GAS, GASOLINE AND OIL ENGINES

AN UP-TO-DATE BOOK ON THE SUBJECT OF EXPLOSIVE MOTOR POWER

DESCRIPTIVE OF THE THEORY AND POWER OF INTERNAL COMBUSTION ENGINES, ILLUSTRATING THEIR DESIGN, CONSTRUCTION, AND OPERATION

FOR

STATIONARY, MARINE, AND VEHICLE MOTIVE POWER

A WORK DESIGNED FOR THE GENERAL INFORMATION OF EVERY ONE INTERESTED IN THE NEW AND POPULAR PRIME-MOVER, AND ITS ADAPTATION TO THE INCREASING DEMAND FOR A CHEAP, SAFE, AND EASILY MANAGED MOTIVE POWER FOR ALL PURPOSES

Giving the Construction and details of nearly every type of American Gas, Gasoline and Oil Engine

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"Compressed Air and its Applications," etc., etc.

Tenth Edition, Reset, Revised and Enlarged

WITH 312 ILLUSTRATIONS

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PREFACE TO THE TENTH EDITION.

The rapid progress in explosive motor design, and the adaptation of this class of prime movers to a vast extent for almost every want for small and intermediate power purposes in all parts of the world, has made a demand for the publication of more extensive details and descriptions of motor working parts, and especially of the heretofore troublesome conditions experienced in converting the fuel of explosive combustion into its best form for economical consumption for power, and its reliable ignition and combustion.

With this view the Author has revised the former editions of this work and added much new matter that shows progress in design, especially in the atomizing and vaporization of fuel elements, together with extended discussions on the management and care of explosive motors, with fully illustrated and described methods of ignition by the electric current and its generation.

The illustrated details of new Gas, Gasoline and Oil Vapor Motors and their parts, newly introduced, are in such proportions, together with the table of sizes of parts of motors of various powers, has been made so clear that almost any mechanical engineer or amateur draughtsman should be able to make the working drawings for an explosive motor for any kind of fuel in use for such purpose.

The new fuel, Alcohol, and its combination with gasoline for motive power is making an extended and economic exhibit in Europe and only requires legal regulation and freedom from revenue tax to make it a most acceptable material of explosive power for motor service in the United States.

The great increase of late in the number of motor builders with improved and special designs of motors for vehicle, launch and yacht propulsion, and as auxiliary power for yachts and fishing boats, has been the means of largely increasing the range of usefulness of this modern power. Its adaptation to the successful operation of bicycles has become a fact and is shown by illustrated descriptions of the latest models.

The ideal of a prime moving power, so cheap, so safe, and so easily managed, that is now in successful operation, and that has culminated in its real growth in the past quarter of a century, marks an epoch for the beginning of the twentieth century, that is a marvel in promoting our industries by the use of this new and economical power.

In view of the progress of the subject matter of this book the publishers have therefore reset this entire work, bringing it up to date.

SEPTEMBER, 1902. GARDNER D. HISCOX.

PREFACE.

THE entire lack of literature on explosive motors made in the United States, with the exception of such as have appeared from time to time in our journals and magazines, and the constant inquiry for information on the subject, has induced the author of this work to endeavor to present in practical shape for the ordinary reader the principles and practice of this class of motors as they are manufactured in our own country. German, French, and English books on gas, gasoline, and oil engines scarcely allude to American engines or American practice.

The author has been favored by a large number of explosive-motor builders with illustrations and details of motors of their manufacture. He hopes that, by the publication of his work, many inquiries will be answered, and that seekers for small power will find in the explosive motor the economical prime-mover they desire.

GARDNER D. HISCOX.

JANUARY 1st, 1897.

PREFACE TO THE SECOND EDITION.

THE early exhaustion of the first edition has verified the author's prediction that there was need of a work of this character. The second edition has been corrected, revised, and contains much new matter, including data relating to the adaptation of these motors to vehicles and launches, a branch of the subject that is of great and growing interest.

The patents of 1897 under their proper heading have been added, and, to forestall inquiry, a list of the names and addresses of the builders of explosive motors in the United States, so far as they could be ascertained, has also been appended.

THE AUTHOR.

APRIL 15th, 1898.

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GAS, GASOLINE, AND OIL ENGINES.

CHAPTER I.

INTRODUCTORY.

MUCH attention is now being given by mechanical engineers to the economical results developed in the working of gas, gasoline, and oil engines for higher powers from producer and other cheap gases. In an economical sense, for small powers steam has been left far behind.

It now becomes a question as to how to adapt the design of the new prime-movers to a wider range of usefulness.

The best steam engines now made run with a consumption of about one and three-fourth pounds of coal per horse-power per hour; while from two and one-half to seven pounds is the cost of power per horse-power per hour in the various kinds of engines now in use. This only covers the cost of fuel; the attendance required in the use of small steam power is often far greater in cost than the fuel.

When we come to require the larger powers by steam, in which economy may be obtained by compounding and condensing, the facility for obtaining the requisite water-supply is often a bar to its use. The direction in which lies the line of improvement for larger powers with the utmost economy is as yet a mooted point of discussion in explosive motor engineering.

The expansion of single-cylinder dimensions involves practical problems in the progress of ignition of the charge, as well as the thoroughness of mixture of the combustibles, and the interference of the products of the previous combustion by producing areas of imperfect or non-combustion or "stratification," as treated in foreign publications.

The enlargement of cylinder area is a source of engine-friction economy, while, on the contrary, the multiplication of cylinders involves numbers and complexity of moving parts, which go to make disparity between the indicated and brake horse-power, which is the measure of machine efficiency

An impulse at every stroke, so desirable in an explosive motor and so satisfactorily carried out in the steam engine in connection with the compound system, seems to have as yet no counterpart in the explosive motor. Condensation is impossible, and the trials of explosion at every stroke in European engines have not proved satisfactory in service, and in order to accomplish the desired result resort has been had to duplicating single-acting cylinders. This class of explosive engines seems to fill the bill in effect; yet the complication of a two-cylinder engine as a moving mechanism must compete with a single-cylinder steam engine.

The principal types of explosive motors seem to have gone through a series of practical trials during the past thirty years, which have finally reduced the principles of action to a few permanent forms in the design of motors, that show by long-continued use the prospect of their staying qualities and their efficiency; for these will no doubt be the principal points in the final judgment of purchasers in the selection of motive power. For a gas, gasoline, or oil explosive power to approximate an ideal standard as a prime-mover, it should be simple in design, not liable to get out of order, the parts must be readily accessible, the ignition of the charge must be positive, the governing close, the engine must run quietly, and must be durable and economical in the use of fuel. These points of excellence have been striven for by many designers and builders, with varying success. But to get the entire combination without the sacrifice of some good point is not an easy matter.

But for all, the internal combustion engine has come seemingly like an avalanche of a decade; but it has come to stay, to take its well-deserved position among the powers for aiding labor.

HISTORICAL.

Although the ideal principle of explosive power was conceived some two hundred years since, and experiments made with gunpowder as the explosive element, it was not until the last years of the eighteenth century that the idea took a patentable shape, and not until about 1826 (Brown's gas-vacuum engine) that a further progress was made in England by condensing the products of combustion by a jet of water, thus creating a partial vacuum.

Brown's was probably the first explosive engine that did real work. It was clumsy and unwieldy and was soon relegated to its place among the failures of previous experiments. No approach to active explosive effect in a cylinder was reached in practice, although many ingenious designs were described, until about 1838 and the following years. Barnett's engine in England was the first attempt to compress the charge before exploding. From this time on to about 1860 many patents were issued in Europe and a few in the United States for gas engines, but the progress was slow, and its practical introduction for ordinary power purposes came with spasmodic effect and low efficiency.

From 1860 on, practical improvement seems to have been made and the Lenoir motor was produced in France and brought to the United States. It failed to meet expectations, and was soon followed by further improvements in the Hugon motor in France (1862) followed by Beau de Rocha's four-cycle idea, which has been slowly developed through a long series of experimental trials by different inventors. In the hands of Otto and Langdon a further progress was made, and numerous patents were issued in England, France, and Germany, and followed up by an increasing interest in the United States with a few patents.

From 1870 on, improvements seem to have advanced at a steady rate, and largely in the valve gear and precision of governing for variable load.

The early idea of the necessity of slow combustion was a great drawback in the advancement of efficiency, and the suggestions of de Rocha, in 1862, did not take root as a prophetic truth until many failures and years of experience had taught the fundamental axiom that rapidity of action in both combustion and expansion was the basis of success in explosive motors.

With this truth and the demand for small and safe prime-movers, the manufacture of gas engines increased in Europe and America at a more rapid rate, and improvements in perfecting the details of this cheap and efficient prime-mover have finally raised it to the dignity of a standard motor and a rival of the steam engine for small and intermediate powers, with a prospect of largely increasing its individual units to the hundred, if not to the thousand, horse-power in a single engine. The efforts of Otto, in Germany, in developing the four-cycle type, have given his name to the compression engine, which is a well-deserved tribute to genius.

The fourteen hundred patents issued during the past thirty years in the United States have had a simplifying tendency in construction, and have brought the efficiency of the gas, gasoline, and oil explosive engines to their present high degree of economy and widespread adoption as a prime-mover.

In this work the various changes that the gas engine has undergone in design in its European development are not considered essential to American readers, as the best European ideas have been adapted here with the spirit of American enterprise in perfecting details of construction and the application of the best material for wear in all its parts; so that in representing as many engines of American manufacture as can be obtained, the whole range of practical design will be sufficiently illustrated and described as to give a fairly good explanation of their operation to the general reader and the users of American gas, gasoline, and oil engines.

The intense interest manifested by American engineers and inventors in the new motive power is well shown in the progress of patents issued during the past twenty-five years. In 1875 3 patents were issued in the United States for gas engines; 1876, 3 patents; 1877, 5 patents; 1878, 1 patent; 1879, 6 patents; 1880-81, 7 each year; 1882, 14 patents; 1883 was a booming year in gas-engine invention—no less than 40 patents were issued that year, followed by 36 patents in 1884 and 40 patents in 1885. 46 in 1886, 25 in 1887, 31 in 1888, and 58 in 1889, with an average of about 80 patents per annum during the past thirteen years, over 1,400 having been issued up to July 1st, 1902.

The application of the gasoline motor to marine propulsion and to the horseless vehicle, the tricycle and bicycle, has had a most stimulating effect in adapting ways and means for applying this power to so many uses. Even aerial navigation has come in for its share in motor patents.

Although the denser population of Europe claims a very large representation of explosive motors in use for all purposes, the manufacture in the United States is fast forging ahead in its output of explosive motor power, for there are now more than one hundred and fifty establishments in the United States engaged in their manufacture, and the motors in operation number many thousands. Their safety and easy management as well as their economy have made in their adoption as agricultural helpers a marvellous inroad on the old-fashioned hand and horse power. Their later developed adaptability as a means for generating electricity for electric lighting and transmission of power is fast expanding the use of lighting and power in fields that the higher cost of small steam power had precluded. Thus the incentive to invention has been the father to a fast-growing industry, that has and will continue to ameliorate the labor of our small industries by the supply of small, reliable, and cheap power for all purposes; and present indications are that the explosive motor will become a prominent source of power for vehicles, for larger sizes of vessels than heretofore used, and for stationary power, rivalling steam power of but a few years since.

The advent of the 20th century has been a progressive one in explosive engine building, with a large increase in the annual number of patents issued (122), mostly relating to the minor details of governing and ignition; although some general principles in compounding and compressing the air or charge by duplex areas of piston and cylinder, in order to lessen the number of impulse cycles, have been patented. These complexities do not add to the needed simplicity of the perfect explosive motor, so much desired in the realm of this new prime-mover.

The use of the explosive motor for marine and vehicle service has had large expansion. Launches and yachts fitted with explosive motors are now fast taking rank with steam and other motors on all the navigable waters of the United States; nor does the explosive principle lag in its application to the motor vehicle, the tricycle and the bicycle.

The amateur craze for motive power seems to have spread with the bicycle pace, until the fever has broken out in a multitude of young machinists with motor proclivities.

The expiration of patents in England, Germany, France and the United States has now cast loose many of the bonds that have in a measure retarded the freedom of manufacture in the explosive motor line, so that the fundamental principles of construction are no longer a hindrance to the amateur experimenter.

Over 500 patents in England and as many more in Germany and France and 160 in the United States have expired by limitation at this date, September, 1902; so that there should be no difficulty now in the construction of a good and economical explosive engine without infringing on patents in force.

September, 1902.

CHAPTER II.

THEORY OF THE GAS AND GASOLINE ENGINE.

THE laws controlling the elements that create a power by their expansion by heat due to combustion, when properly understood, become a matter of computation in regard to their value as an agent for generating power in the various kinds of explosive engines.

The method of heating the elements of power in explosive engines greatly widens the limits of temperature as available in other types of heat engines. It disposes of many of the practical troubles of hot-air and even of steam engines, in the simplicity and directness of application of the elements of power. In the explosive engine the difficulty of conveying heat for producing expansive effect by convection is displaced by the generation of the required heat within the expansive element and at the instant of its useful work. The low conductivity of heat to and from air has been the great obstacle in the practical development of the hot-air engine; while, on the contrary, it has become the source of economy and practicability in the development of the internal-combustion engine.

The action of air, gas, and the vapors of gasoline and petroleum oil, whether singly or mixed, is affected by changes of temperature, practically in nearly the same ratio; but when the elements that produce combustion are interchanged in confined spaces, there is a marked difference of effect. The oxygen of the air, the hydrogen and carbon of a gas, or vapor of gasoline or petroleum oil are the elements that by combustion produce heat to expand the nitrogen of the air and the watery vapor produced by the union of the oxygen in the air and the hydrogen in the gas, as well as also the monoxide and carbonic-acid gas that may be formed by the union of the carbon of gas or vapor with part of the oxygen in the air.

The various mixtures as between air and gas, or air and vapor, with the proportion of the products of combustion left in the cylinder from a previous combustion, form the elements to be considered in estimating the amount of pressure that may be obtained by their combustion and expansive force.

The phenomena of the brilliant light and its accompanying heat at the moment of explosion have been witnessed in the experiments of Dugald Clerk in England, the illumination lasting throughout the stroke; but in regard to time in a four-cycle engine, the incandescent state exists only one-quarter of the running time. Thus the time interval, together with the non-conductibility of the gases, makes the phenomena of a high-temperature combustion within the comparatively cool walls of a cylinder a practical possibility.

The natural laws, long since promulgated by Boyle, Gay Lussac, and others, on the subject of the expansion and compression of gases by force and by heat, and their variable pressures and temperatures when confined, are conceded to be practically true and applicable to all gases, whether single, mixed, or combined.

The law formulated by Boyle only relates to the compression and expansion of gases without a change of temperature, and is stated in these words:

If the temperature of a gas be kept constant, its pressure or elastic force will vary inversely as the volume it occupies.

It is expressed in the formula $P \times V = C$, or pressure $\times$ volume = constant. Hence, $\frac{C}{P} = V$ and $\frac{C}{V} = P$.

Thus the curve formed by increments of pressure during the expansion or compression of a given volume of gas without change of temperature is designated as the isothermal curve in which the volume multiplied by the pressure is a constant value in expansion, and inversely the pressure divided by the volume is a constant value in compressing a gas.

But as compression and expansion of gases require force for its accomplishment mechanically, or by the application or abstraction of heat chemically, or by convection, a second condition becomes involved, which was formulated into a law of thermodynamics by Gay Lussac under the following conditions:

A given volume of gas under a free piston expands by heat and contracts by the loss of heat, its volume causing a proportional movement of a free piston equal to $\frac{1}{273}$ part of the cylinder volume for each degree Centigrade difference in temperature, or $\frac{1}{492}$ part of its volume for each degree Fahrenheit.

With a fixed piston (constant volume), the pressure is increased or decreased by an increase or decrease of heat in the same proportion of $\frac{1}{273}$ part of its pressure for each degree Centigrade, or $\frac{1}{492}$ part of its pressure for each degree Fahrenheit change in temperature.

This is the natural sequence of the law of mechanical equivaleut, which is a necessary deduction from the principle that nothing in nature can be lost or wasted, for all the heat that is imparted to or abstracted from a gaseous body must be accounted for, either as heat or its equivalent transformed into some other form of energy.

In the case of a piston moving in a cylinder by the expansive force of heat in a gaseous body, all the heat expended in expansion of the gas is turned into work; the balance must be accounted for in absorption by the cylinder or radiation.

This theory is equally applicable to the cooling of gases by abstraction of heat or by cooling due to expansion by the motion of a piston.

The denominators of these fractions represent the absolute zero of cold below the freezing-point of water, and reads $-273°$ C. or $-492.66° = -460.66°$ F. below zero; and these are starting-points of reference in computing the heat expansion in gas engines.

According to Boyle's law, called the first law of gases, there are but two characteristics of a gas and their variations to be considered, viz., volume and pressure; while by the law of Gay Lussac, called the second law of gases, a third is added, consisting of the value of the absolute temperature, counting from absolute zero to the temperatures at which the operations take place.

The ratio of the variation of the three conditions—volume, pressure, and heat from the absolute zero temperature—has a certain rate, in which the volume multiplied by the pressure and the product divided by the absolute temperature equals the ratio of expansion for each degree.

The expansion of a gas $\frac{1}{273}$ of its volume for every degree Centigrade, added to its temperature, is equal to the decimal .00366, the coefficient of expansion for Centigrade units. To any given volume of a gas, its expansion may be computed by multiplying the coefficient by the number of degrees, and by reversing the process the degree of acquired heat may be obtained approximately. These methods are not strictly in conformity with the absolute mathematical formula, because there is a small increase in the increment of expansion of a dry gas, and there is also a slight difference in the increment of expansion due to moisture in the atmosphere and to the vapor of water formed by the union of the hydrogen and oxygen in the combustion chamber of explosive engines.

The ratio of expansion on the Fahrenheit scale is derived from the absolute temperature below the freezing-point of water (32°) to correspond with the Centigrade scale; therefore $\frac{1}{492.66} = .0020297$, the ratio of expansion from 32° for each degree rise in temperature on the Fahrenheit scale.

As an example, if the temperature of any volume of air or

have the formula for the acquired heat, derived from combustion at constant volume from atmospheric pressure to gauge pressure plus atmospheric pressure as derived from Example I., by which the expression—

$$\frac{\text{absolute pressure} \times \text{absolute temp.} + \text{initial temp.}}{\text{initial absolute pressure}}$$

= absolute temperature + temperature of combustion, from which the acquired temperature is obtained by subtracting the absolute temperature.

Then, for Example 1, $\frac{69.47 \times 460.66 + 60}{14.7} = 2460.66$, and $2460.66 - 460.66 = 2000°$, the theoretical heat of combustion. The dropping of terminal decimals makes a small decimal difference in the result in the different formulas.

By Joule's law of the mechanical equivalent of heat, whenever heat is imparted to an elastic body, as air or gas, energy is generated and mechanical work produced by the expansion of the air or gas. When the heat is imparted by combustion within a cylinder containing a movable piston, the mechanical work becomes a measurable amount by the observed pressure and movement of the piston.

The heat generated by the explosive elements and the expansion of the non-combining elements of nitrogen and water vapor that may have been injected into the cylinder as moisture in the air, and the water vapor formed by the union of the oxygen of the air with the hydrogen of the gas, all add to the energy of the work from their expansion by the heat of internal combustion.

As against this, the absorption of heat by the walls of the cylinder, the piston, and cylinder head or clearance walls, becomes a modifying condition in the force imparted to the moving piston.

It is found that when any explosive mixture of air and gas or hydrocarbon vapor is fired, the pressure falls far short of the pressure computed from the theoretical effect of the heat produced, and from gauging the expansion of the contents of a cylinder.

It is now well known that in practice the high efficiency which is promised by theoretical calculation is never realized; but it must always be remembered that the heat of combustion is the real agent, and that the gases and vapors are but the medium for the conversion of inert elements of power into the activity of energy by their chemical union.

The theory of combustion has been the leading stimulus to large expectations with inventors and constructors of explosive motors; its entanglement with the modifying elements in practice has delayed the best development in construction, and as yet no positive design of best form or action seems to have been accomplished.

One of the most serious entanglements in the practical development of pressure due to the theoretical computations of the pressure value of the full heat is probably caused by imparting the heat of the fresh charge to the balance of the previons charge that has been cooled by expansion from the maximum pressure to near the atmospheric pressure of the exhaust. The retardation in the velocity of combustion of perfectly mixed elements is now well known from experimental trials with measured quantities; but the principal difficulty in applying these conditions to the practical work of an explosive engine where a necessity for a large clearance space cannot be obviated, is in the inability to obtain a maximum effect from the imperfect mixture and the mingling of the products of the last explosion with the new mixture, which produces a clouded condition that makes the ignition of the mass irregular or chattering, as observed in the expansion lines of indicator cards.

Stratification of the mixture has been claimed as taking place in the clearance chamber of the cylinder; but this is not satisfactory, in view of the vortical effect of the violent injection of the air and gas or vapor mixture. It certainly cannot become a perfect mixture in the time of a stroke of a high-speed motor of the two-cycle class. In a four-cycle engine, making 300 revolutions per minute, the injection and compression take place in one-fifth of a second—far too short a time for a perfect infusion of the elements of combustion.

In an experimental way, the velocity of explosion of a perfect mixture of 2 volumes of hydrogen and 1 volume of oxygen has been found to approximate 65 feet per second; and for equal volumes of hydrogen and oxygen, 32 feet per second; with 1 volume coal gas to 5 volumes air, $3\frac{1}{4}$ feet per second; 1 volume coal gas to 6 volumes of air, 1 foot per second; and with an increasing proportion of air, 10 to 9 inches per second. These velocities were obtained in tubes fired at one end only. When the ignition was made in a closed tube, so that compression was produced by the expansion from combustion, the velocity was largely increased; and with compressed mixtures, a great increase of velocity was obtained over the above-stated figures.

The different values of time, pressure, and computed heat of combustion are shown in Table 1, and graphically compared in the diagram Fig. 1.

The mixtures were Glasgow, Scotland, coal gas and air. The table and the diagram (Fig. 1) make an excellent study of the conditions of time and pressure, as well as also of the control of the work of a gas engine, by varying the proportions of the mixture.

TABLE I.—EXPLOSION AT CONSTANT VOLUME IN A CLOSED CHAMBER.

Diagram curve Fig. 1.	Mixture injected.	Time of explosion. Second.	Gauge pressure. Pounds per square inch.	Computed temperature, Fahr.
a	1 volume gas to 13 volumes air.	0.28	52	1,916°
b	1 " " " 11 " "	0.18	63	2,309
c	1 " " " 9 " "	0.13	69	2,523
d	1 " " " 7 " "	0.07	89	3,236
e	1 " " " 5 " "	0.05	96	3,484

The irregularity of the explosive curves in the diagram is fair evidence of imperfect diffusion of the gas and air mixture

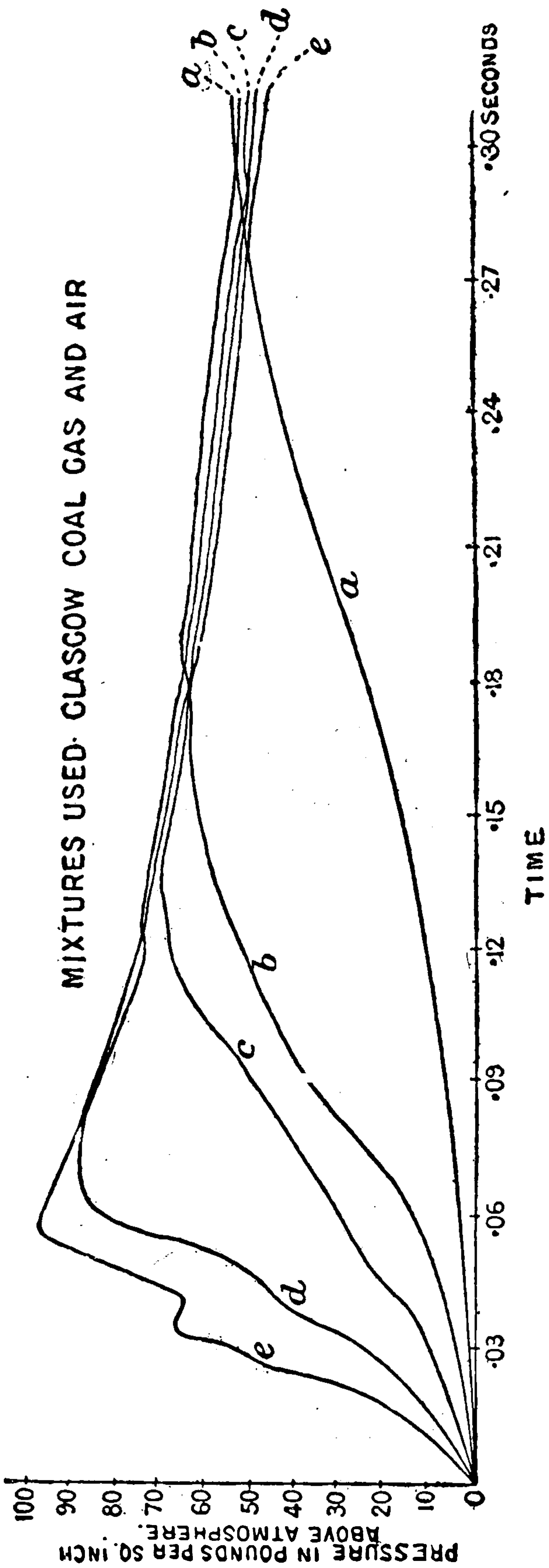


FIG. 1.—DIAGRAM OF MOMENTS OF COMBUSTION IN A CLOSED CHAMBER, CONSTANT VOLUME.

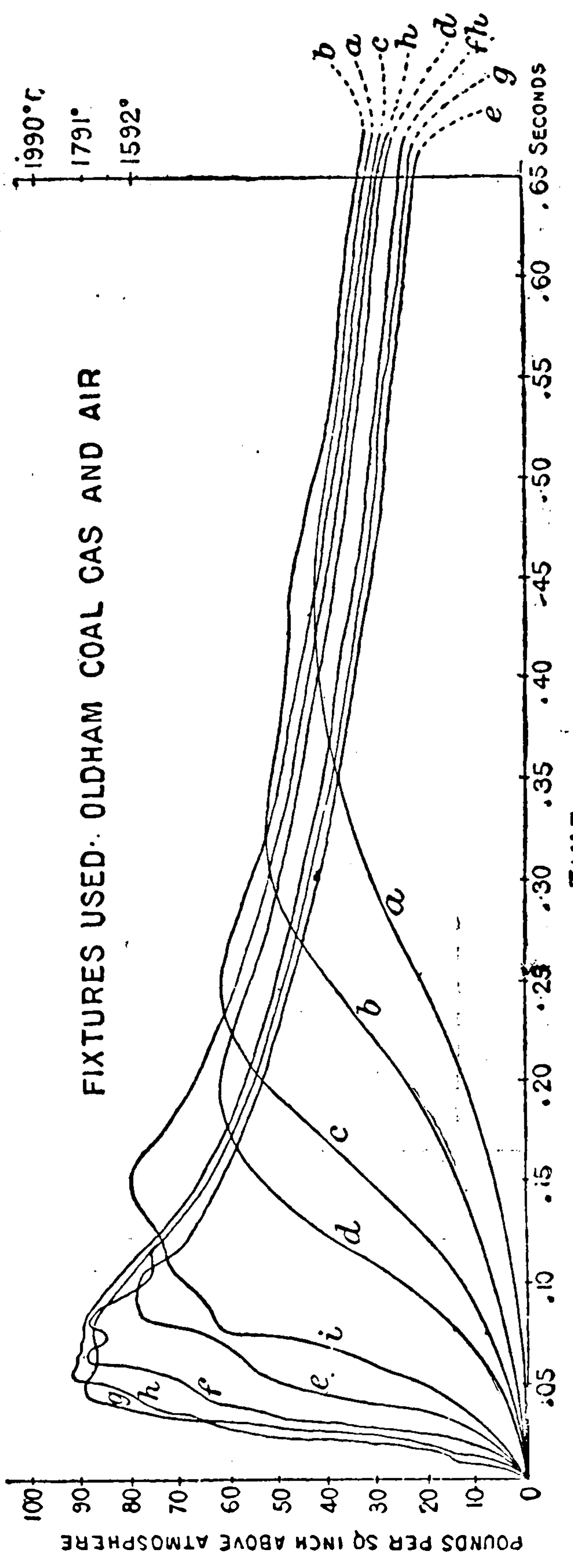


FIG. 2.—DIAGRAM OF MOMENTS OF COMBUSTION IN A CLOSED CHAMBER. CONSTANT VOLUME.

at the moment of combustion, assuming that the indicator was in perfect action.

Experiments with mixtures of coal gas and air made at Oldham, England, show a slight variation of effect, which is probably due to different proportions of hydrogen and carbon in the Oldham gas, with the same elements in the Glasgow gas. In Table 2 the injection temperature is given, which in itself is not important further than as a basis for computing the theoretical temperature of combustion.

A record of the hygrometric state of the atmosphere in its extremes would be valuable in showing the variation in explosive effect due to the vapor of water derived from the air under different hygrometric conditions.

TABLE II.—EXPLOSION AT CONSTANT VOLUME IN A CLOSED CHAMBER.

Diagram curve Fig. 2.	Mixture injected.	Temp. of injection, Fahr.	Time of explosion. Second.	Observed gauge pressure. Pounds.	Computed temp. Fahr.
a	1 volume gas to 14 volumes air.	64°	0.45	40.	1,483°
b	1 " " " 13 " "	51	0.31	51.5	1,859
c	1 " " " 12 " "	51	0.24	60.	2,195
d	1 " " " 11 " "	51	0.17	61.	2,228
e	1 " " " 9 " "	62	0.08	78.	2,835
f	1 " " " 7 " "	62	0.06	87.	3,151
g	1 " " " 6 " "	51	0.04	90.	3,257
h	1 " " " 5 " "	51	0.055	91.	3,293
i	1 " " " 4 " "	66	0.16	80.	2,371

In an examination of the times of explosion and the corresponding pressures in both tables, it will be seen that a mixture of 1 part gas to 6 parts air is the most effective and will give the highest mean pressure in a gas engine.

In this diagram the undulations of the rising curves due to irregular firing of the mixture are well marked. There is a limit to the relative proportions of illuminating gas and air mixture that is explosive, somewhat variable, depending upon the proportion of hydrogen in the gas. With ordinary coal gas, 1 of gas to 15 parts air; and on the lower end of the scale, 1 volume of gas to 2 parts of air are non-explosive. With gasoline vapor the explosive effect ceases at 1 to 16, and a saturated mixture of equal volumes of vapor and air will not explode, while the most intense explosive effect is from a mixture of 1 part vapor to 9 parts air. In the use of gasoline and air mixtures from a carburetter, the best effect is from 1 part saturated air to 8 parts free air.

PROPERTIES AND EXPLOSIVE TEMPERATURE OF A MIXTURE OF ONE PART OF ILLUMINATING GAS OF 660 THERMAL UNITS PER CUBIC FOOT WITH VARIOUS PROPORTIONS OF AIR WITHOUT MIXTURE OF CHARGE WITH THE PRODUCTS OF A PREVIOUS EXPLOSION.

Proportion, Air to Gas, by Volumes.	Pounds in One Cubic Foot of Mixture.	Specific Heat. Heat Units Required to Raise 1 lb. 1° Fahrenheit.		Heat to Raise One Cubic Foot of Mixture 1° Fahr.	Heat Units Evolved by Combustion.	Ratio, Col. $\frac{6}{5}$	Usual Combustion Efficiency.	Usual Rise of Temperature due to Explosion at Constant Volume.
		Constant Pressure.	Constant Volume.					
6 to 1......	.074195	.2668	.1913	.014189	94.28	6644.6	.465	3090
7 to 1.....	.075012	.2628	.1882	.014116	82.	5844.4	.518	3027
8 to 1......	.075647	.2598	.1858	.014059	73.33	5216 1	.543	2832
9 to 1......	.076155	.2575	.1846	.014013	66.	4709.9	.56	2637
10 to 1......	.076571	.2555	.1825	.013976	60.	4293.	.575	2468
11 to 1......	.076917	.2540	.1813	.013945	55.	3944.	.585	2307
12 to 1......	.077211	.2526	.1803	.013922	50.77	3646.7	.58	2115

The weight of a cubic foot of gas and air mixture as given in Col. 2 is found by adding the number of volumes of air multiplied by its weight, .0807, to one volume of gas of weight .035 pound per cubic foot and dividing by the total number of volumes; for example, as in the table $6 \times .0807 = \frac{.5192}{7} = .074195$ as in the first line, and so on for any mixture or for other gases of different specific weight per cubic foot. The heat units evolved by combustion of the mixture (Col. 6) are obtained by dividing the total heat units in a cubic foot of gas by the total proportion of the mixture, $\frac{660}{7} = 94.28$ as in the first line of the table. Col. 5 is obtained by multiplying the weight of a cubic foot of the mixture in Col. 2 by the specific heat at constant volume (Col. 4), $\frac{\text{Col. } 6}{\text{Col. } 5} =$ Col. 7 the total heat ratio, of which Col. 8 gives the usual combustion efficiency — Col. 7 $\times$ by Col. 8 gives the absolute rise in temperature of a pure mixture.

CHAPTER III.

UTILIZATION OF HEAT AND EFFICIENCY IN GAS ENGINES.

THE utilization of heat in any heat engine has long been a theme of inquiry and experiment with scientists and engineers, for the purpose of obtaining the best practical conditions and construction of heat engines that would represent the highest efficiency or the nearest approach to the theoretical value of heat, as measured by empirical laws that have been derived from experimental researches relating to its ultimate value. It is well known that the steam engine returns only from 12 to 18 per cent. of the power due to the heat generated by the fuel, about 25 per cent. of the total heat being lost in the chimney, the only use of which is to create a draught for the fire; the balance, some 60 per cent., is lost in the exhaust and by radiation. The problem of utmost utilization of force in steam has nearly reached its limit.

The internal-combustion system of creating power is comparatively new in practice, and is but just settling into definite shape by repeated trials and modification of details, so as to give somewhat reliable data as to what may be expected from the rival of the steam engine as a prime-mover.

For small powers, the gas, gasoline, and petroleum oil engine is forging ahead at a rapid rate, filling the thousand wants of manufacture and business for a power that does not require expensive care, that is perfectly safe at all times, that can be used in any place in the wide world to which its concentrated fuel can be conveyed, and that has eliminated the constant handling of crude fuel and water.

The utilization of heat in a gas engine is mainly due to the manner in which the products entering into com-

the assumed heat of combustion, would represent the total efficiency. The formula $\frac{H-H'}{H}$ represents this condition, so that if the operation of the heat cycle was between 60° and 1,400° F., the equation would be: $\frac{60+460}{1400+460} = .279$ and $1 - 279 =$ .72 per cent. But this cannot represent a working cycle from the change in the specific heat of the gaseous contents of a cylinder while undergoing expansion by the movement of a piston.

The specific heat of air at constant volume is .1685, and at constant pressure is .2375. Their ratio $\frac{.2375}{.1685} = 1.408$. The ratios of the other elements entering into combustion in a gas engine are slightly less than for air; but the ratio for air is near enough for all practical operations. The formula for the application of the condition of work with complete expansion is: $1 - 1.408 \frac{H'}{H}$; or, as for above example, $1 - 1.408 \frac{60+460}{1400+460}$ $= .3928$, and $1 - .3928 = .6071$, or 60 per cent.

As the temperature cannot be utilized for work from the excess of heat in the products of combustion when the expansion has reached the atmospheric line, then the practical amount of expansion and the heat of combustion at the point of exhaust must be considered. In practice, the measured heat of the exhaust at atmospheric pressure, plus the additional heat due to the terminal pressure, becomes a factor in the equation; and, assuming this to be 950° F. in a well-regulated motor, the equation for the above example becomes: $1 - 1.408 \times \frac{950-460}{1400-460} = \frac{490}{940} = .521 \times 1.408 = .733$, and $1 - .733 = .26$, or an efficiency of 26 per cent. The greater difference in temperature, other things being equal, the greater the efficiency.

