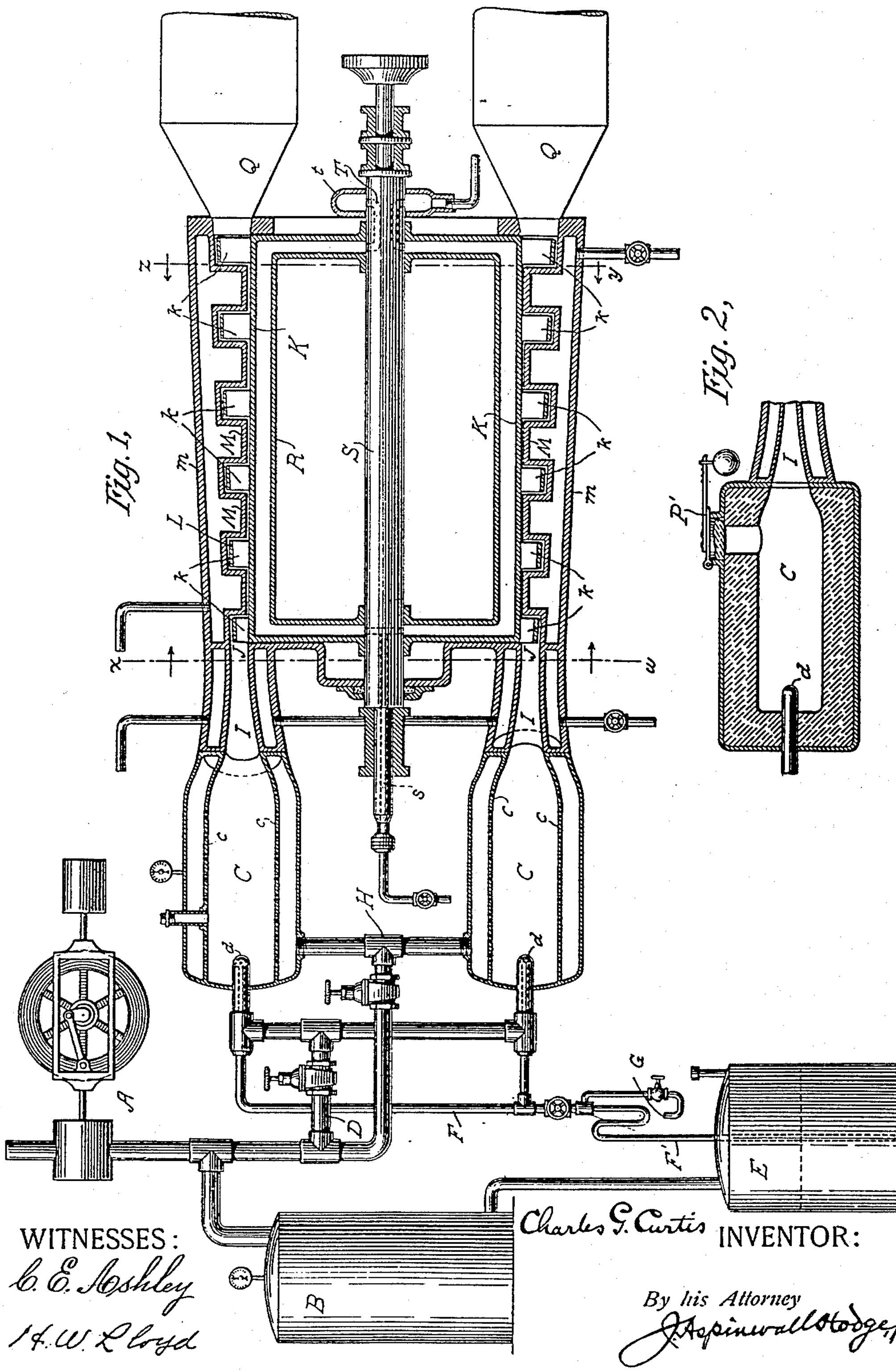
No. 635,919. Patented Oct. 31, 1899.

C. G. CURTIS.

APPARATUS FOR GENERATING MECHANICAL POWER.

(Application filed June 24, 1895.)

(No Model.) 6 Sheets—Sheet 1.



WITNESSES:

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H. W. Lloyd

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(No Model.) 6 Sheets—Sheet 2.

