(No Model.)

4 Sheets—Sheet 1.

F. G. BATES.

GAS APPARATUS.

No. 573,958. Patented Dec. 29, 1896.

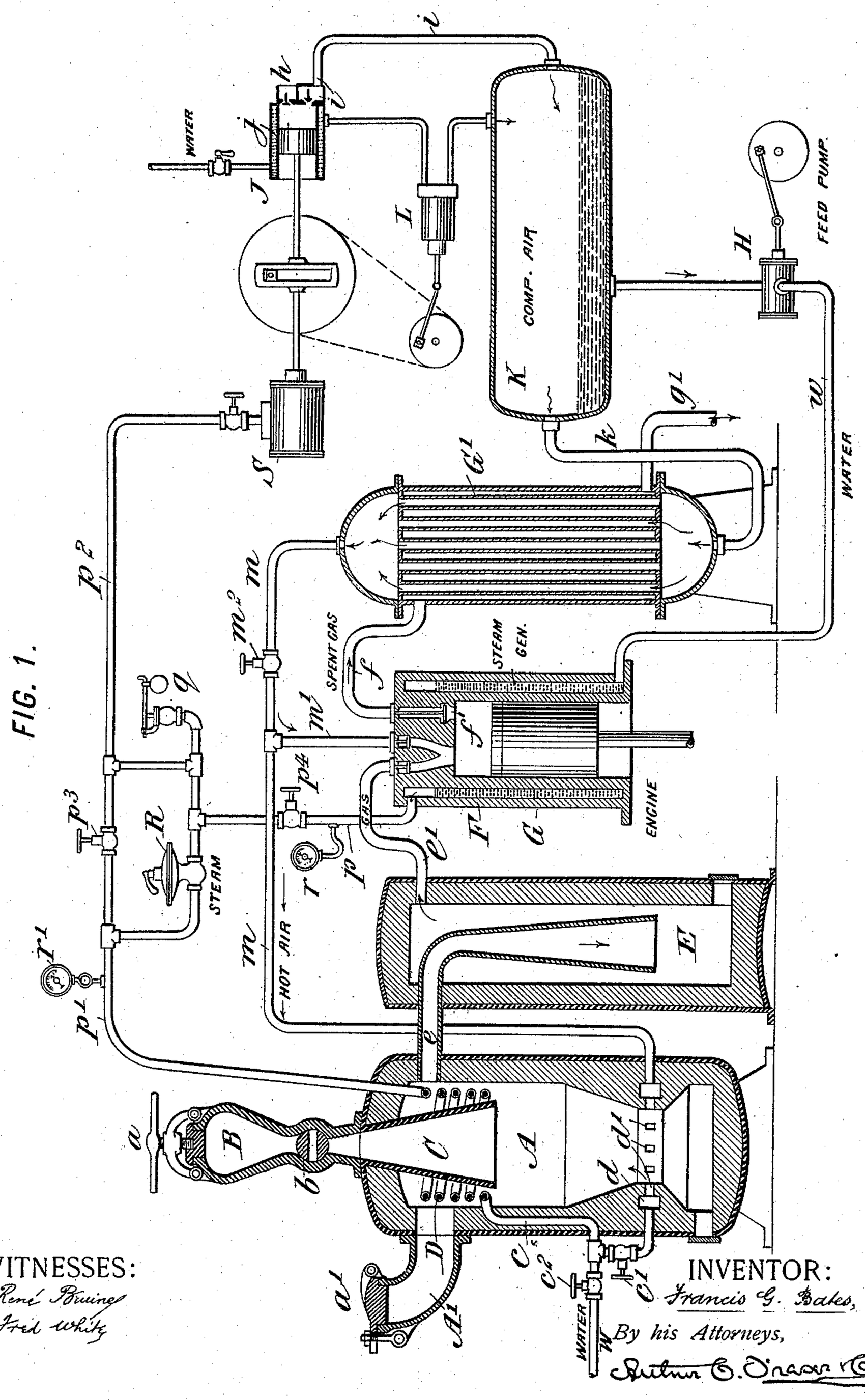

FIG. 1.

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(No Model.) 4 Sheets—Sheet 2.

