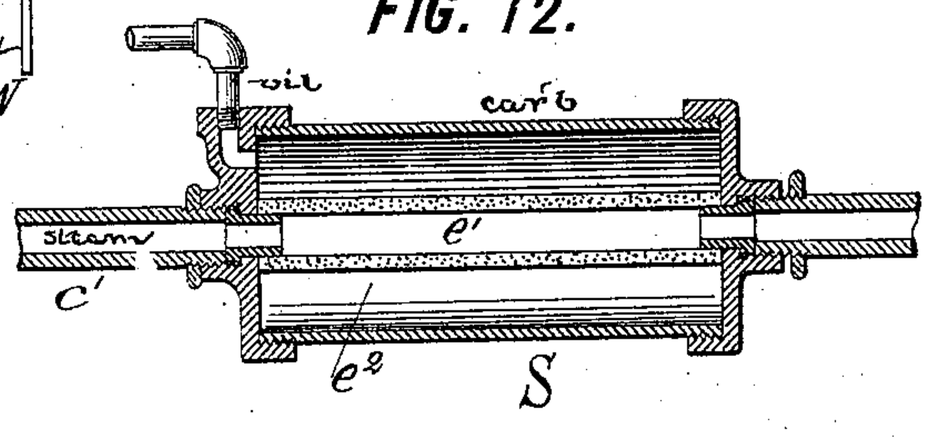


FIG. 11.

FIG. 12.



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(No Model.) 4 Sheets—Sheet 4.

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PROCESS OF AND APPARATUS FOR MANUFACTURING GAS.

No. 576,801. Patented Feb. 9, 1897.

FIG. 13.

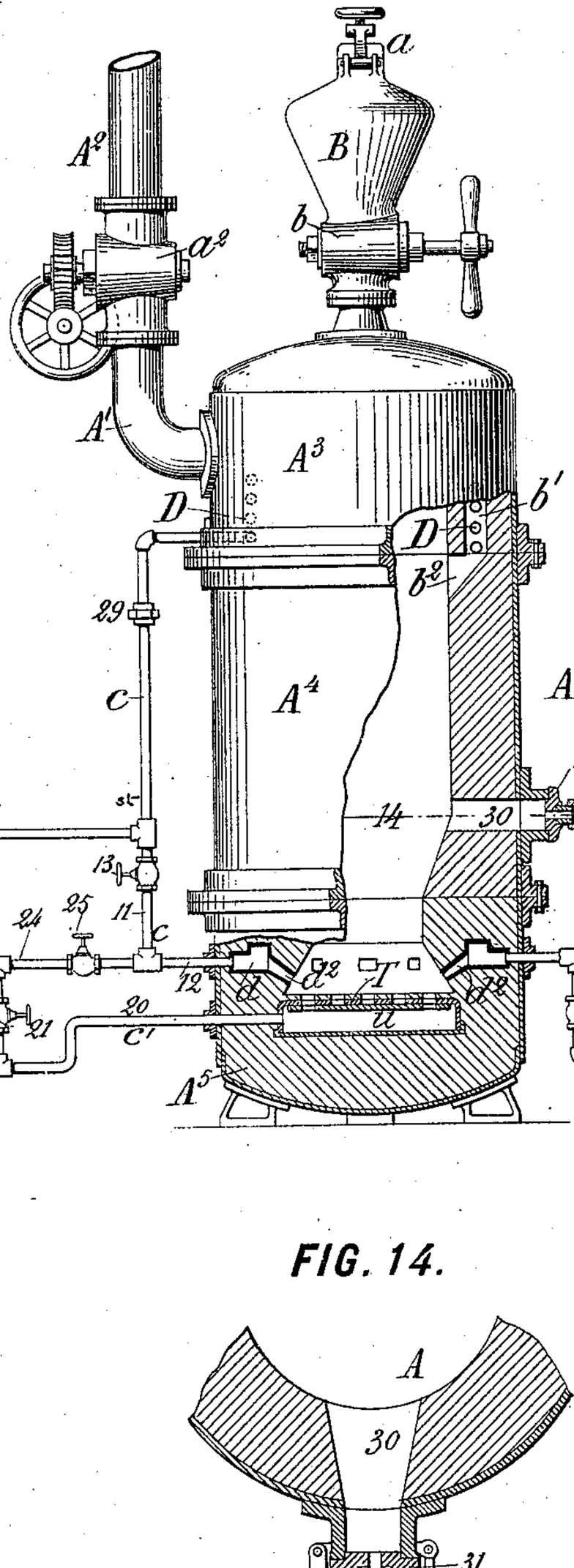

FIG. 14.

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UNITED STATES PATENT OFFICE.

FRANCIS G. BATES, OF PHILADELPHIA, PENNSYLVANIA.

PROCESS OF AND APPARATUS FOR MANUFACTURING GAS.

SPECIFICATION forming part of Letters Patent No. 576,801, dated February 9, 1897.

Application filed June 4, 1896. Serial No. 594,303. (No model.)