In this way efficiencies are worked out through intricate formulas for a variety of theoretical and unknown conditions of combustion in the cylinder: ratios of clearance and cylinder volume, and the uncertain condition of the products of combustion left from the last impulse and the wall temperature. But they are of but little value, except as a mathematical inquiry as to possibilities. The real commercial efficiency of a gas or gasoline engine depends upon the volume of gas or liquid at some assigned cost, required per actual brake horse-power per hour, in which an indicator card should show that the mechanical action of the valve gear and ignition was as perfect as practicable, and that the ratio of clearance space

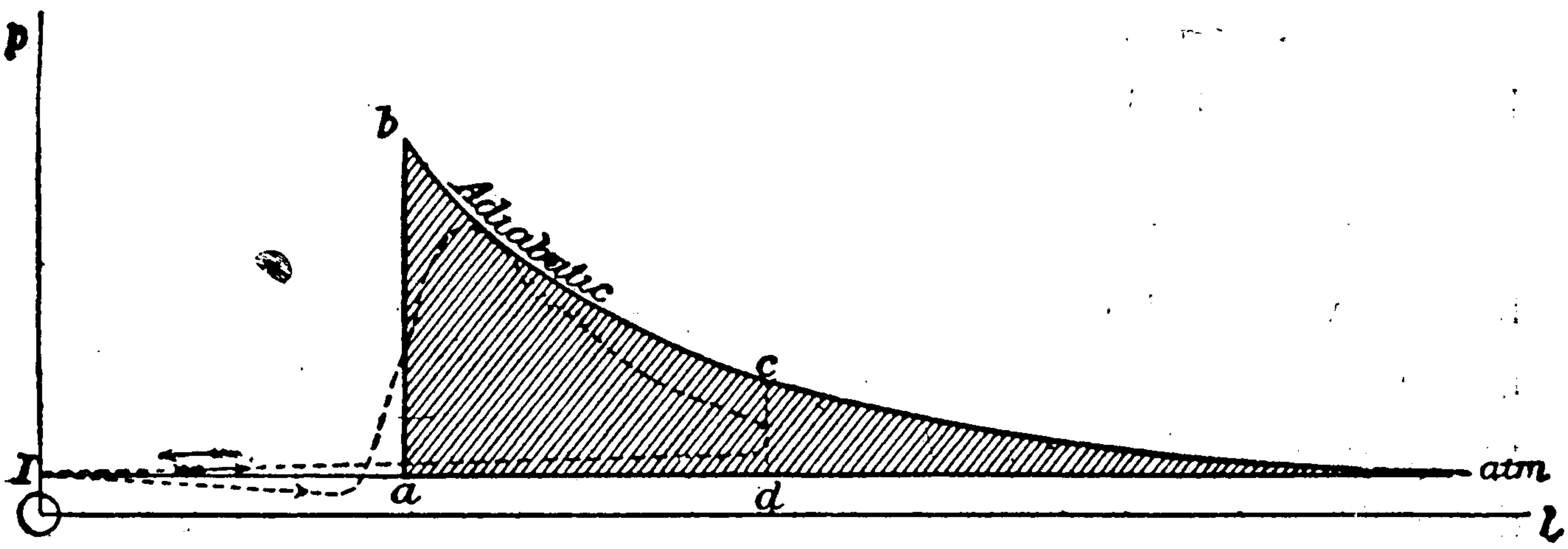


FIG. 4.—COMPARATIVE CARD.

and cylinder volume gave a satisfactory terminal pressure and compression—the difference between the power figured from the indicator card and the brake power being the friction loss of the engine.

In practice, the heat value of the gas per cubic foot may vary from 30 per cent. with illuminating and natural gases to 75 or 80 per cent. as between good illuminating gas and Dowson gas; then, in order that a given size engine should maintain its rating, a larger volume of a poorer gas should be swept through the cylinder. This requires adjustment of the areas in all the valves to give an explosive motor its highest efficiency for the kind of fuel that is to be used.

The practical effect of the work done by the half-cycle in the earlier type of the two-cycle engine is graphically shown in Fig. 4. in which *t*, *d* represents the stroke of the piston; the dotted line, the indicator card; and the space in the lines, *a*, *b*, *c*, *d*, the ideal diagram of a perfect gas exhausting at the point *d*, in its incomplete adiabatic expansion. In the valnation of such a card, the depression of the indraught below the atmospheric line and the pressure of the exhaust line should have due consideration as negative quantities to be deducted from the pressure values above the atmospheric line. This class of engines is fast becoming obsolete as a type.

In four-cycle engines the efficiencies are greatly advanced by compression, producing a more complete infusion of the mixture of gas or vapor and air, quicker firing, and far greater pressure than is possible with the two-cycle type just described.

In the practical operation of the gas engine during the past fifteen years, the gas-consumption efficiencies per indicated horse-power have gradually risen from 17 per cent. to a maximum of 28 per cent. of the theoretical heat, and this has been done chiefly through a decreased combustion chamber and increased compression—the compression having gradually increased in practice from 30 lbs. per square inch to above 80; but there seems to be a limit to compression, as the efficiency ratio decreases with the increase in compression.

It has been shown that an ideal efficiency of 33 per cent. for 38 lbs. compression will increase to 40 per cent. for 66 lbs., and 43 per cent. for 88 lbs. compression. On the other hand, greater compression means greater explosive pressure and greater strain on the engine structure, which will probably retain in future practice the compression between the limits of 40 and 60 lbs.

In experiments made by Dugald Clerk with a combustion chamber equal to 0.6 of the space swept by the piston, with a compression of 38 lbs., the consumption of gas was 24 cubic feet per indicated horse-power per hour. With 0.4 compression space and 61 lbs. compression, the consumption of gas was 20 cubic feet per indicated horse-power per hour; and with

0.34 compression space and 87 lbs. compression, the consumption of gas fell to 14.8 cubic feet per indicated horse-power per hour—the actual efficiencies being respectively 17, 21, and 25 per cent. This was with a Crossley four-cycle engine.

In Fig. 5 is represented an ideal card of the work of a perfect compression cycle in which the gases are compressed. Additional pressure is instantly developed by combustion or heat at constant volume, and then allowed to expand to atmospheric

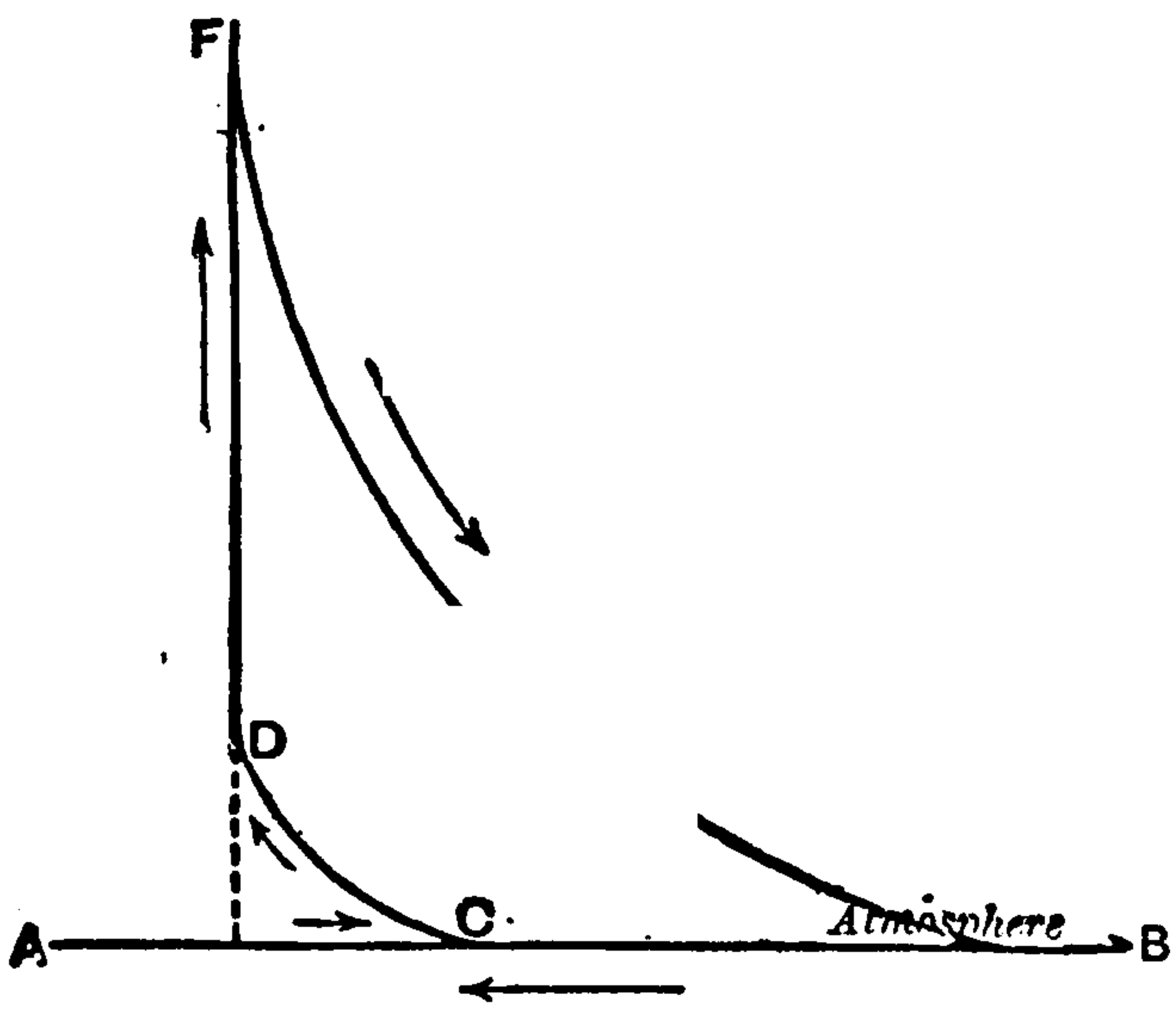


FIG. 5.—DIAGRAM OF A PERFECT CYCLE WITH COMPRESSION.

pressure—the curves of compression and expansion being adiabatic, as for a dry gas.

In this diagram the lines follow Carnot's cycle, in which the whole heat energy is represented in work. The piston stroke commencing at O, compression completed at D, pressure augmented from D to F, expansion doing work from F to B, and exhausting along the atmospheric line B A. The gases in this case expand till their pressure falls to the atmospheric line, and their whole energy is supposed to be utilized. In this imaginary cycle, no heat is supposed to be lost by absorption of walls of a cylinder or by radiation, and no back pressure during exhaust, or friction, are taken into account.

The efficiencies in regard to power in a heat engine may be divided into four kinds, of which·

I. The first is known as the *maximum theoretical efficiency* of a perfect engine (represented by the lines in the indicator diagram, Fig. 5). It is expressed by the formula $\frac{T_1 - T_0}{T_1}$ and shows the work of a perfect cycle in an engine working between the received temperature + absolute temperature (T_1) and the initial atmospheric temperature + absolute temperature (T_0).

II. The second is the *actual heat efficiency,* or the ratio of the heat turned into work to the total heat received by the engine. It expresses the *indicated horse-power.*

III. The third is the ratio between the second or *actual heat efficiency* and the first or *maximum theoretical efficiency* of a perfect cycle. It represents the greatest possible utilization of the power of heat in an internal-combustion engine.

IV. The fourth is the *mechanical efficiency.* This is the ratio between the actual horse-power delivered by the engine through a dynamometer or measured by a brake (brake horse-power), and the indicated horse-power. The difference between the two is the power lost by engine friction.

In regard to the general heat efficiency of the materials of power in explosive engines, we find that with good illuminating gas the practical efficiency varies from 20 to 30 per cent.; kerosene motors, 15 to 20; gasoline motors, 18 to 22; acetylene, 25 to 35; alcohol, 20 to 30 per cent. of their heat value. The great variation is no doubt due to imperfect mixtures and variable conditions of the old and new charge in the cylinder; uncertainty as to leakage and the perfection of combustion. In the Diesel motors operating under high pressure, up to nearly 500 pounds, an efficiency of 36 per cent. is claimed.

CHAPTER IV.

HEAT EFFICIENCIES.

THE efficiency of an explosive engine is the ratio of heat turned into work in proportion to the total amount of heat produced by combustion in the engine. On general principles the greater difference between the heat of combustion and the heat at exhaust is the relative measure of the heat turned into work, which represents the degree of efficiency without loss during expansion. The mathematical formulas appertaining to the computation of the element of heat and its work in an explosive engine are in a large measure dependent upon assumed values, as the conditions of the heat of combustion are made uncertain by the mixing of the fresh charge with the products of a previons combustion and by absorption, radiation, and leakage. The computation of the temperature from the observed pressure may be made as before explained, but for compression engines the needed starting-points for computation are very uncertain, and can only be approximated from the exact measure and value of the elements of combustion in a cylinder charge.

Then theoretically the absolute efficiency in a perfect heat engine is represented by $\frac{T - T_1}{T}$, in which T is the acquired temperature from absolute zero; T_1, the final absolute temperature after expansion without loss.

Then, for example, supposing the acquired temperature of combustion in a cylinder charge was raised 2000° F. from 60°: the absolute temperature would be $2000 + 60 + 460 = 2520°$, and if expanded to the initial temperature of 60° without loss the absolute temperature of expansion will be $60 + 460 = 520$, then $\frac{2520 - 520}{2520} = .79$ per cent., the theoretical efficiency for the above range of temperature. In adiabatic compression or expansion, the ratio of the specific heat of air or other gases becomes a logarithmic exponent of both compression and expansion. The specific heat of air at constant volume is .1685 and at constant pressure, .2375 for 1 lb. in weight; water = 1. for 1 lb. Then $\frac{.2375}{.1685}$ = the ratio y = 1.408.

Then for the following formulas the specific heat $= K_v =$ .1685 constant volume, and $K_p = .2375$ constant pressure.

The quantity of heat in thermal units given by an impulse of an explosive engine is, $K_v\,(T - t)$ = heat units. Then using the figures as before, $.1685 \times (2520 - 520) = 337$ heat units per pound of the initial charge.

The heat in thermal units discharged will be $K_p\,(T_1 - t)$, $T_1 = t\left(\frac{T}{t}\right)^{\frac{1}{y}}$; t = absolute initial temperature, say 520°.

Then using again the figures as before and assuming that $T = 2{,}520°$ F., then $T_1 = 520\left(\frac{2520}{520}\right)^{\frac{1}{1.408}} = 520 \times (\log.\ 4.846 \times .7102) = 1594°$ absolute, and $1594 - 520 = 1074°$ F. Then the heat in thermal units discharged will be $.2375 \times (1594 - 520) = .2375 \times 1074 = 255$ heat units.

With the absolute temperature at the moment of exhaust known, the efficiency of the working cycle may be known, always excepting the losses by convection through the walls of the cylinder.

The formula for this efficiency is: eff. $= 1 - y\frac{T_1 - t}{T - t}$; then by substituting the figures as before, $1 - 1.408\,\frac{1594 - 520}{2520 - 520} = \frac{1074}{2000} = .537 \times 1.408 = .756$, and $1 - .756 = 24$ per cent.

To obtain the adiabatic terminal temperature from the relative volumes of clearance and expansion, we have the formula $\frac{V_0}{V}^{-y-1} = \frac{T_1}{T}$, in which $\frac{V_0}{V}$ is the ratio of expansion in terms of the charging space in engines of the Lenoir type to the whole

V_0 = volume at *b*.
V = volume at *c*.
V_c = volume at *f*.
vo = V or volume at compression = volume at exhaust.
K_v = .1685 specific heat at constant volume.

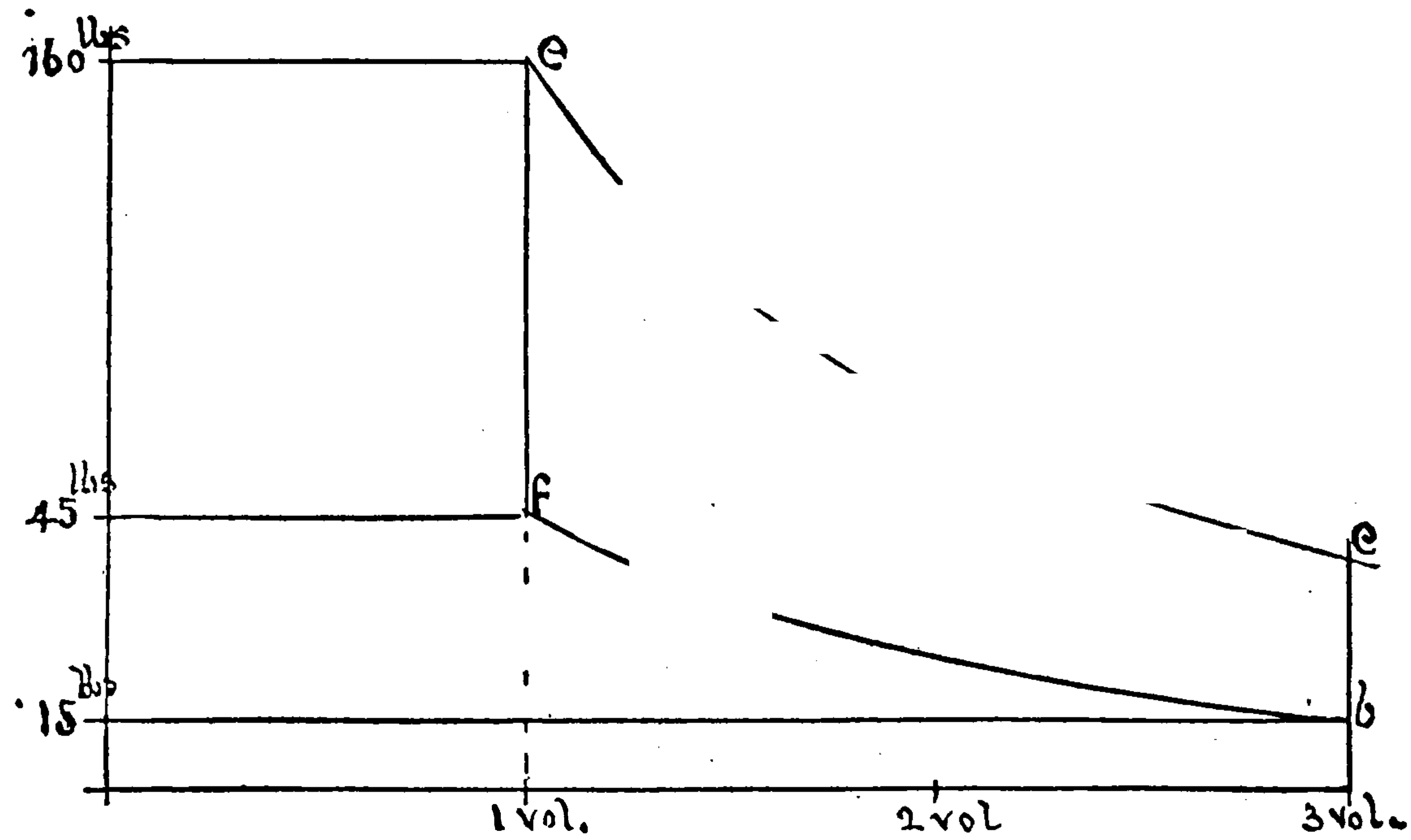


FIG. 6*—THE FOUR-CYCLE COMPRESSION CARD.

Let T = abs. acquired temp. = 2520° F. as before.
t = abs. normal temp. = 520° or 60° F.

t_c = abs. temp. of compression $= t\left(\frac{P_c}{P}\right)^{\frac{y-1}{y}} = \frac{1.408 - 1}{1.408}$

$= 0.29$. Then $520^\circ \left(\frac{60}{15}\right)^{0.29} = 777^\circ$ absolute.

T_1 = abs. temp. of expansion $= \frac{T\,t}{t_c}$ or $\frac{2520^\circ \times 520}{777} =$ 1686°.

The terms being assumed and known from assumed data, the efficiency $= 1 - \frac{K_v(T - t_c) - K_v(T_1 - t)}{K_v(T - t_c)}$.

Reducing, efficiency $= 1 - \frac{T_1 - t}{T - t_c}$; substituting figures as above found, $1 - \frac{1686 - 520}{2520 - 777} = .333$ per cent.; also $1 - \frac{T_1}{T} = \frac{1686}{2520} = .333$ and $1 - \frac{t}{t_c} = \frac{520}{777} = .333$.

For obtaining the efficiency from the relative volumes at both ends of the piston stroke, with an expansion in the cylinder equal to twice the clearance space, by which the total volume at the end of the stroke will be three times the volume of the clearance space,—efficiency in this case may be expressed by the formula $1 - \left(\frac{V_0}{V_c}\right)^{\gamma-1}$; substituting, the values become $1 - \left(\frac{1}{3}\right)^{.408}$; using logarithms as before, log. $3 = 0.477121 \times .408 = 0.194665$, the index of which is 1.565, and $\frac{1}{1.565} = .639$. Then $1 - .639 = .36$ per cent.

USUAL TEMPERATURES OF COMBUSTION.

Clearance Per Cent. of Piston Volume.	Ratio of Compression $\frac{V}{V_e} = \frac{P + C \text{ Vol.}}{\text{Clearance.}}$	Rise in temperature of various mixtures of air and gas by explosion, from the compression temperature due to the ratio in col. 2, when mixed with the products of combustion from a previous explosion left in the clearance space. For gas of 660 thermal units per cubic foot.						
		6 to 1.	7 to 1.	8 to 1	9 to 1.	10 to 1.	11 to 1.	12 to 1.
		Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.
.50	3.	2.027	1 877	1.865	1.739	1.629	1 524	1.398
.444	3.25	2.107	1.960	1.938	1.807	1 693	1.584	1.452
.40	3.50	2.177	2.032	2 001	1.866	1 748	1 635	1 500
.363	3.75	2.237	2.094	2.056	1 917	1.795	1.679	1.540
.333	4.	2.290	2.149	2 104	1.961	1.837	1.718	1.576
.285	4.5	2.378	2.242	2.185	2.036	1.907	1.783	1 636
.25	5.	2.448	2.317	2.249	2 096	1.963	1.836	1 683
.222......	5 5	2.506	2.379	2.302	2.145	2.008	1.878	1.722
.20	6.	2.554	2.431	2.346	2.186	2.046	1 914	1 755

The above heat values are approximate resulting temperatures usual in gas engines, in consideration of the heat values of each element in the gas and its distribution to the air and heated contents of the clearance space from a previous explosion and the estimated absorption of heat by the walls of the clearance space at the moment of combustion.

CHAPTER V.

RETARDED COMBUSTION AND WALL-COOLING.

SOME of the serious difficulties in practically realizing the condition of a perfect cycle in an internal-combustion engine are shown in the diagram Fig. 6, taken from an English Otto

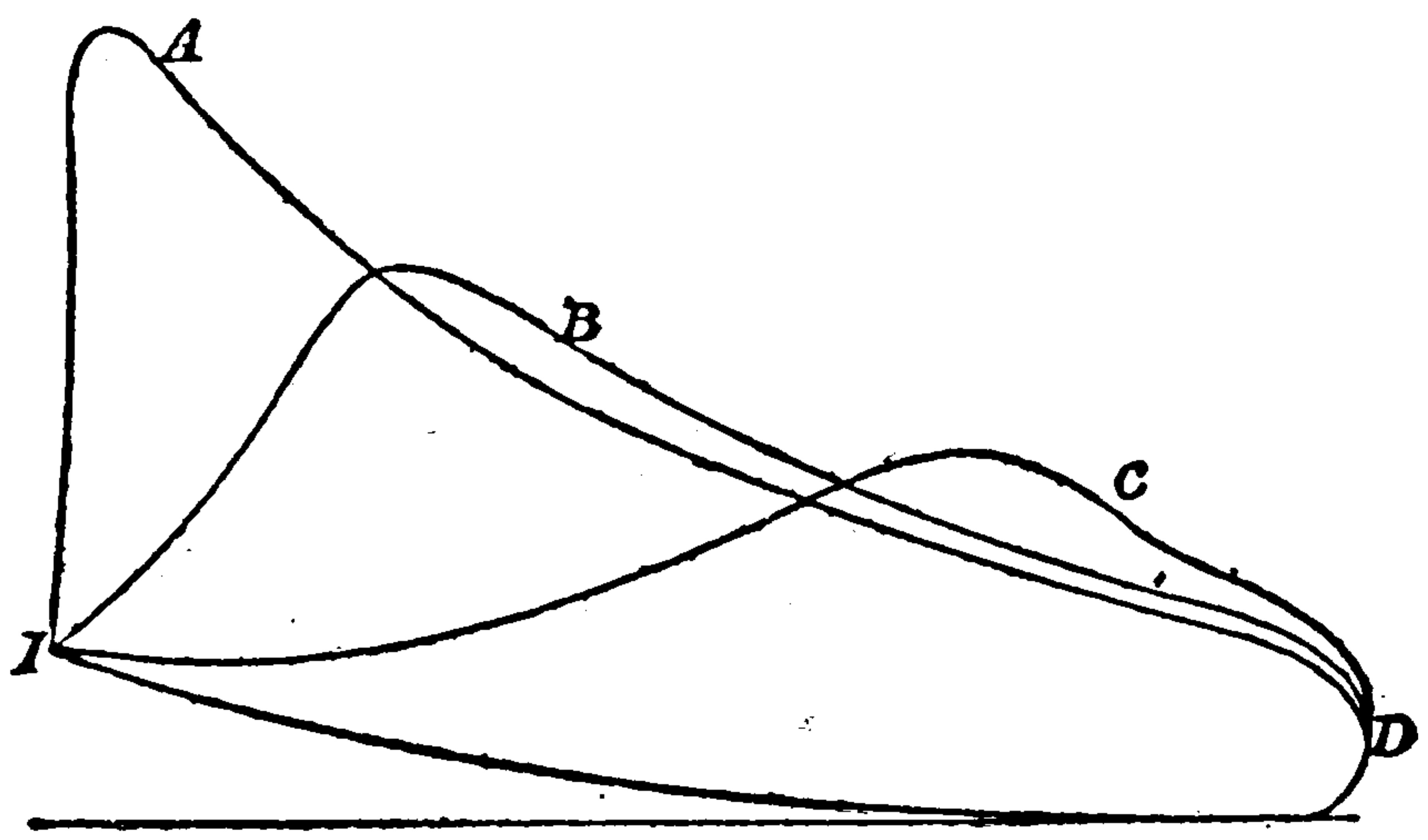


FIG. 6.—VARIABLE CARD.

gas engine, in which the cooling effect of the walls are shown by the lagging of the explosion curve, by the missing of several explosions when the cylinder walls have been unduly cooled by the water-jacket. The same delay is experienced in starting a gas engine. The indicator card I A D representing the normal condition of constant work in the cylinder; the curve I B D an interruption of explosions for several revolutions; and I C D a still longer interruption in the explosions with the engine in continuous motion.

In an experimental investigation of the efficiency of a gas engine under variable piston speeds made in France, it was found that the useful effect increases with the velocity of the piston—that is, with the rate of expansion of the burning gases with mixtures of uniform volumes; so that with the variations of time of complete combustion at constant pressure, as illustrated on page 15, and the variations due to speed, in a way compensate in their efficiencies. The dilute mixture, being slow burning, will have its time and pressure quickened by increasing the speed.

TABLE V.—TRIAL EFFICIENCIES DUE TO INCREASED PISTON SPEED.

$$\text{Efficiency} = \frac{\text{work of indicator diagram}}{\text{theoretical work.}}$$

Mixtures.	Time of explosion. Second	Piston speed. Foot per second.	Computed work diagram. Foot-pounds.	Theoretical work of the gas. Foot-pounds.	Efficiency.
1 volume coal gas to 9.4 volumes air (.1093 cubic feet mixture)	.53	1.181	70.8	4917	1.44
1 volume coal gas to 9.4 volumes air	.40	1.64	85.3	4917	1.70
1 " " " " 9.4 " "	.25	3.01	105.5	4917	2.10
1 " " " " 9.4 " "	.16	4.55	125.8	4917	2.60
1 " " " " 6.33 " " (.073 cubic feet mixture)	.15	5.57	127.2	4793	2.60
1 volume coal gas to 6.33 volume air	.09	9.51	289.9	4793	6.00
1 " " " " 6.33 " "	.06	14.1	364.4	4793	7.50

These trials give unmistakable evidence that the useful effect increases with the velocity of the piston—that is, with the rate of expansion of the burning gases.

The time necessary for the explosion to become complete and to attain its maximum pressure depends not only on the composition of the mixture, but also upon the rate of expansion.

This has been verified in experiments with the Kane-Pennington motor, at speeds from 500 to 1,000 revolutions per minute, or piston speeds of from 16 to 32 feet per second.

The increased speed of combustion due to increased piston speed is a matter of great importance to builders of gas engines, as well as to the users, as indicating the mechanical direction of improvements to lessen the wearing strain due to high speed and to lighten the vibrating parts with increased strength, in order that the balancing of high-speed engines may be accomplished with the least weight.

From many experiments made in Europe, it has been conclusively proved that excessive cylinder cooling by the water-jacket is a loss of efficiency.

In a series of experiments with a simplex engine in France, it was found that a saving of 7 per cent. in gas consumption per brake horse-power was made by raising the temperature of

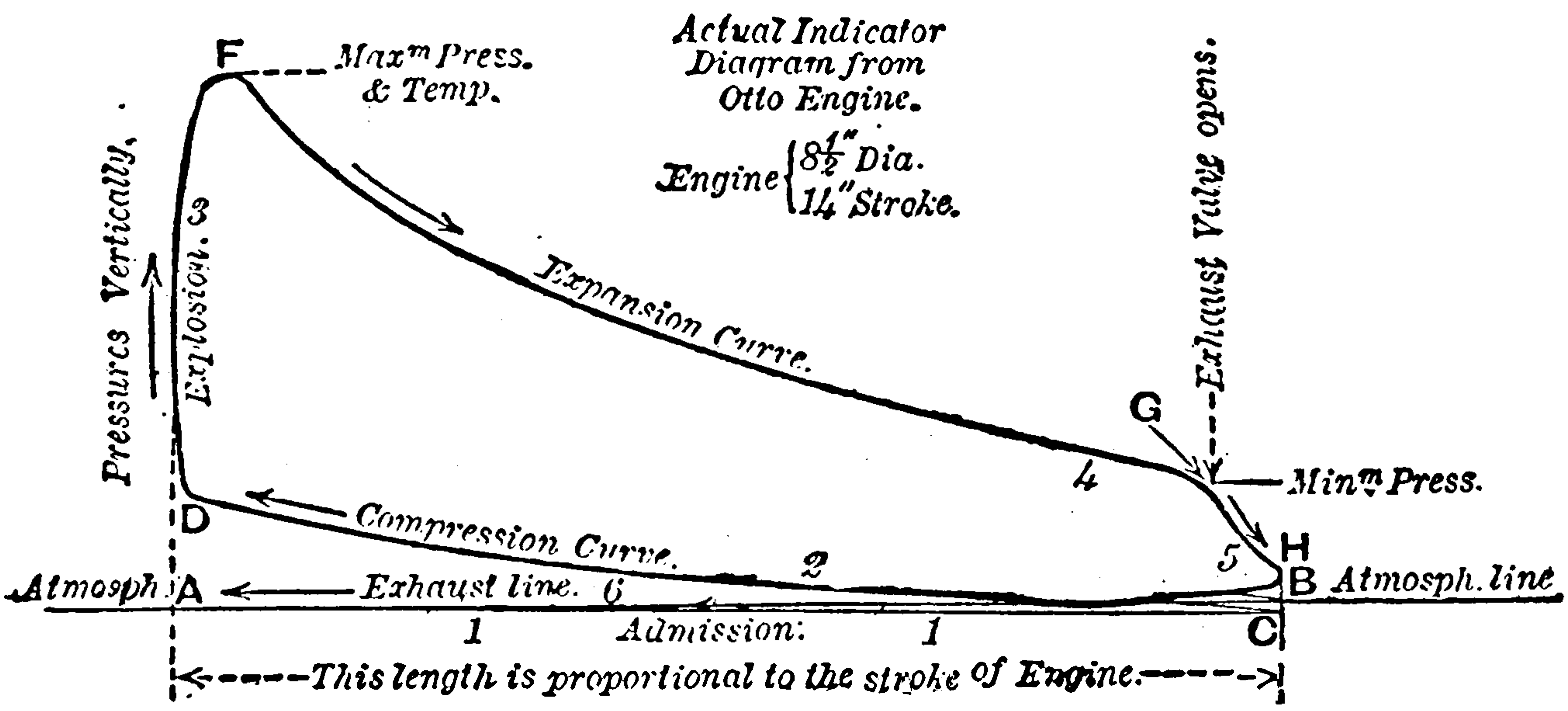


FIG. 7.—OTTO FOUR-CYCLE CARD.

the jacket water from 141° to 165° F. A still greater saving was made in a trial with an Otto engine by raising the temperature of the jacket water from 61° to 140° F.—it being 9.5 per cent. less gas per brake horse-power.

In view of the experiments in this direction, it clearly shows that in practical work, to obtain the greatest economy per effective brake horse-power, it is neessary:

1st. To transform the heat into work with the greatest rapidity mechanically allowable. This means high piston speed.

2d. To have high initial compression.

3d. To reduce the duration of contact between the hot gases and the cylinder walls to the smallest amount possible; which means short stroke and quick speed.

4th. To adjust the temperature of the jacket water to obtain the most economical output of actual power. This means water tanks or water coils, with air-cooling surfaces suitable

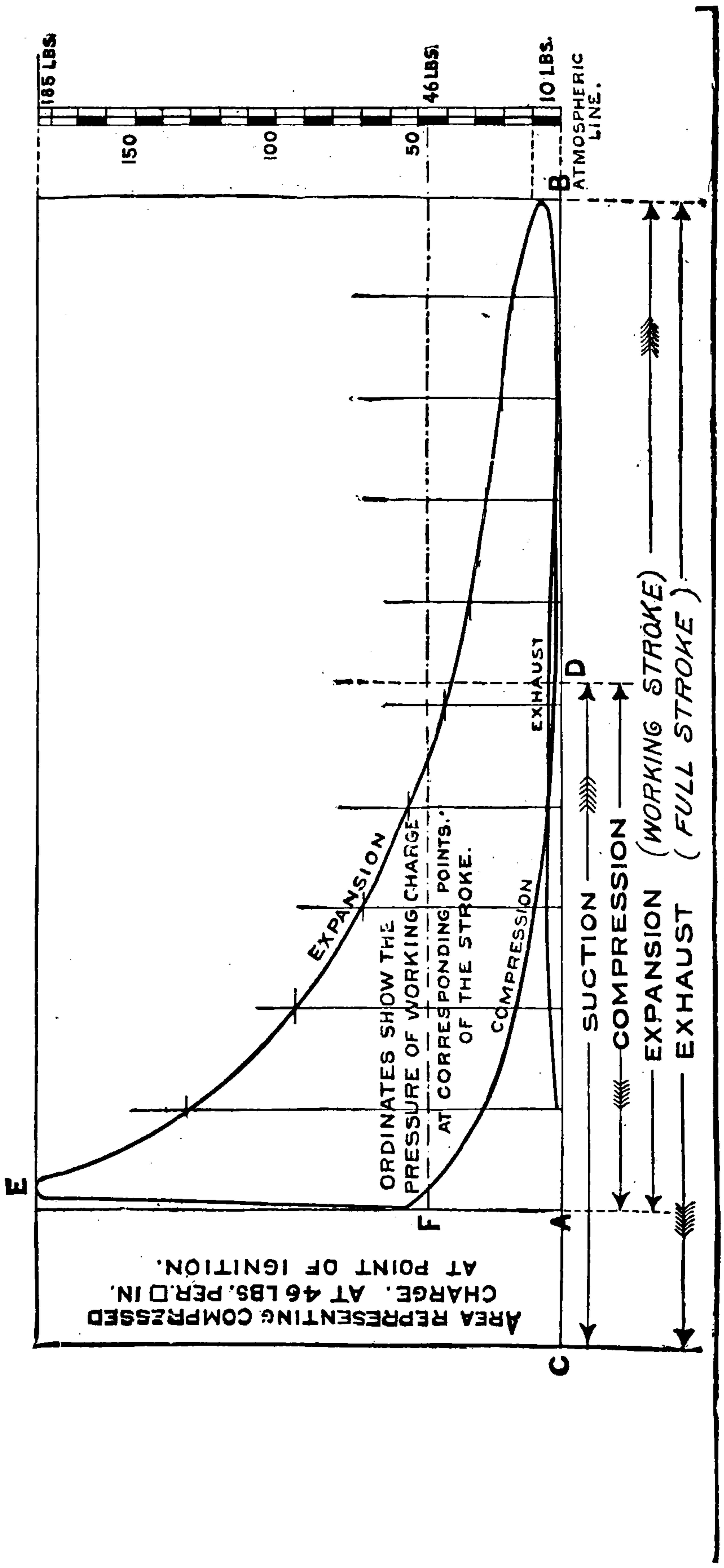


FIG. 8.—INDICATOR CARD, ATKINSON.

and adjustable to the most economical requirement of the engine.