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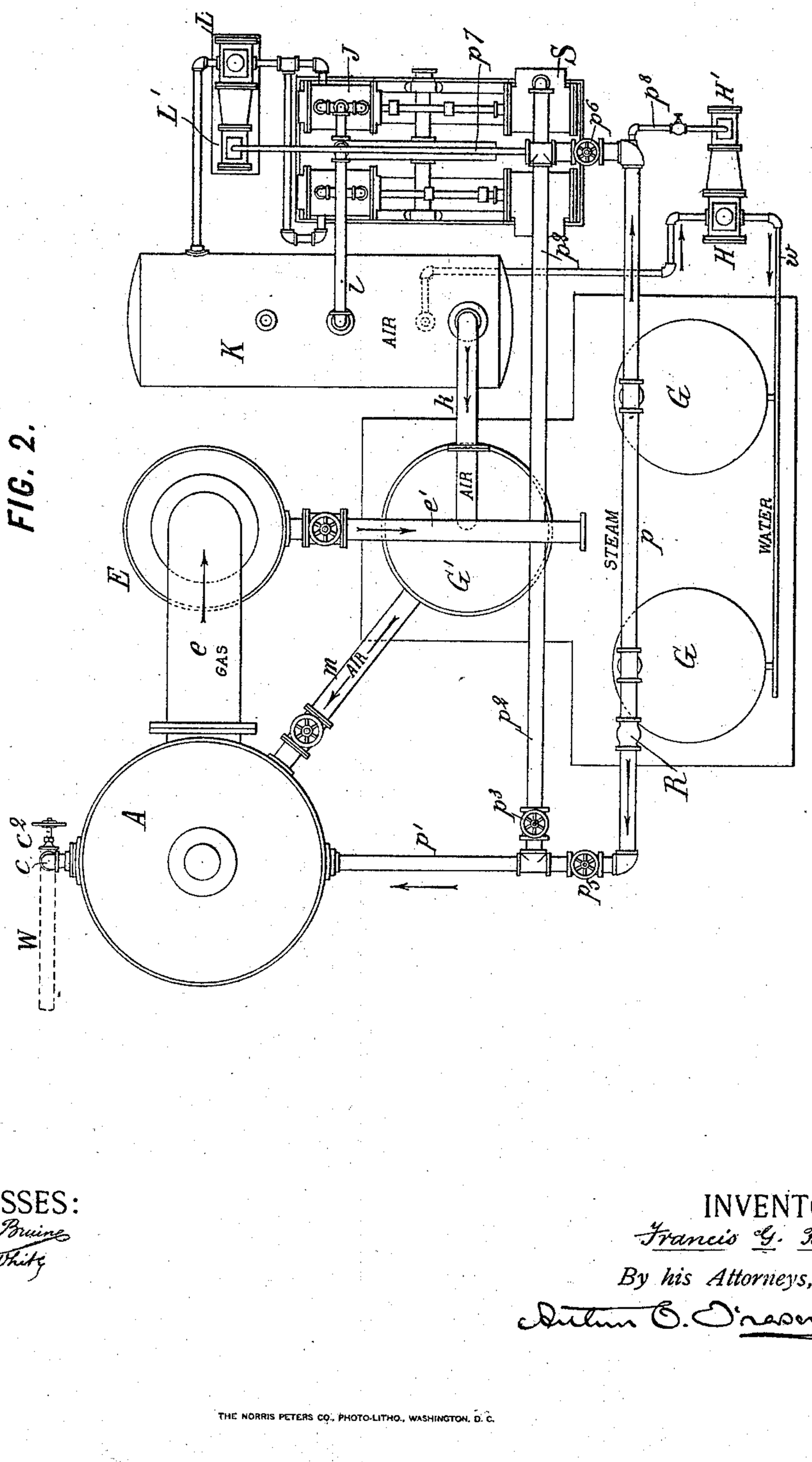
GAS APPARATUS.

No. 573,958. Patented Dec. 29, 1896.

FIG. 2.



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(No Model.) 4 Sheets—Sheet 3.