Fig. 3,

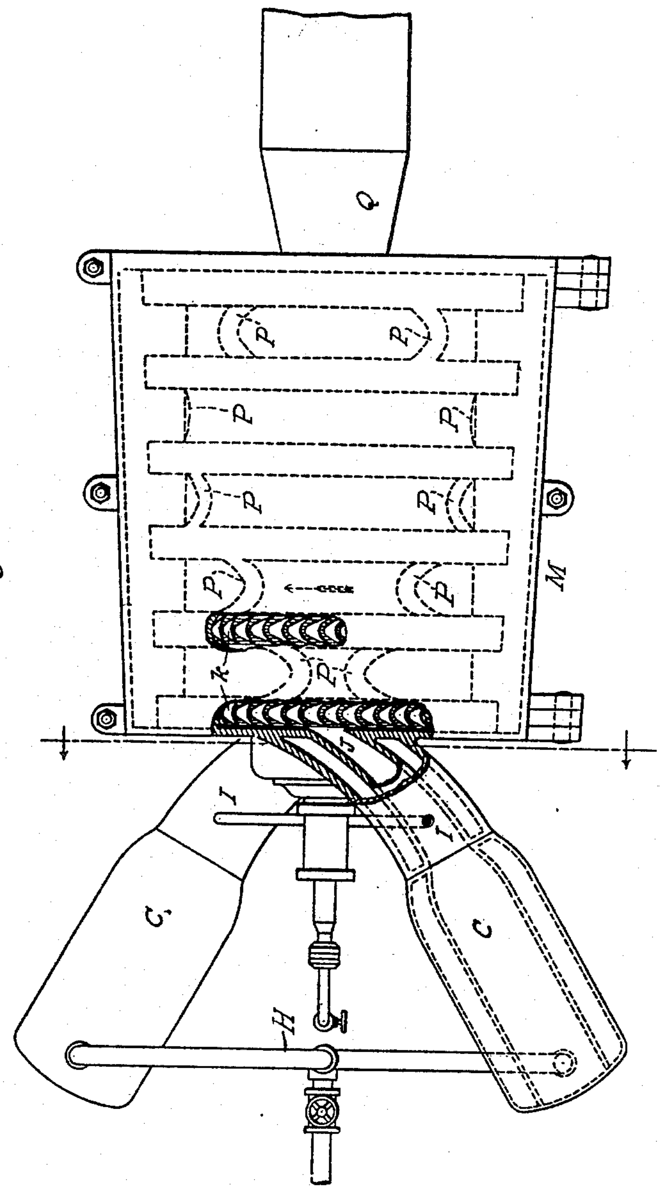

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Fig. 5.

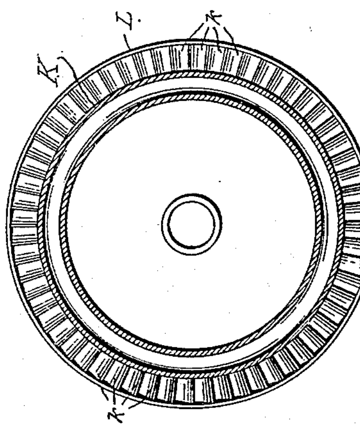


Fig. 7.

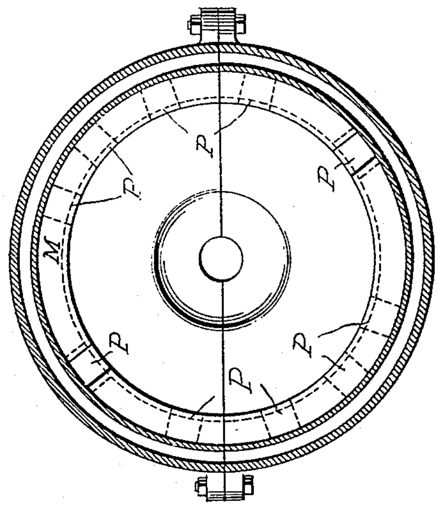


Fig. 4.

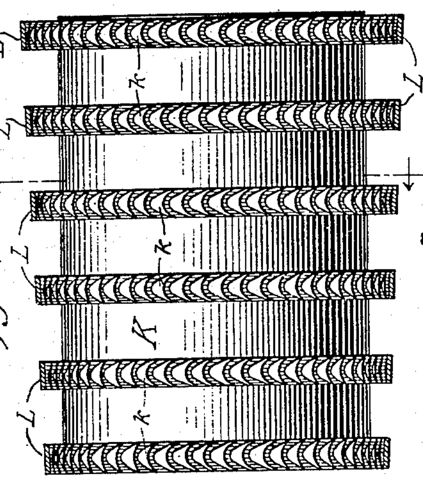
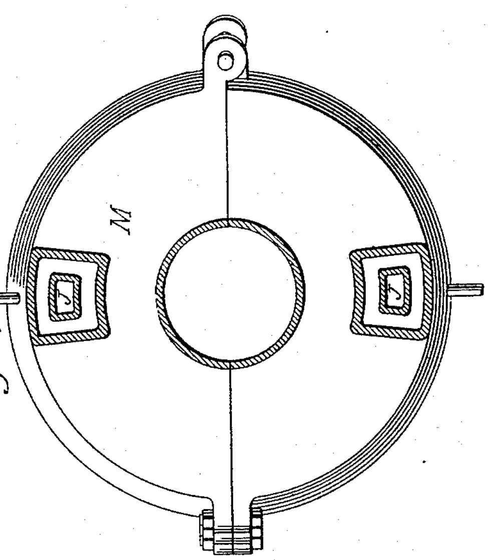


Fig. 6.