5th. To reduce the wall surface of the clearance space or combustion chamber to the smallest possible area, in proportion to its required volume. This lessens the loss of the heat of combustion by exposure to a large surface, and allows of a higher mean wall temperature to facilitate the heat of compression.

It will be noticed that the volumes of similar cylinders increase as the cube of their diameters, while the surface of their

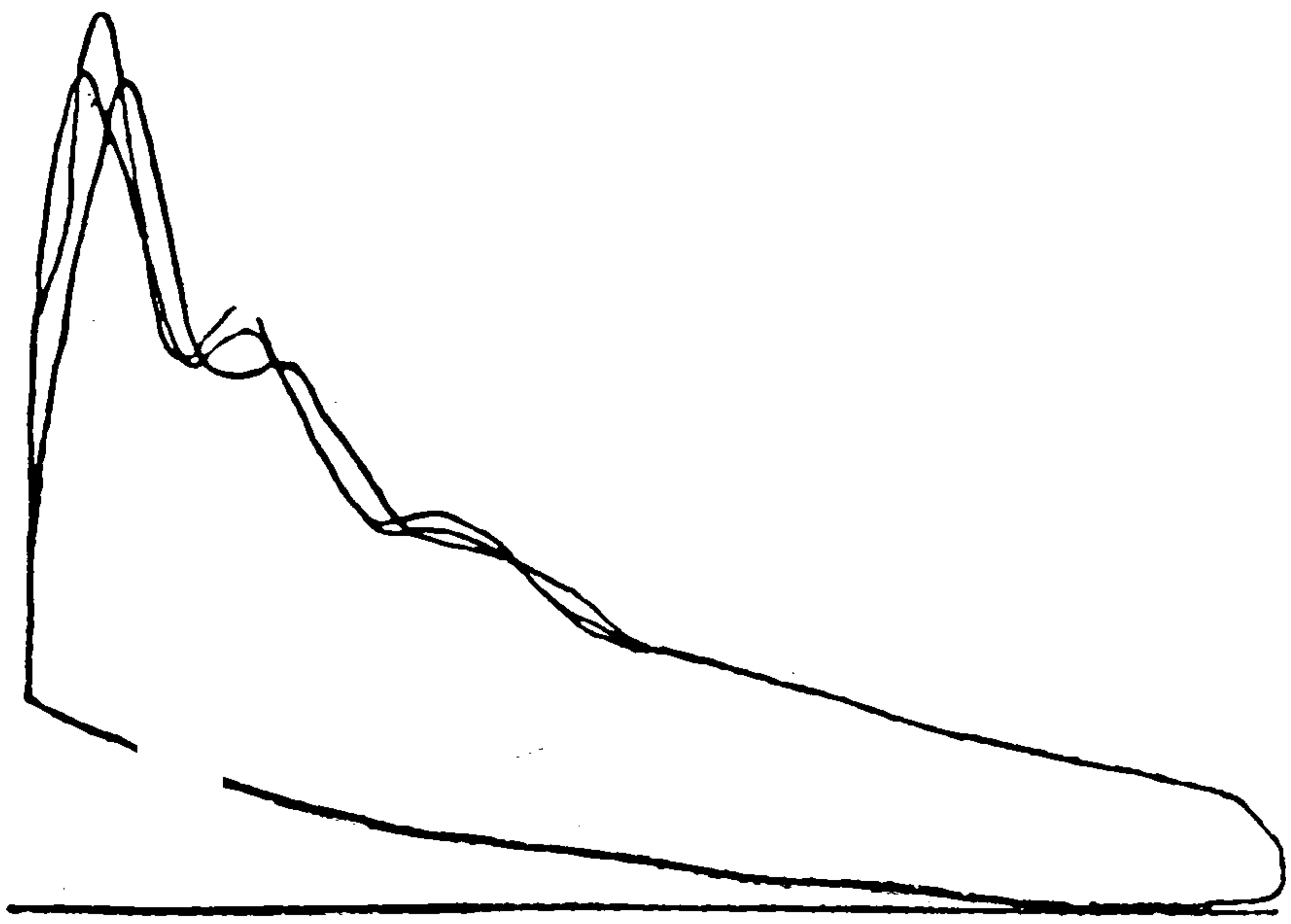


FIG. 9.—INDICATOR CARD, FULL LOAD.

cold walls varies as the square of their diameters; so that for large cylinders the ratio of surface to volume is less than for small ones. This points to greater economy in the larger engines.

The study of many experiments goes to prove that combustion takes place gradually in the gas-engine cylinder, and that the rate of increase of pressure or rapidity of firing is controlled by dilution and compression of the mixture, as well as by the rate of expansion or piston speed.

The rate of combustion also depends on the size and shape of the exploding chamber, and is increased by mechanical agitation of the mixture during combustion, and still more by the mode of firing. A small intermittent spark gives the most uncertain ignition, whereas a continuous electric spark passed through an explosive mixture, or a large flame as the shooting

delineated through two of its four cycles. The curve of explosion shows that firing commenced slightly before the end of the stroke, and that combustion lagged until a moment after reversal of the stroke. The expansion line is somewhat higher than the adiabatic curve, indicating a partial combustion taking place during the stroke of the piston, and particularly

FIG. 11.—TYPICAL COMPRESSION CARD. MEAN PRESSURE, 76 LBS. PER SQUARE INCH.

manifested by the rounding-off of the apex of the card.

In Fig. 8 is represented a card from the Atkinson gas engine. The peculiar design of this engine enables the largest degree of expansion known in gas-engine practice.

Fig. 9 is a card from a compression engine, showing an irregularity in firing the charge, and probably an irregular progress of combustion by defective mixture. This card was made when running at full load, and computed at 69 lbs. mean pressure.

Fig. 10 represents a card from the same engine at half-load and lessened combustion charge. It shows the same characteristics as to irregularity, and also a lag in firing and a fitful after-combustion; but from weak mixture and interrupted firing the cooling influence of the cylinder walls has prolonged the combustion with ignition pressure. Mean pressure, about 68 lbs. per square inch.

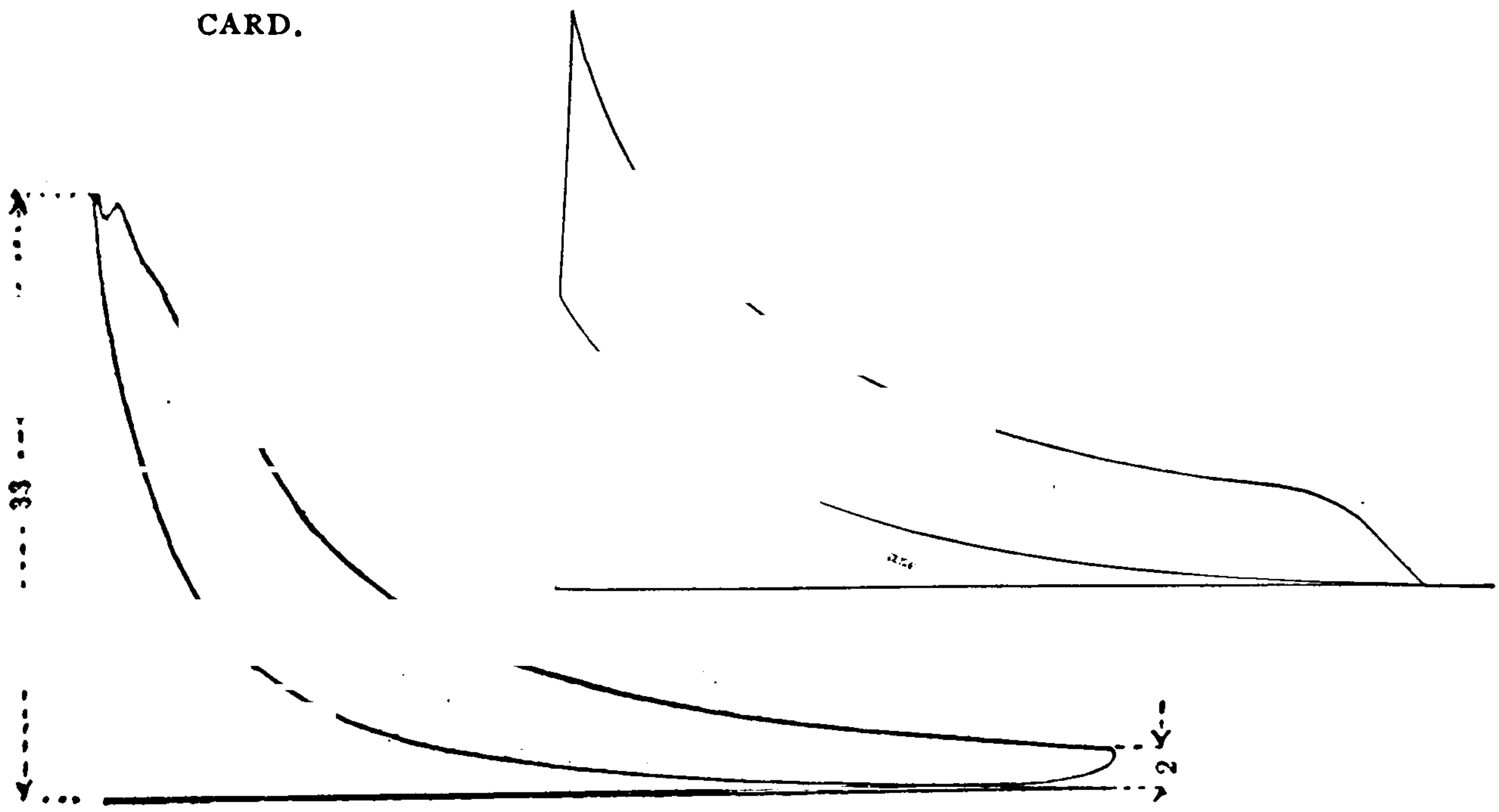
Fig. 11 represents a typical card of our best compression engines, with time igniter, at full load and uninterrupted firing.

The kerosene motor card of the Mietz & Weiss engine (Fig. 11A) taken from a 20 H.P. actual, motor with cylinder 12 inches × 12 inches, at 300 revolutions per minute, shows a compression of nearly one-half the explosive force. Its efficiency is very high, and by test gave 21½ horse-power from 16½ pints of oil per hour.

A most unique card is that of the Diesel motor, which involves a distinct principle in the design and operation of internal com-

FIG. 11B.—DIESEL MOTOR CARD.

FIG. 11A.—KEROSENE MOTOR CARD.



bustion motors, in that instead of taking a mixed charge for instantaneous explosion, its charge primarily is of air and its compression to a pressure at which a temperature is attained above the igniting point of the fuel, then injecting the fuel under a still higher pressure by which spontaneous combustion takes place gradually with increasing volume over the compression for part of the stroke or until the fuel charge is consumed. The motor thus operating between the pressures of 500 and 35 pounds per square inch, with a clearance of about 7 per cent., has given an efficiency of 36 per cent. of the total heat value of kerosene oil.

CHAPTER VI.

CAUSES OF LOSS AND INEFFICIENCY IN EXPLOSIVE MOTORS.

THE difference realized in the practical operation of an internal-heat engine from the computed effect derived from the values of the explosive elements is probably the most serious difficulty that engineers have encountered in their endeavors to arrive at a rational conclusion as to where the losses were located and the ways and means of design that would eliminate the causes of loss and raise the efficiency step by step to a reasonable percentage of the total efficiency of a perfect cycle.

The loss of heat to the walls of the cylinder, piston, and clearance space, as regards the proportion of wall surface to the volume, has gradually brought this point to its smallest ratio in the concave piston head and globular cylinder head, with the smallest possible space in the inlet and exhaust passage. The wall surface of a cylindrical clearance space or combustion chamber of one-half its unit diameter in length is equal to 3.1416 square units, its volume but 0.3927 of a cubic unit; while the same wall surface in a spherical form has a volume of 0.5236 of a cubic unit. It will be readily seen that the volume is increased 33⅓ per cent. in a spherical over a cylindrical form for equal wall surfaces at the moment of explosion, when it is desirable that the greatest amount of heat is generated and carrying with it the greatest possible pressure from which the expansion takes place by the movement of the piston.

The spherical form cannot continue during the stroke for mechanical reasons; therefore some proportion of piston stroke or cylinder volume must be found to correspond with a spherical form of the combustion chamber to produce the least loss of heat through the walls during the combustion and expansion part of the stroke.

This idea we illustrate in Figs. 12 and 13, showing how the relative volumes of cylinder stroke and combustion chamber

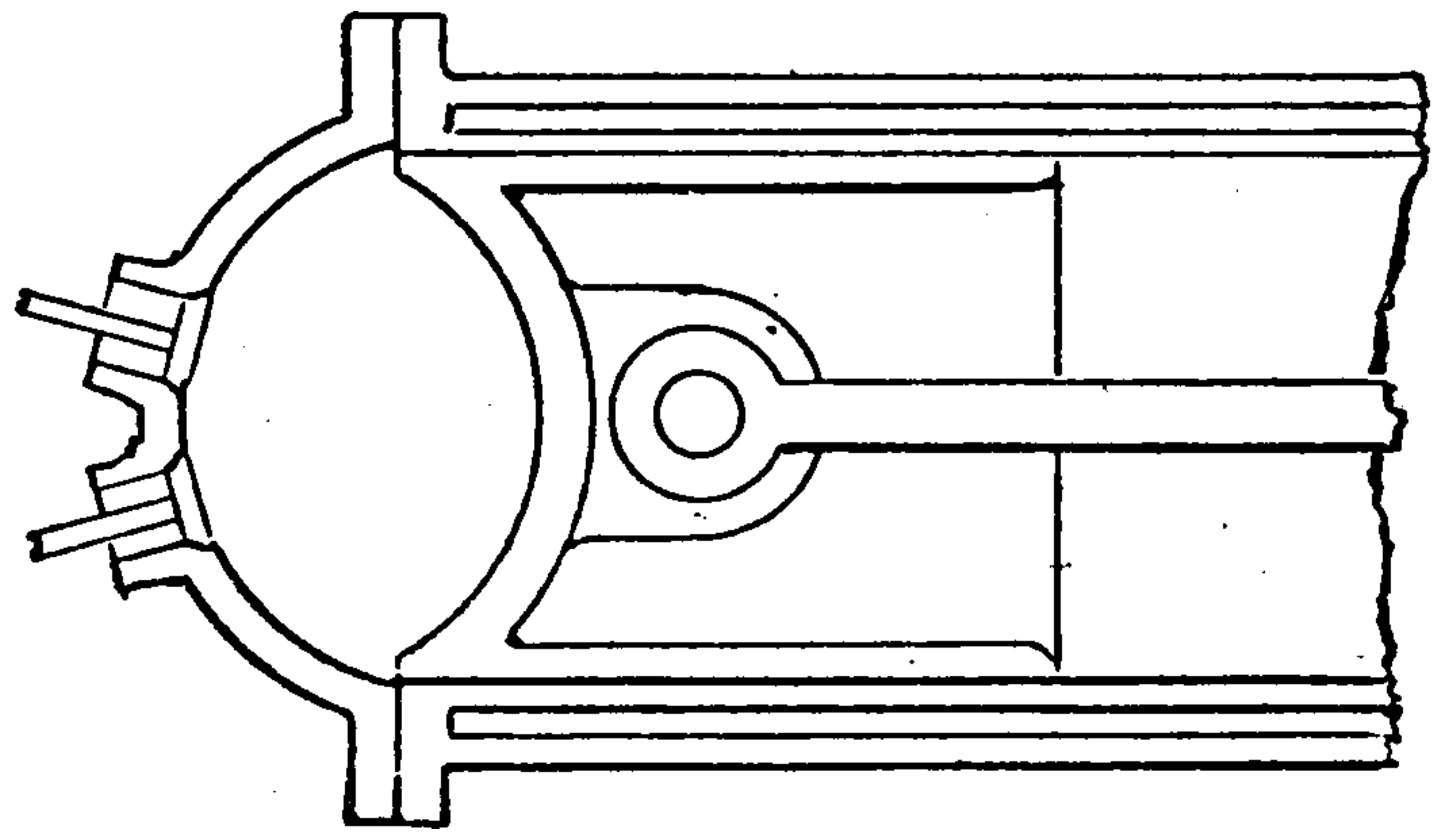


FIG 12.—SPHERICAL COMBUSTION CHAMBER.

may be varied to suit the requirements due to the quality of the elements of combustion. In Fig. 12 the ratio may also be decreased by extending the stroke. The mean temperature of the wall surface of the combustion chamber and cylinder, as indicated by the temperatures of the circulating water, has been found to be an important item in the economy of the gas

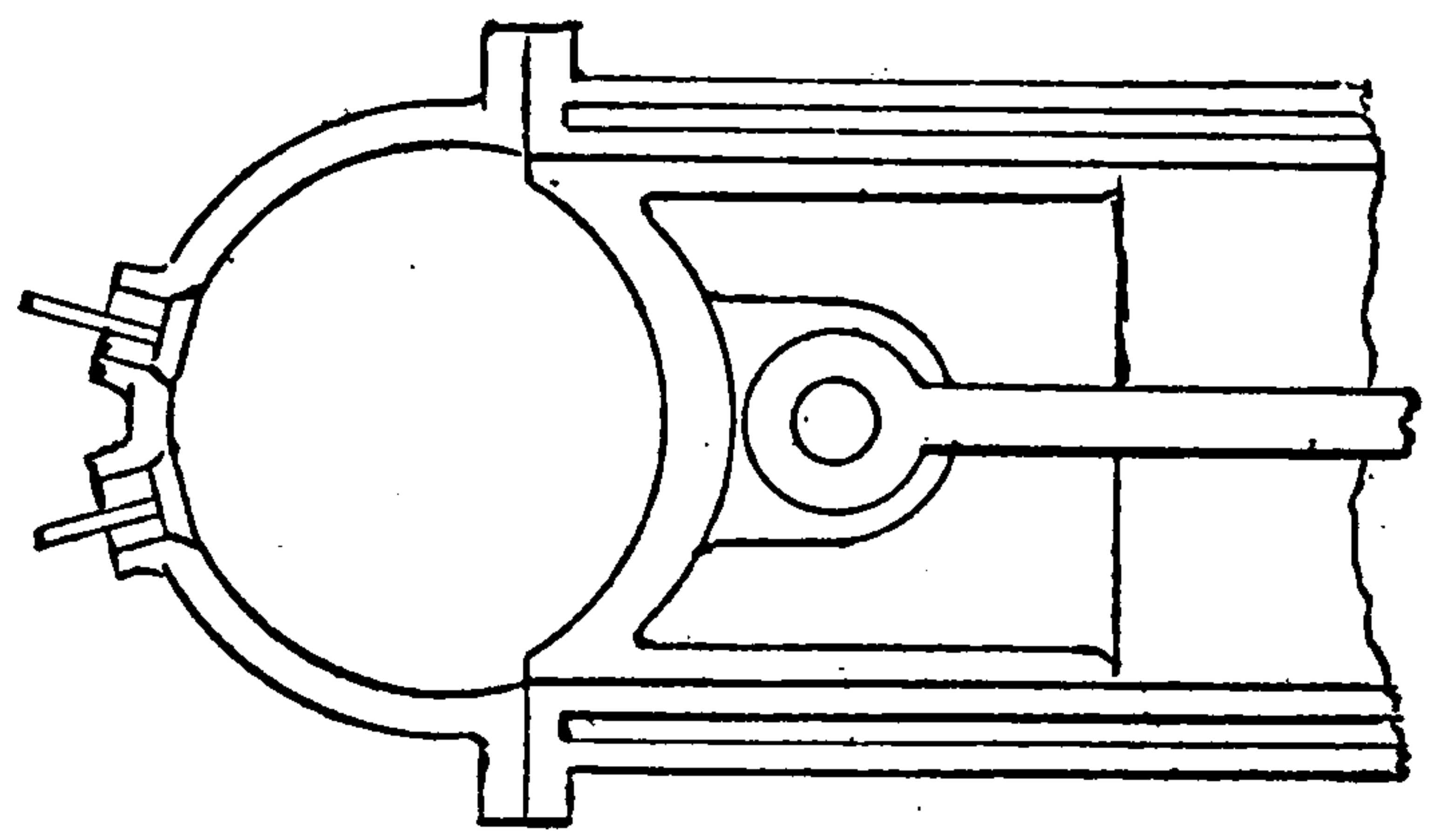


FIG. 13.—ENLARGED COMBUSTION CHAMBER.

engine. Dugald Clerk, in England, a high authority in practical work with the gas engine, found that 10 per cent. of the gas for a stated amount of power was saved by using water at a temperature in which the ejected water from the cylinder jacket was near the boiling point, and ventures the opinion that a still higher temperature for the circulating water may be used as a source of economy.

This could be made practical by elevating the water tank and adjusting the air-cooling surface, so as to maintain the inlet water at just below the boiling-point, and by the rapid circulation induced by the height of the tank above the engine and the pressure, to return the water from the cylinder jacket a few degrees above the boiling-point.

For a given amount of heat taken from the cylinder by the largest volume of circulating water, the difference in temperature between inlet and outlet of the water jacket should be the least possible, and this condition of the water circulation gives a more even temperature to all parts of the cylinder; while, on the contrary, a cold water supply, say at 60° F., so slow as to allow the ejected water to flow off at a temperature near the boiling-point, must make a great difference in temperature between the bottom and top of the cylinder, with a loss in economy in gas and other fuels, as well as in water, if it is obtained by measurement.

In regard to the actual consumption of water per horsepower and the amount of heat carried off by it, the study of English trials of an Atkinson, Crossley, and Griffin engine showed 62 lbs. water per indicated horse-power per hour, with a rise in temperature of 50° F., or 3,100 heat units were carried off in the water out of 12,027 theoretical heat units that were fed to the motor through the 19 cubic feet of gas at 633 heat units per cubic foot per hour.

Theoretically, 2,564 heat units per hour is equal to 1 horsepower. Then 0.257 of the total was given to the jacket water, 0.213 to the indicated power, and the balance, 53 per cent., went to the exhaust, radiation, and the reheating of the previons charge in the clearance and in expanding the nitrogen of the air. Other and mysterious losses, due to the unknown condition of the gases entering into and passing through the heat cycle, have been claimed and mathematically discussed by authors, which have failed to satisfy the practical side of the question, which is the main object of this work.

In a trial with the Crossley engine, 42 lbs. of water per horse-power per hour were passed through the cylinder jacket, with a rise in temperature of 128° F.—equal to 5,376 heat units to the water from 12,833 heat units fed to the engine through 20.5 cubic feet of gas at 626 heat units per cubic foot.

In this trial, 41 per cent. of the total heat was carried away in the water; 2,564 heat units being equal to one indicated horse-power per hour, then 5,376 + 2,564 = 7,940 were directly accounted for, leaving 38 per cent. to the exhaust and other losses. As these engines were both of the compression type, and the Crossley engine having double the clearance space of the Atkinson engine, and with so great a difference in the volumes of the previous explosion held over, a just comparison of the effect of different cylinder temperatures cannot be made. The efficiencies were found, including gas used for ignition, to be for the Atkinson, 22.8 per cent.; for the Crossley, 21.2 per cent.; and for the Griffin, a double-acting engine, 19.2 per cent. of the total gas power used. The efficiency of other engines of the four-cycle compression type in Europe varies from 17 to 22 per cent., some of the lower efficiencies being claimed as due to the composition of the low-power Dowson and water gases.

An experimental test of the performance of a gas engine below its maximum load has shown a large increase in the consumption of gas per actual horse-power, with a decrease of load, as the following figures from observed trials show: An actual 12 H.P. engine at full load used 15 cubic feet of gas per horse-power per hour; at 10 H.P., 15½ cubic feet; at 8 H.P., 16½ cubic feet; at 6 H.P., 18 cubic feet; at 4 H.P., 21 cubic feet; at 2 H.P., 30 cubic feet of gas per actual horse-power per hour. This indicates an economy in gauging the size of a gas engine to the actual power required, in consideration of the fact that the engine friction and gas consumption for ignition are constants for all or any power actually given out by the engine.

CHAPTER VII.

ECONOMY OF THE GAS ENGINE FOR ELECTRIC-LIGHTING.

In the lighting of large dwellings or other buildings, where there is no power used for other purposes, the use of gas or gasoline engines for operating an electric generator is not only cheaper in running expenses than the steam engine, but the comparison holds good for the lighting of towns and villages at the usual cost of gas to consumers; but when the generation of producer gas can be made for such use on the premises of the electric plant and by the same persons that operate the electric plant, the saving in cost of electric-lighting is several-fold less than by direct gas-burning.

In many towns where oil producer gas is used, the cost of material used in making the gas is less than thirty-five cents per thousand feet of gas produced. In such places the labor of producing the gas for a town of say fifteen hundred inhabitants is from two to three hours per day, and in some towns, as observed by the author, three hours every other day—giving ample time for the same operator to run the electric plant in the evening, or both may be run simultaneously.

When the mere fact of the cost of gas for direct lighting and its cost for producing the same light by its use in a gas engine to run an electric generator is considered, the difference in favor of electric-lighting in preference to direct gas-lighting is most apparent.

It has been known for some years that for equal light power but about one-half the volume of gas consumed in direct lighting will produce the same amount of candle-power when used in a gas engine for generating electricity for lighting.

640 cubic feet of gas were consumed per hour, equal to $\frac{640}{5}$ = 128 gas-lights and a direct gaslight efficiency of $\frac{128}{220}$ = 58 per cent. Again reducing to 100 lamps, 320 cubic feet of gas was used, equal to 64 gas-lights with an efficiency of 64 per cent. for direct gaslighting.

It will readily be seen by inspection of these figures that the greatest economy in gas-engine power will be found in gauging the size of a gas engine by the work it is to do when the work is a constant quantity.

In a trial by the writer of a Nash gas engine of 5 B.H.P., driving by belt a Riker 3 kilowatt bipolar generator of 120 volts, 25 ampere capacity, the engine speed was 300 revolutions and the generator 1,400 revolutions per minute; consumption of New York gas, 105 cubic feet per hour. With 50 120-volt A.B.C. lamps in circuit giving a brilliant white light of fully 16 candle-power, the actual voltage by meter was 120, amperage by meter 24, voltage and amperage perfectly steady with continuous running. By turning in resistance and reducing the voltage to 110 and the amperage to 21, the lights were still brilliant in the 50 lamps. With the lamps cut out to 40, the voltmeter vibrated 2 volts and immediately came back to 110 volts, with the amperemeter at 17. With a further and sudden cutting out the light to 20 lamps, the voltage fell to 105 with but slight vibration; amperage, 11. With 15 lamps on, the voltage crept up to 110, amperage 6½, and with 10 lamps only the voltage vibrated for a few seconds and rested at 110, amperage 4½. The engine seemed to answer the change of load remarkably quick, so that there was no perceptible change in speed.

The investment of local lighting-plants by the use of gas, gasoline, and oil engines in factories and large buildings in Europe has been found a great source of economy as against the direct use of municipal electric current or the direct use of gas.

The gasoline or oil engine makes a most favorable return in economy when used for local lighting as against the prevailing price charged by the operators of large steam-power installations for town and city lighting.

In a trial of eleven days by a 10 H.P. four-cycle gas engine of the Raymond vertical pattern, belted direct to a 150-light direct-current generator making 1,600 revolutions per minute, with the current measured by a recording wattmeter, giving a steady current to 90 16-candle-power lamps on a factory circuit, the total cost of gas at $1.50 per 1,000 cubic feet with lubricating oils was $20.16. The kilowatts produced by measure was 239.1 or a cost of .0844 cents per kilowatt. The price of the current by the same measure from the electric company was 20 cents per kilowatt—a saving of 57 per cent. In places where gas is $1 per 1,000 feet, the cost would have been only 5⅝ cents per kilowatt.

In the lighting of churches the gas or gasoline engine has been found to be not only economical, but has largely contributed to the cheerful surroundings of a lighted church at less than one-half the cost of gas for direct lighting, and with no more attention in starting the engine, cleaning, etc., than required for lighting and regulating the ordinary gas lights.

The year 1902 has ushered in a most extended use of explosive engines as prime-movers for generating the electric current for lighting and the transmission of power. For this purpose the duplex vertical engine and direct connected multipolar generators are used, from which very favorable results have been obtained. Trials with a 22 B. H. P. two-cylinder vertical engine of the National Meter Co., direct coupled with a 15 kilowatt, 6 pole, compound wound Riker generator, using illuminating gas of 701 thermal units per cubic foot, with engine and generator running at 300 revolutions per minute, are quoted. The output was 13,125 watts, or equal to 345 lamps of 3.8 watts each—say 16 candle-power, with a total B.H.P. = 22.71. Total consumption of gas per B.H.P. = 17.62 c. ft. Relative illuminating power of electric light 2.21 as compared with equal consumption by direct gas lighting. Efficiency of engine 20.6 per cent.; efficiency of generator 83.1 per cent.

Statements of still greater economy for lighting by gas and gasoline engines, in which claims for from 14 to 16 cubic feet of gas and 1/8 gallon of gasoline per B.H.P. are made for large-sized electric plants, and but a trifle more for smaller sizes. Electric lighting by the power of the explosive engine is conceded to be economical at all ranges of its power, but with gasoline and oil vapor the cost of fuel for light drops to less than 1-10 of a cent per 16 candle-power light per hour.

Electric lighting plants operated by gas, gasoline and oil motors are making rapid advances in the number of units of power, and the small powers of the date of the early edition of this work, have gradually advanced to unit installments of 50, 100 and 150 horse-power in double and triple-cylinder motors, and by duplicating the motor-units, almost any desired installation can be made on the most economical running basis.

The American practice of construction seems to favor the smaller cylinder volume and their duplication for the higher powers. In this manner power installations for from 1,000 to 10,000 incandescent lights may be made a most economical plant with illuminating gas, gasoline, producer gas or petroleum oil.

CHAPTER VIII.

THE MATERIAL OF POWER IN EXPLOSIVE ENGINES.

THE composition of gases, gasoline, petroleum oil, and air as elements of combustion and force in explosive engines is of great importance in comparisons of heat and motor efficiencies. By reported experiments with 20-candle coal gas in the United States, by the evaporation of water at 212° F., a cubic foot was credited with 1,236 heat units; while reliable authorities range the value of our best illuminating gases at from 675 to 700 heat units per cubic foot. The specific heat of illuminating gas is much higher than for air, being for coal gas at constant pressure 0.6844 and at constant volume 0.5196, with a ratio of 1.315; while the specific heat for air at constant pressure is 0.2377, and at constant volume is 0.1688, and their ratio 1.408.

The mixtures of gas and air accordingly vary in their specific heat with ratios relative to the volumes in the mixture. The products of combustion also have a higher specific heat than air, ranging from 0.250 at constant pressure and 0.182 at constant volume, to 0.260 and 0.190 with ratios of 1.37 and 1.36.

A cubic foot of ordinary coal gas burned in air produces about one ounce of water vapor, and 0.57 of a cubic foot of carbonic acid gas (CO_2). Its calorific value will average about 673 heat units per cubic foot.

A cubic foot of ordinary coal gas requires 1.21 cubic feet of oxygen, more or less, due to variation in the constituents of different grades of illuminating gases in various localities, for complete combustion.

Allowing for an available supply of 20 per cent. of oxygen in air for complete combustion, then $1.21 \times 5 = 6.05$ cubic feet of air which is required per cubic foot of gas in a gas engine for its best work; but in actual practice the presence in the engine cylinder of the products of a previous combustion, and the fact that a sudden mixture of gas and air may not make a homogeneous combination for perfect combustion, require a larger proportion of air to completely oxidize the gas charge.

It will be seen by inspection of Table 2 that the above proportion, without the presence of contaminating elements, produces the quickest firing and approximately the highest pressure at constant volume, and that any greater or less proportion of air will reduce the pressure and the apparent efficiency of an explosive motor. There are other considerations effecting the governing of explosive engines, in which the gas element only is controlled by the governor, requiring an excess of air at the normal speed, so that an economical adjustment of gas consumption may be obtained at both above and below the normal speed.

TABLE III.—THE MATERIALS OF POWER IN EXPLOSIVE ENGINES—GASES, GASOLINE, AND PETROLEUM OILS.

Various gases, vapors, and other combustibles.	Heat units, per pound.	Heat units, per cubic foot.	Foot-pounds, per cubic foot.
Hydrogen	61,560	293.5	226,580
Carbon	14,540		
Crude petroleum, West Virginia, spec. grav. .873.	18,324		
Light petroleum, Pennsylvania, spec. grav. .841.	18,401		
Benzine, C_6H_6	18,448		
Gasoline	11,000		
28 candle-power illuminating gas	....	950	773,400
19 " " "	....	800	617,600
15 " " "	....	620	478,640
Water gas, American	....	185	142,820
Producer gas, English .66 to.	....	150	115,800
Water producer gas	....	104	80,288
Ethylene olefiant gas, C_2H_4	21,430	1677	
Gasoline vapor	11,000	690	492,680
Acetylene C_2H_2	21,492	868	670,090
Natural gas, Leechburg Pa	....	584	450,848
" " Pittsburg, Pa	....	495	382,140
Marsh gas (Methane), CH_4	23,594	1051	

The various other than coal gas used in explosive engines are NATURAL GAS, ACETYLENE, liberated by the action of water on calcium carbide; PRODUCER GAS, made by the limited action of air alone upon incandescent fuel; WATER GAS, made by the action of steam alone upon incandescent fuel; SEMI-WATER GAS, made by the action of both air and steam upon incandescent fuel—also named DOWSON GAS in England.

Natural Gas.

The constituents of natural gas varies to a considerable extent in different localities. The following is the analysis ot some of the Pennsylvania wells:

NATURAL GAS CONSTITUENTS, BY VOLUME.

Constituents.	Olean, N. Y.	Pitts-burg, Pa.	Leech-burg, Pa.	Harvey well, Butler county.	Burns well, Butler county.
Hydrogen, H	....	22.00	4.79	13.50	6.10
Marsh gas, CH_4	96.50	67.00	89.65	80.11	75.44
Ethane, C_2H_4	....	5.00	4.39	5.72	18.12
Heavy hydrocarbons	1.00	1.00	56		
Carbonic oxide, CO	.50	.60	.26	trace.	trace.
Carbonic acid, CO_2	....	.60	.35	66	.34
Nitrogen, N	....	3.00			
Oxygen, O	2.00	.80			
	100.00	100.00	100.00	100.00	100.00
Heat units, cubic feet, Fah. =	....	892	1051	959	1151

Density, 0.5 to 0.55 (air 1).

The calorific value of natural gas in much of the Western gas fields is below these figures.