To all whom it may concern:

Be it known that I, FRANCIS G. BATES, a citizen of the United States, residing in Philadelphia, in the State of Pennsylvania, have invented certain new and useful Improvements in Processes of and Apparatus for Manufacturing Combustible Gas, of which the following is a specification.

This invention relates to certain improvements in means for making either fuel-gas for driving gas-engines, heating-furnaces, and the like, or illuminating-gas.

In the United States patent to Maurice Lorois, No. 529,453, there is claimed a new process of manufacturing gas characterized by the forcing of air and superheated steam under high pressure through a mass of incandescent fuel, whereby a producer-gas is formed under so high a temperature as to avoid the formation of ammoniacal and tarry impurities.

In the United States patent granted to Maurice Lorois, No. 529,452, for a gas-motor, is shown a combination of the apparatus necessary for producing gas by the said process with a gas-engine specially adapted to be operated by the combustion of such gas.

In an application which I have made for United States patent, filed May 7, 1896, No. 590,529, are set forth certain improvements in means for producing gas by the same general process as that claimed in said Patent No. 529,453, the same being especially adapted for the manufacture of gas independently for heating and illuminating purposes, irrespective of the immediate utilization of such gas by any motor-engine. According to said last-named application heated compressed air is charged with hydrocarbon vapor (by passing it through a carbureter into which oil is forced) and is then forced with superheated steam through a producer-chamber containing a bed of incandescent carbon, a pressure being maintained therein of from fifty to one hundred pounds per square inch. By reason of the pressure and the intense heat the steam is decomposed and the air maintains a partial combustion of the hydrocarbon and the carbon, whereby is produced a gas containing mainly carbon monoxid, hydrogen, and nitrogen, enriched with fixed illuminant hydrocarbon gases. The gas thus produced is of such purity that no scrubbing, washing, or after treatment is required, and it contains no ammonia or condensable hydrocarbons.

The present invention introduces certain improvements and modifications in the process and apparatus for producing gas according to this general system.

By my present invention the liquid hydrocarbon is vaporized by means of superheated steam instead of air, so that the gas-producer is fed with heated compressed air, superheated steam, and hydrocarbon vapors carried by the superheated steam.

My invention also introduces certain improvements in the mechanical construction of the gas-producer.

Figure 1 of the accompanying drawings is a sectional elevation illustrating the entire combination of apparatus adapted for producing fuel or illuminating gas, the arrangement being sufficiently diagrammatic to enable all the connections to be apparent from this one figure. Fig. 2 is a vertical mid-section of the gas-producer, the section being taken in the planes indicated by the lines 2 2 in Figs. 3 and 4. Fig. 3 is a horizontal section thereof on the lines 3 3 in Fig. 2. Fig. 4 is a horizontal section on the line 4 4 in Fig. 2. Figs. 5 and 6 are plans of the ash-grate in two different positions. Fig. 7 is a vertical transverse section of the lower division of the producer in the plane of the line 7 7 in Fig. 4. Fig. 8 is a horizontal section on the line 8 8 in Fig. 7. Fig. 9 is a perspective view of two of the lining-bricks. Fig. 10 is a horizontal section answering to Fig. 8, and Fig. 11 is a vertical section answering to part of Fig. 7, illustrating a modification of the grate. Fig. 12 is a detail section of a suitable construction of carbureter. Fig. 13 is an elevation of the gas-producer, partly in section, showing additional features of my invention. Fig. 14 is a horizontal section on line 14 14 in Fig. 13.

Referring to Fig. 1, let A designate the gas-producer or "gazogene," its general construction being the same as in said Patent No. 529,453. It is provided with a feeding-hopper B, closed at top by a tight-fitting cap *a* and lower down by a rotative cock or valve *b*, which communicates with the interior of

the gas-producer through a conical or downwardly-flaring funnel or magazine C, which enters deeply into the producer-chamber. A superheating-coil D is arranged in the upper part of the chamber around the magazine and communicates through a tube or passage *c* with an annular passage *d*, encircling the lower part of the producer, and from which twyers enter the producer-chamber. From the upper part of the producer leads a gas-outlet flue *e*, which communicates with the upper part of a descending flue or vertical chamber E, through which the hot gas circulates downwardly around a coil F, constituting a steam-generator. From somewhat above the bottom of the chamber E leads an outlet *f*, through which the gas is conducted to an air-heater G, through which it flows to a gas-outlet pipe *g*, leading to a pressure-regulator H for reducing the pressure of the gas before it is delivered by the pipe *g'*, which leads to the place of use.

A pump or air-compressor J is arranged to draw in air through an inlet *h* and expel it through an outlet *i* into the compressed-air reservoir or tank K. The pump J is shown diagrammatically, it being understood that any known construction of air-compressor may be employed, but preference is given to those constructions in which water is pumped along with the air or otherwise applied for the purpose of cooling the compressor. This is indicated diagrammatically in the drawing by the introduction of a water-pipe L, controlled by a valve *l*, which introduces a stream of water into the inlet *h*, so that this water will enter the pump with the air.