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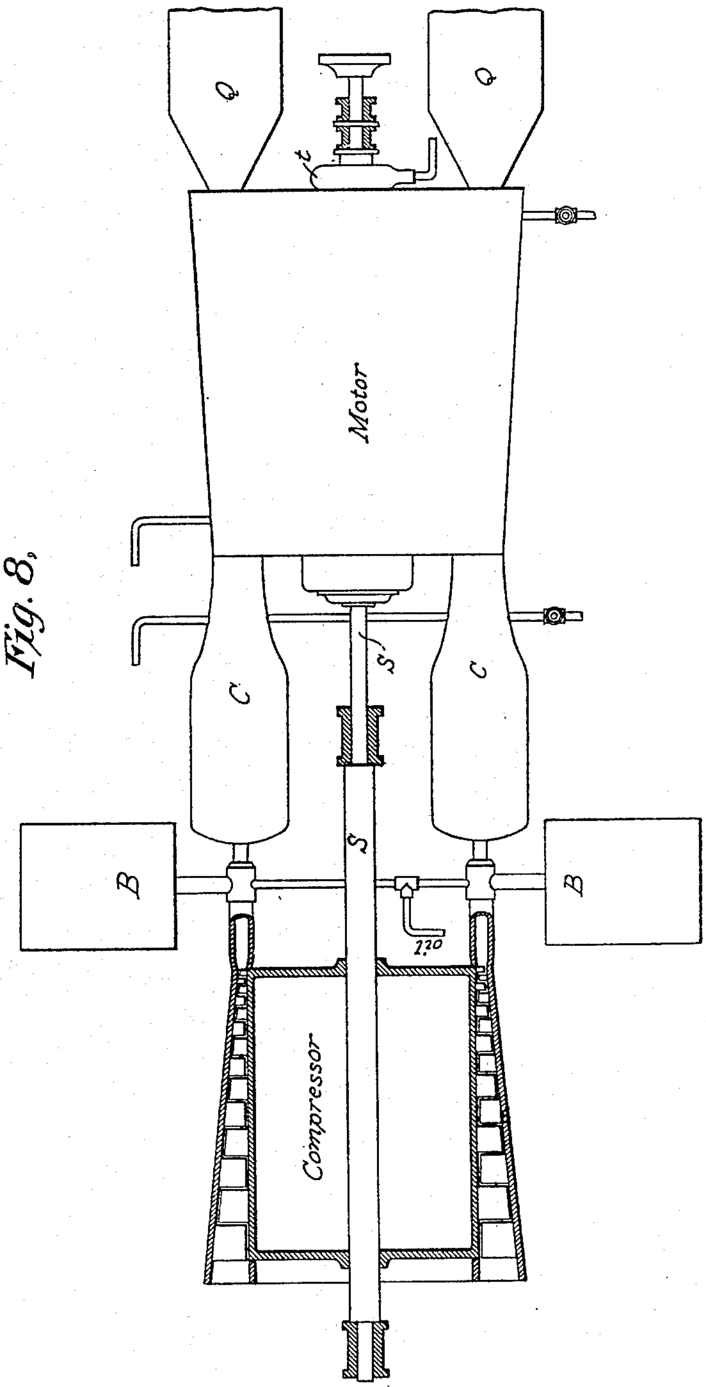
(No Model.) 6 Sheets—Sheet 4.

Fig. 8,



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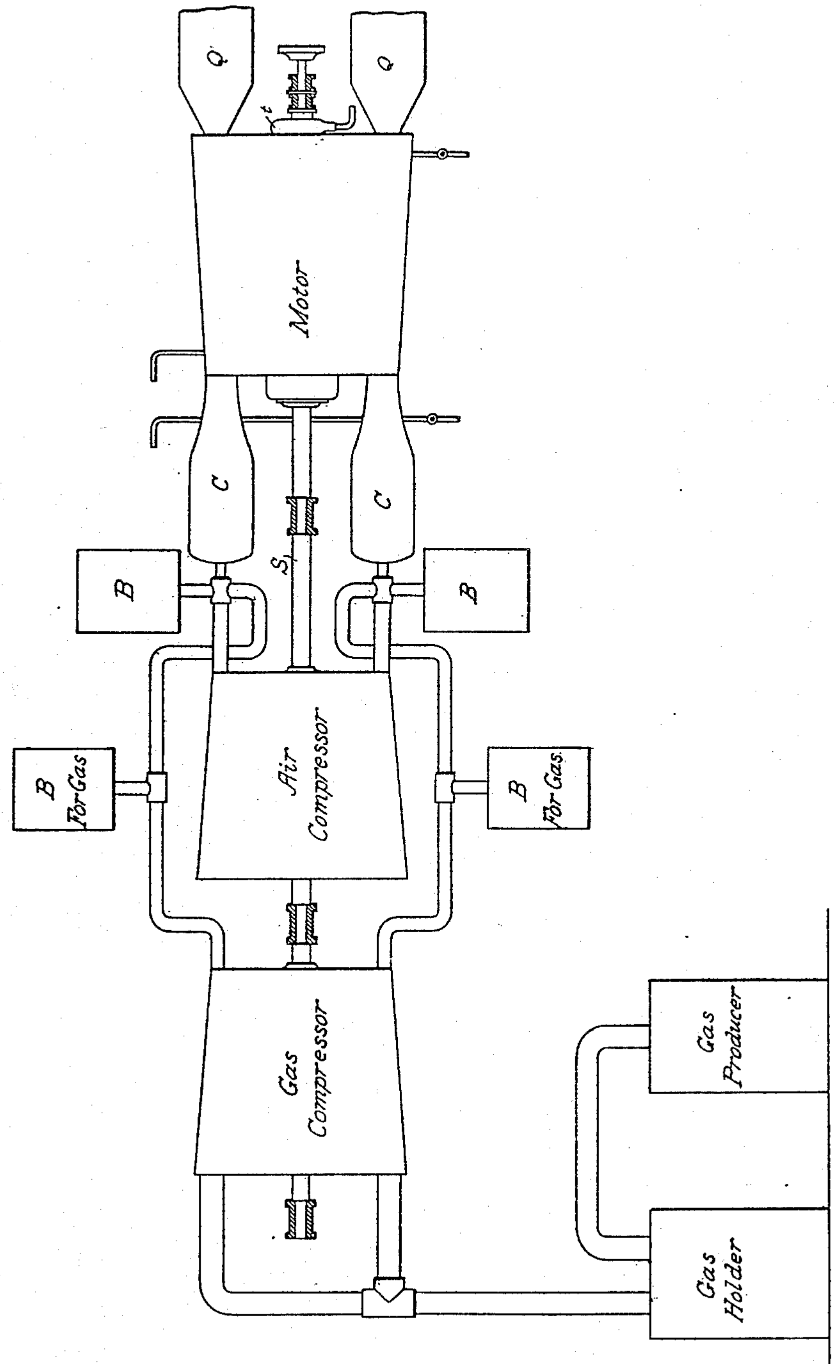
(No Model.) 6 Sheets—Sheet 5.