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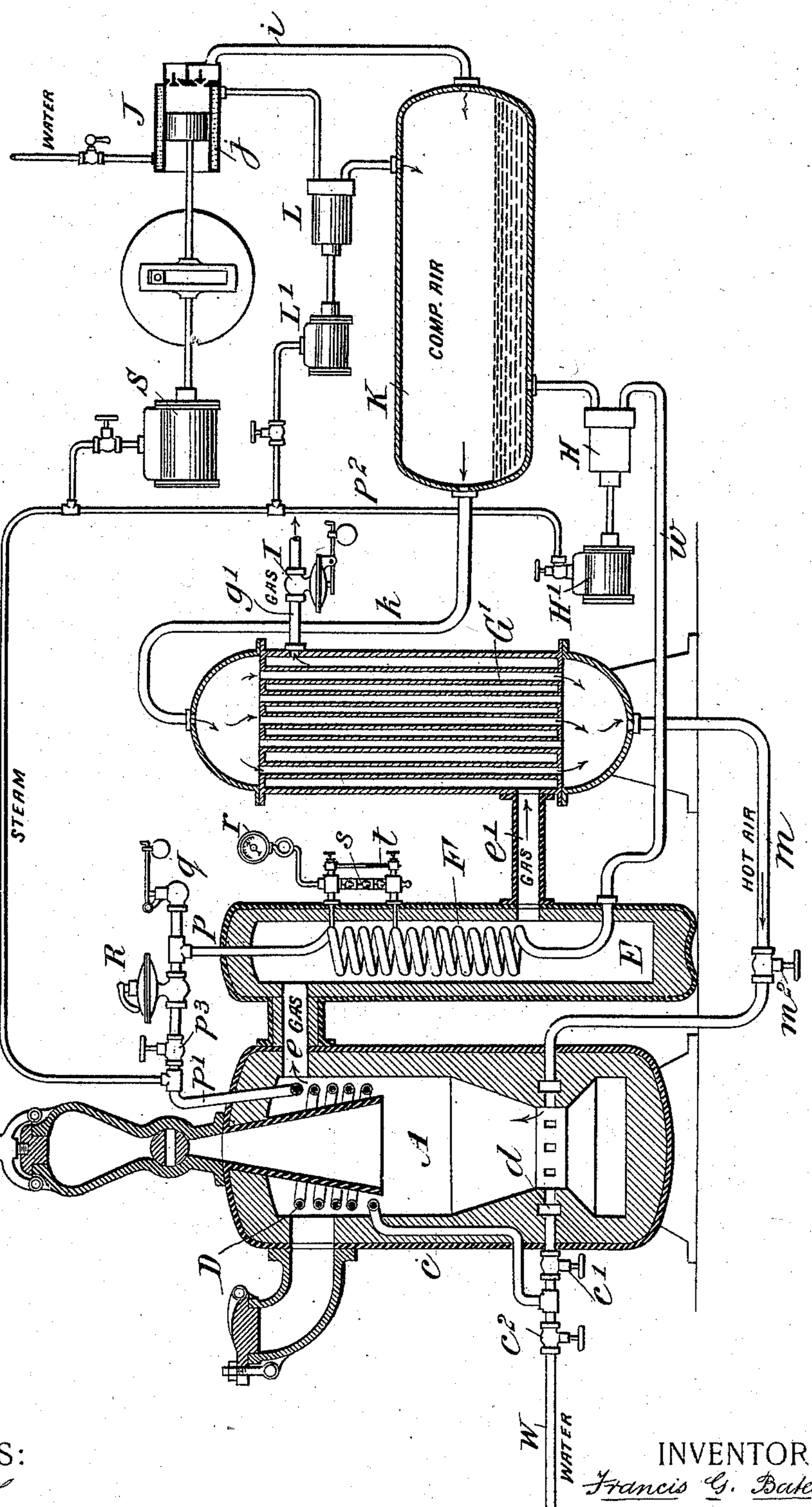
GAS APPARATUS.

No. 573,958. Patented Dec. 29, 1896.

FIG. 3.



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4 Sheets—Sheet 4.

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GAS APPARATUS.

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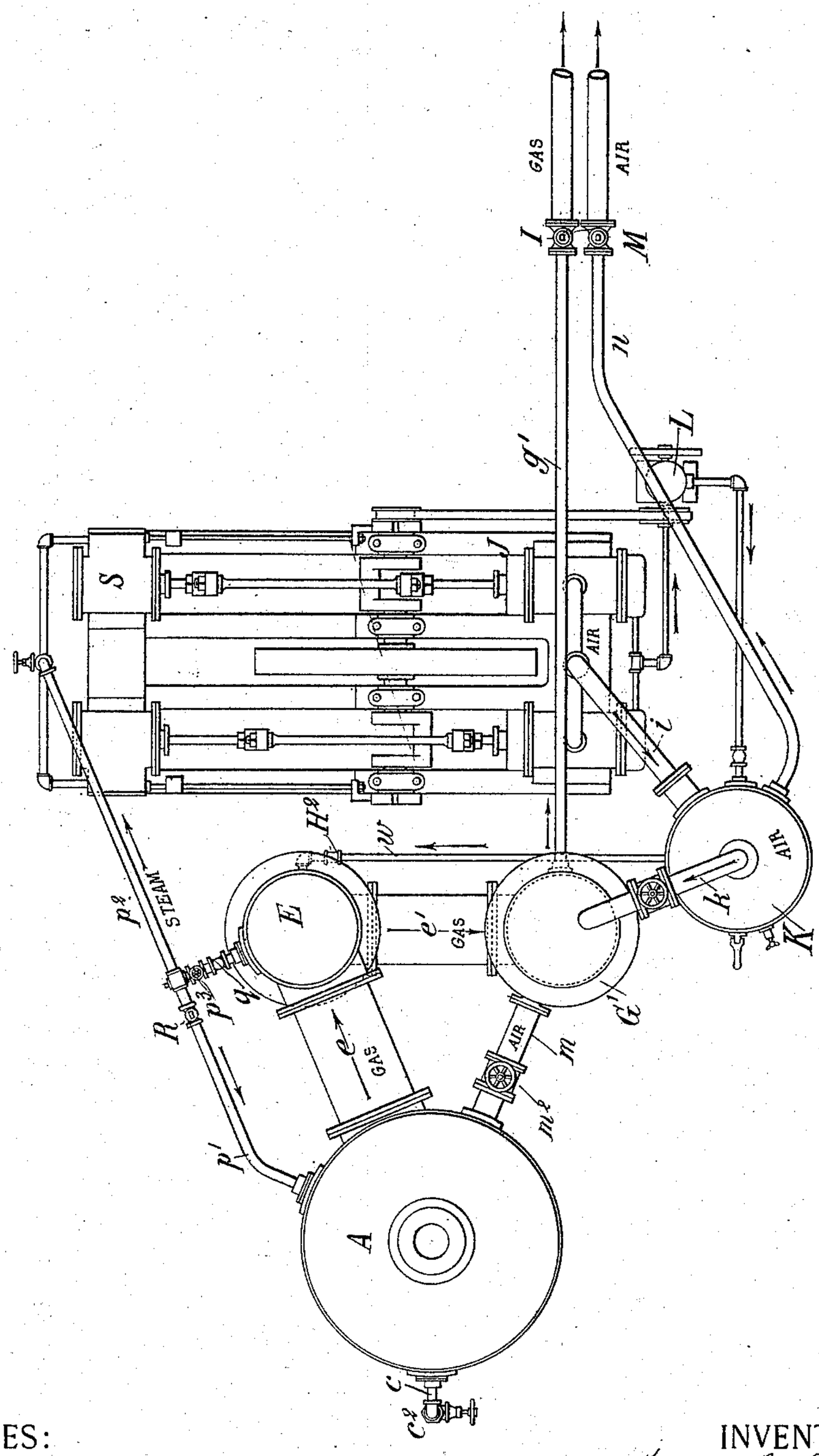
FIG. 4.