From the reservoir K an air-outlet *j* is provided leading by a pipe *k* to the air-heater G, through which the air flows and takes up heat from the hot gas, and is then led by a pipe *m* to the gas-producer A, where it is introduced, preferably, into the annular passage *d* to commingle with the superheated steam before entering into contact with the incandescent fuel. Another air pipe or branch *n* may be provided leading from the compressed-air reservoir (or from the pipe *k*) to a pressure-regulator M, by which the pressure of the compressed air is lowered before it enters the delivery-pipe *n'*, which conducts it to the place of use, these parts being shown in dotted lines.

Water which is drawn, preferably, from the compressed-air reservoir K is forced by a pump I (or an injector or other means) through a pipe *w* into the lower end of the coil F, constituting the steam-generator, and in this coil the water is subjected to the action of the hot gas in the chamber E, whereby steam is generated, which passes from the upper part of this coil through a connecting-pipe *p*, which connects with the upper part of the superheating-coil D, through which the steam circulates, and from the lower part thereof it is led by the pipe or passage *c* to the annular passage *d*, communicating with the twyers. The height of the water in the generator is indicated by a water-tube or glass water-gage *q*, which connects at top and bottom through horizontal branch pipes with the coil. Petcocks may be advantageously used for the same purpose with or without the water-tube. The steam-pressure is indicated by a gage *y*.

It is advantageous to take the feed-water from the reservoir K, as thereby is utilized the heat due to compression of the air which has been taken up by this water. It is preferable to generate steam at a higher pressure than that which prevails throughout the remaining portion of the apparatus. Accordingly the pump I is adapted to increase the pressure of the water from that prevailing in the reservoir K to the higher pressure in the steam-generator F. To again reduce the pressure, an automatic regulator or pressure-reducer R is applied, preferably in the steam-pipe *p*. A safety-valve Q is provided to relieve any dangerous excess of pressure from the steam-generator. The water-level in the steam-generator is shown by the dotted line *x x*.

The gas-producer A is provided, as heretofore, with a flue or elbow A', closed by a cap *a'*, so that in starting the apparatus this cap may be opened and the elbow may be connected by a flue A^2, Fig. 2, to the chimney.

So far as described the apparatus does not differ materially from that shown in my said pending application. I will now proceed to describe more especially the features introduced by my present invention.

The superheating-coil D has heretofore been arranged in the producer-chamber and just outside of the funnel C. I have found that the heat to which the coil is exposed when thus located is so intense that the life of the coil is undesirably short. To remedy this inconvenience, I construct the fire-brick or other refractory lining of the producer with an annular chamber or channel *b'* and locate the superheating-coil D in this annular chamber. To provide sufficient communication between this chamber and the producer-chamber, I construct ports b^2 at intervals communicating from the producer-chamber to the bottom portion of the annular chamber *b'*. The preferred construction of fire-bricks by which this result is attained is shown in Fig. 9, where *r* is a fire-brick of the tier just beneath the annular chamber *b'*, *r'* and r^2 being the inner and outer bricks between which this chamber is formed, and like bricks being arranged below them, as indicated by dotted lines. The brick *r* is cut away at one end, as clearly shown, so that when brought against the flat radial face of the next like brick the inclined passage b^2 will be formed between them.

Peep-holes or eye-sights *s s* are provided at different levels in the furnace, through which an operator may look to ascertain the height of the fuel and the progress of the combustion. These are constructed to withstand the

heavy pressure under which the process is conducted, and they communicate with openings s' in the fire-brick lining in alinement with them.

The descending discharge-pipe c from the superheater is provided with a branch pipe or bend c', extending outside the gas-producer and provided with a controlling-valve c^2. This pipe terminates in the ash pit or box u beneath the grate of the producer in order to inject superheated steam into the ash-pit and up through the openings in the grate.

For the purpose of introducing vaporized petroleum or other hydrocarbon into the generator along with the superheated steam which is introduced this steam is caused to pass through what I call a "carbureter" S, which may be of any construction suitable for the purpose. Into this carbureter crude petroleum or other liquid hydrocarbon is forced by a pump P, through a pipe 8, under a pressure slightly greater than that of the superheated steam, so that the oil is forced into contact with the steam, and by the heat of the latter the oil is vaporized and presumably more or less decomposed, and the hydrocarbon vapors or gases thus formed are carried with the steam into the bottom of the gas-producer and injected up through the mass of incandescent fuel therein. Any construction of carbureter by which oil may be brought into contact with the steam may be suitable for use in this connection, the particular construction shown being illustrated in detail in Fig. 12 and consisting of an annular oil-chamber e^2, into which the oil is forced around a porous tube e', which is in communication with the steam-pipe c', so that the superheated steam passes through this tube, while the oil is forced under pressure through the pores thereof. My invention is not limited to the use of this one particular construction, which is illustrated solely because it is believed to be a suitable construction and the best for the purpose known to me. Other forms are illustrated in my said application.