Fig. 9.



WITNESSES:

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No. 635,919.

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(No Model.)

6 Sheets—Sheet 6.

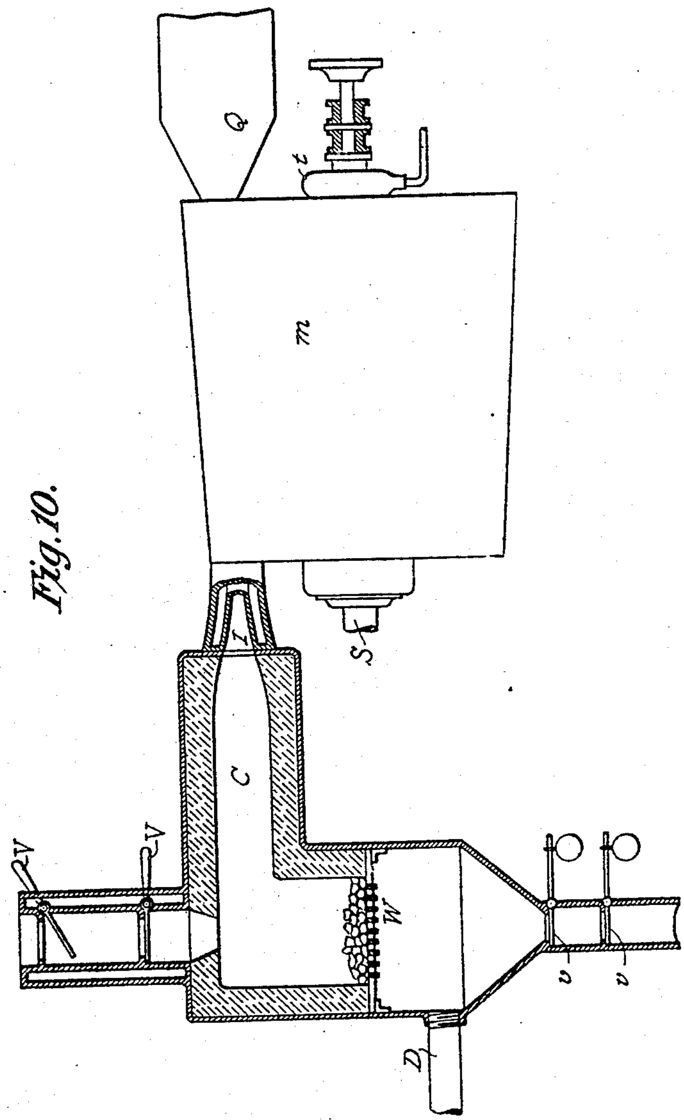

Fig. 10.

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UNITED STATES PATENT OFFICE.

CHARLES G. CURTIS, OF NEW YORK, N. Y.

APPARATUS FOR GENERATING MECHANICAL POWER.

SPECIFICATION forming part of Letters Patent No. 635,919, dated October 31, 1899.

Application filed June 24, 1895. Serial No. 553,866. (No model.)

To all whom it may concern:

Be it known that I, CHARLES G. CURTIS, of the city and State of New York, have invented a new and useful Apparatus for Generating Mechanical Power, of which the following is a specification.

This invention relates to a new apparatus for developing mechanical motion or power directly from the combustion of various kinds of fuel without the intervention of steam or other medium.