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UNITED STATES PATENT OFFICE.

FRANCIS G. BATES, OF PHILADELPHIA, PENNSYLVANIA.

GAS APPARATUS.

SPECIFICATION forming part of Letters Patent No. 573,958, dated December 29, 1896.

Application filed June 8, 1896. Serial No. 594,632. (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 Gas Apparatus, of which the following is a specification.

This invention relates to apparatus wherein gas is produced under pressure by passing hot air and superheated steam into contact with incandescent carbonaceous matter.

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 apparatus for producing gas by the said process with a gas-engine especially adapted to be operated by the combustion of such gas.

My invention is applicable to either the manufacture of gas *per se* or to a motive-power apparatus comprising a gas-generating plant in combination with a gas-engine.

My invention constitutes an improvement upon or addition to the apparatus disclosed in the said patents of Maurice Lorois. In operating such a process it is necessary to compress air by means of an air-compressor to whatever pressure is maintained in the apparatus, usually in practice from fifty to one hundred pounds per square inch. The operation of this air-compressor involves a considerable expenditure of power, which heretofore in a gas-motor has been taken usually from the motor-engine, although sometimes the air-compressor has been driven by some extraneous source of power. When the air-compressor is driven from the gas-engine, it absorbs a considerable proportion of the power generated by the engine, it being found, for example, that in a one-hundred-horse-power engine twenty-two-horse power is required to run the air-compressor. In the manufacture of fuel or illuminating gas independently of the immediate production of power it has heretofore been found necessary to provide some extraneous source of power for operating the air-compressor. Ordinarily the most convenient source of such power is a gas-engine driven by the gas produced by the apparatus; but it is found that the compression of air by this means involves the consumption of a large proportion of the gas which is produced. My present invention remedies these inconveniences and is based upon a discovery which I have made, namely, that in the normal operation of an apparatus of this character, where the steam required for the generation of gas is produced (as in said Lorois patents) by the utilization of the waste heat of the gas, there exists a steam-generating capacity in excess of that necessary for providing only the amount of steam required for the production of gas, and that by a proper proportioning of the parts of the apparatus the steam-generator may be made to furnish sufficient steam under suitable pressure to supply not only that which is required in the gas-producer, but also enough to operate a steam-driven air-compressor of ample capacity for compressing all the air required by the apparatus. In addition I utilize the excess of steam thus produced for driving the feed-pump by which water is supplied to the steam-generator. I have even found it possible to obtain a sufficient excess of steam in this way to enable it to be used as a source of power for doing outside or extraneous work.