In experiments recorded by Brannt, "Petroleum and Its Products," with the *oil gas* as made for town lighting in many parts of the United States, of specific gravity about 0.68 (air 1), mixtures of oil gas with air had the following explosive properties:

Oil gas, volumes.	Air, volumes.	Explosive effect
1	4.9	None.
1	5.6 to 5.8	Slight.

Oil gas, volumes.	Air, volumes.	Explosive effect.
1	6 to 6.5	Heavy.
1	7 to 9	Very heavy.
1	10 to 13	Heavy.
1	14 to 16	Slight.
1	17 to 17.7	Very slight.
1	18 to 22	None.

It will be seen that mixtures varying from 1 of gas to 6 of air, and all the way to 1 of gas to 13 of air, are available for use in gas engines for the varying conditions of speed and power regulation; and that 1 of gas to from 7 to 9 of air produces the best working effect. Its calorific value varies in different localities from 550 to 650 heat units per cubic foot. Ordinary oil illuminating gas varies somewhat in its constituents, and may average: Hydrogen, 39.5; marsh gas, 37.3; nitrogen, 8.2; heavy hydrocarbons, 6.6; carbonic oxide, 4.3; oxygen (free), 1.4; water vapor and impurities, 2.7; total, 100; and is equal to 617 heat units per cubic foot.

Producer Gas.

The constituents of producer gas vary largely in the differeut methods by which it is made; in fact, all of the following gases are made in producers, so called. The constituents of the low grade of this name are:

Carbonic oxide, CO	22.8	per cent.
Nitrogen, N	63.5	"
Carbonic acid, CO_2	3.6	
Hydrogen, H	2.2	"
Marsh gas (methane), CH_4	7.4	
Free oxygen, O	.5	
	100.0	

The average heating power of this variety of producer gas is about 111 heat units per cubic foot.

0.66 to 0.70; naphtha "B" (ligroine), boiling at from 200° to 240° F., specific gravity 0.71 to 0.74 naphtha "A" (putzoel), boiling at from 250° to 300° F.

The commercial gasoline of the American trade is a combination of the above fractional distillates, boiling at from 125° to 200° F., specific gravity 0.63 to 0.74.

Kerosene, boiling at from 300° to 500° F., specific gravity 0.76 to 0.80.

Gas oil, boiling at above 500° F., specific gravity above 0.80.

Crude petroleum, boiling uncertain from its mixed constituents, specific gravity about 0.80.

The vapor of commercial gasoline at 60° F. is equal to 130 volumes of the liquid, sustains a water pressure of from 6 to 8 inches, and will maintain a working pressure of 2 inches, or equal to any gas service when the temperature is maintained at 60° F., and with an evaporating surface equal to 5¼ square feet per required horse-power, using proportions of 6 volumes of air to 1 volume of gasoline vapor.

Commercial kerosene requires a temperature of 95° F. to maintain a vapor pressure of from ¼ to ½-inch water pressure, requiring a much larger evaporating surface than for gasoline. It may be vaporized by heat from the exhaust, and is so used in several types of oil engines.

TABLE IV.—PERCENTAGE, SPECIFIC GRAVITY, AND FLASHING POINT OF THE PRODUCTS OF PETROLEUM.

Products.	Per cent. of each.	Specific gravity.	Flashing point, Fah.
Rhigolene and chimogene	Trace.		
Gasoline	.02	0.650	10°
Benzine naphtha	.10	0.700	14
Kerosene, light	.10	0.730	50
Kerosene, medium	.35	0.800	150
Kerosene, heavy	.10	0.890	270
Lubricating oil	.10	0.905	315
Cylinder oil	.05	0.915	360
Vaseline	.02	0.925	
Residuum and loss	.16		
	1.00		

Crude petroleum and kerosene are available also by injection in a class of oil engines of the Hornsby-Akroyd type, in which the oil can be so atomized and vaporized as to make its entire volume available as an explosive combustible, in order that the accumulation of refuse shall be at a minimum. Crude oil is also used in the "Best" oil-vapor engine.

ACETYLENE GAS.

FOR EXPLOSIVE ENGINES.

Much interest has been lately shown and some experiments made in regard to the availability of carbide of calcium for generating acetylene gas as a fuel in the motive power of the horseless carriage and launches. Liquid acetylene has been also suggested as the acme of concentrated fuel for power.

The gas liquefies at — 116° F. at atmospheric pressure, and at 68° F. at 597 lbs., per square inch. Its liquid volume is about 62 cubic inches per pound.

The specific gravity of gaseous acetylene (C_2H_2) is .91 (air 1), and its percentage of carbon .923, and of hydrogen .077. Its great density as compared with other illuminating gases and the large percentage of carbon is probably the source of its wonderful light-giving power.

It is credited by hydrocarbon heat values with 18,260 thermal units per pound of the gas (14½ cubic feet) and 1259 thermal units per cubic foot.

One volume of the gas requires 2½ volumes of oxygen for perfect combustion, which is equivalent to 12½ volumes of air, provided that all the oxygen of the air can be utilized in the operation of a gas engine; probably the best and most economical effect can be had from the proportion of 1 of acetylene to 14 or 15 of air. This proportion has been used in Italian motors with the best effect.

One pound of calcium carbide will yield 5¾ cubic feet of acetylene gas, and requires a little over a half pound of water to completely liberate the gas, so that where weight is a factor, as with carriages, tricycles and bicycles, the output of gas will be but 3.83 cubic feet per pound of generating material. The large proportion of air required for perfect combustion makes a favorable compensation for the necessity for carrying water for generating the gas, as compared with gasoline, which yields but 2.8 cubic feet of vapor per liquid pound with its best explosive effect of 9 volumes of air to 1 volume of vapor.

In liberating the gas from carbide in a close vessel the pressure may rise to a dangerous point, depending upon the clearance space in the vessel, say from 300 to 800 lbs. per square inch. In this manner a few accidents have occurred.

One pound of liquid acetylene, when evaporated at 64° F., will produce 14½ cubic feet of gas at atmospheric pressure, or a volume 400 times larger than that of the liquid. Its critical point of liquefaction is stated to be 98° F.; above this temperature it does not liquefy, but continues under the gaseous state at great pressures.

The heat unit value of acetylene gas from its peculiar hydro carbon elements, it will be seen, is far greater than that of gasoline vapor per cubic foot, but experiments seem to have cast a doubt upon the theoretical value, and assigned a much less amount, or about 868 heat units per cubic foot.

As the comparative volume of explosive mixtures of gas or vapor and air is largely in favor of acetylene over gasoline, and as the weight of material for a given horse-power per hour also favors the use of acetylene, it will no doubt become a useful and economical element of explosive power for vehicles and launches; always provided that the commercial production of carbide of calcium becomes available as a merchandise factor in cities and towns.

The explosive mixture of acetylene and air spontaneously fires at lower temperatures than illuminating gas mixtures; it varies from 509° to 515° F., while illuminating gas mixtures range from 750° to 800° F. Claims of a higher temperature have been made.

In the use of liquid acetylene, the cost of liquefying the gas may be a bar to its ordinary use, but for special purposes there are possibilities that only future experiments and trials may develop into useful work from this unique element. In trials of acetylene for power in gas engines, made in Paris, France, it was found that a much less volume of acetylene was required for equal work with illuminating gas and that it was a practical explosive fuel. The only change required was found to be a more perfect regulation of the valve movement, or a smaller valve to meet the smaller volume of acetylene. In these experiments the explosive mixture was approximately 10 parts air to 1 part acetylene; and using from 4 to 7 cubic feet of gas per horse-power per hour.

From another account of trials in France, it appears, as the result of experiments made by M. Ravel, that 6.35 cubic feet of acetylene gas generate 1 horse-power per hour, which is equivalent to a reduction of two-thirds as compared with petroleum. As to the explosiveness of mixtures of air and acetylene, it was found that 1.35 parts of this gas mixed with 1 part of air began to be explosive, the explosive force of such mixture rising rapidly as the dilution with air increases, attaining finally a maximum when there are 12 volumes of air with 1 volume of acetylene; then as the proportion of air is increased beyond this limit, the explosive force subsides, until at 20 to 1 it becomes entirely extinct. The flashing point approximates 900° F., whereas in the case of most other gases used to generate power the requisite ignition temperature is about 1100° F. The temperature of combustion is very much higher than that of the other gases with which it can be compared. The special characteristics of this gas, therefore, are great rapidity of the transmission of flame, low ignition temperature, high combustion temperature and extraordinary energy evolved in the explosion.

For comparison of gasoline and acetylene, a series of tests were made with mixtures of air and vaporized gasoline in the ratio 4 to 1, which gave the greatest explosive pressure, 165 pounds, at initial pressure of 20 pounds. At the same initial pressure the 9 to 1 mixture of air and acetylene produced a pressure $\frac{273}{165}$ greater than that by the gasoline, so that the volume of acetylene to give the same pressure need only be $\frac{1}{2} \times \frac{165}{273} = 0.304$ of the gasoline.

Taking the theoretical indicator diagrams for the explosion of these two mixtures, the area of the acetylene diagram measured 4.91 square inches, and that of gasoline 1.79 square inches, giving a ratio of power nearly 3 to 1. Indicator diagrams show that the time-rate of the acetylene explosion is five times faster than that of the mixture of gasoline and air. As vaporized gasoline acts more slowly than acetylene, the practical test makes acetylene (mixture 9 to 1) 3.28 times more powerful than gasoline (ratio of 4 to 1), whereas theoretically it should be only three times as great.

The calorific value of the acetylene used was 1,350 thermal units and that of gasoline 700 heat units per cubic foot. A cubic foot of each of the above mixtures at initial atmospheric pressure would give 90 pounds and 43 pounds per square inch respectively. Allowed to expand adiabatically to 10 cubic feet, the calculated external work,—

$$W = \frac{p_1 v_1}{K - 1} \left\{ 1 - \left(\frac{v_1}{v_2} \right)^{K-1} \right\}, \text{ (where } K = 1.405\text{)},$$

would be for acetylene 22,403 foot pounds, and for gasoline 12,132 foot-pounds. But only 0.0625 cubic feet of acetylene was used, while 0.20 cubic feet of gasoline vapor was needed, or 3.2 times as much. With the given ratios of mixtures only 0.0312 cubic feet of acetylene is required to do the same work that 0.20 cubic feet of vaporized gasoline will do. Or comparing equal quantities of the two gases, acetylene has about 6.5 times the intrinsic energy of vaporized gasoline at the given ratios of air and gas.

Assuming an engine of total efficiency from fuel to useful work of 15 per cent., and a consumption of 22 cubic feet of gasoline vapor per H.P. per hour, the cost of 1 H.P.-hour would be 1.3 cents, at 58 cents per 1,000 cubic feet of vaporized gasoline. The cost per H.P. per hour for acetylene in an engine of equal efficiency would be 2.6 cents, with acetylene $8 per 1,000 cubic feet, or 4 cents per pound. To do the same work with acetylene in place of vaporized gasoline, therefore, would be about twice as expensive. For this reason acetylene would only be of practical use to produce power where safety and light compact engines were required, as in automobiles and launches. In the event of a 50 per cent. reduction in the price of calcium carbide, however, it might probably come into more general use for gas engines.

ALCOHOL AS A MOTIVE POWER.

For some time past the French public has been studying a question interesting from the standpoint of the engineer, important from an economical point of view; the question of alcohol in its domestic and industrial applications. Among the latter the utilization of this combustible in explosive motors is the most interesting, and this is why the experiment has been tried of substituting for imported gasoline a national product resulting from French or colonial crops. One of the unquestioned advantages of alcohol over gasoline is that alcohol is a fixed product, whatever may be its use. The same alcohol for motive purposes can therefore be produced in any part of the globe, and its origin is revealed only by special aromas, which are of no consequence when it is used as a motive force.

If the consumption of alcohol motors is compared with that of gasoline it is seen at once that the former consumes considerably more than the latter; and as the alcohol is the more costly of the two combustibles, the problem would seem *a priori* insoluble from an economic point of view.

Since denatured alcohol contains 4,172 heat units per pound, while gasoline contains 11,000, it has been found necessary to raise the calorific power of the former and at the same time lower its price, and so it has been mixed with high grade gasoline of 70 degs. gravity, which contains about 11,000 heat units per pound, and which can be produced under good conditions at a low net cost. Mixtures containing from 50 per cent. to 75 per cent. of alcohol have been used; but it is the 50 per cent. mixture, which has a calorific power of 7,586 heat units per pound, which seems to be the most advantageous at the present state of development. From the result of numerous trials made in France it has been found that the consumption of 50 per cent. carburetted alcohol is nearly the same as that of gasoline for a given power, and this notwithstanding the difference in the theoretical calorific powers of the two combustibles, from which it follows that the efficiency of the alcohol motor is greater than that of the gasoline.

Some very exact experiments made by Prof. Musil at Berlin have shown the efficiency of various kinds of motors to be as follows: Motors run on city gas (according to the type), 18 to 31 per cent.; portable steam motors, 13; kerosene motors, 13; gasoline motors, 16; alcohol motors (mean figure), 23.8 per cent.

The high efficiency is evidently due to the great elasticity derived from the expansion of the water vapor that is contained or produced by the alcohol at the moment of its combustion, this expansion tending to make the explosions in the cylinders less violent than when gasoline is used, and thus giving a longer life to the wearing parts of the motor. So much has this been found to be the case that in order to increase the beneficial action of the water vapor the German Motor Construction Company, of Marienfeld, recommends a mixture containing 20 per cent. of water, and it has built motors to run on such a mixture that consume only .17 pound per horse-power-hour. The fact must not be overlooked that in order to secure good efficiency with either pure or carburetted alcohol recourse must be had to specially con-

CHAPTER IX.

CARBURETTERS.

THE use of the vapor of gasoline, naphtha, and petroleum oil for operating internal-combustion engines is increasing to a

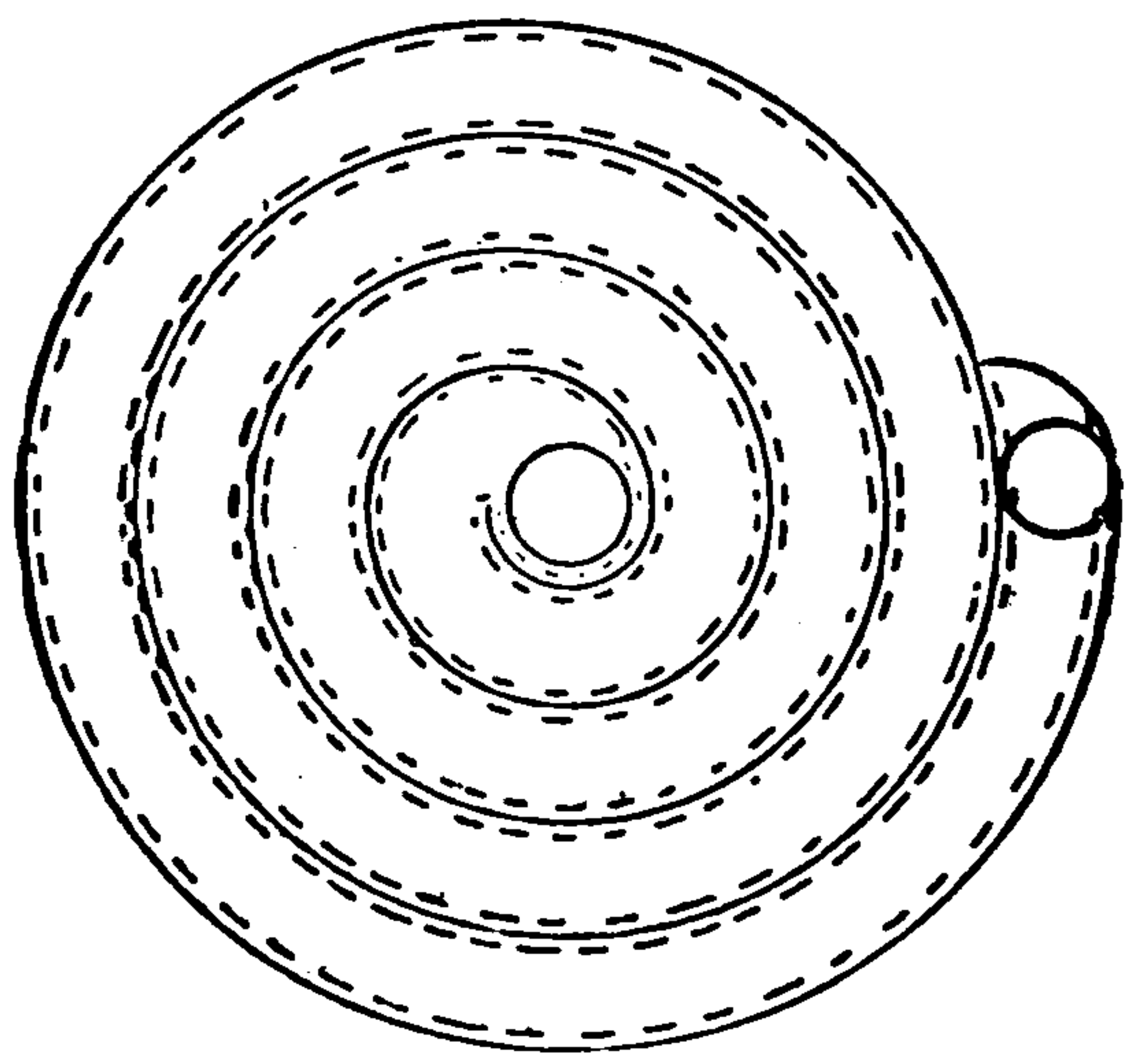


FIG. 14.—THE CIRCULAR CARBURETTER, PLAN.

vast extent in all parts of the civilized world, and will be no doubt the cheapest medium for generating power so long as petroleum and its products are at the present low price. In

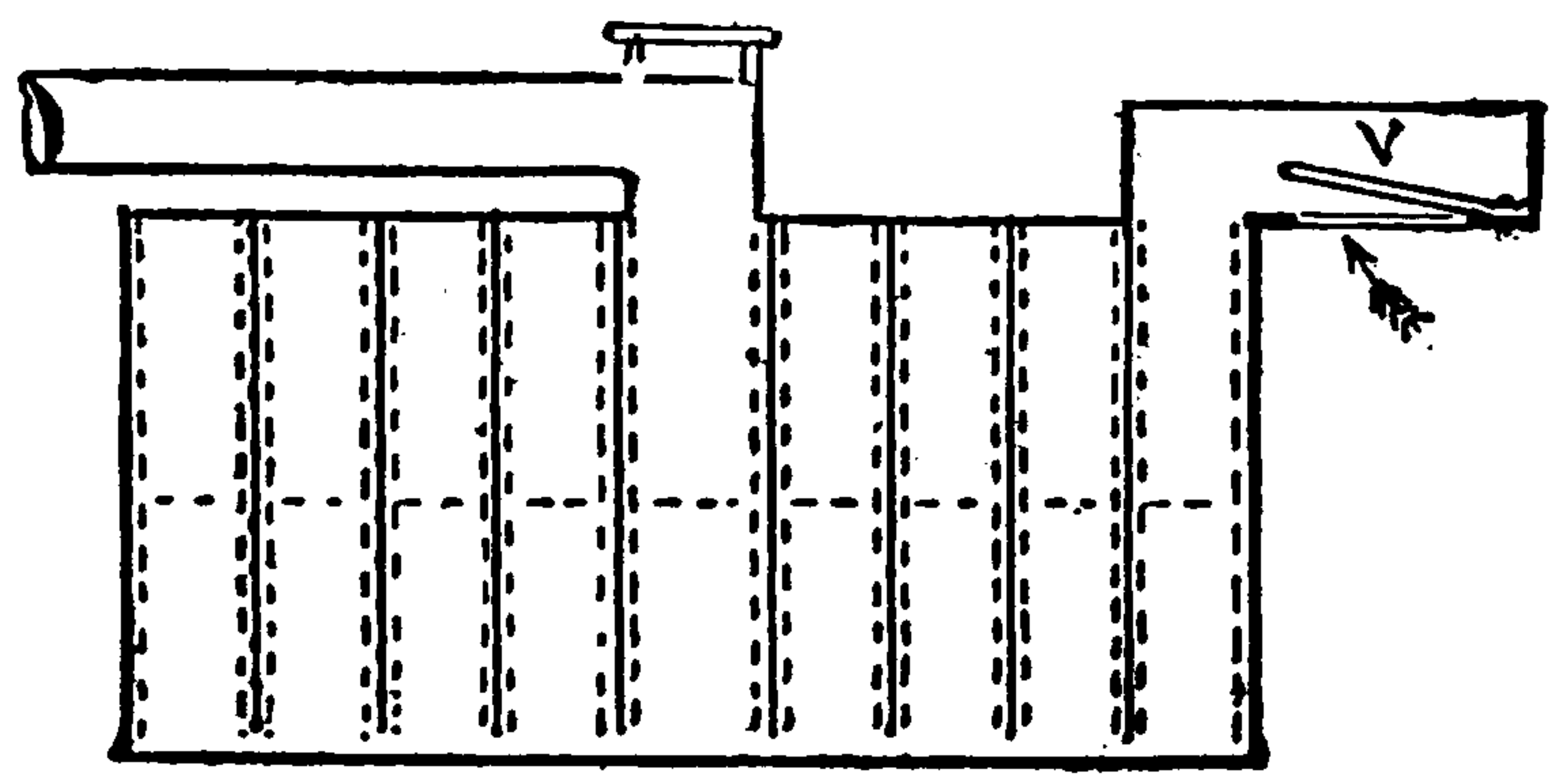


FIG. 15.—THE CIRCULAR CARBURETTER, SECTION.

gas-engine running, air saturated with the vapor of gasoline and naphtha is in general use, and when so used is produced by passing air through the liquid or over a surface largely extended by capillary attraction of the fluid by fibrous surfaces dipping into the fluid, by vaporizing the fluid by means of the heat of the exhaust, and by injecting the fluid in small portions into the air-inlet chamber or under its valve, and directly into the clearance space of the cylinder.

In Figs. 14 and 15 is illustrated a form of carburetter,

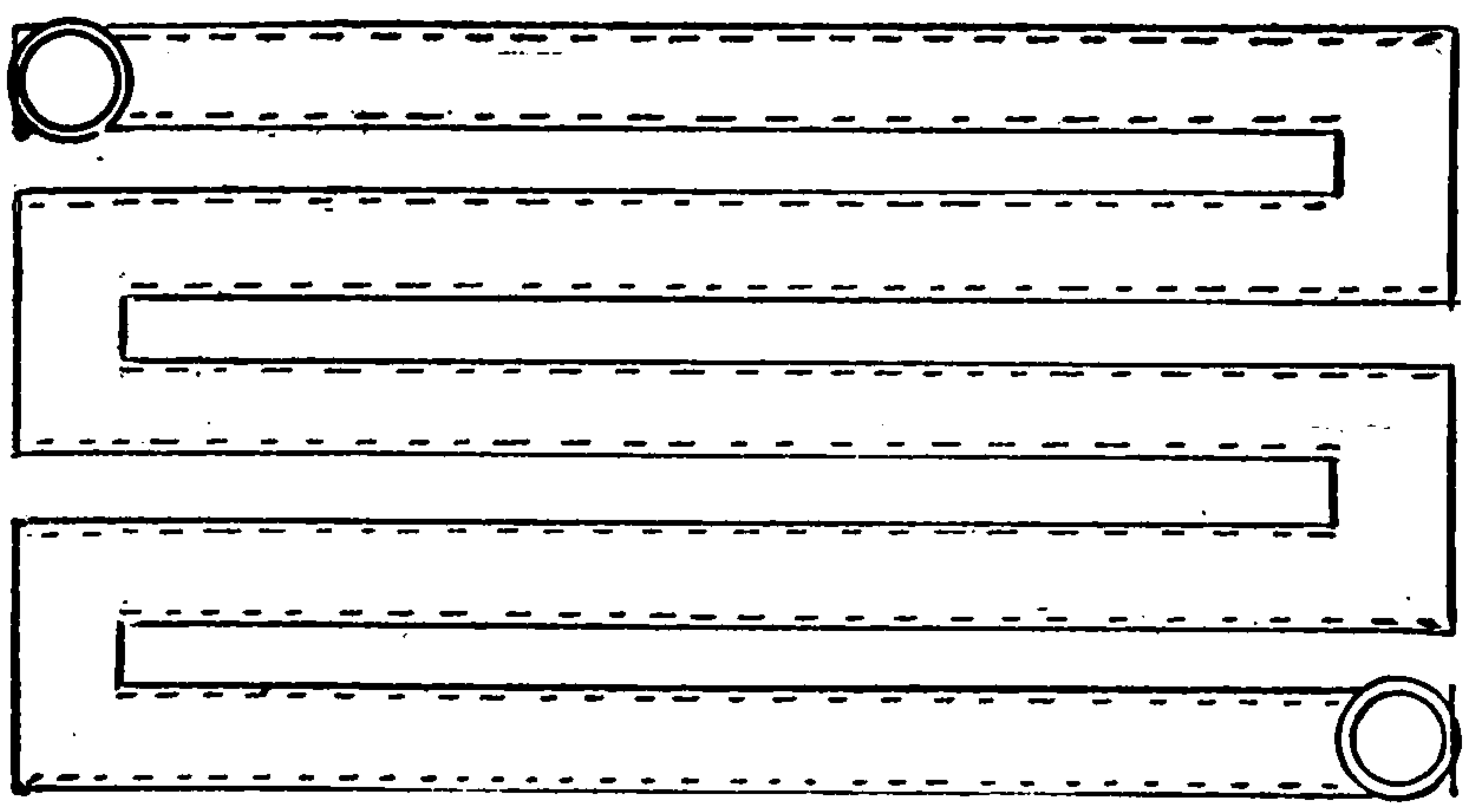


FIG. 16.—PLAN OF VENTILATING CARBURETTER.

made by the writer many years since, for carburetting air and low-grade illuminating gas.

This carburetter may be made of heavy tinplate. The spiral partition, made of tinplate, is perforated with sufficient small holes at top and bottom to fasten strips of cotton or woollen flannel on both sides of the spiral plate by stitching with coarse

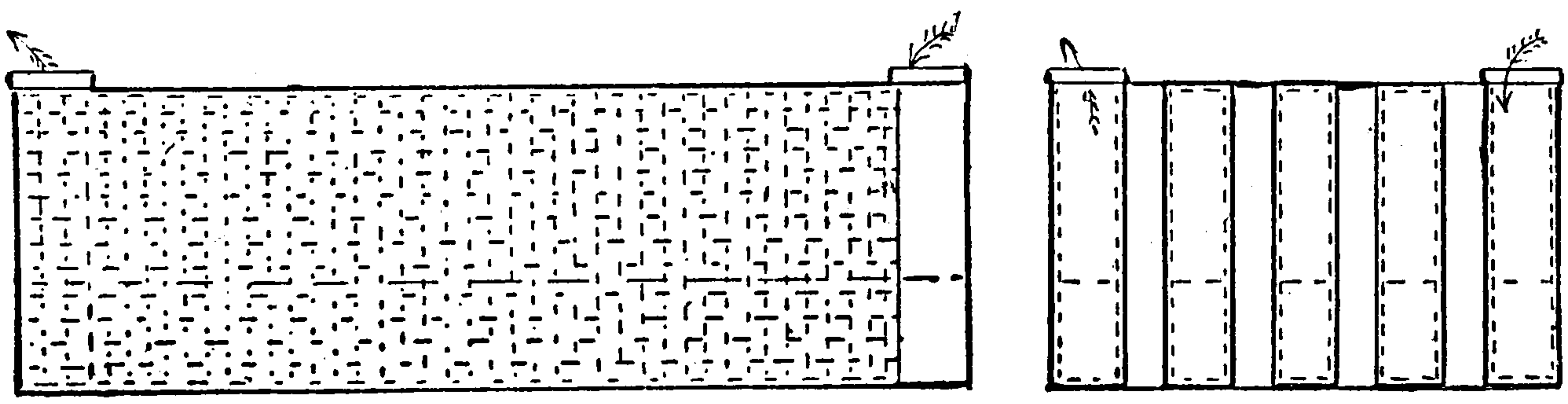


FIG. 17.—SECTIONS OF VENTILATING CARBURETTER.

thread and needle. The spiral plate should extend so as to nearly touch the bottom of the tank; the bottom is to be soldered on last. The valve V, for the purpose of preventing the escape of the vapor when the carburetter is not in use, may be made as light as possible, of tin plate or brass, and faced with soft leather wet with glycerin or a composition of glycerin and glue jelly, which always keeps soft and is not injured by the gasoline or its vapor. By this arrangement many square feet of surface may be obtained in a small space and perfect uniformity of saturation insured. As the enclosed walls of this form become very cold by long-continued use, an improvement was made by

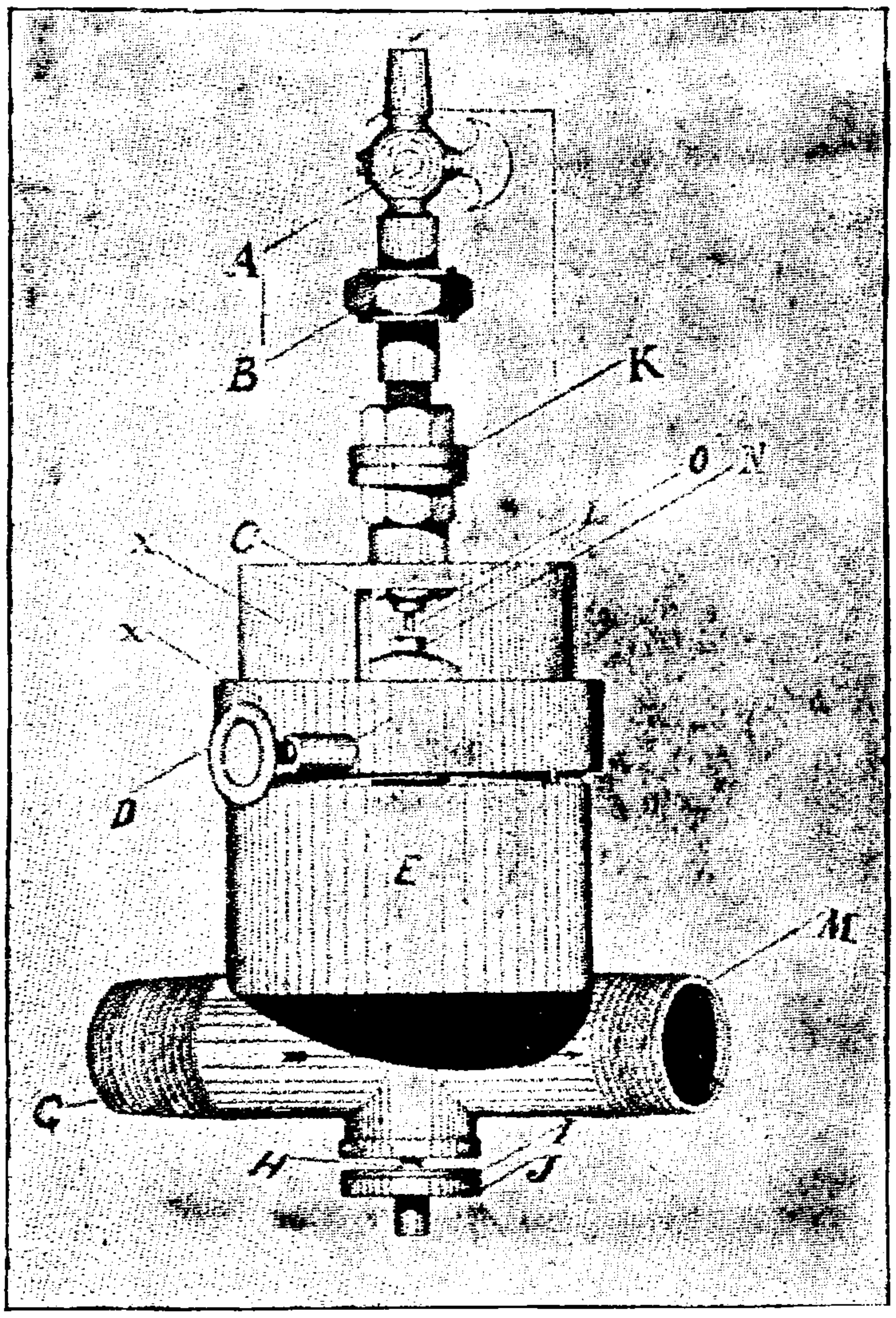


FIG. 18.—UNION AND GLOBE ENGINE VAPORIZER.

making each division wall with an outside surface, so that there was a natural down-draught of air on the outside of the entire evaporating surface of the carburetter. In Figs. 16 and 17 are shown the plan and sections.

In this form the air spaces prevent excessive cold by a circulation of air downward against the cooling surface of the walls—the whole interior vertical walls being lined with cloth fastened to a wire frame made to fit each section and pushed into place before the ends of the sections are soldered on.

Very good carburetters have been made by a long cast-iron

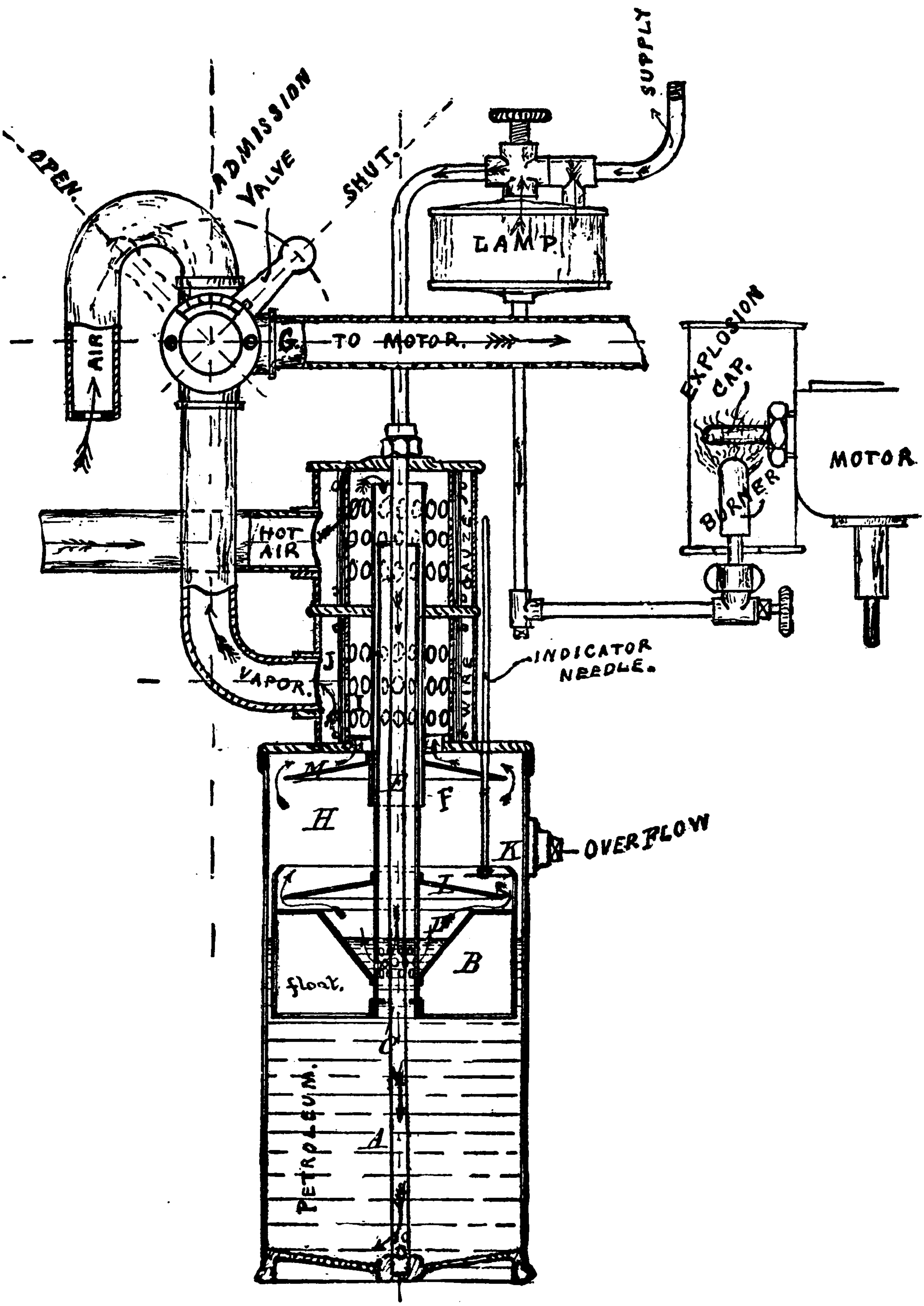


FIG. 19.—THE DAIMLER CARBURETTER.

box with a cover bolted on with a packing of glue and glycerin jelly on felt or asbestos packing, in which a frame of wire-work and cloth or yarn is made to give the desired evaporating surface.