The lower part of the gas-producer is provided with a grate T, consisting in the construction shown of a stationary circular plate having perforations at suitable intervals. For opening or closing these perforations a movable plate or disk T′ is arranged beneath the plate T and movable relatively thereto, preferably by being mounted on a central pivot, and provided with means for turning it for a distance sufficient to open or close the respective openings. In the construction shown in Figs. 2 to 6 perforated tubes U U are provided extending upwardly from and fixed at their lower ends to the stationary grate T. In Fig. 2 the middle of these tubes, which is in section, serves as the pivotal connection on which the movable plate T′ is mounted. All the tubes U are preferably closed at their upper ends and open at their bottoms and arranged to communicate through holes in the grate T with the ash-chamber u beneath. The movable plate T′ has holes t, which in one position communicate with the openings in which the tubes are placed, as shown in Fig. 5; but when the disk is turned to the position shown in Fig. 6 these holes are brought out of register with the tubes, so as to close the openings to the latter. The grate T is provided with a separate series of ash-openings t', and the disk T′ has a corresponding series of openings t^2, which in the position shown in Fig. 6 coincide with the openings t', so that ashes may fall through; but in the position shown in Fig. 5 these openings do not coincide, so that the ash-openings t' are closed. The position in Fig. 5 is the normal operative position in which the superheated steam and vaporized hydrocarbon which enter the ash-pit can circulate up into and through the tubes U U, and passing out through the perforations therein are sufficiently subdivided, so that they are introduced in small jets into the lower part of the producer-chamber. The position shown in Fig. 6 is that occupied during the removal of ashes, as will be described. For turning the disk from one position to the other it is provided with a rack or cog-teeth u', Fig. 7, engaged by a pinion v, which is fixed on a rotary shaft v', which passes out through a stuffing-box and has a handle or wheel v^2 on its outer end by which to turn it, Fig. 2.

The tubes U U may be omitted, although their use is considered preferable. In Figs. 7 and 8 the tubes are not shown.

Heretofore in order to remove the ashes resulting from the combustion of the coal or other fuel it has been necessary to suspend from time to time the operation of generating gas, to cut off by means of valves the communication between the gas-producer and the remaining apparatus, to let off the pressure from the producer, and then by opening an ash-door to get access to the lower part of the producer and draw out the ashes. The door V in Fig. 7, communicating with the passage V′ through the wall of the producer, constitutes the means heretofore provided for removing the ashes.

My invention provides an improved means by which the operation is greatly facilitated and by which the complete cessation of the operation of gas-producing is avoided. From the ash pit or chamber u a passage u^2 is provided, which communicates with an ejector W, consisting of a funnel around which is formed an annular steam-space w', which is preferably contracted toward its outer or discharge end and which communicates with any suitable source of steam under pressure, which is admitted by a pipe w^2, Fig. 7. To the ejector is coupled an ash-delivery pipe W′. In order to discharge ashes by this apparatus, the grate-disk T′ is first moved to close the openings to the tubes U U and open the ash-openings t', the steam-valve c^2 being also closed to cut off the introduction of superheated steam into the ash-pit. More or less

ashes will thereupon slip down through the openings t' into the ash-pit. By then suddenly admitting steam into the ejector W and opening the cap W^2, which normally closes the ash-outlet pipe, a powerful outward current of steam is set up, as indicated by the arrows entering the pipe W′ in Fig. 7, whereby all ashes lying in the chamber u are sucked out by the vacuum thus suddenly produced. The pressure in the body of the gas-producer assists this operation by causing an outflow through the ash-openings t', which carries with it a further quantity of ashes which may have accumulated above the grate. When the ashes have been blown out and before the pressure in the producer is too far lowered, the steam is shut off and the cap W^2 closed, whereupon the pressure quickly rises again to the normal.

In the construction of grate shown in Figs. 7 and 8, where the tubes U are omitted, all the openings in the disk T′ may register simultaneously with the openings in the grate, instead of there being an alternate register of two different series of openings, as in the construction shown in Figs. 2 to 6.

In Figs. 10 and 11 is shown a modified construction of the grate, wherein the under plate T′ is made to slide in a straight line instead of turning on a pivot. The under plate (here lettered T^2) is arranged to slide in ways u^3 and is provided with a straight rack u', which is engaged by the pinion v, which is mounted and connected, as before, with the handle v^2. In one position of the sliding plate the ash-openings t' are open, and in the opposite position these openings are closed and the openings communicating with the tubes U are open.