In the most common mode of generating power at the present time—by the evaporation of water into steam and its slow expansion in a reciprocating device—it is well known that only a very small portion, not exceeding fifteen per cent., of the total energy contained in the combustible is utilized, the larger portion of the heat of the fuel—about sixty per cent.—being expended in the mere evaporation of the water and disappearing as latent heat without doing any useful work. Besides being exceedingly wasteful of fuel the use of steam requires apparatus of high cost in the way of boilers, furnaces, and complex engines which are also very costly to repair and maintain and which, considering their size, develop comparatively small amounts of power. In marine practice, for example, the great weight of the boilers and engines and of the fuel and the enormous space they require are of great consequence, and it will be readily seen that a method of generating power which dispenses with this great weight and the necessity of so much space will render it possible not only to attain much greater speed, but to operate vessels with greater economy.

I will describe my invention by reference to the accompanying drawings, in which—

Figure 1 is a side sectional view of my improved combustion-engine and showing my new method of developing power. Fig. 2 is a detail sectional view of my combustion-chamber, showing one form thereof. Fig. 3 is a top view of my improved compound rotary engine or motor, showing a portion of the case or body broken away in order to more plainly show its internal construction. Figs. 4 and 5 are respectively side and end views, partly in section, of the revolving part of my compound motor, showing the shape and arrangement of the guide vanes or blades against which the moving gas impinges. Figs. 6 and 7 are sectional transverse views of the stationary case or shell, taken on the two planes *w x* and *y z*, respectively. Fig. 8 is a general view showing two of my improved turbines on the same shaft, one operating as the motor and the other as an air-compressor. Fig. 9 is a general view of my improved combustion-engine, showing the manner of utilizing "producer" or other gas as fuel. Fig. 10 is a view, partly in section, illustrating my invention as applied to the use of coal or other solid fuel and showing the manner of utilizing ordinary coal as fuel.

In Fig. 1 I have specifically shown my improved apparatus as adapted to the use of liquid fuels, more especially petroleum in the crude or reduced form. Petroleum becomes an available and very valuable fuel in my improved combustion-engine for the reason that it effects such a saving in the quantity required and for the further reason that oil involves practically no expense in handling and feeding and eliminates all ashes and smoke.

In Fig. 1, A represents an air compressor or blower, which may be of the ordinary type of air-compressor, designed to operate with the highest economy of power, but which should not be provided with any means of cooling the air during or after compression, as it is desirable that all the work done, and consequently the heat produced during compression, should remain in the air to be afterward utilized. While a reciprocating compressor may be employed in my invention, it is preferable to have a special new form of rotary compressor, which I have devised, adapted to the work. Such a compressor or blower I will describe later on. The compressor A is connected with the receiver or reservoir B and supplies the requisite amount of air under the desired pressure to the double combustion-chamber C C through the pipe D and nozzles *d d*, the flow being controlled by suitable valves, as shown, if desired.

E represents an air-tight oil holder or tank which is connected with the air-receiver B by a pipe, as shown, so as to put the oil it contains under pressure. F is another pipe reaching nearly to the bottom of the tank, through which pipe the oil is fed to the combustion-chamber C C. The oil may either be introduced into the combustion-chamber in the liquid form, being carried in with and atomized by a jet of air under a pressure sufficiently greater than that in the combustion-chamber, as I will more particularly describe, or the oil may be first vaporized or converted into a gas before it enters the chamber. This of course may be done by any of the well-known means—by passing the oil through a coil or portion of pipe kept hot by a burner G, for example, by which the oil is volatilized before entering the combustion-chamber. By connecting the oil-tank E with the air-reservoir B the oil is kept under pressure, and consequently the oil or its vapor enters the chamber under the same or approximately the same pressure as the air. If the oil be injected into the chamber as a liquid, this may be done by means of an ordinary "atomizing-nozzle," consisting of an internal perforated nozzle through which the oil passes and an inclosing perforated nozzle through which the compressed air passes, as indicated in Fig. 1. The rate of flow of both the oil and the air and their relative proportions may of course be regulated by means of valves, as shown, or in any desired way. I prefer, however, to introduce into the combustion-chamber a quantity of air which is in excess of that required to effect complete combustion of the oil for two reasons—first, so as to increase the volume of the gases which issue from the chamber, and, second, so as to reduce the temperature of the gases to as low a point as practicable. This can be done in my invention and, indeed, can be carried to a point where the air introduced into the chamber is several times as great as that required for complete combustion without serious loss of power. This will be understood when it is considered that I cause the compression of the air to take place without any cooling action, and consequently the air enters the combustion-chamber containing all the heat developed during compression, which represents all the work done by the compressor, (less, of course, the usual losses by friction of the apparatus, &c.,) and all this heat becomes available in the chamber for causing expansion of the gases and doing useful work in the motor. In this way a large portion of the work expended in compressing the air is recovered in the motor. By the employment of a rotary compressor such as I shall presently describe and by directly connecting it with the shaft of the motor itself the losses incident to compression are reduced to a small amount. At the same time a rotary form of compressing device is better adapted to stand high temperatures, such as are developed by compressing air without cooling to pressures of several hundred pounds per square inch.

The compressed air may be introduced into the chamber in various ways. The theoretical amount required for combustion may be introduced with the oil through a nozzle, and the excess of air may be brought in through the same opening, or this excess may be introduced at some other part of the combustion-chamber—through the pipe H, for example, as shown in Fig. 1. Here the excess of air enters the chamber on the side into an annular space formed by a perforated wall C C, forming a sort of air-jacket, the air passing through the perforations into the interior of the chamber, where combustion takes place. It is important, however, where high temperatures are employed and the size of chamber is small compared with the zone of combustion that the chamber should be properly lined with heavy walls of fire-brick, as I have indicated in Fig. 2, both in order to avoid injury to the shell and loss of heat by conduction.