For any carburetter of the forms here described, the depth should be limited to 8 inches, as the capillarity of the fibrous material is of little or no value at a greater height than 6 inches above the fluid, which should not be charged above 3 inches in depth for best effect.

In Fig. 18 is represented a vaporizer used by the Globe Gas Engine Company of Philadelphia. It consists of a metal body E, inside of which is a ball-shaped valve N, seated on the end of a tube with its spindle extending below the air pipe and attached to a disc at J for regulating the lift of the air and gasoline valve; O is spindle of gasoline valve. The gasoline tank is so placed as to flow the liquid to the vaporizer. The air is heated by passing through a jacket on the exhaust pipe.

Fig. 19 represents a sectional view of the Daimler carburetter. The incoming air is heated by passing through a jacket on the exhaust pipe, and charged to saturation with vapor in the carburetter, the saturated air charge being regulated by a three-way cock, which allows a further dilution with air for the explosive mixture.

The gasoline supply is made through the small central tube to the bottom of the carburetter, which insures a uniform density in the fuel. The float B by its weight keeps a constant level in the conical cup D, where evaporation takes place. The float and its guide-pipe move down as the gasoline is used. The hot air passes down through the guide-tube and out through the perforation beneath the fluid in the conical cup D, then over two diaphragms, and through the perforated screen and to the vapor tube. The perforated screen in both inlet and outlet chamber prevents the jerky motion of the air caused by the suction of the piston. The lettering in the cut fairly explains the ignition arrangement.

In Fig. 20 is represented the carburetter of the Gilbert & Barker Manufacturing Company, Springfield, Mass. It is made of wrought iron, has four divisions, in which perforated capillary partitions are set around each division or story of the carburetter, thus greatly enlarging the evaporating surface. The air enters the lower compartment, becomes saturated, and leaves the carburetter from the top. Provision is made for

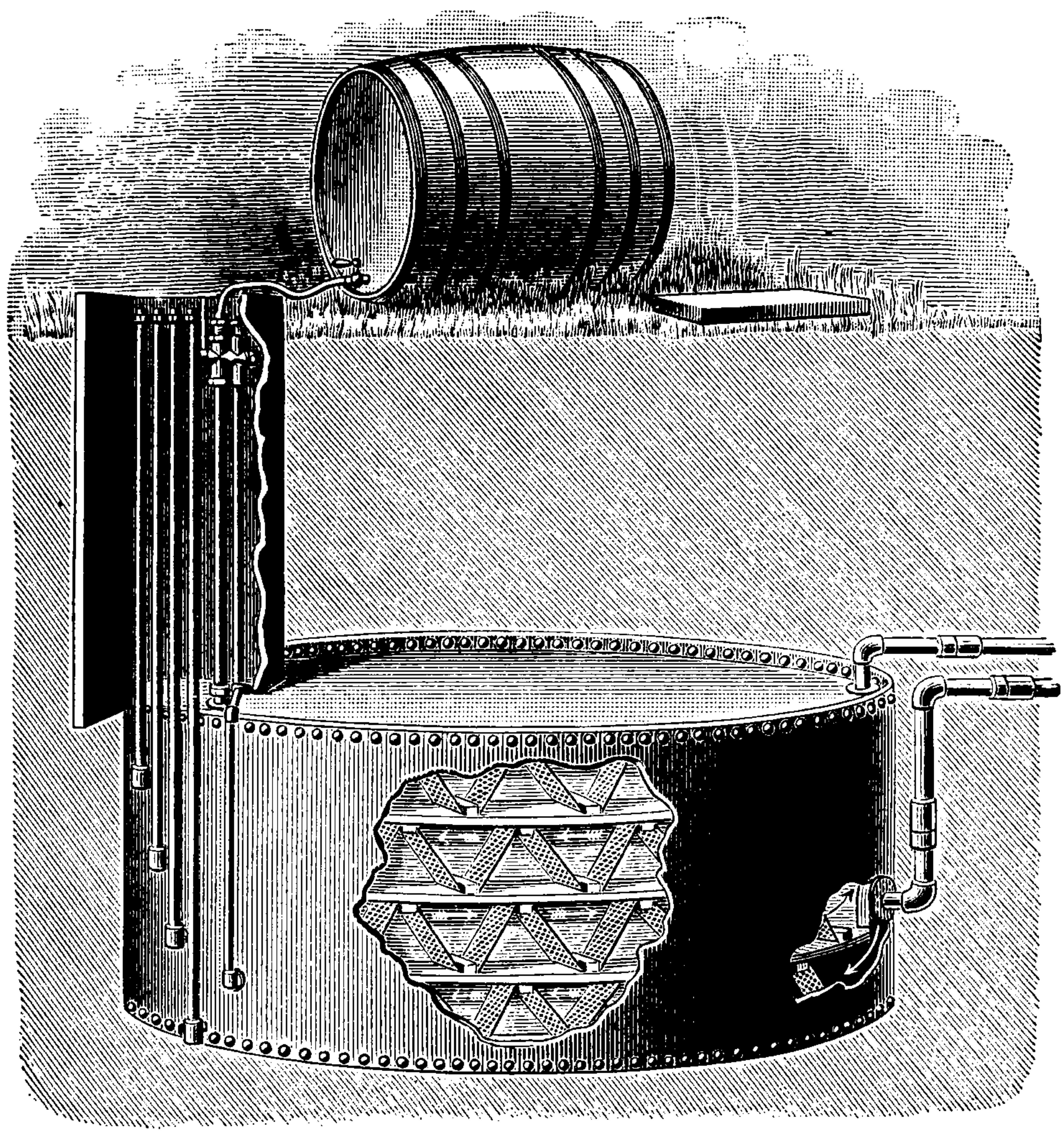


FIG. 20.—GILBERT & BARKER CARBURETTER.

pumping out any residue that may require removal when the carburetter is placed underground.

Many other forms of carburetter have been tried, without, however, securing better results than with those here described.

Saturated air with gasoline vapor has a heat value of about 200 heat units per cubic foot.

A claim has been made in France that by saturating part of the exhaust and by heating the gasoline, also by the exhaust, a concentrated vapor was produced, which, used with the air, produced a power value of $\frac{2}{100}$ of a gallon of gasoline per horse-power per hour. We await its confirmation. There is no doubt that greater economics are in progress in the operation of gasoline and oil engines; but the use of part of the products of combustion from the exhaust tends to lessen its value, if it has a value above its use as a part of the contents of the clearance space now in use in engines of the compression class.

The evaporation of gasoline of 74 specific gravity at a temperature of 60° F. varies somewhat from the form of its elementary constituents; so that an average of 1,173 grains per square foot of saturated surface per hour in the open air may be assumed as the basis for carburetting surface.

When evaporated in a closed vessel, as a carburetter, the vapor may start at about 1,000 grains per square foot of surface per hour; but if the area of evaporating surface is so extended that little or no tension or pressure is produced by its evaporation, due to the draught upon it by the motor, and the temperature of the gasoline is kept near to 60° F., the evaporation may be relied on at about 800 grains per square foot per hour.

This gives a basis for computing the area of carburetted surface at any assumed consumption of gasoline per horsepower per hour. For example, gasoline weighing 6 lbs. per gallon, with an assumed requirement of $\frac{1}{10}$ of a gallon per horse-power per hour, and an evaporation of 800 grains per hour per square foot, will require $\frac{\frac{6}{10} \times 7000}{800} = 5\frac{1}{4}$ square feet of evaporating surface in the carburetter per horse-power.

With our present experience there is no doubt in regard to the advantage, economy and safety in the use of carburetters for gasoline, in which the air becomes thoroughly saturated with the gasoline vapor before it meets the free air at the charging valve. Air saturated with gasoline vapor is not explosive, and is considered in practice to be as safe in pipes and gas holders as any other gas used for illuminating purposes. It does not become explosive until further diluted to 5 parts of air to 1

struction in the United States appears to be increasing in the line of more perfect mixture of the explosive fuel before injection into the cylinder; and to this we probably owe the possibilities now claimed of from 12 to 14 cubic feet of good illuminating gas, and $\frac{1}{10}$ of a gallon of gasoline per indicated horse-power per hour, and which in some cases has raised the pressure of explosion to $3\frac{7}{10}$ times the pressure of compression in four-cycle engines.

In Fig. 20 A is illustrated a novel atomizer and vaporizer for a marine engine. The rising vapor pipe is shortened in the cut for the convenience of illustration.

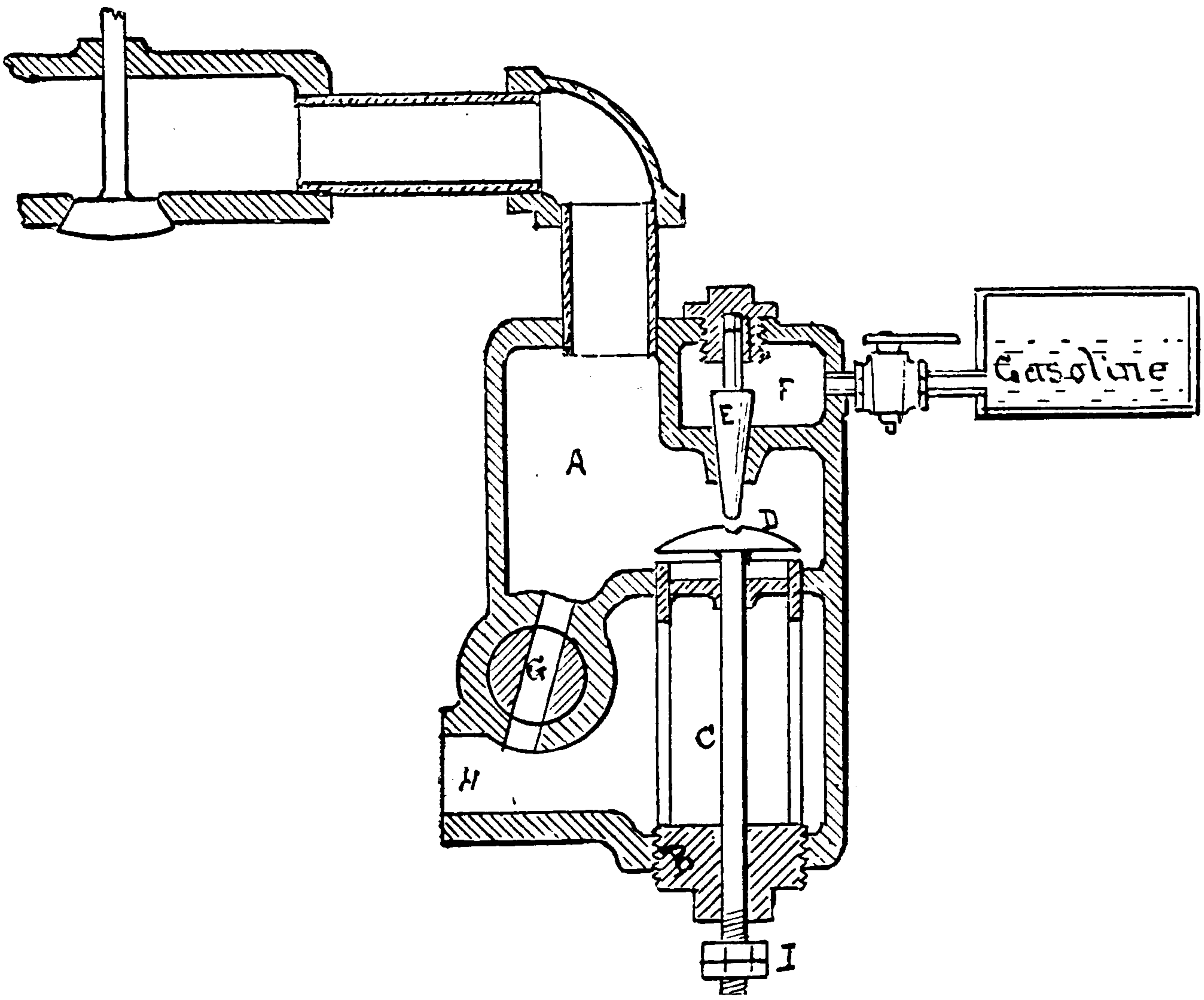


FIG. 20A.—GASOLINE ATOMIZER AND VAPORIZER.

The gasoline tank is placed in the bow of the boat and the atomizer at the base of the engine. The gasoline flows to the chamber F by gravity and is stopped by the deep-seated conical valve E. The cage of the air inlet valve D is screwed into the metal box at B and is adjustable so as to bring the push-cente of the valve D to the proper distance for operating the gasoline inlet valve E. The lift of the air valve D is also adjustable in its lift by the lock-nuts at I on the spindle C, which is guided by a cross-bar near the top of the cage. The main air inlet is at H with a diffusion inlet at G regulated by a plug-cock. The gasoline is thoroughly atomized by the action of the two valves E and D, and meeting the fresh air through G is vaporized in its passage through the pipe and inlet-valve chamber.

VAPOR GAS FOR EXPLOSIVE MOTORS.

Much of the risk and inconvenience of handling gasoline for motive power may be avoided by using the mixture of air and gasoline vapor as a gas, and under the same conditions at the motor as with illuminating gas. Many power plants now utilize the vapor of gasoline generated at or in the immediate vicinity of the motor cylinder. This requires the presence of gasoline in quantity within the building, which largely increases the insurance risk, and is always a source of discussion and doubt with underwriters.

The vapor gas as now extensively used for lighting dwellings and factories has been brought to such perfection in its generation and application to lighting purposes, as well also to many other applications for heat generated by Bunsen and other forms of gas burners, that it may now be considered the most convenient form for a gas-generating system for isolated places, where an element is required for both lighting and power. The nncertainty of perfect diffusion of vapor and air in the present methods of producing the mixture of vapor and air near or within the cylinder cannot be considered the highest economy in the element of power production, in view of the assumed fact that commercial gasoline of an average of .75 gravity, weighing about 6¼ lbs. per gallon, is claimed by the builders of the most economical motors to require but ⅛ gallon per actual horse-power per hour. This is equal to .78 of a pound, and the pound is credited with 11,000 heat units, or 8580 heat units per horse-power per hour.

This at 774 foot pounds per heat unit is equal to 8,640,920 foot pounds per horse-power per hour. The actual or brake horse-power per hour is 1,980,000 foot pounds or .229 per cent. of the theoretical value of gasoline. With more perfect mixtures of vapor of gasoline and air the percentage in efficiency should

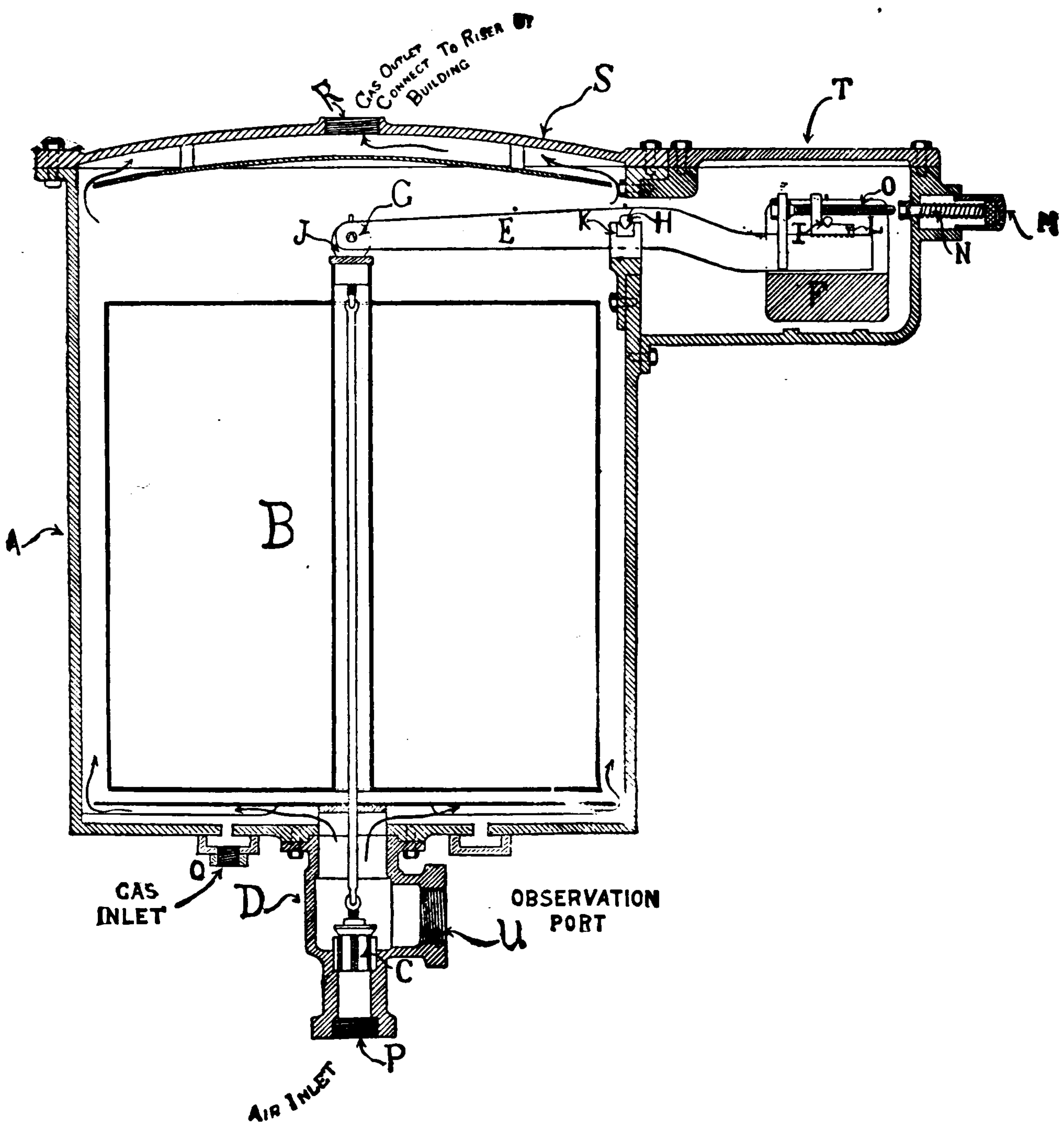


FIG. 20B.—THE DIFFERENTIAL GRAVITY REGULATOR.

be increased and a uniformity in the action of the motor obtained by a more perfect diffusion of the elements of combustion.

One of the means for automatically regulating the mixture of vapor and air is illustrated in the combined mixer and regulator of the Gilbert & Barker Mfg. Co., 82 John Street, New York, Fig. 20 B, and in Fig. 20 C, the mixer and meter air pump placed within a building. The carburetter, as shown in Fig. 20, p. 65, is placed in the ground or a vault outside of the building. The air is forced by the air meter pump at a low pressure (1 to 1½ inches water pressure) to the carburetter on the outside of the building and returned through another pipe, loaded with the vapor of gasoline, to the regulator, where, by a differential gravity balance, a supplementary valve is opened by which a direct current of air enters from the pressure pipe of the air meter pump and dilutes the direct vapor charge from the carburetter to a uniform mixture, and thus producing a constant flow of gas of a gravity for the best effect in lighting, and also, when further diluted at the inlet valve, for the best explosive effect in a motor.

The pure vapor of gasoline is of a gravity of 2.8 (air 1) and the air gas vapor as it comes from the carburetter may be of varying gravities from 2.5 to 1.5 (air 1), and it is the difference in the gravity of air and the heavier vapor of gasoline and air as it comes from the carburetter that operates the diluting mechanism of the apparatus to produce a mixture of uniform quality. For this purpose, the float B is a sealed metal can, containing air which with its weight and the air inlet valve C is exactly balanced by an adjustable counterpoise F and enclosed within a cast-iron case. The vapor gas enters at the bottom through an annular inlet Q from the carburetter and fills the case with a vapor mixture slightly heavier than the balanced can of air, which is thus caused to rise and open the direct air inlet valve C, admitting air at a slightly increased pressure, due to differential friction, as between the short-air connection with air pump and the long-pipe connection to the carburetter and back to the regulator.

By the delicate screw adjustment of the counterpoise weight at O the exact conditions for a uniform gravity gas supply may be obtained for lighting. This is assumed to be also the most economical for combustion in an explosive motor; it then requiring only the regulating admixture of air at the inlet valve of the motor cylinder for adjusting the force of explosion and for regulating the speed of the motor.

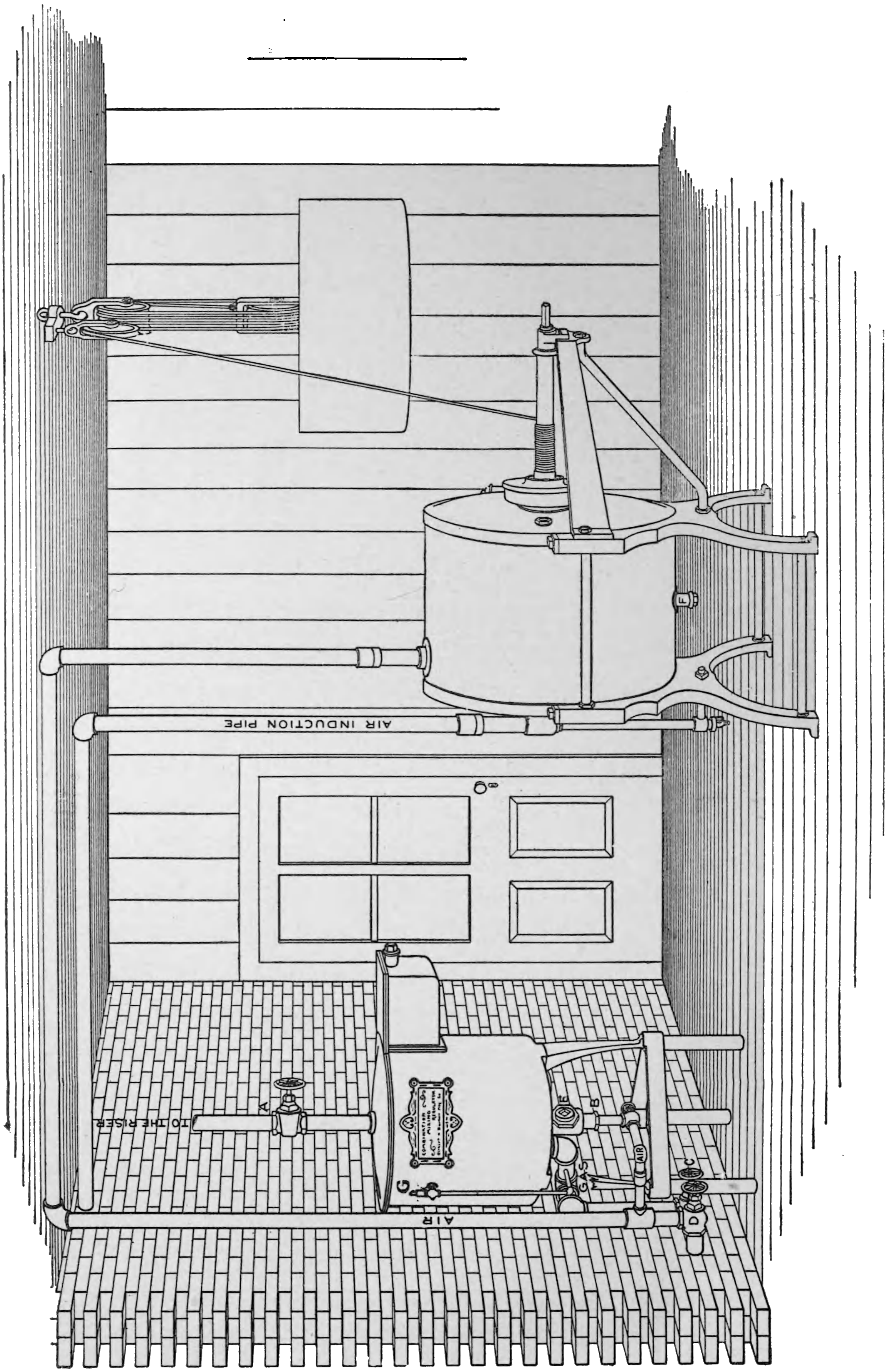


FIG. 20C.—THE METER AIR PUMP AND REGULATOR.

Fig. 20C shows the arrangement of setting the air pump and regulator with the short-circuit of the air pipe to give a preponderance to the air pressure at the regulating valve C. For motor service a gas equalizing bag should be used as with other kinds of gas supply.

A strong feature of this carburetter, as illustrated at page 65, is the large evaporating surface, it being in fact a compound generator consisting of a number of independent and perfect evaporators, one placed over the other. The effect of cold by evaporation commences at the bottom pan, and the saturation of the air is completed in the next pan, and so on successively, so that deterioration does not commence until the last or top pan is partially exhausted.

The air pump is of the wet gas meter type with the motion inverted and propelled by a weight as shown in Fig. 20C, or by a small overshot water wheel operated by a jet from any source of water pressure.

ATOMIZING CARBURETTERS AND VAPORIZERS.

In Fig. 20D is illustrated a heat vaporizer used on the "Capitaine" motor in which the inlet nozzle V is ribbed on the outside

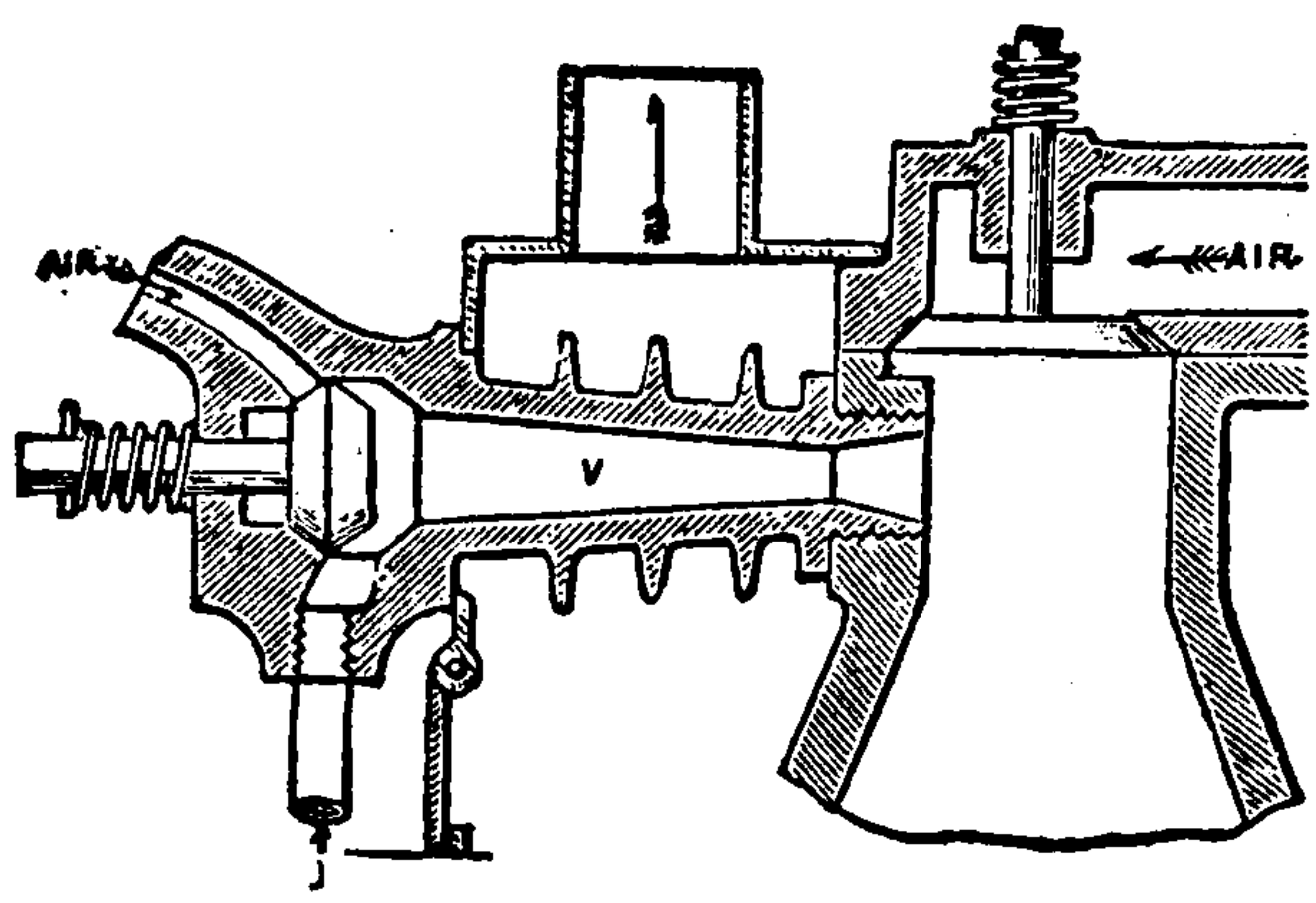


FIG. 20D.—HEAT VAPORIZER.

and is enclosed in a chamber through which the exhaust passes.

Gasoline and air are drawn into the nozzle regulated by the small valve, and additional air for the explosive mixture is drawn in by the piston through the large valve. By this arrangement the gasoline is broken up and thrown against the hot walls of the nozzle by the air drawn through the small air inlet.

The atomizing vaporizer (Fig. 20E) is conveniently placed on the side of a cylinder with the exhaust valve G spindle in line with the exhaust push rod.

The gasoline is injected through the small valve C, opened

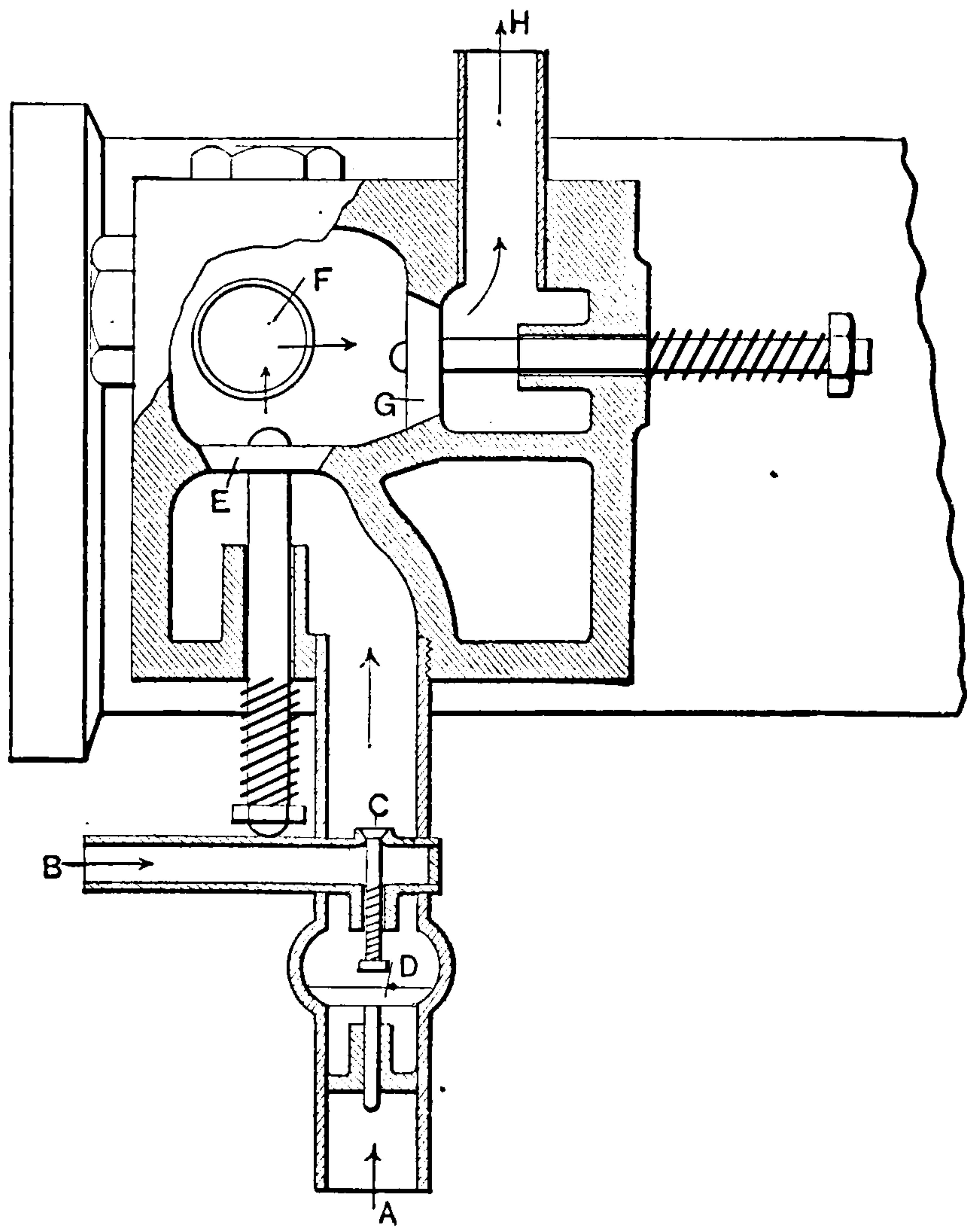


FIG. 20E.—ATOMIZING VAPORIZER.

by the lift of the air valve D. The inlet valve E makes a closure of the vaporizing chamber during the compression and exhaust stroke of the piston.