Fig. 13 illustrates more in detail the preferred pipe connections and some features of construction not yet described. The pipe c, leading downward from the superheater D, extends outside the shell of the producer A and extends downward as a pipe 11 and thence horizontally as a pipe 12 to communicate with the annular passage or twyer-box d, a section of pipe 11 being provided with a valve 13 for shutting off the passage of steam by this course. The same arrangement is shown in dotted lines in Fig. 2 and may take the place of the section of pipe shown in full lines therein and marked 14. The branch pipe c' in Fig. 13 consists of pipe-sections 15, 16, and 17, leading to the carbureter S, and pipe-sections 18, 19, and 20, leading thence to the ash-pit u. The valve c^2 is shown as arranged in the pipe-section 16, and another valve 21 is arranged between the pipe-section 18 and the ash-pit, being in the section 19. By opening valves c^2 and 21 superheated steam is passed through the carbureter S and discharged into the ash-pit, as already described. A by-pass pipe 22 is provided, closed by a valve 23, so that by closing valve 21 and opening valve 23 superheated steam may be introduced into the ash-pit u without being carbureted. In some cases it is preferable to introduce the carbureted superheated steam through the twyers, and to admit of this the pipe c' is connected with the pipe c through a pipe-section 24, controlled by a valve 25, so that by opening this valve and valve c^2 and closing the other valves the superheated steam will pass through the carbureter and by pipe-sections 18, 24, and 12 into the twyer-box. The arrangement shown thus permits of, first, the introduction of superheated steam directly into the twyer-box without carbureting; second, the introduction of carbureted superheated steam in the twyer-box; third, the introduction of superheated steam without carbureting into the ash-pit, and, fourth, the introduction of carbureted superheated steam into the ash-pit.

Fig. 13 also shows the provision of another carbureter S′ in connection with the pipe m, conveying heated compressed air to the twyer-box. In this pipe is introduced a valve 26, and on opposite sides of this valve are connected the opposite ends of a by-pass pipe or branch 27 27, in which is connected the carbureter S′, valves 28 28 being provided for closing the by-pass. For introducing plain heated air without carbureting the valve 26 is opened and the other valves are closed. For carbureting the air the valve 26 is closed and the valves 28 are opened, so that the hot air passes around through the carbureter S′. Oil is forced into this carbureter through a pipe 9, branching from the pipe 8, leading from the pump P, all as shown in dotted lines in Fig. 1. By this means the vaporized hydrocarbon oil may be introduced either with the heated compressed air (as claimed in my application Serial No. 590,529, filed May 7, 1896) or with the superheated steam, as I have already described, or both the air and steam may be carbureted.

As clearly shown in Fig. 13, the gas-producer A is made in three sections, (lettered respectively A^3, A^4, and A^5.) The construction of the gas-producer with the lower portion A^5 in a separate section, so that it may be taken off to renew the lining in the hottest portion of the producer-chamber adjacent to the twyers, is not of my invention, being claimed in the application of Maurice Lorois, Serial No. 522,006, filed September 4, 1894. According to my invention I make an additional division at the lower portion of the annular chamber b', in which the superheating-coil D is placed. This division is preferably located between the chamber b' and the communicating passages b^2, as clearly shown in Fig. 13. The purpose of this division is to enable ready access to be had to the coil D in case of any accident, such as the bursting of this coil. To facilitate thus gaining access thereto, the pipe c, instead of extending down within the refractory lining, as heretofore, is carried outside the same in the upper section A^3 and extended down exteriorly to the middle section

A^4, and is provided with a coupling or union 29, by which to disconnect it when the sections A^3 and A^4 are to be separated.

At times some difficulty is encountered by reason of the clogging of the fuel just above the inclined portion of the producer-chamber leading down to its contracted portion or throat. To enable ready access to be had to the producer-chamber for clearing it of such obstruction I provide a poke-hole 30 through the wall of the producer, closed by a cap 31, which is tightly forced to its seat by means of a screw 32 and lever 33, as shown in Fig. 14. To enable the condition opposite the opening 30 to be observed, I provide the door 31 with a peep-hole or eye-sight 34, of the same construction as the eye-sights *s* in Fig. 2.

Experience has shown that at times the fire in the lowest portion of the producer-chamber will go out, notwithstanding that a fierce combustion is maintained directly above. To prevent this and insure the complete combustion and conversion into ash of all the solid fuel, I deflect downwardly one or more of the twyers d', two such twyers being shown as turned downwardly in Fig. 13, the angle of inclination there shown being about thirty degrees, this angle, however, being variable, it being only necessary that the inclination shall be sufficient to direct the air and steam to a point sufficiently beneath that fed by the remaining twyers to prevent the going out of the fire in the bottom portion of the producer-chamber. These downwardly-inclined twyers are lettered d^2. I prefer to thus incline two diametrically opposite twyers, as shown in Fig. 13, and as indicated also at d^2 d^2 in Fig. 4.

Instead of employing the cap a' as a means for opening and closing the connection between the elbow A′ and chimney-flue A^2, Fig. 2, as heretofore, I prefer to employ a permanently-connected rotary valve a^2, the stem of which is operated by a worm and worm-wheel, as shown in Fig. 13.