In Fig. 1 I have shown the combustion-chamber made in two like parts, or practically two combustion-chambers, each of which discharges its products of combustion independently into different portions of my rotary motor or turbine; but it will be evident that a single chamber will answer and the gases of combustion made to discharge through any form or number of orifices into the motor or turbine.

The gases resulting from combustion, together with the surplus air, all under pressure, I conduct, through contracting passages I I, to two orifices J J of the proper size, where they enter my improved motor or turbine, the construction of which I will now describe.

K K is a cylindrical shell mounted upon a shaft in suitable bearings, as shown, so as to be capable of revolving at the desired speed. From the surface of this cylinder project a series of rings of curved guide vanes or blades *k k*, leaving spaces or passages between the blades of the general shape indicated in Figs. 3, 4, and 5. These blades are formed out of solid rings of steel by milling the passages transversely through the solid stock, and the series of blades are preferably made of an increasing depth, as shown in the drawings, to provide an increased cross-section of passages, and thus allow for the gradually-diminishing velocity of the gases as they pass through the turbine. Upon the outside of the blades are shrunk rings L L, &c. This cylindrical shell, with its projecting blades, constitutes the revolving portion of my turbine and revolves within a stationary exterior shell M, formed with inwardly-projecting rings of metal (or other material) which exactly fill the spaces between the rings or revolving blades, leaving, however, a clearance on all sides of the blades sufficient to allow rotation without touching. It will be observed that these solid or continuous rings increase in depth to correspond with the varying depth of the revolving blades, and they are in reality chambered out or hollow, as shown in Figs. 1 and 7. These hollow portions, together with an external wall or case M, forms an annular space through which water may be circulated, thus forming a water-jacket to keep the shell sufficiently cool. The passages I I, through which the gases are led after issuing from the combustion-chamber, should likewise be water-jacketed, as shown in the drawings, in order to prevent overheating.

At certain points in the circumference I form curved passages P through the inwardly-projecting stationary rings M, two on opposite sides of the shaft. The passages are curved in the opposite direction from the blades and are so positioned that the first one is slightly in advance of the orifice J, (in the direction of revolution, as indicated by the arrow,) the second considerably more in advance, the third a still greater distance in advance of the second, and so on until we come to the orifice or exhaust-passage Q, through which the gases emerge from the turbine.

The orifices or nozzles J, through which the gases issue, are set at an angle with the rings of revolving blades *k k*, so that the escaping gases impinge upon the blades at as nearly a tangential direction as practicable. I have shown two of these nozzles set diametrically opposite; but only one may be employed, or any desired number may be used and set at different points of the circumference, all feeding into the turbine in a similar tangential direction, and these nozzles may be supplied with the gases from a single combustion-chamber or from separate chambers, as desired.

Having described the construction of my new improved combustion-engine or turbine, I will now explain its general theory and mode of operation.

The requisite fuel (whether liquid, gaseous, or solid) being fed or introduced into the combustion-chamber in a suitable way, I cause a continuous flow of the desired quantity of air by first compressing the air to a pressure in excess of that maintained in the combustion-chamber, and this flow is maintained at a constant rate by preserving the relation between the pressure developed by the compressor and that in the combustion-chamber. The effect of the chemical action or combustion which takes place between the fuel and the oxygen of the air is to generate a large quantity of heat in the products of combustion, and the great rise of temperature thus developed would have the effect of greatly increasing the pressure of these gases were it not for the fact that any increase of pressure is prevented by the more rapid escape of such products through the orifices or nozzles J into the engine or turbine. The real effect, therefore, of the heat developed is to increase the volume of the products of combustion and also the volume of the inert nitrogen and the surplus air, which also becomes heated by contact with the actual products of combustion and which are carried along with such products as they issue from the combustion-chamber. The consequence is that the volume of the gases issuing from the chamber is a number of times greater than the combined volumes of the air and fuel entering the chamber. If, therefore, the orifice or orifices through which the gases issue and the passages through the turbine be properly proportioned, the velocity of the gases after combustion as they issue from the chamber and enter the turbine is much greater than that at which the air and fuel enter the chamber, and as the same quantity or weight of material enters the chamber as leaves it it is this increase of velocity which explains the development of power, enabling much more power to be obtained from the turbine or engine than is required to operate the air-compressor.

I will now describe how the body or column of gases generated in my combustion-chamber is utilized in my improved engine or turbine and the *vis viva* converted thereby into mechanical work.