The constant-level feed atomizer (Fig. 20F) is of French origin and used on the "Abeille" automobile motor. It regulates its feed from a higher level reservoir or tank, by means of a float B in the receiver A, which, by its floating position, opens a small conical valve on the lower end of the spindle C through the opera-

which have screw needle valves for regulating the flow of gasoline. The inrush of air when the valve opens by the draft of the piston atomizes the inflowing gasoline and precipitates the atoms upon the deep wings of a fan *h* hung upon the central spindle *j*. The fan is set in motion by the inrush of air, and throwing the excess of gasoline against the hot walls of the annular exhaust chamber *a'f*, produces a perfect mixture of vapor and air before passing through the second inlet valve A. The exhaust in passing around the annular chamber also imparts heat to the annular gasoline

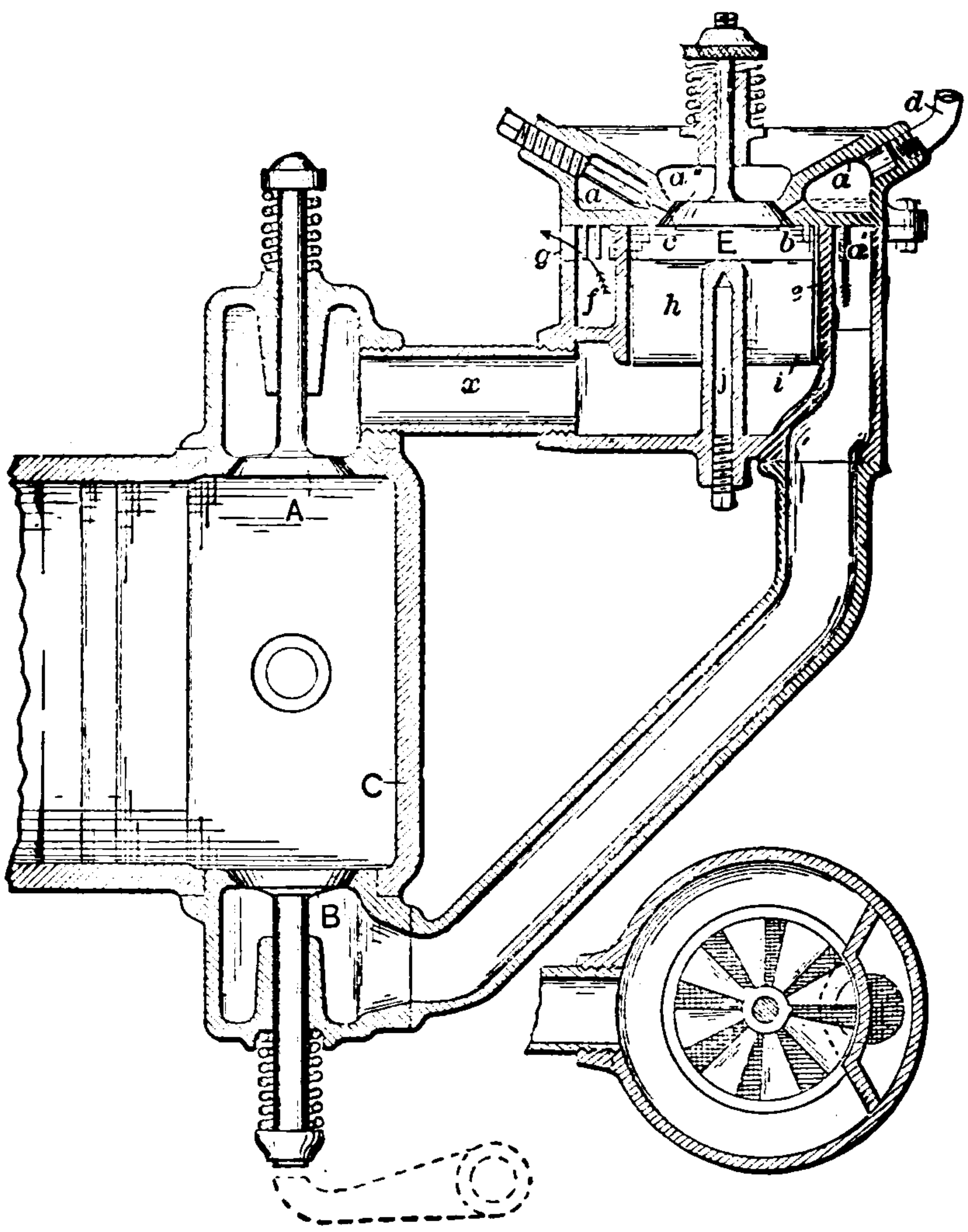


FIG. 20G.—THE "HAY" VAPORIZER.

chamber *aa'* and makes its final exit through the slotted apertures in the outer casing, as at *g*, or may pass into an exhaust-pipe.

We illustrate in Figs. 20H and 20I two forms of atomizers or mixing valves which have been designed for use on gasoline engines. They take the place of carburetters, and, for certain purposes, users have found them efficient and reliable. The construction of these valves is very simple. They have few parts, and there is no liability of their proving troublesome after having been used a short while.

Referring to the sectional views it will be seen that the valve disk E is held against its seat by a light spring M. The seat of this valve is wide, and the port opening slightly smaller in diameter than the pipe connections. The body of the valve L below the valve disk is of full area. At the side of the valve body is a gasoline inlet O tapped for ¼-inch pipe thread. From the side gasoline inlet O a passageway of ample area leads around and through the valve body and is in communication with the main

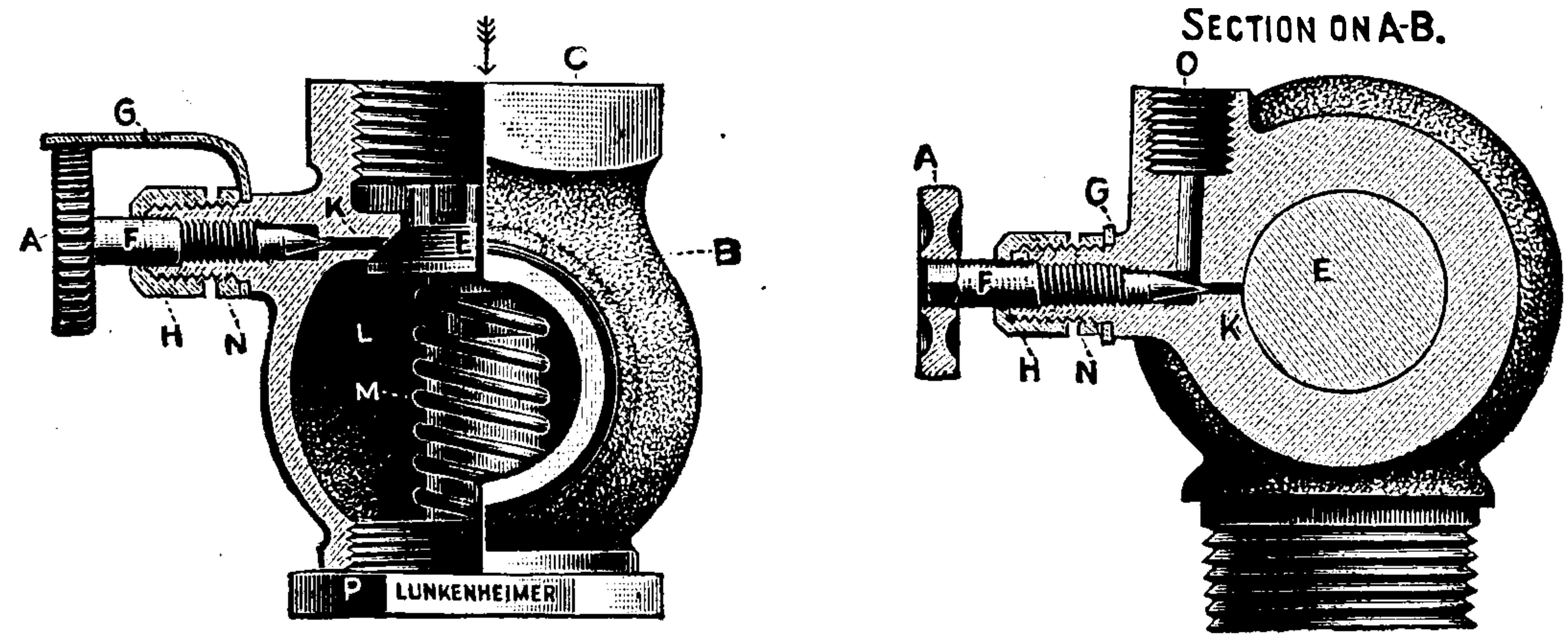


FIG. 20H.—ANGLE ATOMIZER.

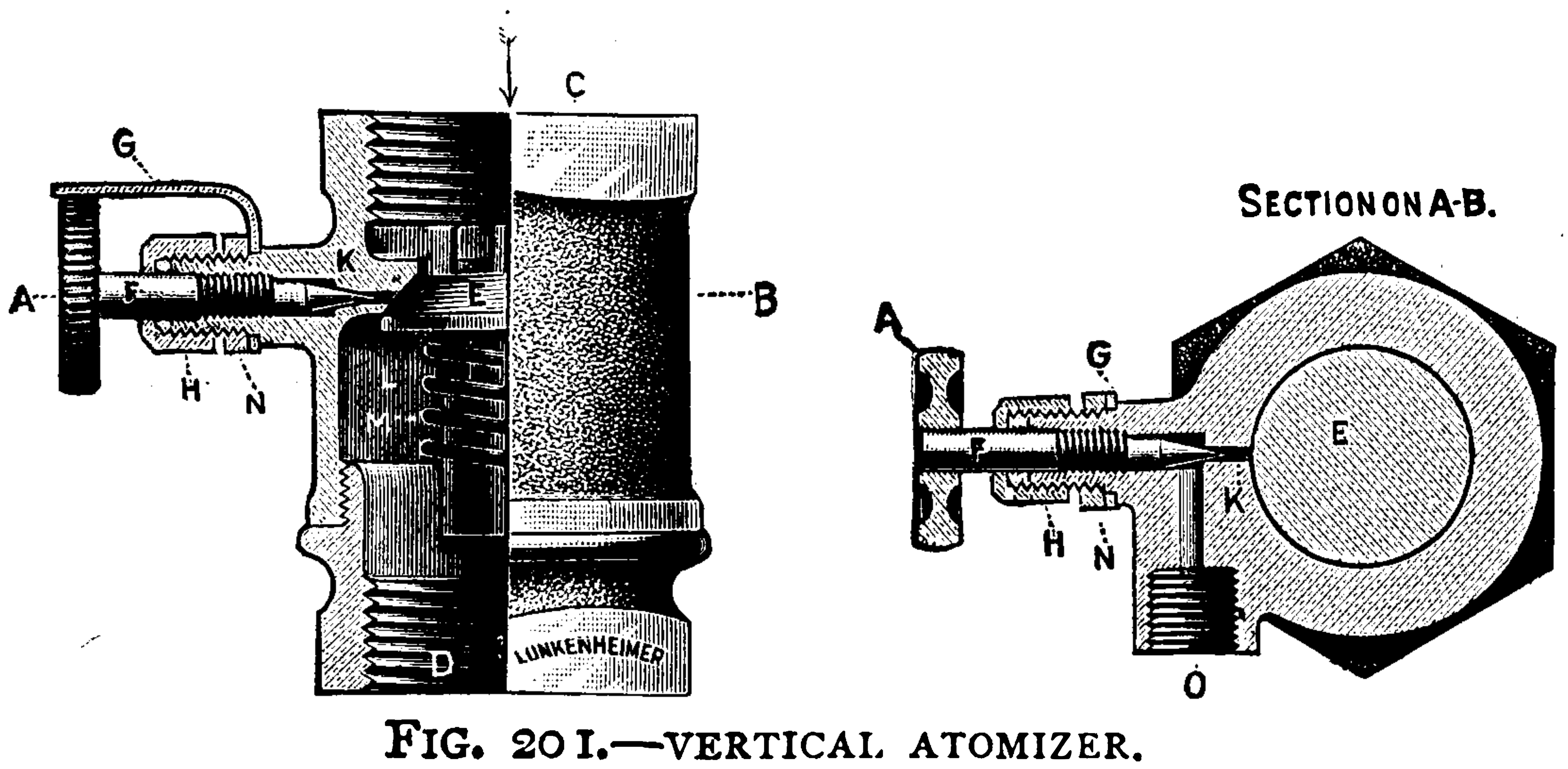


FIG. 20 I.—VERTICAL ATOMIZER.

valve seat. The opening of this passageway K into the valve seat is controlled by a small needle valve F, which has an indicator arm G.

The valve stem F has a stuffing box H so as to enable it to be well packed to prevent leakage of gasoline.

In this construction no gasoline is spilled, nor will it accumulate in the valve body; any excessive amount will be drawn into the vaporizing space between this and the inlet valve. The sizes are designated by the pipe size of the screw and are rated for cylinder sizes as follows:

Diameter of Cylinder, inches.....	2	3½	4½	5½	7	8	10	12	14
Size Pipe Connection on Generator Valve, inches...	½	¾	1	1¼	1½	2	2½	2½	3

The above proportions are based on a piston travel of not more than 600 feet per minute. For higher speeds than this the generator valve should be the next size larger than shown above.

The valves are made by the Lunkenheimer Company, Cincinnati, O.

The plan and section of a noiseless automatic carburetter is

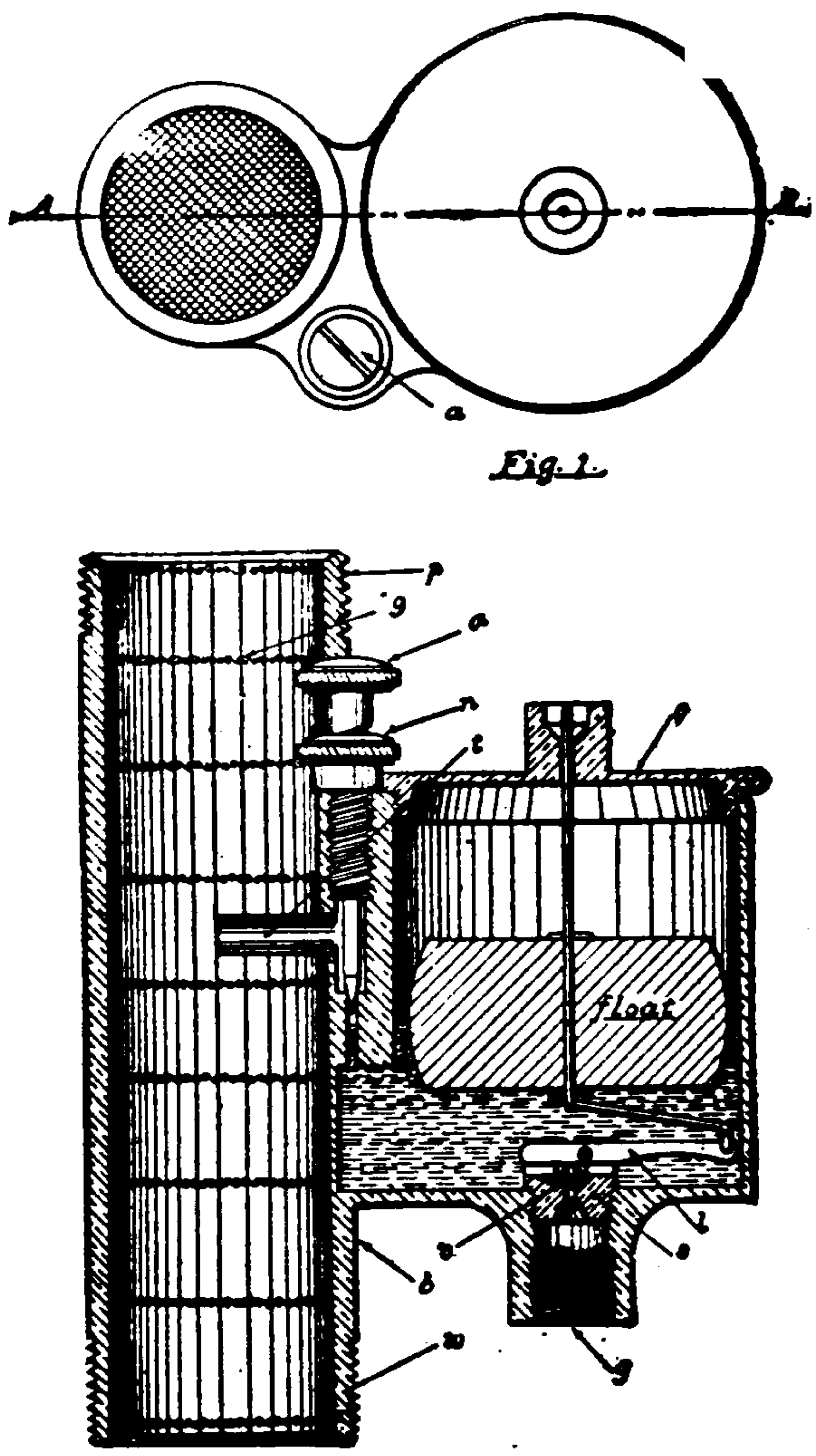


FIG. 20J.—KINGSTON CARBURETTER.

shown in Fig. 20 J. It is well suited for charging multiple cylinder motors and is very uniform in its supply. The upper section of the cut shows the plan of the float tank, valve and the wire gauze in the air pipe, of which there are sufficient in number, say nine, to give a large wire surface for fully evaporating any charge of gasoline for the motor for which the size of carburetter is adapted.

Referring to section of carburetter as cut on a line AB, with position of adjusting screw shown at *a*. The level of gasoline being lifted automatically by the suction of the motor, the supply is shown below point of adjusting screw, the gasoline being regulated by the needle point on screw which forms the spraying nozzle and the constant level being maintained at all times by the ball valve *v*, which has a capacity much greater than outlet at needle point, so it is easy to see that it would be impossible to lower the level of gasoline. And the float acting as it does on the lever *l*, and *l* resting as it does squarely on the center of the ball and the ball fitted in a perfect seat, the float being hinged to lever, it will be seen that any vibration that would cause the float to shake within the cup will not disturb the ball, which will maintain a constant level through any kind of vibration, making it perfectly adapted to engines and motors for traction or marine purposes as well as stationary. This carburetter may be used with a throttling governor if desired. It is built in five sizes. No. 0 is the bicycle size; No. 1 the light automobile, marine and stationary size, with 1-inch pipe connection; No. 2 with 1¼-inch pipe connection; No. 3 with 1½-inch pipe connection; No. 4 with 2-inch pipe connection, and larger sizes to order. They are made by the Kingston Manufacturing Company, Kokomo, Ind.

We illustrate in Fig. 20K a vaporizer of the constant-level type with a regulating device in which the index to the gasoline feed is adjusted by a sector and worm screw which cannot be displaced by jar or vibration. A very suitable and easily attached vaporizer for medium to small sized motors.

Referring to Fig. 20L it will be seen that the device is very compact, practically all of it being contained in a space but little larger in diameter than the ordinary inlet pipe. Gasoline enters from the supply through the pipe *m* filling the reservoir *d* and overflowing through the passage *g* to the pipe *l*. Air enters through the openings in the cap *e*, which serves to throttle the air supply. Passing around the chamber *d* it produces a draft which draws fuel from the reservoir through the nipple *c* and the plug valve *i* which is counterbored at *j*. Passing onward the mixture of gasoline and air leaves the casing *a* through the pipe *b* which is threaded so that it may be connected to the inlet of the engine.

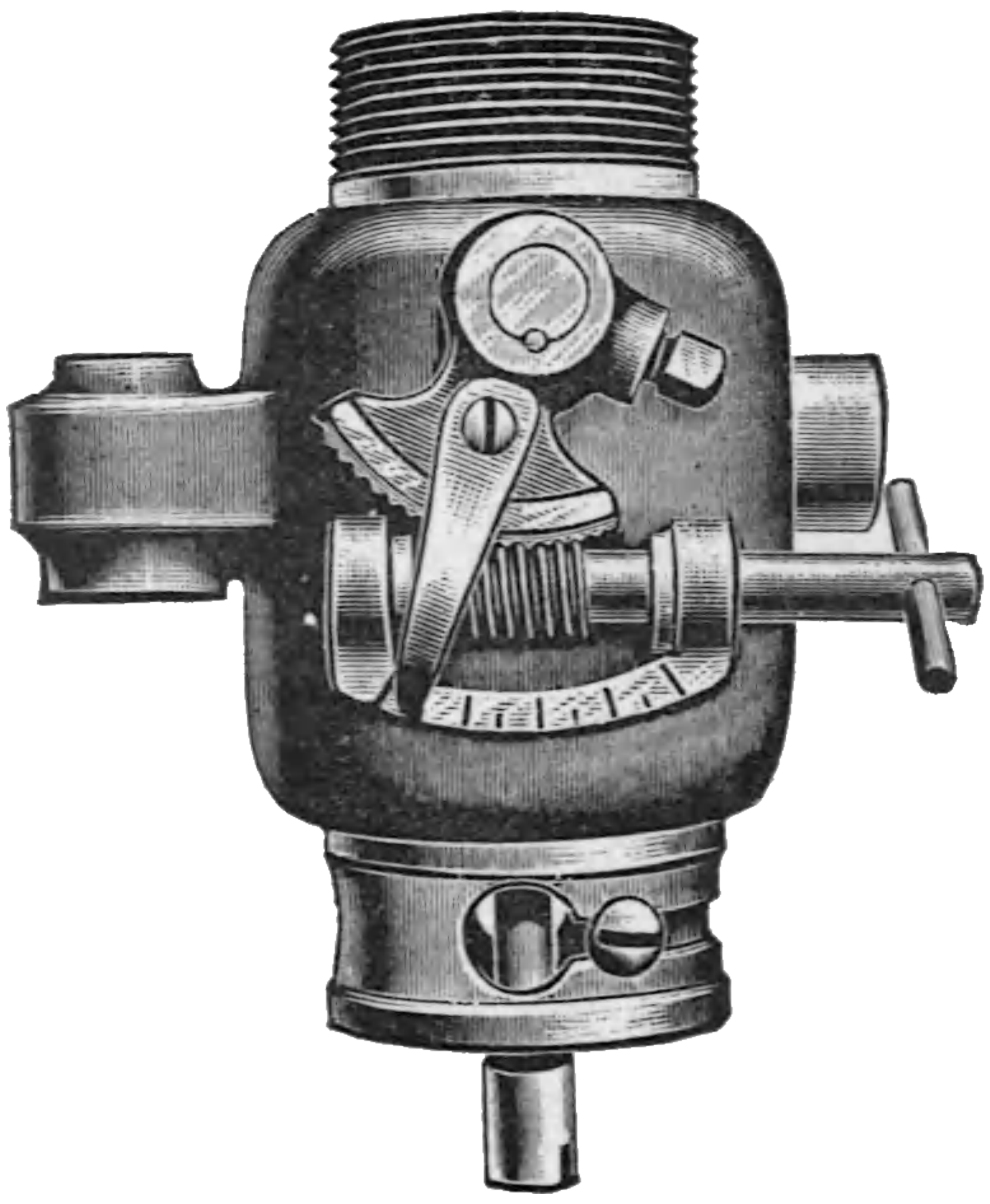


FIG. 20K.—ALDRICH VAPORIZER.

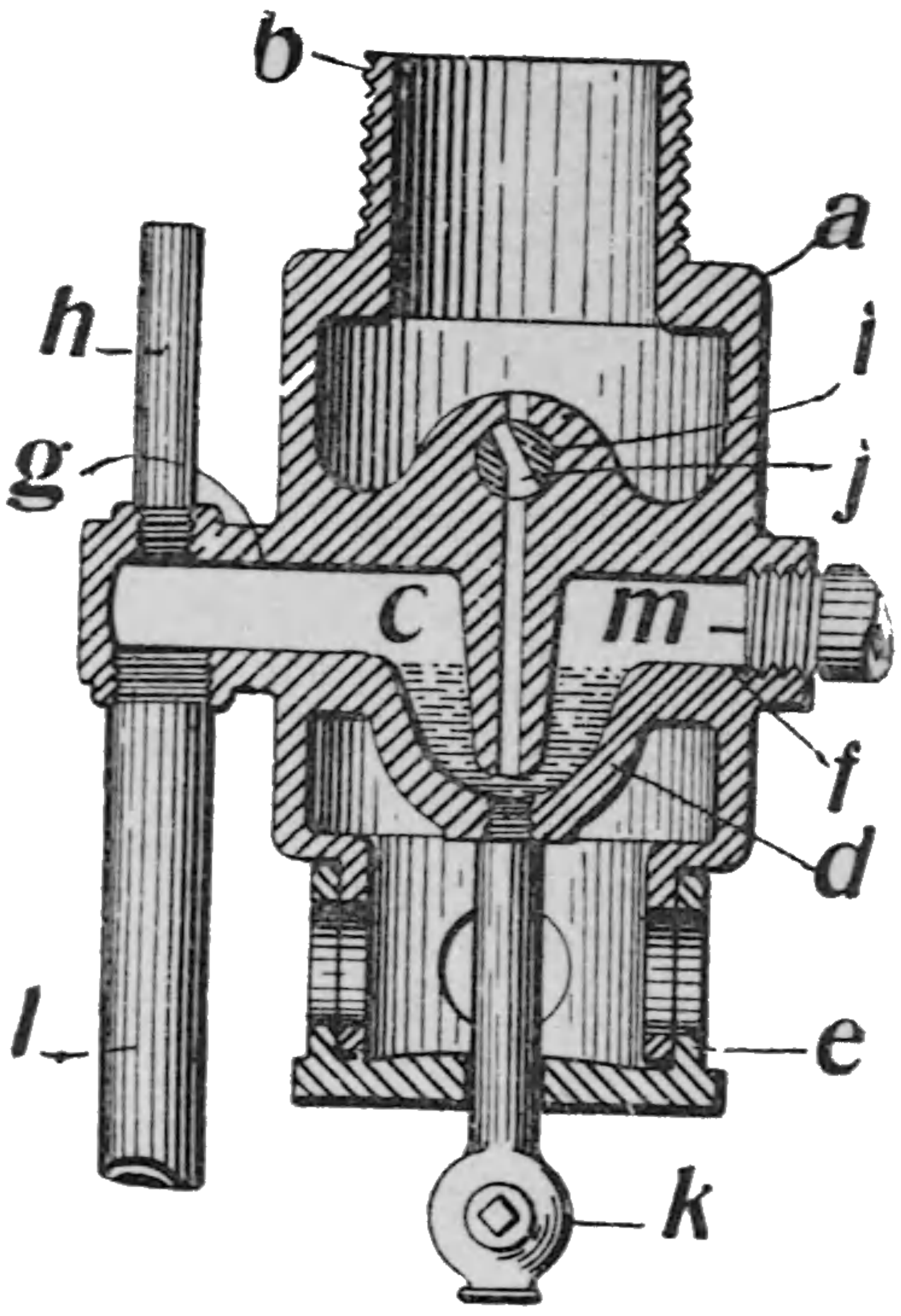


FIG. 20L.—SECTION.

The vent *h* keeps the pressure constant within the reservoir and the gasoline may be drained through the cock *k*.

Those who have had experience with gasoline vaporizers will at once recognize the good features of this device, which are the location of the gasoline nozzle in the center of the air passage, the location of the fuel valve close to the opening of the nozzle into the air passage and the general compactness of the entire vaporizer. It is manufactured by R. & W. T. Aldrich, Millville, Mass.

CHAPTER X.

CYLINDER CAPACITY OF GAS AND GASOLINE ENGINES.

THE cylinder volume of gas and gasoline engines seems to be as variable with the different builders as it is with steam engines in its relation to the indicated power.

The proportion of diameter to stroke varies from equal measures up to 38 per cent. greater stroke than the measure of the cylinder diameter. The extreme volumes of cylinder capacity (measured by the stroke) varies from 28 to 56 cubic inches for a 1 H.P. engine and from 48 to 98 cubic inches for a 2 H.P. engine; for a 3 H.P. engine from 77 to 142 cubic inches, while for a 6 H. P. engine it ranges from 182 to 385 cubic inches. This disparity in sizes for equal indicated power may be caused by the different kinds of gas and its air mixtures under which the trials for indicated power may have been made, or it may be partly due to relative clearance and facility for exploding the charge at some fixed time.

It may be readily seen from inspection of the heat value of different kinds of gas—varying as they do from about 950 heat units per cubic foot for the highest illuminating gas to from 185 to 66 heat units in the different qualities of producer gas—that large variations in effective power will result from a given sized cylinder. It will also be plainly seen that with the extreme dilution of producer gas with the neutral elements that produce no heat effect, that no combination with air that also contains 80 per cent. of non-combustible element can produce even a modicum of power in the same sized cylinder as is used for a high-power gas.

In view of this it seems necessary to build explosive engines with cylinder capacities due to the heat unit power of the combustible intended to be used, as well as to the method of its application.

In the following tables are given the indicated and actual power, revolutions, and size of cylinder and stroke of various styles of gas engines for comparison:

The Sintz.				The Atkinson Cycle.			
Horse-power.	Revolutions per minute.	Diameter of cylinder. Inch.	Stroke. Inch.	Horse-power.	Revolutions per minute.	Diameter of cylinder. Inch.	Stroke. Inch.
1........	425	3½	3½	2........	180	4¾	4¾
2........	400	4	4	3........	180	5¾	5½
3........	375	4¾	5	5........	160	6 7/16	8¼
4........	350	5	6	7........	150	7½	8¾
6........	300	5¾	6	9........	150	8¼	9
8........	270	6½	7	12........	140	9½	11 3/16
10........	250	8	8	16........	130	10	11 15/16
15........	225	9	9	20........	120	12	12¼

The Nash.				Pacific.			
Actual horse-power.	Revolutions per minute.	Diameter of cylinder. Inch.	Stroke. Inch.	Actual horse-power.	Revolutions per minute.	Diameter of cylinder. Inch.	Stroke. Inch.
⅛........	350	3	4	1½........	250	4¾	6
½........	350	3½	4	4½........	225	6½	9
1........	325	4	4½	6........	200	7	10
2........	300	5	5				
3........	300						
4........	300						
5........	280						

Lawson Engine.				Star.			
Actual horse-power.	Revolutions per minute.	Diameter of cylinder. Inch.	Stroke. Inch.	Actual horse-power.	Revolutions per minute.	Diameter of cylinder. Inch.	Stroke. Inch.
1........	180	4½	8	2........	250	4½	6
2........	160	5	10	3........	240	5	6
4........	160	6½	12	4........	220	5½	10
6........	160	7½	14	6........	220	6½	12
				8........	180	7	13
				10........	180	8	14

In the following table of gas and gasoline engine dimensions we have figured the speed at about the maximum rate and have endeavored to show about the average practice with builders of four-cycle engines in the United States for ordinary power use.

The table has been computed for convenient measurement for amateur use and may not meet the exact and decimal values for expert designers.

In assigning these values a consideration of 60 pounds M.E.P., with a clearance of from 30 to 35 per cent. of the piston stroke has been made for the combustion chamber.

The tabulated horse-power has been computed on the basis of the M. E. P. of 60 pounds per square inch with an adiabatic compression of $\frac{39}{100}$ of the total volume and a mean back pressure from the compression stroke of 26 pounds per square inch, which is deducted from the mean of the explosive pressure stroke of 89 pounds per square inch; which being 63 pounds, from which a deduction of 3 pounds is made for losses from leakage, leaves a net mean pressure of 60 pounds.

Then the cylinder area × mean explosive pressure — mean compression pressure × impulse stroke travel in feet per minute and product divided by 33,000 = indicated horse-power.

$$\frac{A \times \text{M E P.} \times S}{33{,}000} = \text{I.H P.}$$

To obtain the value of S, multiply the stroke in feet or decimals of a foot by one-half the number of revolutions per minute, which is the impulse travel of the piston per minute. If misfires are made they should be deducted from the half number of revolutions in practice.

As an example of an 8 × 10 four-cycle engine at 300 revolutions per minute, we have area of cylinder 50.26 square inches and $S = \frac{10}{12} \times \frac{300}{2} = 125$ feet piston travel per minute. Then $\frac{50.26 \times 60 \times 125}{33{,}000} = 11.41$ I.H.P., which we have rated as 10 actual horse-power in the table. In the smaller engines the difference between indicated and actual horse-power increases as the size diminishes.

The thicknesses of cylinder wall, water-jacket and water space have been assigned with due regard for overcharged explosions and the possibilities in core-making for the water space; they are often made thicker than given in the table.

The length of the connecting rod from center to center is made from medium practice, or about 2 1/4 times the stroke with the piston pin at the center of the piston.

The figured dimensions of piston pins of the same bearing length as the crank-pin, as also the crank-pins and shaft, are derived approximately from formulas which we find variable with different writers as well as variable in size by different builders of explosive motors. The dimensions in the table are a medium suitable to a clearance ratio of 3 to 3.5.

APPROXIMATE DIMENSIONS OF FOUR CYCLE MOTOR PARTS.

For M.E.P. 60 lb. Clearance, 30 to 33 per cent. Compression, 50 to 60 lb. Explosive Pressure, 160 to 200 lb.

Actual Horse Power.	Revolutions.	Cylinder Diameter.	Stroke.	Clearance. Inches.	Thickness Cylinder Wall.	Water Space.	Water Shell.	Length Connecting Rod	Size Piston Pin.	Size Crank Pin.	Width Crank Pin.	Size Main Journal.	Length Main Journal.	Diameter Fly Wheels.	Weight Fly Wheels.	Size Inlet Valve.	Size Exhaust Valve.
		Ins.	Ins	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins	Ins.	Ins	Lb.	Ins.	Ins.
1/4	500	2	3 1/2	1	5/16	3/16x3/4	Ribs	8	5/16	5/8	5/8	1/2	1	13	66	1/2	5/8
1/2	450	2 1/2	4	1 1/8	3/8	3/16x1 Ribs	Ribs or	9	3/8	3/4	3/4	5/8	1 1/4	15	133	5/8	3/4
3/4	425	3	4 1/4	1 1/4	3/8	3/8	1/4	9 1/2	7/16	1	1	3/4	1 1/2	17	200	3/4	7/8
1	400	3 1/2	4 1/2	1 3/8	7/16	1/2	3/8	10 1/4	1/2	1 1/4	1 1/4	1	2	18	270	7/8	1
1 1/2.. .	350	4	5	1 5/8	1/2	5/8	3/8	11 1/4	5/8	1 3/8	1 1/2	1 1/8	2 1/4	20	475	1	1 1/8
2	350	4 1/2	5 1/4	1 7/8	1/2	5/8	3/8	12	3/4	1 1/2	1 5/8	1 1/4	2 1/2	23	525	1 1/8	1 1/4
3	350	5	6 1/4	2 1/8	9/16	3/4	1/2	14 1/4	7/8	1 7/8	2	1 1/2	3	26	575	1 1/4	1 1/2
4 3/4.. ...	325	6	7 1/2	2 3/8	5/8	3/4	1/2	17	1 1/8	2 1/8	2 1/4	1 3/4	3 1/2	32	800	1 1/2	1 3/4
7	320	7	8 3/4	2 3/4	11/16	3/4	1/2	20	1 1/4	2 1/2	2 3/4	2 1/4	4 1/2	38	900	1 3/4	2
10	300	8	10	3 1/4	3/4	1	1/2	22 1/2	1 1/2	3	3 1/2	2 5/8	5 1/4	44	1130	2	2 1/2
13	275	9	11 1/4	4	3/4	1	1/2	25 1/4	1 5/8	3 1/4	3 3/4	2 7/8	5 3/4	50	1500	2 1/4	2 3/4
17	250	10	12 1/2	4 3/8	3/4	1 1/8	5/8	28 1/4	1 3/4	3 3/4	4	3 1/4	6 1/2	64	2350	2 1/2	3
22	200	12	15	5	7/8	1 1/8	5/8	34	2	4 1/4	4 1/2	3 7/8	7 3/4	66	3600	3	3 1/2
30	175	14	17 1/2	5 7/8	7/8	1 1/4	5/8	39 1/2	2 1/4	4 3/4	5 1/4	4 1/4	8 1/2	72	6000	3 1/2	4
43	160	16	20	6 5/8	1	1 1/4	5/8	45	2 1/2	5 3/8	5 3/4	4 5/8	9 1/4	82	9500	4	5
57	150	18	22 1/2	7 1/2	1 1/8	1 3/8	3/4	50	2 3/4	5 3/4	6 1/2	5 1/4	10 1/2	96	10500	5	6

The diameters and weights of flywheels vary to a considerable extent among engines by different builders to adapt them to special service where the steadiness of speed is a special factor of design.

For electric-lighting purposes, either or both diameter and weight of the flywheels may be increased above the tabulated figures, which have been computed for ordinary power service.

The sizes of the inlet and exhaust valves have been figured for a free inlet and discharge at the maximum speed in the second column of the table. For higher speeds of special motors the valve area should be somewhat increased.

TEMPERATURE AND PRESSURES.

Owing to the decrease from atmospheric pressure in the indrawing charge of the cylinder, caused by valve and frictional obstruction, the compression seldom starts above 13 pounds absolute, especially in high-speed engines. Col. 3 in the following table represents the approximate absolute compression pressure

GAS ENGINE CLEARANCE RATIOS, APPROXIMATE COMPRESSION, TEMPERATURES OF EXPLOSION AND EXPLOSIVE PRESSURES WITH A MIXTURE OF GAS OF 660 HEAT UNITS PER CUBIC FOOT AND MIXTURE OF GAS 1 TO 6 OF AIR.