In the operation of gas-producing apparatus of the character described some difficulty has been heretofore encountered in the starting of the apparatus, it being necessary first to kindle and bring to incandescence a mass of fuel in the gas-producer at substantially atmospheric pressure before it is possible to commence the proper conduct of the process under heavy pressure. In such starting of the apparatus it has been found necessary to rely upon extraneous power for driving the air-compressor and the water-feed pump until such a pressure is attained in the apparatus that the normal operation of gas-production is commenced. Consequently in the case of a motive-power apparatus the engine has been helpless as a source of power until started and worked up to the required inter-

nal pressure by the aid of some extraneous power. This difficulty has constituted a serious obstacle to the introduction of motive-power apparatus of this order. My invention overcomes this disadvantage by providing means in connection with the gas-producer whereby the operation of kindling the fire therein serves for getting up steam, so that by the time a sufficient mass of incandescent fuel is provided to enable the process to be operated in its normal manner there has been reached a sufficient pressure of steam to drive the air-compressor and feed-pump until the apparatus can be brought so nearly to its normal condition of operation as to enable it to maintain its own cycle of operations, as it does when under normal operation at full pressure. To this end I provide a coil of pipe in the gas-producer, which at starting is filled with water and which as the fire is kindled receives the heat from the burning fuel, so that the water it contains is converted into steam under suitable pressure. By preference I utilize for this purpose the superheating-coil heretofore employed in the gas-producer for heating the steam on its way from the steam-generator to the twyers of the producer.

Having now given a general idea of the novel features of my invention, I will proceed to describe the same in detail with respect to its preferred applications, referring for this purpose to the accompanying drawings, wherein—

Figure 1 is a diagrammatic sectional elevation illustrating the entire combination of apparatus constituting a gas-motor or motive-power apparatus of the general character of that illustrated in said Patent No. 529,452. Fig. 2 is a plan view showing one suitable and practicable preferred arrangement of the apparatus. Fig. 3 is a diagrammatic sectional elevation of the entire combination of apparatus employed for the manufacture of gas, either fuel or illuminating gas, according to the general system disclosed in said Patent No. 529,453. Fig. 4 is a plan of the preferred arrangement of this apparatus.

I will first briefly describe the motive-power apparatus with reference 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 *d'* 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 and then upwardly for the purpose of precipitating any dust or ashes that have been carried over with the current of gas, so that the hot gas, free from dust, ascends to the upper part of the chamber or dust-separator E, whence it passes out by a pipe *e'* to the cylinder of the gas-engine G. This engine need not here be described in detail, as its construction is fully set forth in said Patent No. 529,452. Suffice it to say that it receives gas through the pipe *e'* and hot compressed air through a pipe *m'*, suitable valves being provided to control the inflow of gas and air and suitable means being provided to ignite the mixture thereof upon their admission to the cylinder, so that as they burn and expand they force down the piston thereof, and on the return stroke an exhaust-valve *f'* is opened to permit the spent gas to pass out through a pipe *f* to the air-heater G'. To keep the engine-cylinder cool, it is provided with a water-jacket F, and this jacket constitutes a steam-generator, since the water in flowing through it is converted into steam. The hot spent gas flows through the heater G' and finally passes off by a pipe *g'*, which conducts it, preferably, to a flue or chimney.

A pump or air-compressor J is arranged to draw in air through the inlet *h* and expel it through an outlet *i* into the compressed-air reservoir or tank K. From the reservoir K the air passes by a pipe *k* to the air-heater G', through which the air flows and takes up heat from the hot spent gas. In the construction shown the air flows through the tubes, while the gas flows around them; but any other construction of surface heater or heat-interchanger may be employed. The gas thus heated is then led by a pipe *m*, part of it flowing through the pipe *m'* to the air-inlet of the engine and the remainder being conducted by the 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.

Water is forced by a feed-pump H through the pipe *w* and into the lower part of the water-jacket or steam-generator F. The steam is taken from the upper part of this jacket by a pipe *p*, which conducts the steam to a pipe *p'*, by which it is led to the upper part of the superheating-coil D, through which the steam circulates, and from its lower part the superheated steam is led by the pipe *c* to the annular passage *d*, communicating with the twyers.

The water which is fed to the steam-generator is preferably first utilized to cool the air-compressor J, either by circulating in a jacket around the air-compressing cylinder or by being sprayed or otherwise introduced into the cylinder, both methods being common in air-compressors. I have shown the provision

of a water-jacket *j* around the compressor, into which water is admitted by a pipe *l*, and the water heated by flowing through the jacket is then pumped by a pump L into the compressed-air reservoir K, from which it is drawn by the feed-pump H. The heat due to the compression of the air is thus taken up by the water and economized for heating the feed-water.

In the operation of this apparatus air is compressed and heated and steam is generated and superheated. The compressed air and superheated steam, both at a pressure of from forty to one hundred pounds per square inch, are then commingled and passed under this pressure through a mass of incandescent fuel in the gas-producer, whereby they are converted into a producer-gas of great richness and of such purity that no subsequent purification is required further than the disengagement of the dust or ashes that may be mechanically carried over with the gas, which is accomplished by the separator E. The hot gas is then admitted together with hot air into the engine-cylinder and a combustion takes place, whereby power is developed. The heat given out during this combustion is utilized in part to heat the steam-generator F and in part is carried off by the spent or exhaust gases to the air-heater G', where most of the remaining heat is utilized in heating compressed air.