The apparatus shown is designed to be operated in the following manner: A fire is kindled in the producer A and supplied with coal or other suitable fuel, the fire being continued until a suitable bed of incandescent fuel has been obtained. During this time air is blown through the producer under low pressure and the products of combustion escape through the branch pipe A′, which is opened to the chimney-flue A^2. When a sufficient bed of incandescent coal is attained, the flue connection is disconnected (by closing cap a' in Figs. 1 and 2 or by closing valve a^2 in Fig. 13) and the apparatus is ready to be operated under pressure for producing gas. The air-compressor J then forces compressed air into the reservoir K and at the same time introduces water, which is warmed by the heat liberated upon the compression of the air, as described. Initially the steam-generator F is filled with water in any suitable way, as by pouring water in beforehand or by forcing it in by the pump J. As the compressor forces air into the gas-producer the hot gas coming off from it heats the generator F and soon raises a sufficient steam-pressure, whereupon the regular operation of the apparatus is inaugurated. Thereupon water is continuously drawn from the reservoir K by the pump I and forced to a higher pressure into the generator F, from which the steam coming off passes to the regulator R and permits the escape of only a predetermined volume of steam, which passes through the superheating-coil D, which is exposed to the hot gas in the upper part of the producer, and the superheated steam then enters the annular passage *d*, whereby it commingles with the hot compressed air from the reservoir K, which has been heated by passing through the heater G, and the commingled steam and air then enter through the twyers into the producer-chamber. If illuminating-gas is being made, or if it is desired to substitute crude oil or other liquid hydrocarbon as fuel in place of coal to greater or less extent, the oil is introduced to the carbureter S under pressure by the pump P or other means, so that the superheated steam becomes saturated with vaporized hydrocarbons. The high heat to which the steam and air, with or without hydrocarbons, are subjected in the producer-chamber serves to convert them into a fixed gas, which rises through the producer-chamber and in the upper part thereof heats the superheating-coil D, then passes out by passage *e*, descends through chamber E, giving up heat to the steam-generating coil F, passes thence by passage *f* to the air-heater G, where it gives up heat to the air flowing through the tubes, and finally, being thus cooled and its heat effectively utilized and economized, it passes out by the pipe *g* to the pressure-regulator H, which is set to retain in the apparatus the predetermined pressure under which the gas is produced—say, for example, one hundred pounds—the gas passing this regulator being reduced to any desired lower pressure and passing off by the pipe *g′* to the place of use or to a storage vessel or gas-holder. For burning the gas under the best conditions in glass or steel furnaces or for other such purposes it is preferable to take compressed air to the same points of use of the gas by means of a pipe *n′*, the air-pressure being reduced in like manner by the pressure-regulator M; but for illuminating purposes the gas will ordinarily be burned without compressed air and as city gas is now commonly burned.

The apparatus requires to be regulated from time to time according to variations in rate of consumption of the gas and other conditions. The amount of water introduced by pipe L should be so regulated as to maintain an approximately uniform water-level in the reservoir K. The air-compressor should be driven faster or slower according as the rate of outflow of the gas increases or diminishes. The feed-pump I should be controlled as with

any steam-boiler, so as to maintain the water-line in the generator at an approximately uniform level.

The pressure to be maintained in the apparatus may vary practically between a minimum of about forty-two pounds per square inch to a maximum of one hundred pounds or more. The minimum temperature has been determined by experiment to be approximately the lowest pressure at which perfectly pure gas free from condensable carburets, tarry matters, and ammoniacal products can be produced. Below that pressure the gas becomes progressively more and more impure, although for some purposes a gas sufficiently pure may be made at a pressure as low as eighteen pounds per square inch. In the making of fuel-gas, however, without the introduction of hydrocarbons, it is preferable to operate under a pressure of about fifty pounds per square inch. Upon the addition of hydrocarbon oil it is preferable to increase this pressure, and in the production of illuminating-gas it is necessary, or at least desirable, to adopt a considerably higher pressure, the best results being attained with a pressure approximating one hundred pounds per square inch. Under this pressure there is maintained in the gas-producer a temperature so high that all that portion of the hydrocarbon introduced with the hot air which is not by undergoing partial combustion converted into carbon monoxid is completely converted into the higher or more volatile hydrocarbons, or in other words becomes "fixed." It results in my process of making illuminating-gas that the fixation of the enriching or illuminant ingredients is effected by the same operation by which the steam is decomposed and the body of the gas (consisting chiefly of hydrogen and carbon monoxid) is generated, whereas in the production of water-gas, as is well known, the gas-body or non-luminous gas is first produced, and this is subsequently charged with the enriching hydrocarbons, after which the latter are fixed by circulating the gas through a fixation-chamber containing baffle-brick or other obstructions which have been previously highly heated, so that the process both of fixation and gas generation are necessarily intermittent, whereas in my process they are continuous. A further difference is that by my process a far higher temperature is maintained in the gas-producer than can possibly be maintained in the fixation-chamber of the water-gas process, by which I am able to effect a complete and absolute fixation of the hydrocarbons, whereas in the water-gas processes the hydrocarbons are never wholly fixed, the result being that when water-gas is transmitted through mains it suffers invariably some loss in illuminating power by reason of condensation of the hydrocarbons, which remain in the mains. The gas resulting from my process therefore differs from ordinary water-gas in three respects—first, that it comes from the producer so pure and devoid of tarry and ammoniacal products as to require no subsequent purification; secondly, that its luminous ingredients are in the form of fixed non-condensable gases, and, thirdly, that it contains a higher percentage of inert nitrogen, which in effect dilutes the gas to an extent which practically is advantageous, since otherwise the gas would be so rich in hydrocarbon products as to be difficult of complete and smokeless combustion in ordinary burners.