Clearance Per Cent. of Piston Volume.	Ratio $\frac{V}{V_c} = \frac{P + C \text{ Vol.}}{\text{Clearance.}}$	Approximate Compression from 13 lbs. Absolute.	Approximate Gauge Pressure.	Absolute Temperature of Compression from 560° F. in Cylinder.	Absolute Temperature of Explosion. Gas, 1 part; Air, 6 parts.	Approximate Explosion Pressure Absolute.	Approximate Gauge Pressure.	Approximate Temperature of Explosion, Fahrenheit.
1	2	3	4	5	6	7	8	9
		Lbs.		Deg.	Deg.	Lbs.	Lbs.	Deg.
.50	3.	57.	42.	822.	2488	169	144	2027
.444	3.25	65.	50.	846.	2568	197	182	2107
.40	3.50	70.	55.	868.	2638	212	197	2177
.363	3.75	77.	62.	889.	2701	234	219	2237
.333	4.	84.	69.	910.	2751	254	239	2290
.285	4.50	102.	88.	955.	2842	303	288	2378
.25	5.	114.	99.	983.	2901	336	321	2448

for the clearance percentage and ratio in Cols. 1 and 2, while Col. 4 indicates the gauge pressure from the atmospheric line.

The temperatures in Col. 5 are due to the compression in Col. 3 from an assumed temperature of 560 degs. F. in the mixture of the fresh charge of 6 air to 1 gas with the products of combustion left in the clearance chamber from the exhaust stroke of a medium-speed motor.

This temperature is subject to considerable variation from the difference in the heat unit power of the gases and vapors used for explosive power as also of the cylinder cooling effect.

In Col. 6 is given the approximate temperatures of explosion of a mixture of air 6 to gas 1 of 660 heat units per cubic foot, for the relative values of the clearance ratio in Col. 2 at constant volume.

The formulas for the above approximate table avoiding decimal values are as follows:

$$\frac{\text{Col. } 1 + 1}{\text{Col. } 1} = \text{Col. } 2. \quad 1.35 \log. \frac{V}{V_c} = \log. \frac{p_c}{P} = \text{Col. } 3.$$

$p_c + P$ = absolute pressure Col. 3.

$.35 \log. \text{Ratio} = \log. \frac{t_c}{t}$ Col. 5.

$\frac{p_c T}{t_c} = P$ absolute pressure Col. 7. $P - p$ = Col. 8. $T - 461°$ = Col. 9.

p_c = absolute pressure of compression.

p = initial absolute pressure in cylinder before compression, 13 lb.

P = absolute pressure of explosion.

T = absolute explosion temperature.

t = initial absolute temperature in cylinder after charge 560° Fahr.

t_c = absolute temperature of compression.

The explosive absolute temperature in Col. 6 decreases in proportion to the dilution of the gas with air until with the proportion of 12 air to 1 gas, but 69 per cent. of the temperature given in Col. 6 is available. The decrease in pressure follows in a like proportion.

In Col. 7 is given the absolute explosive pressure due to the conditions in the preceding columns and computed from the formula $\frac{p_c T}{t} = P$, in which p_c = absolute compression pressure Col. 3. T = absolute explosive temp. Col. 6. t = absolute compression temperature Col. 5, for each ratio in Col. 2.

Col. 8 is the gauge pressure derived from the absolute pressures in Col. 7.

Col. 9 is the explosive temperature on the Fahrenheit scale, T — 461 degs.

MUFFLERS ON GAS ENGINES.

The method of muffling the sound of the exhaust, as well also the sound or clack of the valves, was a puzzling problem to the early builders of gas engines. The matter has finally sifted down to a plain cast-iron box of from 1 to 3 cubic feet capacity, set near the engine, and into which the exhaust pipe is connected, and continued by a separate connection to the outside of a building.

Connection of the exhaust with a chimney should not be made under any circumstances, as there are unknown elements of explosion liable to be accumulated in the line of the exhaust that might do damage to a chimney; and for the same reason the muffler-box should be made strong enough for a pressure equal to the explosive power of the gas and air mixture, or say 175 pounds per square inch. This insures safety from any explosion that may accidentally occur in the exhaust by missed explosions in the cylinder, or otherwise.

The muffler pot is also a water-catch, in which part of the water vapor formed by the union of the hydrogen and oxygen is condensed. It should have a draw-off cock a few inches above the bottom, so that the muffler may always have a little water in the bottom, the water having been found to have a deadening effect on the exhaust.

A second muffler pot has been found to still further deaden the exhaust, and is preferable to throttling the exhaust by mufflers with perforated diaphragms.

In all cases an enlargement of the exhaust pipe from the muffler to the roof by one or two sizes larger than the engine exhaust, will modify the intensity of the exhaust at the roof, and often abate a nuisance.

Mufflers for automobiles and launches have been the subject of much designing in order to have them meet the requirement of almost absolute silence so much to be desired. The method of perforated tubes with wire cloth casings of large area for cutting the exhaust into infinitesimal streams and of so large an area that the back pressure may be reduced to an imperceptible amount, seems to be in the right direction for vehicles, and an extension of the terminal under water at the stern of launches with a small vent above water has given good results. The vent prevents water drawing back to the muffler when the motor stops. For large stationary motors a variety of designs for the internal space of a muffler box have been made, all seeming to tend to obtain the desired conditions. A series of perforated plates, both flat and circular; small stones filling the muffler box, through which the exhaust passes; a spiral case within the muffler box; in fact almost any device that tends to stop the sudden impact of the exhaust and its expansion are the means that modify and in a measure prevent the noisy propensities of the explosive motor.

To prevent nuisance to neighbors by open air exhaust, the turning down of the exhaust pipe into a barrel or second muffler pot with a few inches of water, has given satisfaction in many cases. It prevents the spread of oil vapor into neighboring windows.

CHAPTER XI.

GOVERNORS AND VALVE GEAR.

THE regulation of the speed of explosive engines has an important bearing upon their usefulness and freedom from

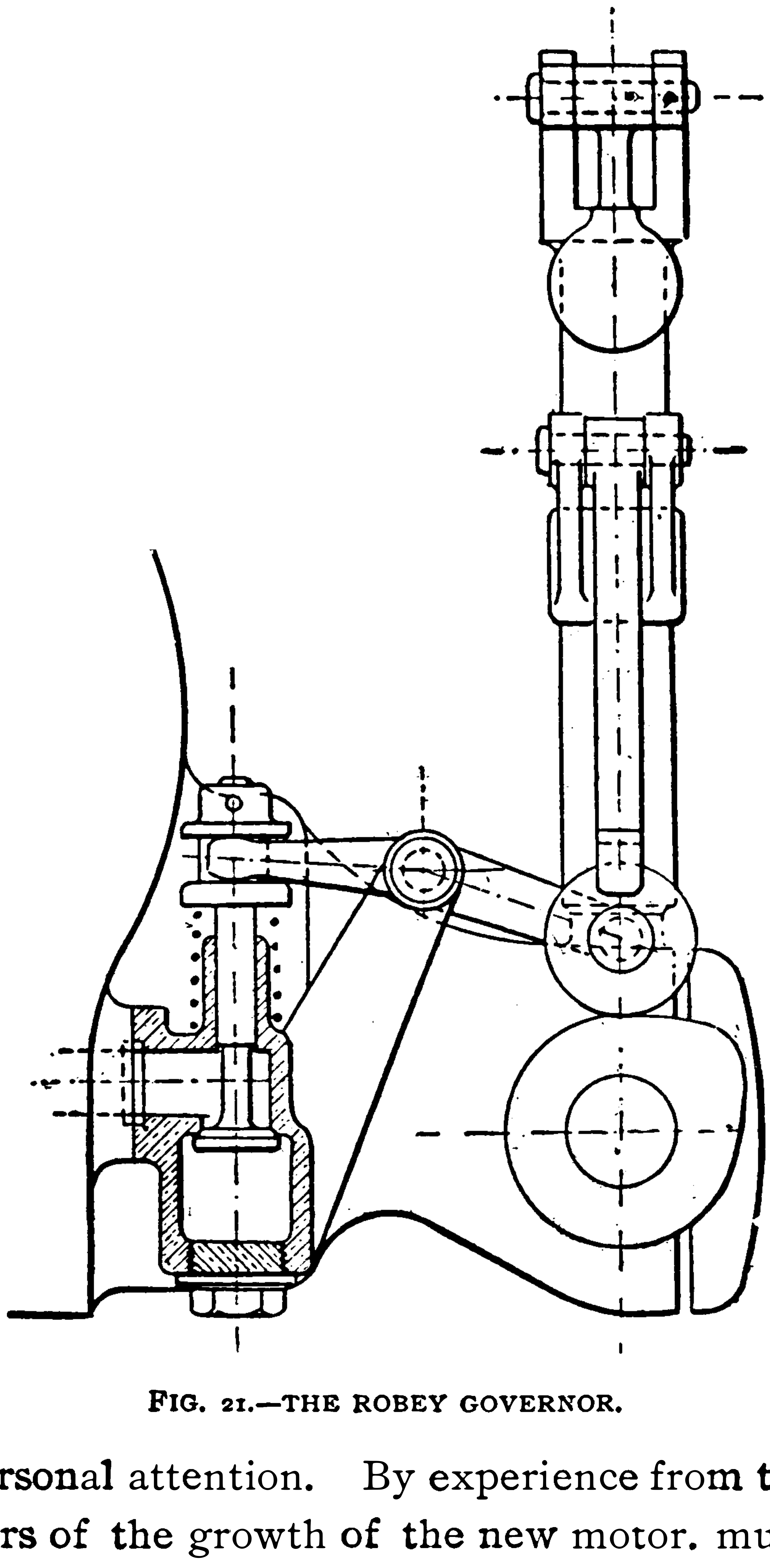


FIG. 21.—THE ROBEY GOVERNOR.

constant personal attention. By experience from trials during the few years of the growth of the new motor. much progress

the governor is claimed to be the most economical as well as the most satisfactory method in use, if the variation in the work of the engine does not carry the charge beyond the limit of combustion; otherwise the second method seems to give the best results.

In Figs. 21 and 21A are two elevations of the centrifugal ball

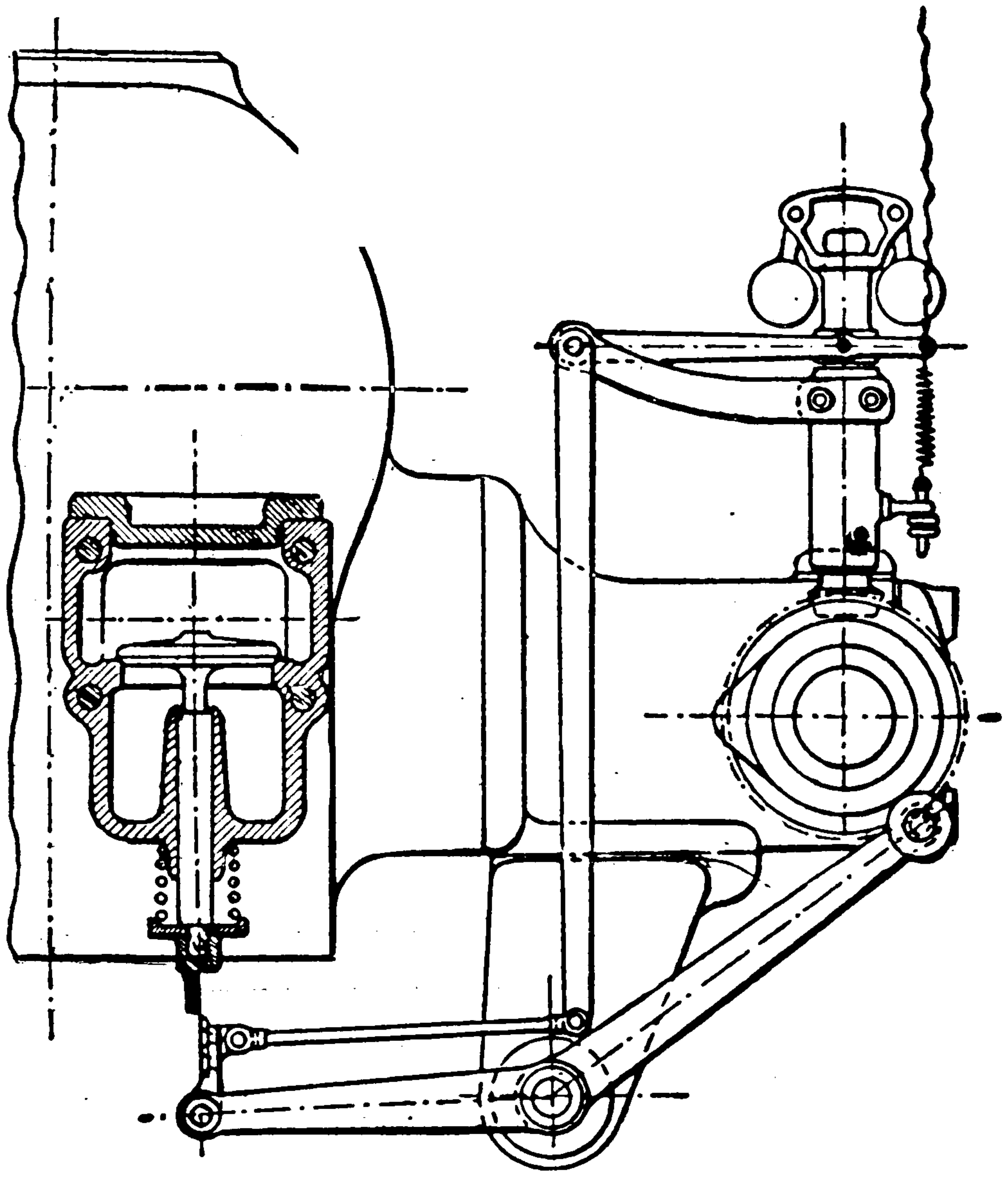


FIG. 22.—THE PICK-BLADE GOVERNOR.

governor, as used on the Robey and other engines in Europe and adopted with many variations on a number of American engines. In this type the bell-crank arm of the governor, by its centrifugal action, raises or depresses a yoke and sleeve which operates a bell-crank lever with a forked end astride a rotating disc which rides on the cam of the secondary shaft. The disc has a lateral motion on the end of the valve lever, so that the action of the governor rides the disc on to or off the cam, and thus makes a hit-or-miss stroke of the valve.

The centrifugal governor (Fig. 22) is another application of the hit-and-miss principle, by the use of a pick-blade operated

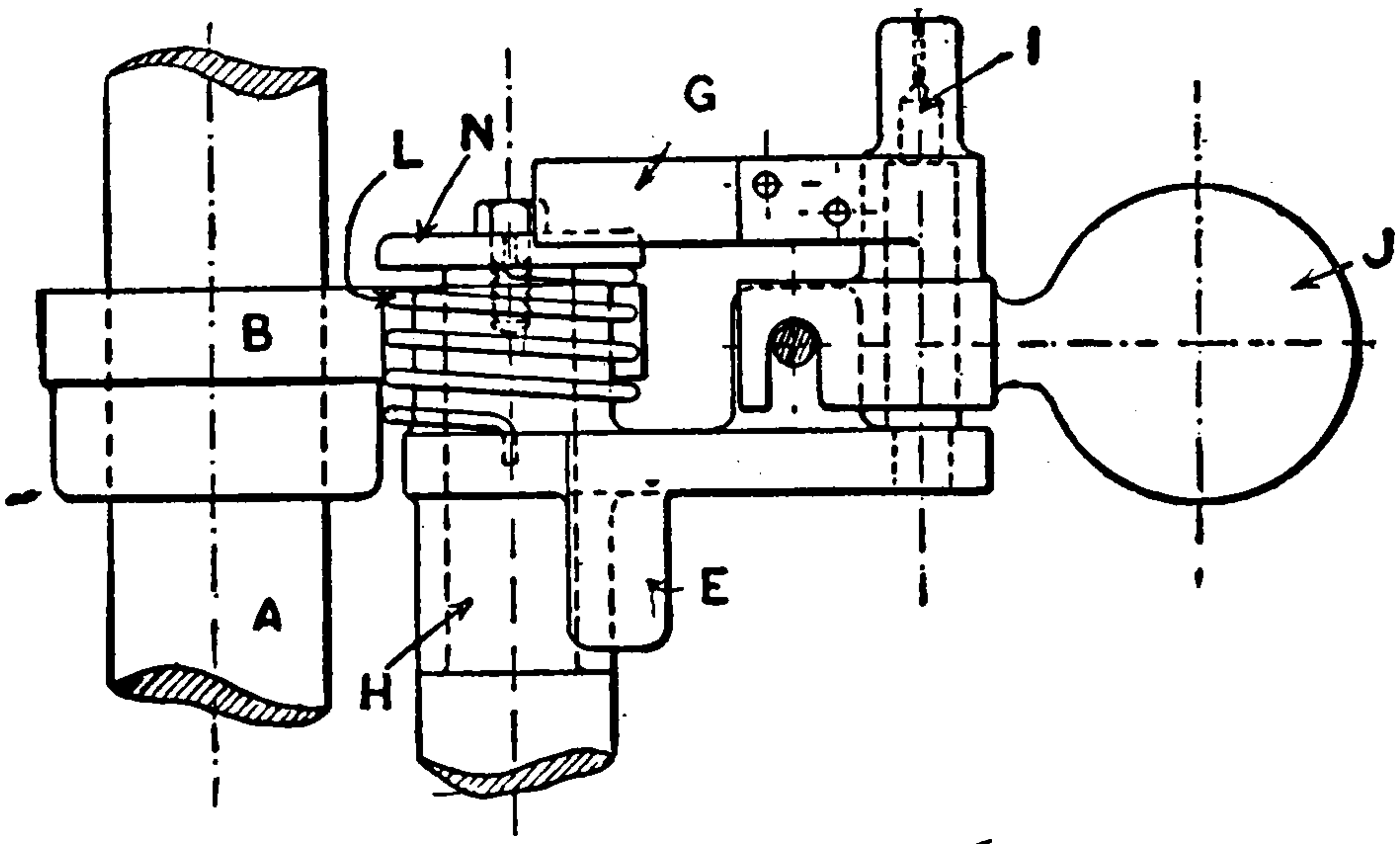


FIG. 23.—INERTIA GOVERNOR, PLAN.

from the governor by a balanced bell crank and connecting rod The cut fully explains the detail of its construction and operation, by which an abnormal speed of the governor pulls the

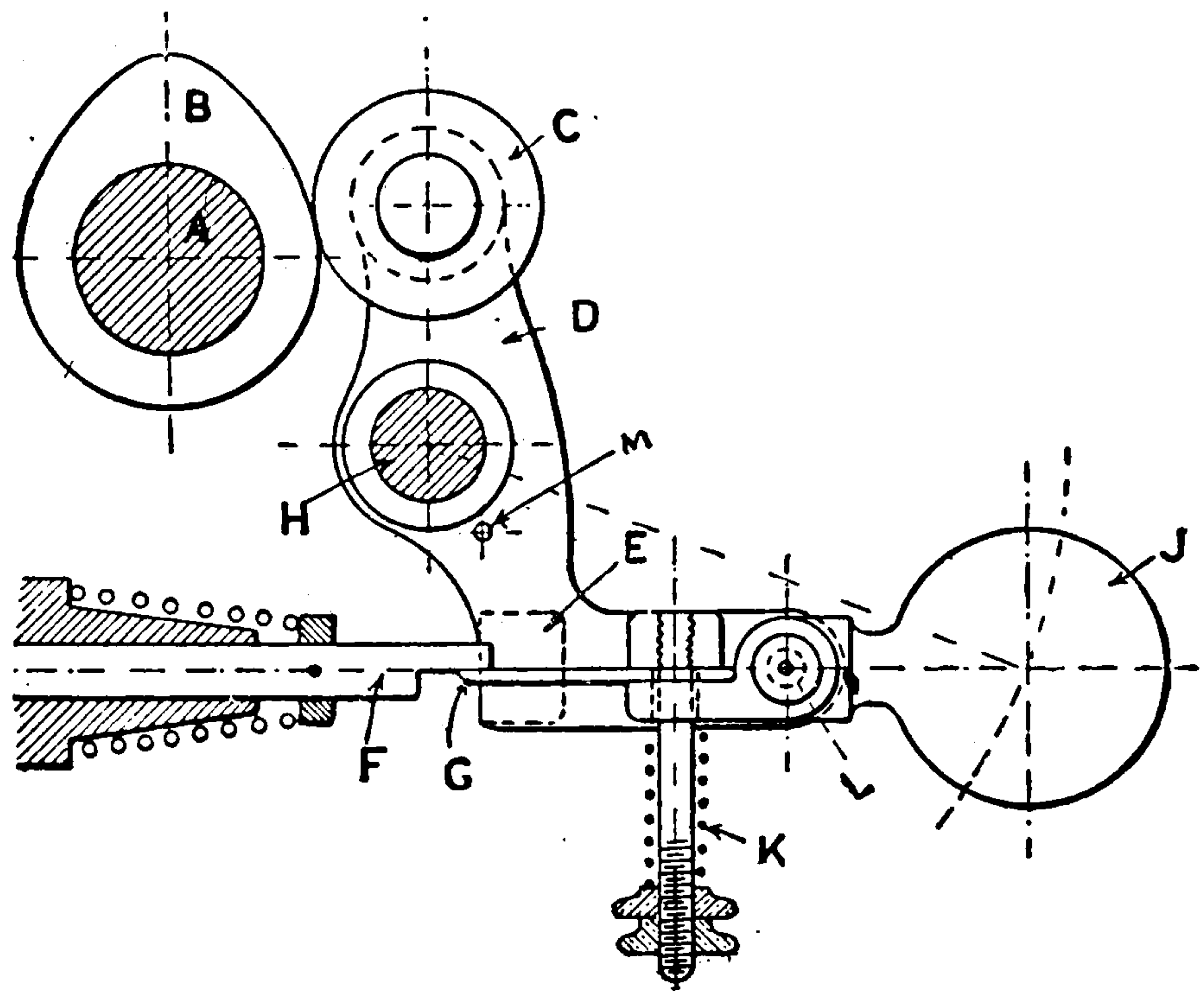


FIG. 24.—INERTIA GOVERNOR, ELEVATION.

pick blade away from the gas-valve spindle. In some forms graduated notches are made on the pick-blade or spindle-blade, so that in action the governor gives a varying charge within certain limits and a mischarge when the speed is beyond the limitation.

The inertia governor used on the Crossley engine in Eng-

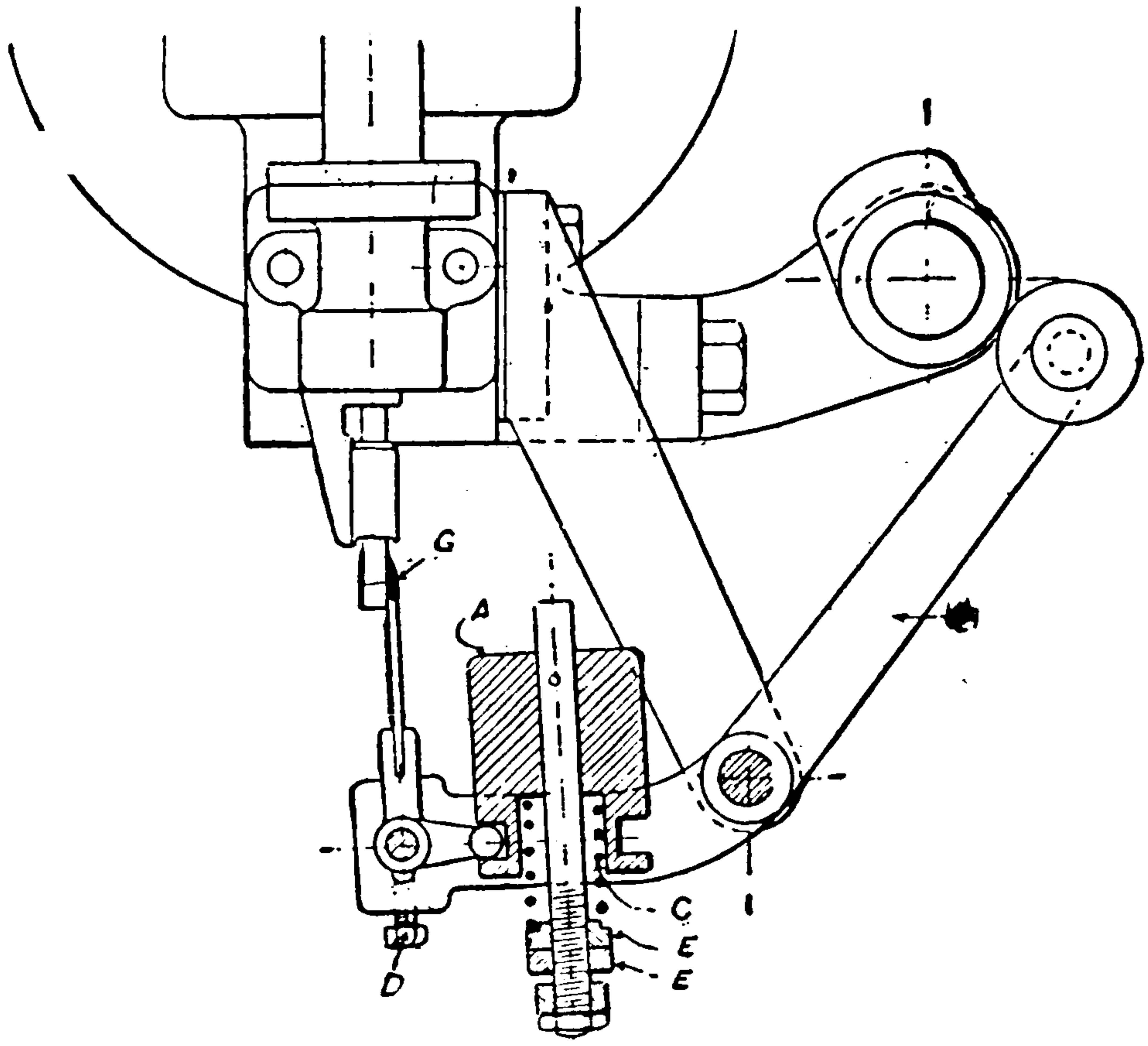


FIG. 25.—THE VIBRATING GOVERNOR, ELEVATION.

land, and with many modifications in use on American engines, is illustrated with plan and elevation in Figs. 23 and 24, in which A is the cam shaft, B cam, C roller, D lever, H lever

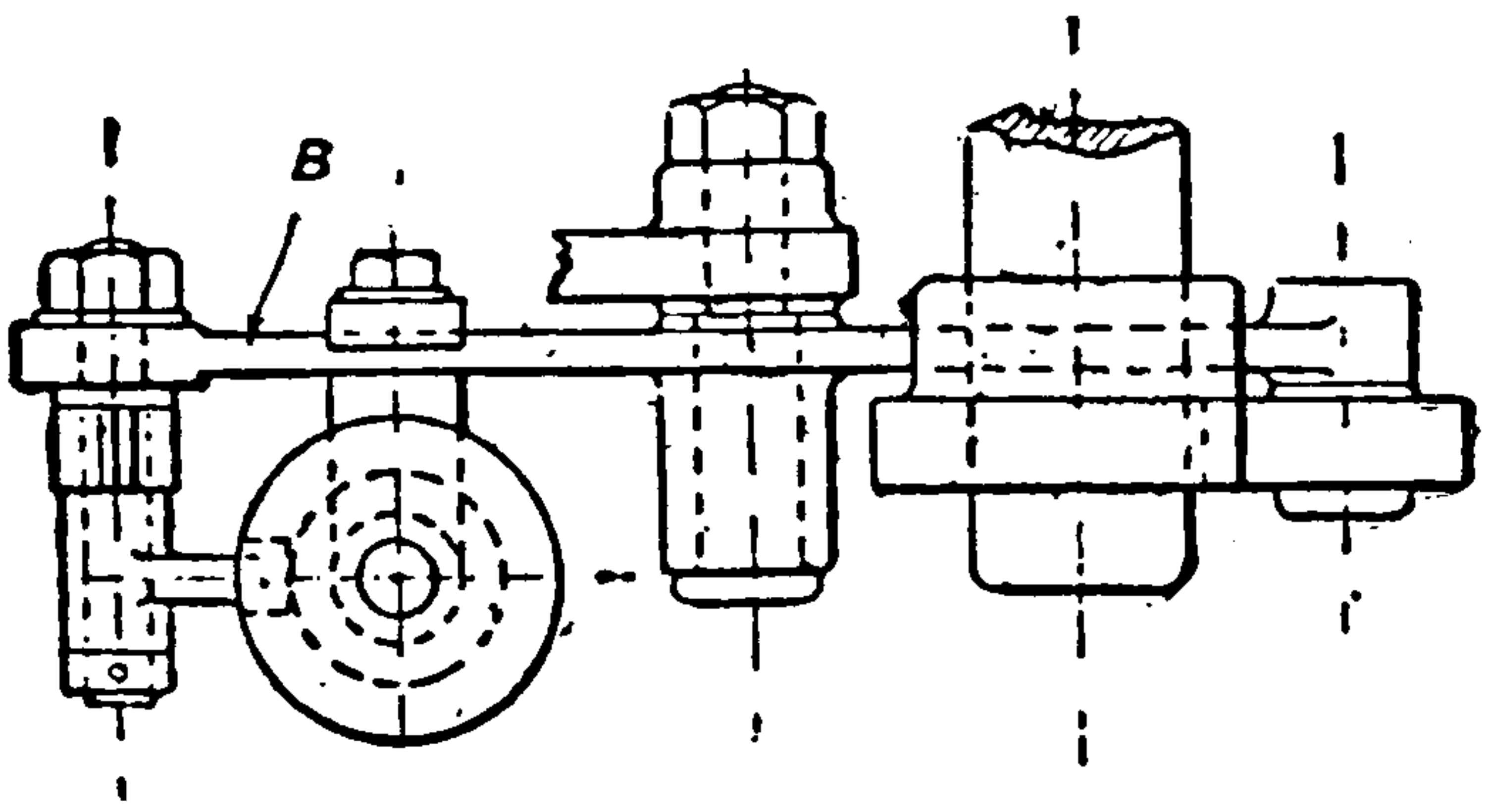


FIG. 26.—THE VIBRATING GOVERNOR, PLAN.

pin, L spring to hold the roller C to the cam, J the governor weight, K the adjusting spring, G the pick-blade, and F the valve stem.

In the action of this governor the initial line of motion of

blade is attached. The balance spring is adjustable for regulating the position of the pick-blade and its contact with the valve spindle. By the variation in overcoming the inertia of the weight by the spring with different vibrating speeds in the lever, the disengagement of the pick-blade with the spindle-blade is varied or a mis-stroke made.

The pendulum governor (Fig. 28) is also an inertia governor in the principle on which it operates. It is attached to the exhaust-valve push-rod, and vibrates horizontally with the rod The weight or ball has an extension or neck, with a pivoted eye, a yoke, and a vertical lug. The eye is pivoted in the box, and the yoke embraces the push-blade stem, which is also pivoted horizontally with the eye in the box or frame. The lug bears on an adjusting spring, which is set up by a screw so as to limit the swing of the ball to the normal speed of the engine, so that when the speed rises above the normal the inertia of the ball holds it back in its vibration and lifts the push-blade out of contact with the valve-stem.

In some engines the position of the ball is reversed, and it stands above the valve push-rod on a finger and is made adjustable in its length of oscillation by its distance from the fulcrum.

Several modifications of the governors here described are in use, devised on the principles of inertia as illustrated in Figs. 24, 25, and 28.

Apart from the ordinary methods of operating the valves of explosive motors by reducing spur gear and the reducing screw gear for driving a cam shaft for four-cycle engines, we illustrate in Fig. 28A and Fig. 28B two very simple methods of operating the charging or exhaust-valve by the direct action of a push-rod from an eccentric on the main shaft.

In Fig. 28A the vertical section shows the form of the cam on the central thread of a two-thread worm on the main shaft with the push-rod and valve. The horizontal diagram shows the worm and intermittent ratchet wheel pivoted in the fork of the push-rod. At every other revolution of the shaft the cam section of the worm falls into a shallow notch of the ratchet and thus gives a push stroke of the valve at every other revolution of the shaft.

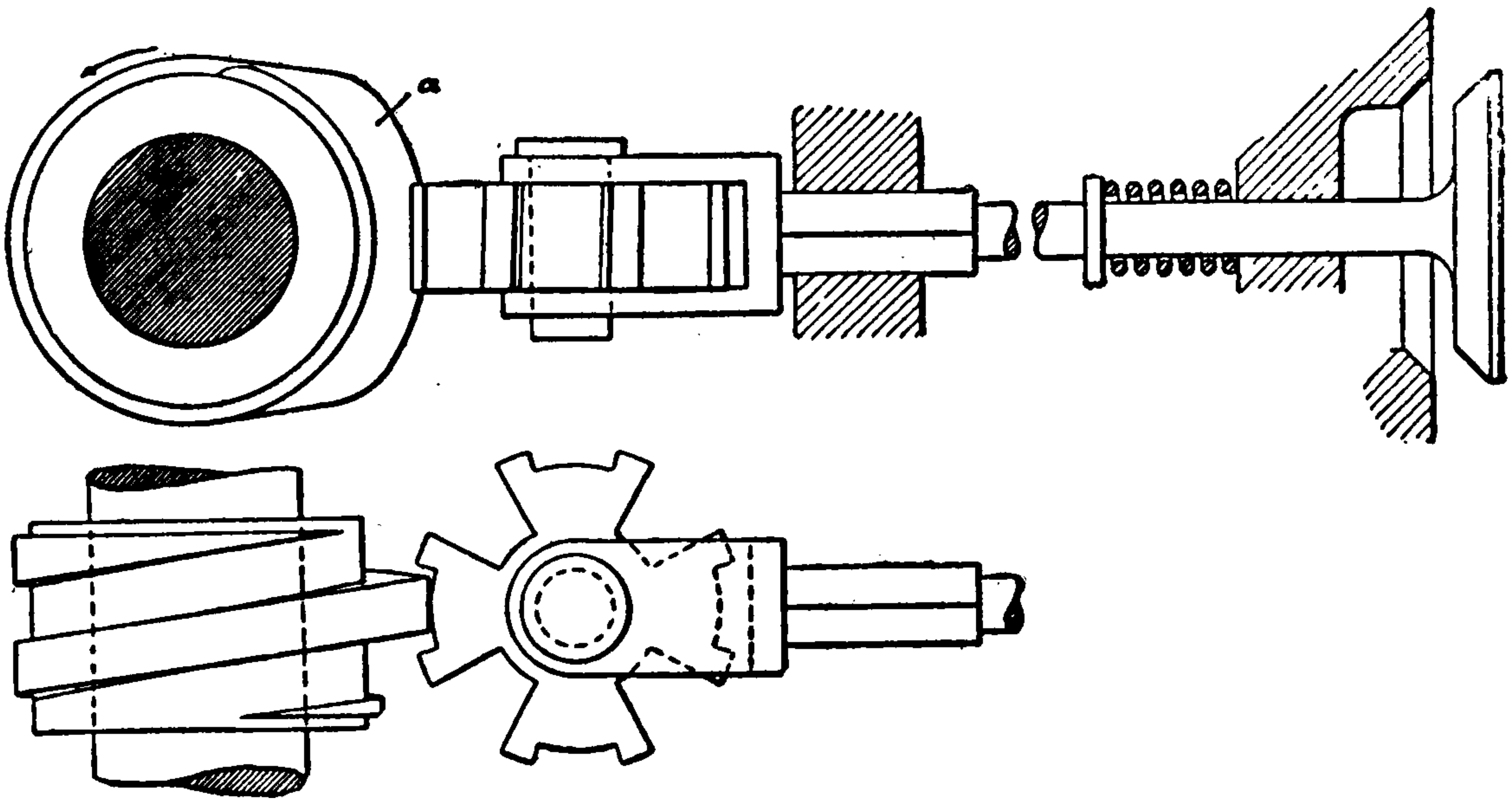


FIG. 28A.—THE WORM CAM PUSH-ROD.