As thus far described there is no special novelty in the apparatus so far as my present invention is concerned. I will now proceed to describe those features that are peculiar to or introduced by my present invention.

The air-compressor J is driven by a steam-engine S, either by being directly coupled thereto, as shown, or by any more or less indirect connection therewith. Steam for driving this engine is taken from the steam-generator F. For this purpose I have shown the pipe *p* branched and connected to a steam-pipe p^2, which leads to the steam-engine S. It is preferable to generate steam at a higher pressure than that of the compressed air, or in other words higher than the pressure prevailing in the remaining apparatus, and in such case it is necessary to interpose a pressure-reducing valve or pressure-regulator R between the pipe *p* and the pipe *p'*, which conducts the steam to the gas-producer. It is preferable, however, to be able to drive the air-compressor engine by a pressure of steam higher than that to which the gas-producer is limited, and for this reason I prefer to take steam to the pipe p^2 from the high-pressure side of the regulator R, as shown. The pipes p^2 and *p'* are in communication with each other through a valve p^3, which is normally closed in order to prevent the high-pressure steam from escaping to the low-pressure side. It is, however, within my invention to take steam to the pipe p^2 from the low-pressure side of the pressure-regulator R, or even to dispense with this pressure-regulator, generating the steam by the pressure as it is required for admission to the gas-producer.

The water-pump L is according to my invention driven by steam from the steam-generator F, to which end it might be provided with its own engine, as shown in Fig. 2, where its engine is lettered L'; or it may be driven through a belt or other connection to the engine S, as shown. The feed-pump H is also according to my invention to be driven by steam from the generator F, and to this end it may be constructed as shown in Fig. 1 and belted from the engine S, or may be provided with its own steam-engine, as shown at H' in Fig. 2.

To enable the superheating-coil D to be used as a steam-generator in first starting the apparatus, I provide the following-described construction: The pipe *c*, which conducts superheated steam to the annular passage *d*, leading to the twyers, is provided with a valve *c'*, by which its communication with the passage *d* may be cut off. The pipe *c* might be carried directly down, as heretofore, and the valve *c'* be embedded in the refractory lining of the producer, but it is preferable, in order to protect the valve from excessive heat, to carry the pipe *c* outside the shell of the producer and connect the valve *c'* in this outside portion of the pipe, as shown. To this portion of the pipe is connected a water-supply pipe W, normally closed by a valve c^2. The steam-pipe *p* leading from the steam-generator is provided with a valve p^4, by which it may be shut off.

Before starting the apparatus the compressed-air cylinder K and the air-passages of the heater G' will normally be charged with compressed air left at the close of the previous operation, and retained by closing the valve m^2 in the air-pipe. The gas-producer A is provided with suitable kindling and with a quantity of fuel, and its passage A' is connected to the chimney-flue by opening the cap *a'*, as heretofore. The valve *c'* is first closed and the valve c^2 opened to fill the coil D with water, the valve p^4 being closed and the valve p^3 opened, so that the steam-pipes *p'* and p^2 are connected as one pipe and cut off from communication with the steam-generator F. The coil D being filled with water, the valve c^2 is closed. Air being introduced to the bottom of the gas-producer, the fire is started, and the producer is operated as an ordinary stove until a hot fire is attained. During this time the heat applied to the coil D generates steam under suitable pressure. Any excess of pressure generated in this coil at this time (or any excess generated during the normal operation of the apparatus in the steam-generator F) finds escape through the safety-valve *q*. The steam thus generated is utilized through the engine S to drive the air-compressor J, and if necessary the water-pump L. When a sufficiently hot fire has been kindled in the producer, the connection with the chimney is re-

moved, the cap a' being closed tight and the air-valve m^2 opened to blow air into the generator and raise a pressure therein, and immediately afterward, when a pressure has been attained, the engine may be started, this initial pressure being amply sufficient for starting it, and a combustion of the generated gas (or more correctly of the carbon monoxid it contains) takes place in the engine-cylinder, giving out heat, which heats the water in the steam-generating jacket F, and in a few minutes generates steam under a pressure which can be determined by the gage r. When the pressure thus attained approximates to the normal working pressure, say, for example, from forty pounds per square inch up, the apparatus is ready to be put into complete operation. Meanwhile the air-compressor is being driven by steam generated in the coil D, which is proportioned to hold sufficient water for making steam enough to drive the compressor during this interval. By means of thus driving the compressor the pressure of air in the cylinder K is kept up, notwithstanding the loss of air due to blowing it through the gas-producer during this preliminary operation. When the generator F has brought the steam up to the required pressure, the valve p^4 is opened, thereby connecting all the steam-pipes together. The valve c^2 is then opened to blow any remaining water in the coil D and pipe c out through the water-pipe W by reason of the steam-pressure being in excess of the hydrant-water pressure in the pipe W. The valve c^2 is then closed and the valve c' opened to admit steam to the passage d, leading to the twyers of the producer, so that steam may be introduced with the compressed air. The valve p^3 should then be closed, whereupon the steam admitted to the producer will be regulated in pressure by the pressure of the regulator R, its reduced pressure being indicated by the gage r'. At the proper time the feed-pump H should be started in order to keep the water-level in the generator F at the proper point. The apparatus is now in full operation. My invention renders this motive-power apparatus completely independent of any other source of power and capable of self-starting after disuse and capable of operating its accessory apparatus, namely, air-compressor and water pump or pumps, without diminution of its own developed mechanical power. My invention increases the net power developed by the apparatus by utilizing otherwise waste heat for the generation of steam sufficient to drive the accessory apparatus, thereby increasing by approximately twenty-five per cent. the power effectively utilized.