According to my invention the process may be operated in three different ways, according to the character of gas that it is desired to produce. For making a fuel-gas of low illuminating power and useful for illuminating purposes only in connection with an incandescent burner, such as the Welsbach, I use a low pressure between, say, the limits of forty-two to sixty pounds per square inch, employing chiefly coal as the source of carbon, with but a small percentage of oil and a minimum proportion of superheated steam. For making a richer fuel-gas, better adapted for illuminating purposes in connection with an incandescent burner, I use nearly the same amount of coal and increase somewhat the proportion of hydrocarbon oil, using, for example, from six to ten per cent. of benzin or other light hydrocarbon, and increase the pressure to from sixty to seventy-five pounds per square inch. For a gas that is distinctively an illuminating-gas, and to which I may impart an illuminating value of considerably over thirty-candle power, I greatly increase the proportion of hydrocarbon oil and raise the pressure to from seventy-five to one hundred pounds per square inch, the higher pressure making the purer and more perfect fixed gas, and one adapted to be conducted through mains at high pressure without loss by condensation. In this latter case the expenditure of coal may be reduced to the minimum, while the proportions of oil and steam are at the maximum. No more definite directions can be given for the practice of the process, as the conditions vary greatly according to the proportions of the apparatus, but any one skilled in the art can readily by following these general directions vary the conditions of the process until the quality of the gas produced is that which in any particular case he desires.

Under the conditions of my invention, after the operation has once been started and the desired pressure and temperature attained, I may dispense with the necessity of further introduction of solid fuel or coal into the gas-producer. To accomplish this result, sufficient oil or hydrocarbon fuel must be injected into the superheated steam or heated air to afford all the fuel required in the process for decomposing the steam and maintaining the high temperature necessary for the formation of the gas. In conducting the process in this manner it may be found advantageous to provide an extended surface of incandescence

in the gas-producer by introducing thereinto a suitable quantity of broken or irregularly-shaped refractory materials, such as pieces of fire-brick or lumps of lime, which under the high heat of the combustion will be maintained incandescent.

My process may be modified by operating the apparatus in an alternate manner as follows: first, forcing air and steam through the gas-producer with little or no hydrocarbon and thereby making a producer-gas, which is discharged into a suitable gas-holder, sufficient air being employed to raise the fuel in the producer to an extremely high state of incandescence, and then, secondly, by greatly reducing or entirely suspending the introduction of air and at the same time introducing oil in large proportion with the superheated steam and thereby generating very rich illuminating-gas, which is discharged into a separate gas-holder. When this latter process has been continued so long that the temperature in the producer becomes materially reduced, it must be suspended and the first operation resumed, the discharge of gas being then directed again into the first gas-holder. In this manner the operation may be conducted alternately, with the result of generating two different qualities of gas.

Preferably the carbureted superheated steam will be introduced into the ash-pit *u* only or chiefly when the perforated tubes U are employed, and the use of these tubes is chiefly advantageous when culm is used as the solid fuel. Under other circumstances it is preferable to introduce the carbureted steam into the twyer-box *d*. When operating under low heat and pressure, it is preferable to carburet only the hot air by using the carbureter S'; but in such case some carburation of the superheated stem may be effected at the same time by introducing the carbureted steam into the twyer-box. When operating under a very high temperature in the gas-producer, say 3,000° Fahrenheit, it is preferable to introduce the oil by carbureting the superheated steam. When making illuminating-gas without the employment of solid fuel in the gas-producer, it is preferable to carburet both the superheated steam and the heated compressed air, the two being thoroughly mixed together in the twyer-box, so that they enter the producer-chamber in a state of admixture.

It must not be understood from the exactness with which I have described my improved apparatus that my invention is necessarily limited to the exact construction and mode of operation set forth. On the contrary, it is susceptible of considerable modification without departing from its essential features. For example, the steam-generator F need not be a coil, but may be constructed in any other form that will be suitable for communicating the heat of the gas to the water. The water may be forced into the generator under the desired increased pressure by any other means than a pump, any known equivalent of a pump for feeding boilers being admissible as a substitute therefor. The water may be introduced into the apparatus otherwise than by the air-compressor.

It will be evident that the pump I might be dispensed with by elevating the reservoir K and compressor J to a sufficient height to afford the requisite hydraulic pressure for forcing the water into the steam-generator.

I claim as my invention the following-defined novel features, substantially as hereinbefore specified, namely:

1. The improved process of making combustible gas which consists in superheating steam, passing the superheated steam into contact with a liquid hydrocarbon whereby it vaporizes the latter, and passing the superheated steam and hydrocarbon vapors through a producer-chamber wherein an elevated temperature is maintained by the combustion of carbonaceous matter, and in which is maintained a pressure of at least forty-two pounds per square inch.