As the gases issue at the desired velocity from the nozzles or orifices J J they impinge upon the first ring of blades or vanes *k k* in a more or less tangential direction and pass through the spaces or passages between them, sweeping around against the concave surfaces of the blades, so as to obtain the full effect of reaction. The gases are thereby deflected and discharged on the other side of the ring in a backward tangential direction and into the curved fixed guide-passages P P, by which their direction is again gradually changed, so that they impinge upon the second ring of blades in a tangential direction similar to that at which they impinge upon the first ring. After sweeping around the curved blades of the second ring they are discharged into the second set of fixed guide-passages P P, by which their direction of motion is again changed, and so on until the velocity of the gas has been sufficiently reduced. In the first ring of blades a certain fraction of the velocity, and consequently an equivalent fraction of the *vis viva*, of the gas is given up to the blades, in a second set a further amount, and in the third set a further amount, &c., the size of the passages or spaces through which the gases pass gradually increasing in cross-section in proportion as the velocity of the gases diminishes. This may be done by making the blades and connecting fixed passages P of gradually-increasing depth, measured radially, or by a gradual increase in the width of the passages P, measured circumferentially. It is important that the gases ejected from the combustion-chamber be made to impinge upon the revolving blades as near tangentially as possible and that after passing through each ring or set of blades they should be discharged into the next guide-passage with their direction reversed as nearly as possible and as gradually and with as little disturbance or churning up as possible. Likewise the fixed guide-passages should also be properly curved and proportioned so that the gases in passing through have their direction of motion similarly changed, but in a reverse direction. It is evident that by this construction each set of revolving blades operate to abstract from the highly-moving gas a greater or less portion of its velocity, and consequently a certain portion of its energy or *vis viva*, depending upon the comparative speeds of the gas and the blades, and if the parts are properly designed it is only necessary to employ a moderate number of rings—that is, to compound the turbine to a moderate extent—in order to abstract from the moving gases the larger portion of their energy and without requiring a speed of revolution too high for practical purposes. As the energy or *vis viva* contained in the moving gas is as the square of its velocity, it is only necessary to cause the turbine to reduce the velocity of the gas fifty per cent. in order to abstract seventy-five per cent. of its *vis viva*, and by constructing the turbine as shown according to my invention it is only necessary that the sum of the speeds of revolution of the several sets of blades should be about one-quarter of that of the gas in order to reduce its speed to that amount, or fifty per cent. If the velocity of the gas be reduced seventy-five per cent. in the turbine—that is, if the gas issue from the turbine at only one-quarter of its initial velocity—it will contain only one sixteenth of its original *vis viva*, so that the other fifteen sixteenths of its energy (less losses by friction, &c.) are given up in the turbine and converted by it into mechanical work. It is to be observed that while the gases are passing through the blades of each ring the ring is revolving at a certain velocity, so that the gases, instead of discharging at points exactly opposite where they enter, are discharged somewhat in advance of these points. Each of the fixed passages P therefore requires to be set a proper amount in advance of the last passage, and as the speed of the gas is constantly diminishing while the speed of all the sets of blades is the same the angular advance of the successive passages P must continually increase, as will be evident from the drawings.

I have already explained how the exterior shell and the walls of the passages P P are prevented from being overheated by the hot gases and kept at a practically constant temperature by means of my improved water-jacket construction. I likewise provide water-jackets around the passages and orifices I I and J J in order to prevent their undue heating by the gases. It is to be observed that the walls of the fixed passages P P are continually exposed to the hot gases, and were it not for the water-jacket which I have provided they would become overheated, possibly destroyed. The revolving blades, however, in my construction of turbine are only exposed to the hot gases during a small fraction of the time, while they are passing each passage P, so that they are not subjected to anything like as great a heating effect. In order to prevent the blades from getting objectionably hot and to maintain the blades and revolving portion at the same temperature as the inclosing shell, I provide a water-jacket, as shown in Figs. 1 and 5, so as to maintain a water circulation on the interior of the shell M, and thereby keep its temperature constant. The blades being of small depth readily give up the heat they receive to the shell M. This water-jacket is formed by an interior cylinder R, leaving an annular space between it and the drum M, and water is fed into the jacket at one end through a hole *s* in the shaft S and a coupling, as shown, connecting with same source of supply under pressure and discharged through a hole T in the other end of the shaft into a stationary annular chamber *t*. By these means, if a proper circulation of water be maintained in the water-jackets, all parts of the turbine are kept at a practically constant temperature and unequal expansion is prevented. It is important that the clearances between the revolving blades and other portions and the stationary portions be as little as it is possible to maintain them without scraping, and if there should be unequal expansion of the parts of the turbine the clearances might require to be much greater in order to avoid touching.

By constructing my improved turbine as described, so that the gases or actuating fluid is caused to pass through one or more passages between the successive rings of blades, instead of through complete rings of fixed guide-blades, as steam-turbines have been constructed heretofore, I am enabled not only to greatly reduce the surface exposed to the gases, and consequently the friction of flow, and to avoid much of the churning of the gases, but also to simplify the construction and to effectually water-jacket all the stationary parts which are exposed to the constant action of the hot gases. By admitting a small amount of air to the spaces in which the rings of blades revolve, so as to maintain a small flow of air continuously therethrough, the blades may be kept as cool as desired and without consuming a material amount of power.

While my improved construction of turbine or rotary engine is specially adapted to be used with the gases generated in my combustion-chamber according to my improved method of developing mechanical power, it will be understood that other forms of turbines or rotary or other engines or devices for converting the energy developed in such combustion-chamber may be employed in my invention.