Fig. 2 illustrates a suitable arrangement of the apparatus and answers to Fig. 1 of said Patent No. 529,452. A is a producer or gazogene. (Shown in top view.) E is the dust-separator or cleaner. G′ is the regenerator or air-heater. G G are the engine-cylinders. K is the compressed-air reservoir. J is the air-compressor, here shown as duplex. S is the steam-engine end thereof. L is the water-pump, driven by its steam-cylinder L′, and H is the feed-pump, driven by its steam-cylinder H′. The arrangement of piping here shown is somewhat different from that illustrated in Fig. 1, the corresponding pipes being designated by like letters. The two power-cylinders have their steam-generating jackets connected with a steam-pipe p, which on one side connects through the pressure-regulator R and cut-off valve p^5 with the pipe p', leading to the gas-producer, while on the other side the pipe p connects through a cut-off valve p^6 with the steam-pipe p^2, which supplies the engine S. This pipe is separated by valve p^3 from the pipe p', essentially as in the first-described construction. The steam for driving the pump L is taken from the pipe p^2 by a pipe p^7. Steam for driving the pump H is taken from the pipe p by a pipe p^8. The details usual with the engine construction, including its valves, the air and gas passages, and exhaust, are omitted.

My invention is equally applicable to the apparatus for the manufacture of gas independently of the immediate production of power.

Fig. 3 shows a gas apparatus constructed according to my invention. A is the gas-producer, of the same construction as already described. The gas-outlet e communicates with a dust-separator or upright chamber E, the outlet e' from which, however, is arranged near the bottom and leads directly to the air-heater G′, from which the cooled gas passes by a pipe g' to a regulating-valve I, which is adjusted to retain in the apparatus the predetermined working pressure, say from fifty to one hundred pounds per inch. The air-compressor J, water-pump L, compressed-air cylinder K, and feed-pump H in this construction are unchanged. The air from the air-compressor passes through pipe k to the heater G′, and thence through a pipe m to the producer A, as before. The principal difference is that the steam-generator F here consists of a coil of pipe arranged in the upright chamber E, so as to be exposed to the heat of the newly-generated gas which is flowing through this chamber. The feed-pump H forces water from the reservoir K through a pipe w into the bottom of the generator-coil F, while the steam passes from the top thereof by a pipe p to the pressure-regulator R and safety-valve q. On the low-pressure side of the regulator R the steam passes through valve p^3 by pipe p' to the superheating-coil D, and also by branch pipe p^2 to the steam-engine S, driving the air-compressor J, the steam engine or cylinder H′ of the pump H, and the steam cylinder or engine L′ of the pump L, the pipe p^2 being suitably branched to connect with each of these engine-cylinders. The superheater D is connected by

pipe *c* through valve *c'* with the annular passage *d*, as before, and by valve c^2 with the water-pipe W. The steam-generator F may be provided with a stand-pipe *s*, having pet-cocks, a water-gage *t*, and a steam-gage *r*.

In starting the apparatus the valves *c'* and p^3 are closed, the valve c^2 is opened to fill the coil D with water, and the top of the generator is connected, as before, with the chimney. The fire is kindled in the same manner as before, and steam is generated in the coil D to drive the air-compressor J. When a sufficient bed of incandescent fuel is attained, the chimney connection is discontinued, the producer closed, the valve m^2 is opened, and compressed air is introduced into the producer until approximately the required working pressure is attained in all the apparatus. The crude gas thus made, passing through the chamber E, heats the coil F and generates steam, and when the steam reaches approximately the working pressure the valve p^3 is opened to permit its passage to the steam-pipes p' p^2. The coil D is then purged of any remaining water by the valve c^2, after which this valve is closed and the valve *c'* opened to admit the steam to the bottom of the producer. The apparatus is thereby brought into full operation. The pumps L and H are started at any suitable time.