2. The improved process of making combustible gas which consists in superheating steam, passing the superheated steam into contact with a liquid hydrocarbon whereby it vaporizes the latter, and passing the superheated steam and hydrocarbon vapors together with heated compressed air through a producer-chamber wherein an elevated temperature is maintained by the combustion of carbonaceous matter, and in which is maintained a pressure of at least forty-two pounds per square inch, whereby the hydrocarbons are partly oxidized and partly converted into fixed gases.

3. The improved process of making combustible gas which consists in superheating steam, passing the superheated steam into contact with a liquid hydrocarbon whereby it vaporizes the latter, and passing the superheated steam and hydrocarbon vapors together with heated compressed air through a producer-chamber wherein an elevated temperature is maintained by the combustion of carbonaceous matter, and in which is maintained a pressure approximating one hundred pounds per square inch, whereby the hydrocarbons are partly oxidized and partly fixed as illuminants at the same high temperature at which the gas is generated, and a gas of high illuminating power is produced.

4. The improved process of making combustible gas which consists in carbureting heated compressed air by passing it into contact with a liquid hydrocarbon to vaporize the latter, carbureting superheated steam, and passing both the carbureted steam and the carbureted air through a producer-chamber wherein an elevated temperature is maintained by the combustion of carbonaceous matter, and in which is maintained a pressure exceeding forty-two pounds per square inch.

5. A gas apparatus comprising a gas-pro-

ducer, a steam-generator, an air-compressor, a heater for heating the compressed air therefrom, a conduit for compressed air leading it through said heater and into said producer, a steam-superheater, a conduit for leading steam from said generator through said superheater to the inlet of said producer, a carbureter in connection with said superheated-steam conduit adapted to introduce a liquid hydrocarbon into contact with the superheated steam to be vaporized thereby and carried into the producer, and a regulating-valve controlling the escape of the resulting gas and retaining a heavy pressure in the producer.

6. A gas apparatus comprising a gas-producer, a steam-generator, an air-compressor, a heater for heating the compressed air therefrom, a conduit for compressed air leading it through said heater and into said producer, a steam-superheater, a conduit for leading steam from said generator through said superheater to the inlet of said producer, a carbureter in connection with said superheated-steam conduit, having oil and steam spaces with an intervening permeable medium, and a force-pump for forcing oil into said carbureter, and through said medium, whereby to introduce the oil into contact with the superheated steam to be vaporized thereby and carried into the producer.

7. The combination of a gas-producer A, having a channel *d* supplying twyers, with a source of steam, a superheater D, a pipe *c* therefrom leading to said channel, and a branch steam-pipe *c'* having a valve c^2 and entering the producer beneath said twyers and a separate inlet for compressed air to said twyers.

8. The combination of a gas-producer, a source of steam, a superheater, a carbureter, a pipe leading from said superheater to the lower part of the producer, with a branch thereof leading through said carbureter and returning into said pipe, and valves controlling said pipes, whereby the steam may be carbureted or not.

9. The combination of a gas-producer, having a channel *d* supplying twyers, a grate, and a space or chamber beneath said grate, with a source of steam, a superheater, a carbureter, a pipe leading from said superheater to the carbureter, and pipes or branches leading from the carbureter to said channel and to said space beneath the grate, with valves for controlling said pipes, whereby the carbureted steam may be admitted to the twyers or to the space beneath the grate.

10. In a gas-producer, the combination of a grate T forming an ash-chamber *u* beneath, a pipe admitting steam into this ash-chamber, said grate having ash-openings and steam-openings, upright tubes U communicating with the steam-openings a movable plate T' mounted beneath the grate and having also ash and steam-openings, with said openings so arranged that in one position of the plate its steam openings register with the steam-openings in the grate while the ash-openings in the latter are closed, and in the other position of the plate its ash-openings register with those in the grate, while the steam-openings in the latter are closed, and means for moving said plate.

11. A gas-producer consisting of a metal shell and a refractory lining, formed with an annular chamber *b'* in said lining, a superheating-coil D in said chamber, and the producer constructed in sections having their divisional plane intersecting said chamber, so that by separating said sections access is had to the coil in said chamber.

12. A gas-producer consisting of a metal shell and a refractory lining, constructed in three sections, the upper section formed with an annular chamber *b'* in the lining, a coil D in said chamber, the lower section formed with twyers *d'* and channel *d*, and a pipe *c* leading from said coil to said channel, extended outside the shell of the producer so as to bridge the intermediate section, and provided with a separable coupling.

13. The combination of a gas-generator A having a grate T, and means for closing the openings in said grate, and a steam-ejector W for removing ashes communicating with the chamber beneath said grate.

In witness whereof I have hereunto signed my name in the presence of two subscribing witnesses.

FRANCIS G. BATES.

Witnesses:
REYNOLDS D. BROWN,
JAMES H. YOUNG.