In Fig. 9 I have shown similar compressors properly designed, both attached to the turbine-shaft, one being adapted to compressing gas (where gas is used as fuel) and the other being adapted for air.

In Fig. 10 I have shown my invention as applied to the use of coal or solid fuel of any kind. Combustion takes place in a closed air or gas tight furnace or chamber C, adapted to withstand the heat and required pressure. The air I introduce continuously from beneath the grate W through the pipe D under the required pressure, and the coal or solid fuel introduced through the double airtight valves V V in the top of the furnace intermittently and as rapidly as required. In a similar way the ashes are removed from the ash-pit by the double valves V V, which permit the introduction of the fuel and the removal of the ashes while combustion is going on under pressure, one valve in each case being kept closed while the other is open.

What I claim as my invention, and desire to secure by Letters Patent, is—

1. The combination of a closed chamber for continuously burning solid, liquid or gaseous fuel under high pressure, an orifice adapted in size and shape to cause the ejection of the products of combustion in a continuous flow from said combustion-chamber at the proper rate to maintain the desired high pressure in the combustion-chamber, whereby the energy developed in the products of combustion is converted into *vis viva*, and a rotary impact-motor into which said orifice leads provided with rotating blades or surfaces against which the continuous stream of products of combustion is directed and adapted to convert such *vis viva* into mechanical work, substantially as set forth.

2. The combination of a closed chamber for continuously burning solid, liquid or gaseous fuel under high pressure, means for introducing said fuel into the chamber in regulated quantities while combustion is going on, means for introducing air in regulated quantities under pressure into said chamber during combustion, an orifice adapted in size and shape to cause the ejection of the products of combustion in a continuous flow from said chamber at a proper rate to maintain the desired high pressure in the combustion-chamber and thereby converting the energy developed in said products of combustion into *vis viva*, and a rotary impact-motor into which said orifice leads provided with rotating blades or surfaces against which the continuous stream of products of combustion is directed and adapted to convert such *vis viva* into mechanical work, substantially as set forth.

3. The combination of a closed chamber for continuously burning solid, liquid or gaseous fuel under high pressure, an orifice adapted in size and shape to cause the ejection of the products of combustion in a continuous flow from said chamber at a proper rate to maintain the desired high pressure in the combustion-chamber, whereby the energy developed in the products of combustion is converted into *vis viva*, and a rotary motor or turbine into which said orifice leads, having a series of movable blades or surfaces against which the stream of products of combustion impinges and is discharged therefrom, successively, during a fraction only of the revolution of the turbine, substantially as set forth.

4. The combination of a closed chamber for continuously burning solid, liquid or gaseous fuel under high pressure, an orifice adapted in size and shape to cause the ejection of the products of combustion in a continuous flow from said chamber at a proper rate to maintain the desired high pressure in the combustion-chamber, whereby the energy developed in the products of combustion is converted into *vis viva*, and a rotary motor or turbine into which said orifice leads, having two or more series of movable blades or surfaces against which the stream of products of combustion impinges successively, one or more curved stationary passages connecting the series of movable blades and changing the direction of the flowing jet and having a water-jacket for cooling the stationary passages of the motor, substantially as set forth.

5. In a compound rotary motor, or turbine, the combination of two or more rings of blades, or surfaces, revolving on the same shaft, against which the actuating fluid acts successively; one or more nozzles or orifices, through which the actuating fluid enters the first ring of blades; one or more intervening guide-passages between each pair of successive rings of blades, the position of the passages being such that, when the actuating fluid leaves the nozzle and has passed through the blades on the periphery of the first revolving ring, it will leave the ring directly opposite the opening of the first of the intervening guide-passages, and after entering the second ring of blades will leave it directly opposite the opening of the intervening guide-passage situated between the second and third revolving rings, and so on.

6. In a compound rotary motor, or turbine, the combination of two or more rings of blades, or surfaces, revolving on the same shaft, against which the actuating fluid acts successively; one or more nozzles or orifices through which the actuating fluid enters the first ring of blades; one or more intervening guide-passages between each pair of successive rings of blades, the position of the passages being such that, when the actuating fluid leaves the nozzle and has passed through the blades on the periphery of the first revolving ring, it will leave the ring directly opposite the opening of the first of the intervening guide-passages, and after entering the second ring of blades will leave it directly opposite the opening of the intervening guide-passages situated between the second and third revolving rings, and so on; and a water-jacket or water-jackets adjacent to, or inclosing, the intervening and stationary passages and nozzles preventing their becoming overheated.

7. In a compound rotary motor, or turbine, the combination of one or more rings of blades, or guide-surfaces, mounted on one side of a cylinder or disk; and means for maintaining

a water circulation on the other side to prevent overheating.

8. In a compound rotary motor, or turbine, the combination of one or more sets of stationary guide blades or passages; one or more sets of revolving guide-blades; means for maintaining a water circulation in close proximity to the stationary guide blades and passages; means for maintaining water circulation in the revolving portions of the motor, whereby unequal expansion and overheating are prevented.

Signed in the city and county of New York and State of New York this 21st day of June, A. D. 1895.

CHAS. G. CURTIS.

Witnesses:
J. ASPINWALL HODGE, Jr.,
LUCIUS C. RYCE.