As applied to a gas-producing apparatus my invention has the advantage of rendering the apparatus self-starting and independent while in operation of all other apparatus, so that it generates all the power required for driving its accessory machinery. This is done without any added expense and solely by the more perfect utilization of the otherwise waste heat of the newly-generated gas. Steam may easily be taken from the steam-generator for driving other apparatus, there being a reasonable excess of evaporating capacity beyond the requirements of the gas-producer and air-compressor and other apparatus accessory to the gas apparatus.

Fig. 4 is a plan view showing the preferred arrangement of apparatus for gas-producing. The same letters being used as in Fig. 3, the correponding parts may easily be identified. The air-compressor J and its steam-cylinder S are duplicated, forming a duplex air-compressor. The water circulating in its jacket is pumped by the pump L into the compressed-air reservoir K and passes thence by the pipe *w*, in which may be introduced a feed-pump or injector, the latter being indicated at H^2. The particular apparatus here shown is designed for making fuel-gas for heating glass-furnaces and analogous purposes, and to this end compressed air is taken from the reservoir K by a pipe *n*, its pressure being lowered by a pressure-governor M, answering to the pressure-governor I in the gas-delivery pipe *g'*. The gas and air delivery pipes are carried together to the place of use, so that compressed air is injected into the furnace with the compressed gases.

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

1. The combination in a gas apparatus, of an air-compressor, an air-heater, a gas-producer, a steam-generator heated by the waste heat given out by the gas, a passage for compressed air leading through said air-heater into said gas-producer, a steam-pipe leading from said generator into the gas-producer, a steam-engine, and a steam-pipe from said generator to said steam-engine, whereby the waste heat of said gas is utilized to generate steam both for making gas and for driving said steam-engine as an auxiliary source of power.

2. The combination in a gas apparatus, of a steam-driven air-compressor, an air-heater, a gas-producer, a steam-generator heated by the waste heat given out by the gas, a passage for compressed air leading through said air-heater into said gas-producer, a steam-pipe leading from said generator to said gas-producer, and a steam-pipe from said generator to the steam-engine driving said air-compressor.

3. The combination in a gas apparatus of a steam-driven air-compressor and a steam-driven feed-pump, a compressed-air reservoir into which said compressor discharges, an air-heater, a gas-producer, a passage for compressed air leading from said reservoir through said heater to said producer, a steam-generator heated by the waste heat given out by the gas, a water-pipe from said feed-pump to said steam-generator, a steam-pipe from said steam-generator leading to the gas-producer, and a steam-pipe from said generator leading to the steam-cylinders of said air-compressor and feed-pump.

4. The combination in a gas apparatus of a steam-driven air-compressor, an air-heater, a gas-producer, a steam-generator heated by the waste heat given out by the gas, a passage for compressed air leading through said air-heater into said gas-producer, a steam-pipe leading from said generator, a steam-pressure regulator, a pipe leading from the low-pressure side of the latter through the superheater in the gas-producer and communicating with the inlet-twyers thereof, and a steam-pipe communicating with the high-pressure side of said regulator and leading to the steam-cylinder of said air-compressor, whereby said generator supplies steam both at reduced pressure for making gas, and at high pressure for driving said air-compressor.

5. In a gas-motor engine, the combination of a steam-driven air-compressor, an air-heater, a gas-producer, an engine-cylinder, a passage for compressed air leading through said air-heater into said gas-producer and engine-cylinder, a passage for gas leading from said producer to said engine-cylinder, a steam-generator constructed as a jacket around said engine-cylinder, a feed-pump and connecting-pipe for forcing water into said steam-gener-

ating jacket, a steam-pipe leading from said generator to said gas-producer, and a steam-pipe leading from said generator to the steam-cylinder of said air-compressor.

6. The combination of a gas-producer, a coil of pipe arranged to be heated by the hot gases generated in said producer, a steam-generator, an air-compressor, a passage for compressed air leading to the inlet of the gas-producer, a steam-pipe leading from said generator to the inlet of the gas-producer, a water-inlet to said coil of pipe, and suitable cocks whereby said coil of pipe may be filled with water when starting the fire in the gas-producer, and be utilized as a temporary steam-generator for getting up a pressure of steam during the starting of the fire.

7. The combination of a gas-producer, a superheating-coil therein, a steam-generator, an air-compressor, a compressed-air passage leading therefrom to the inlet of the gas-producer, a steam-pipe leading from said generator to said superheater and thence to the inlet of the gas-producer, a cock for closing said latter steam-passage, and a water-inlet to the bottom of said superheating-coil, whereby said superheating-coil may be filled with water when starting the fire in said gas-producer, and be utilized as a temporary steam-generator for getting up a pressure of steam during the starting of the fire.

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

FRANCIS G. BATES.

Witnesses:
ARTHUR C. FRASER,
FRED WHITE.