Fig. 28B illustrates another form of ratchet push-rod. In this device the ratchet is mounted on a friction pin which may be adjusted by a thumb-nut and soft washer so as not to turn

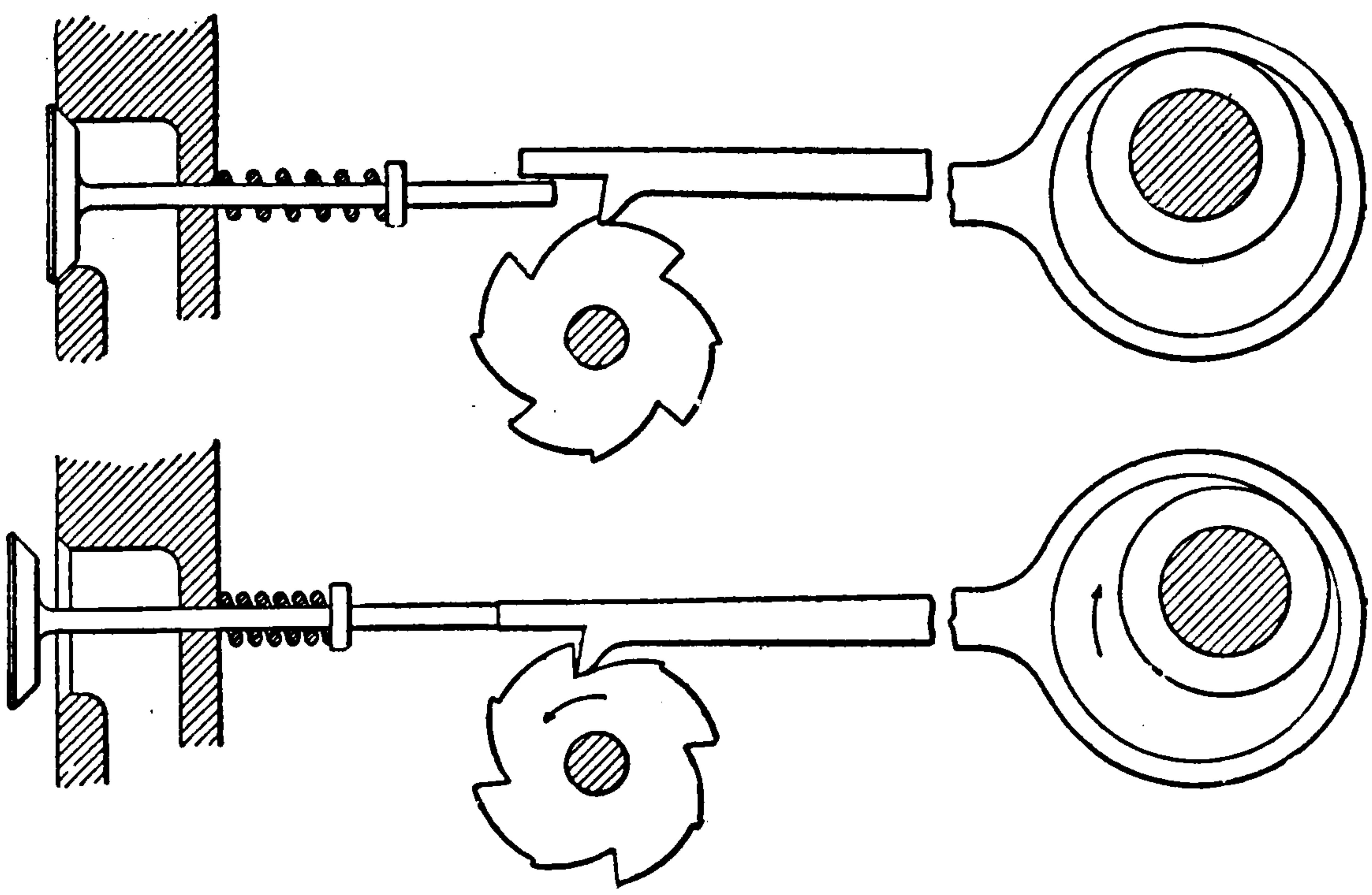


FIG. 28B.—THE RATCHET PUSH-ROD.

backward, yet may easily be rotated forward by the motion of the cam-moved push-rod. The upper figure shows the tooth of the push-rod on the shallow notch and missing contact with the valve spindle; at the next revolution of the shaft the tooth catches the deep notch and makes contact with the valve spindle. The throw of the eccentric should be slightly greater than the distance between two consecutive teeth in the ratchet.

A governor of the inertia or ball type can be attached to the push-rod with a step contact on the valve spindle, making a very simple valve movement and regulation.

GOVERNORS AND VALVE GEAR.

The ring valve gear (Fig. 28C) is another way of operating

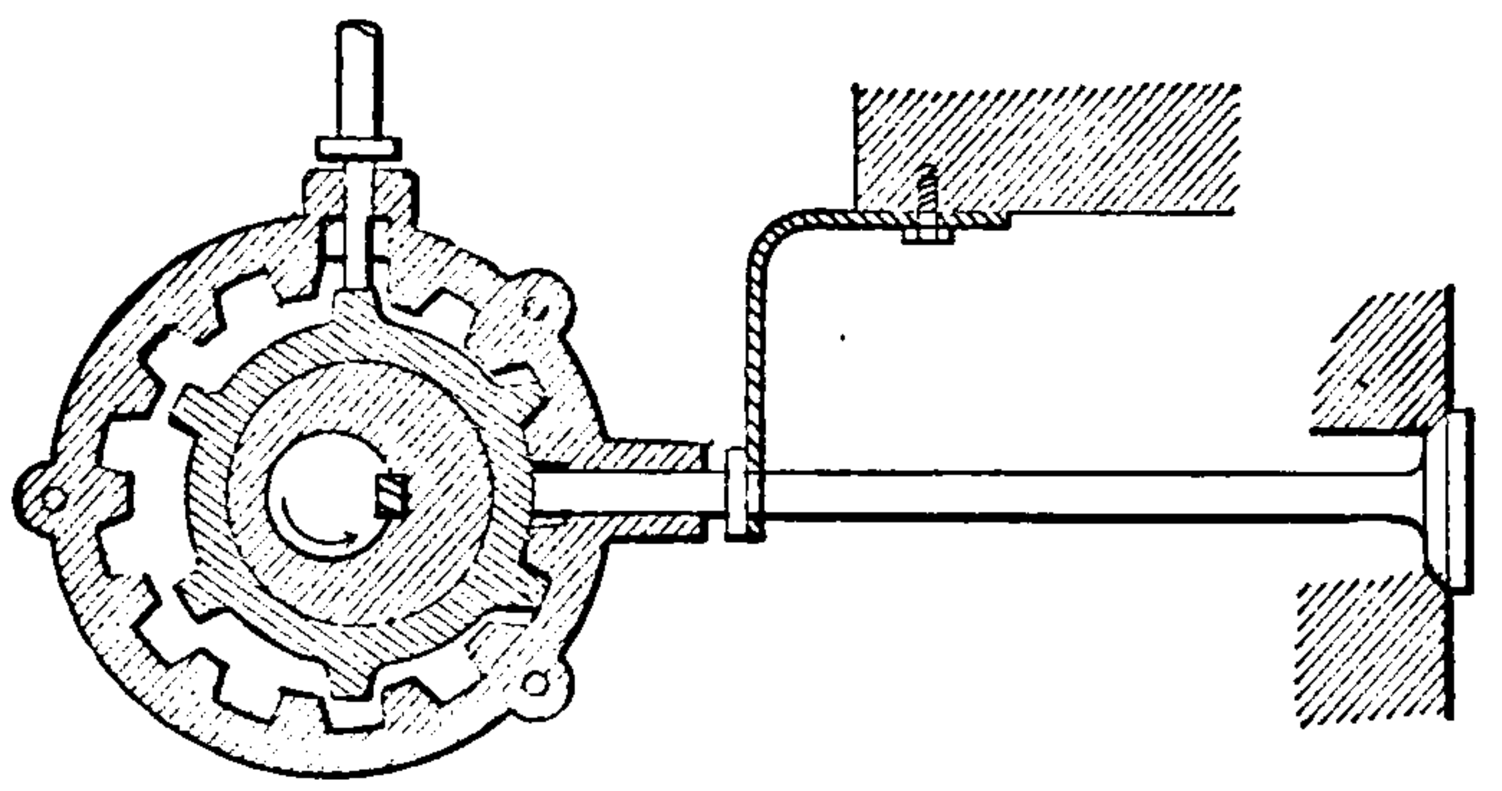


FIG. 28C.—RING VALVE GEAR.

the exhaust push rod of a four-cycle engine directly from a cam on the main shaft. The inner ring gear is swept around within the outer fixed gear, skipping by one tooth at each revolution of the engine shaft.

The outer stationary ring has twice the number of teeth in the ring gear, plus a hunting tooth, which makes a contact of a ring gear tooth with the exhaust valve rod at every other revolution.

A double-grooved eccentric (Fig. 28D) is another method of operating the exhaust valve of a four-cycle engine by traversing the push rod end, in the grooves which cross each other on one side of the cam; the groove on one section of the cam being enough smaller than the groove on the other section to give the valve its direct proper movement.

The spiral gear so much is use on four-cycle engines is a unique problem in design. Its velocity ratio cannot be determined by direct comparison of pitch diameters, as in spur gearing, but must be found from the angles of the spiral in each gear. Thus

arrangement derived from the musical beat pendulum. It is hung in a frame that is attached to and vibrates with the push rod. The swing of the pendulum is adjusted by the distance of the small compensating ball from the center of motion to vibrate

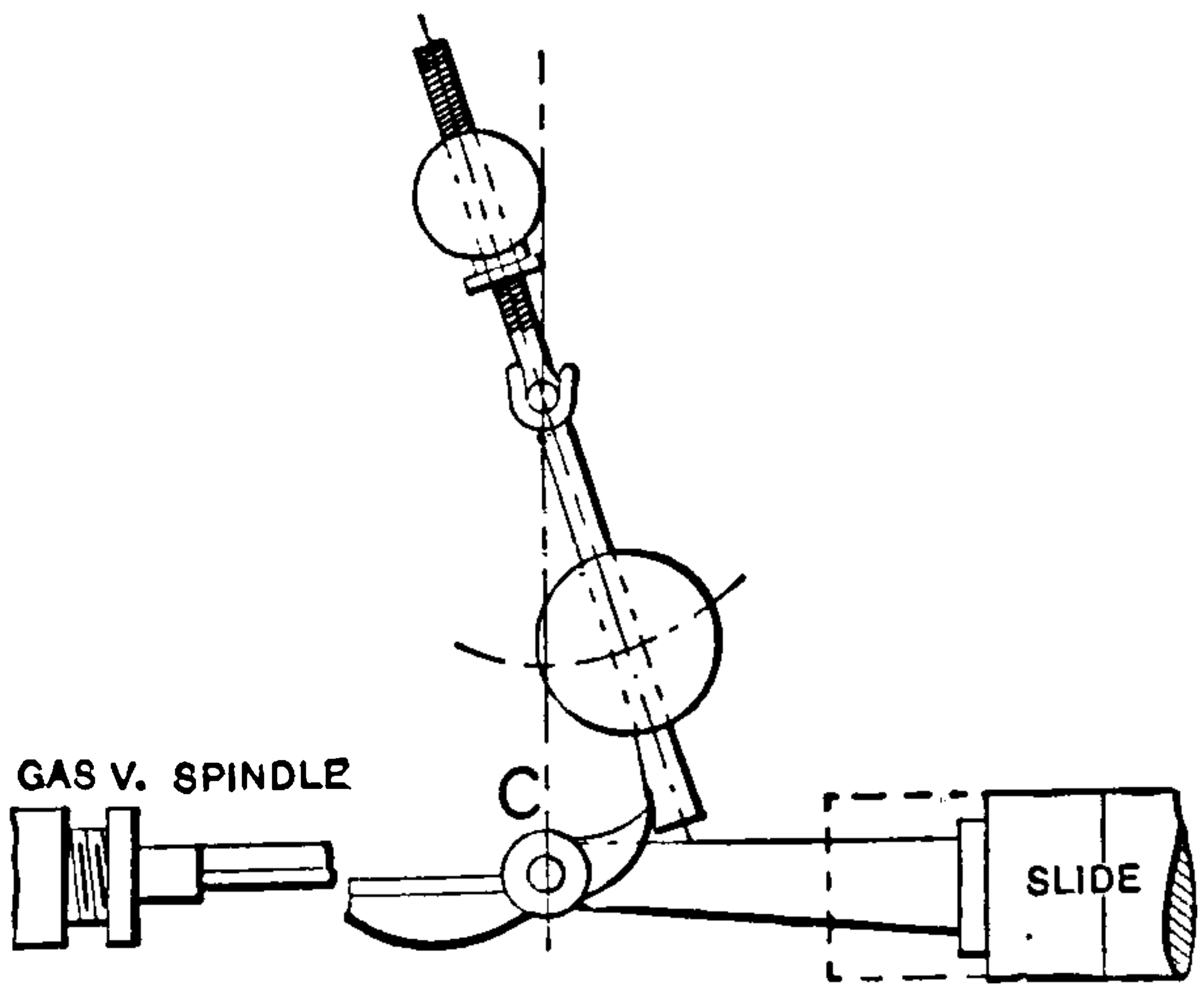


FIG. 28F.—PENDULUM GOVERNOR.

synchronously with the push rod at the required speed of the engine. Increased speed increases the range of vibration and releases the curved pawl of the push blade C and catches it again at the next stroke.

The differential cam (Figs. 28G and 28H) is much in use on the Otto engines in Europe and the United States. It is also

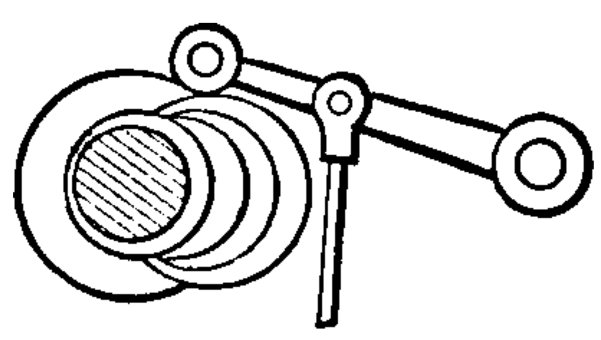


FIG. 28G.—DIFFERENTIAL CAM.

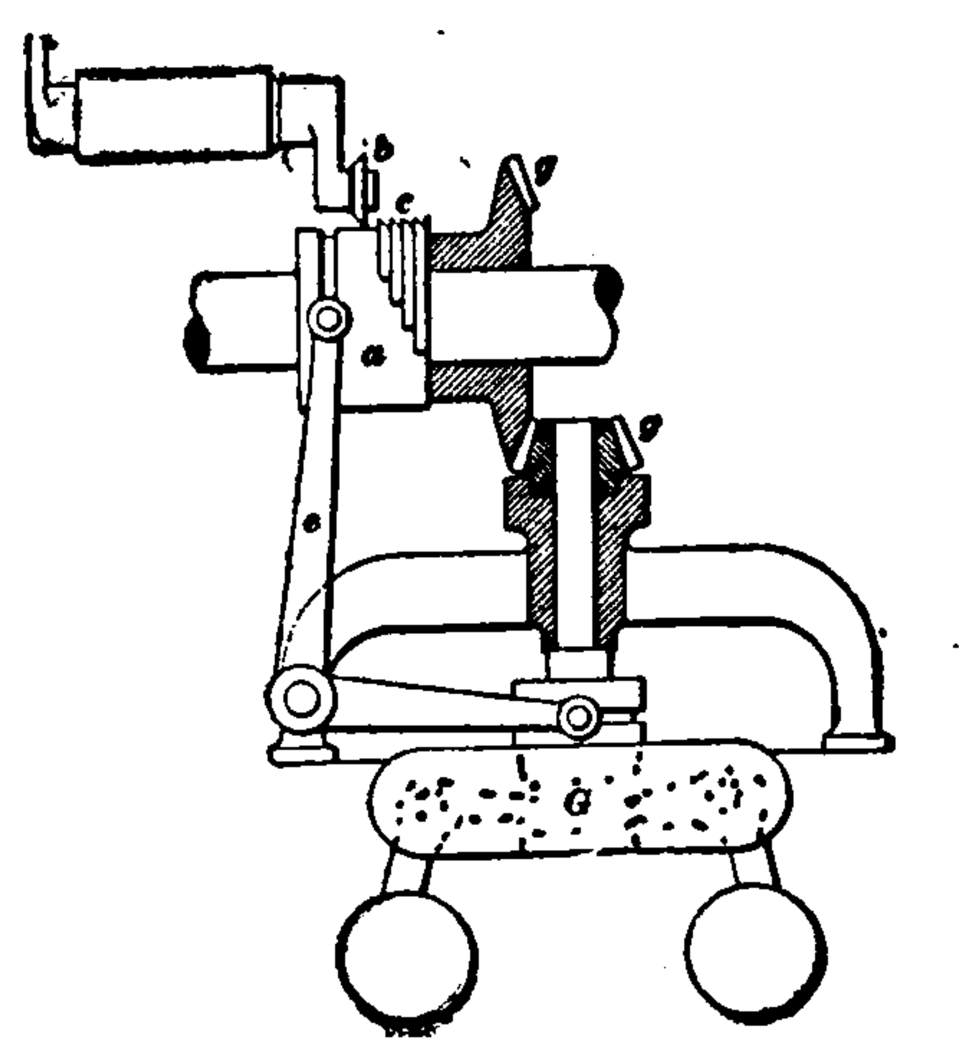


FIG. 28H.—DIFFERENTIAL CAM GOVERNOR.

called the step cam and is made for from closed to four grades of valve lift with corresponding differential charge. The centrifugal movement of the governor balls slides the sleeve on the governor shaft and through the bell crank lever the step cam sleeve *a* on the valve gear shaft. The disk roller *b* on an arm of a rock shaft, rolls upon one or the other cams at *c*, thus varying the movement of the inlet valve, which is connected to another arm of the rock shaft. The tread of the roller *b* is beveled and the steps of the cam are also beveled to match, so that the roller cannot slip off the cam.

The double port inlet valve (Fig. 28 I) is one of the methods of combining the charge of gas and gasoline directly into the cylinder. It is made in reverse design and with a groove around

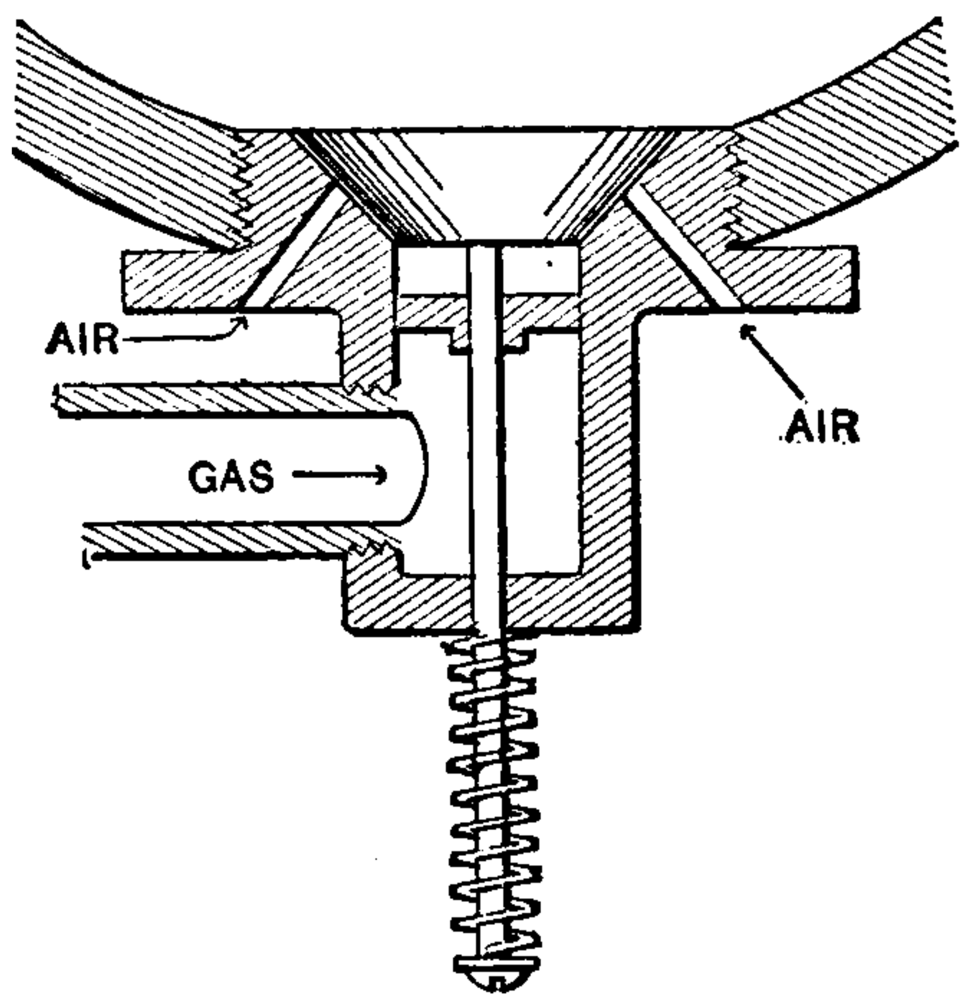


FIG. 28 I.—DOUBLE PORT INLET VALVE.

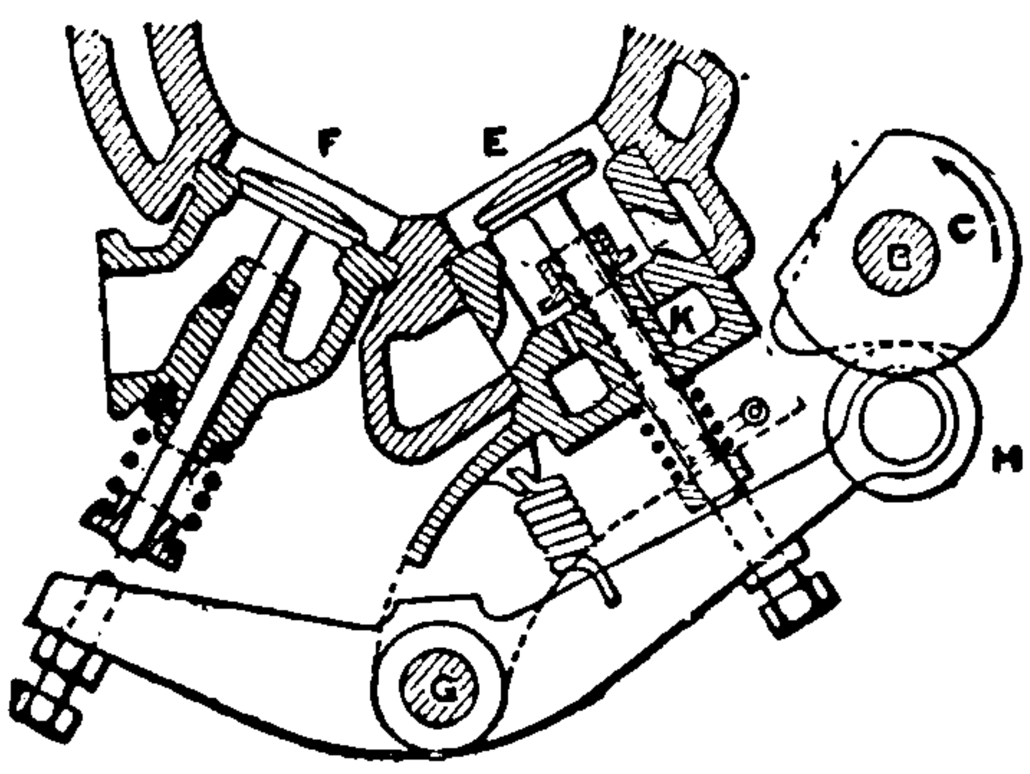


FIG. 28J.—VALVE GEAR.

one or both of the valve disk and valve seat, so that the gas or gasoline may be injected through the seat or from beneath the valve.

In Fig. 28 J is shown a gas engine valve gear in which both are operated by an inlet and exhaust cam through a bent lever. The form and set of the cams give the proper time action and the set screws in the lever adjust the lift of the valves. E, inlet valve. F, exhaust valve. C, a double cam with groove that rides the sliding roller H alternately onto the inlet and exhaust section. The inlet valve is double seated, the small flat disk covering the gas inlet from the chamber K, the air inlet being between the disks.

The "Union" valve gear has a double push rod. The one for the charge is operated by a cam on the reducing gear with a straight lever to bring the rod in line with the valve. A second cam and lever for the exhaust rod changes the direction of the push by a bell crank.

The governing device of the Ruger and Olin gas and gasoline

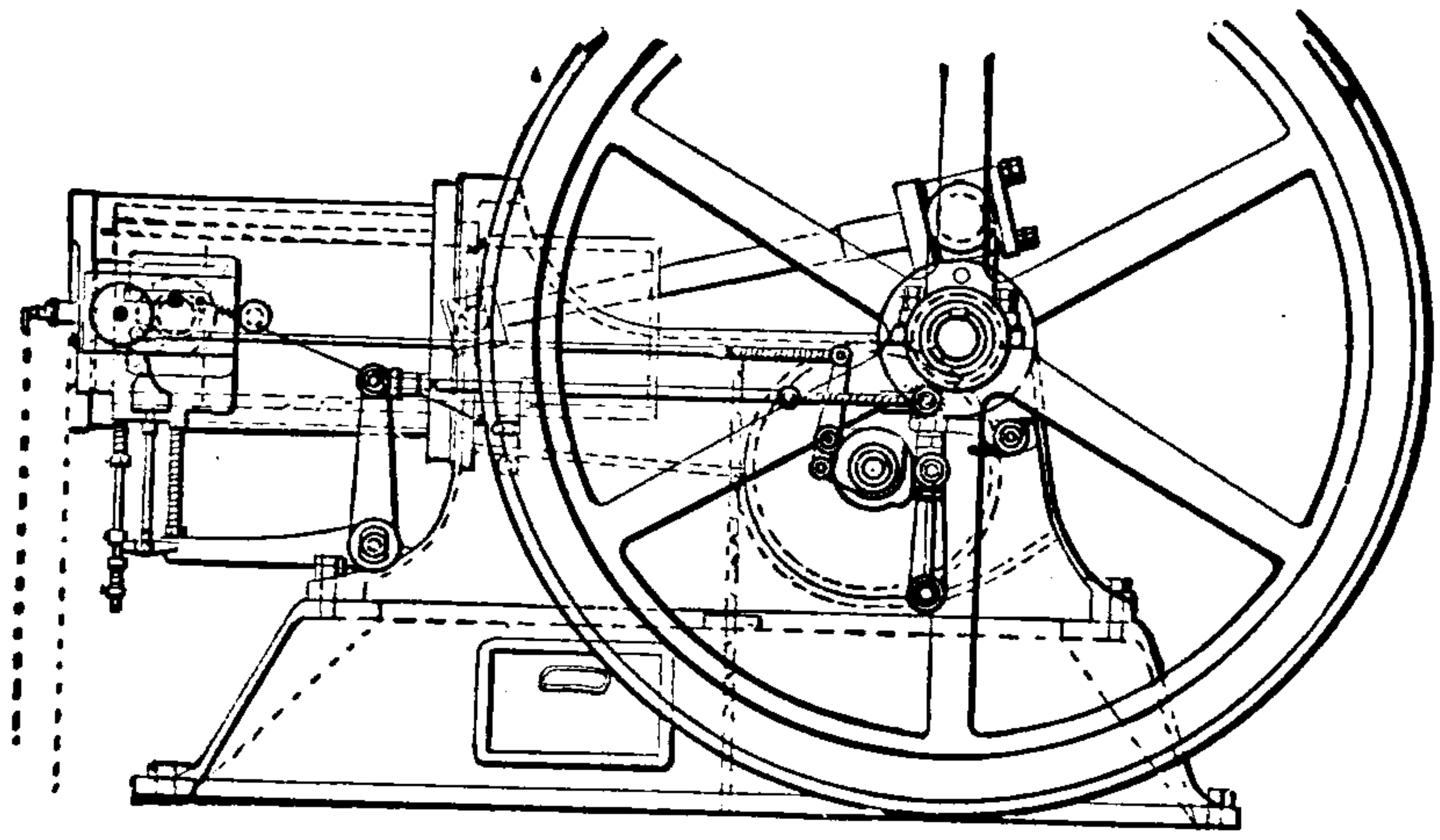


FIG. 28K.—"UNION" VALVE GEAR.

engine is of the centrifugal type and consists of two weighted levers L L, Fig. 28L, which operate a small bell crank and adjust-

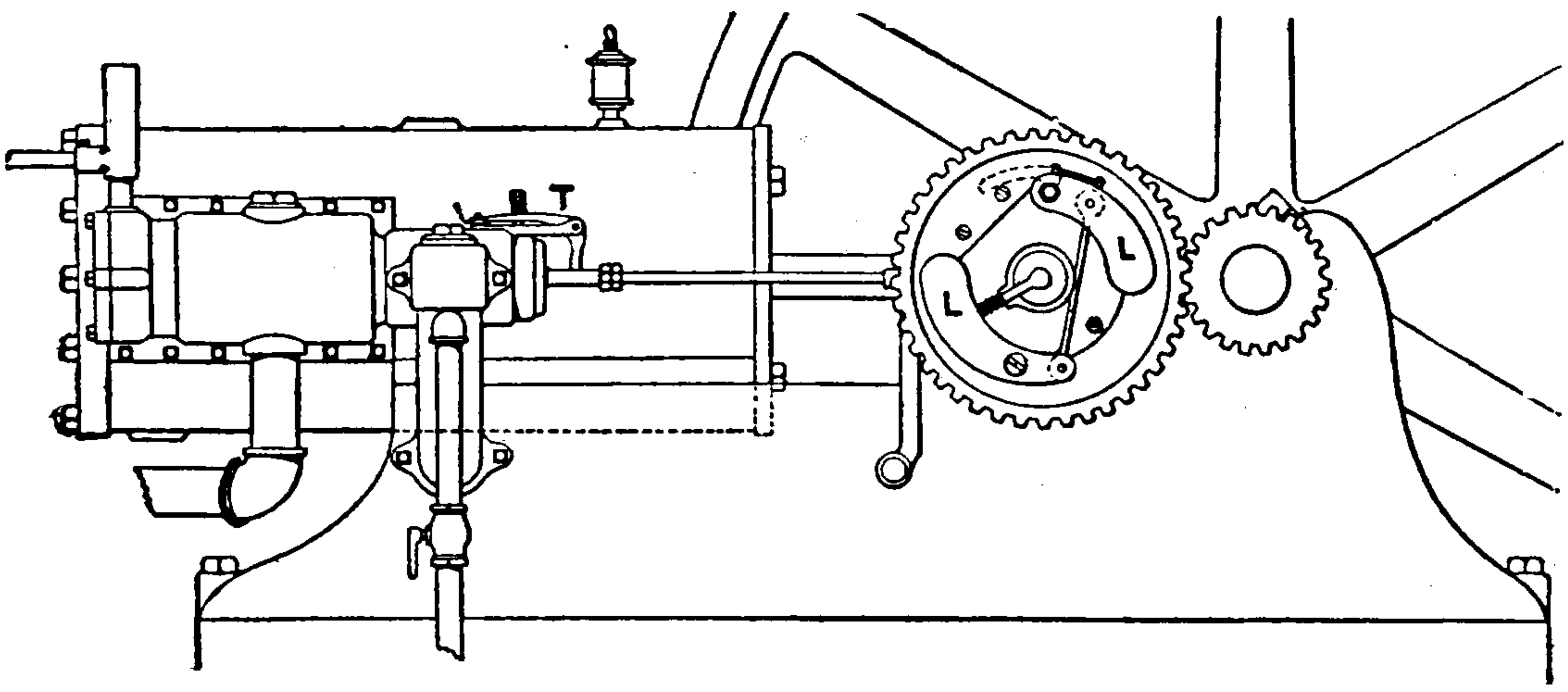


FIG. 28L.—CENTRIFUGAL GOVERNOR.

able spindle which rides the push roller onto or off the exhaust cam, thus holding the exhaust valve open during excessive speed.

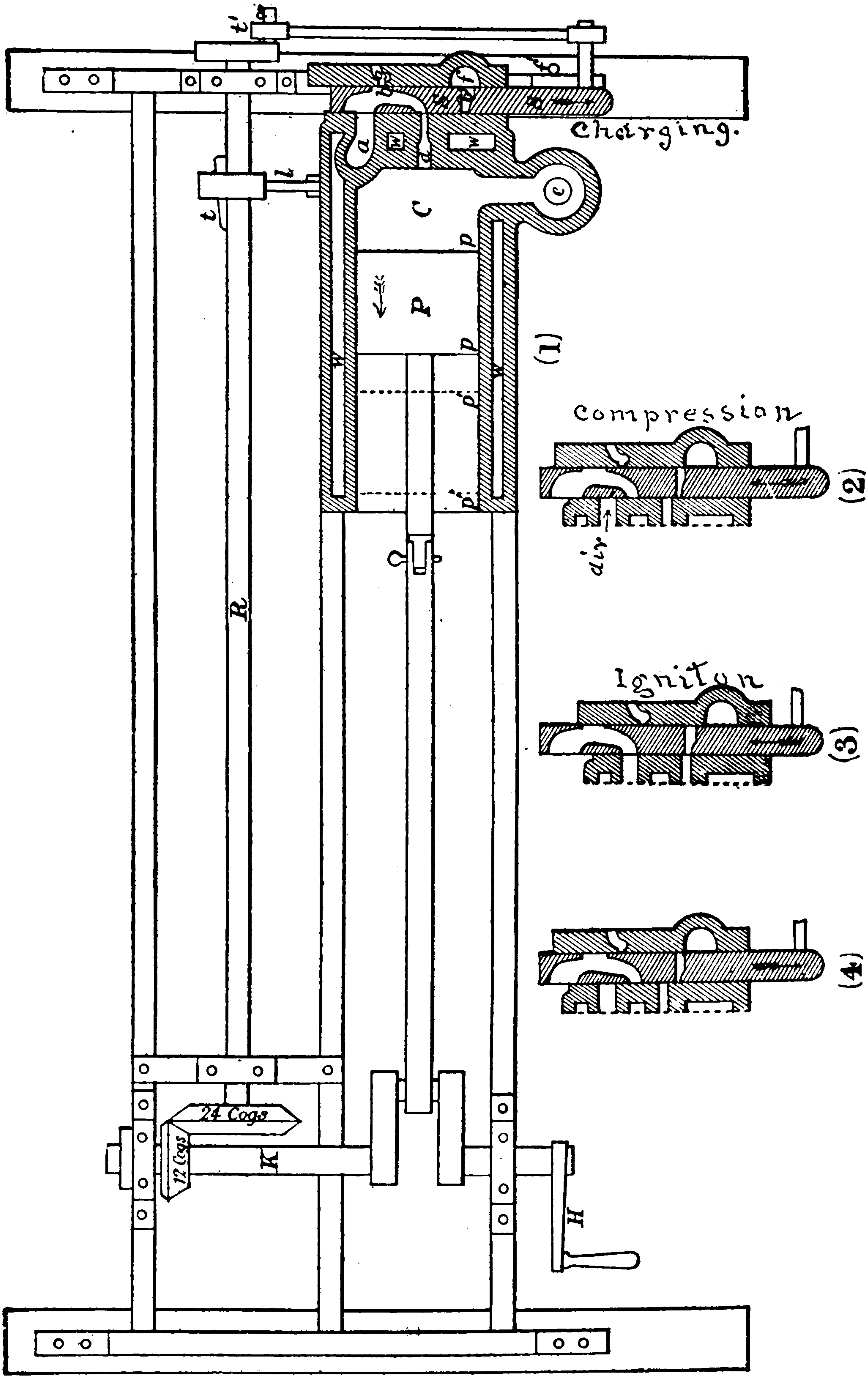


FIG. 31.—OPERATION OF THE OTTO IGNITION SLIDE-VALVE.

draught of the flame and explosion taking place at the point in the stroke at which the charge of gas and air mixture is completed. This igniter may be in the form of a partially aërated gas or vapor mixture, flowing through a tube constructed like a Bunsen burner, as shown in Fig. 29, the burner being set with its mouth just below the igniting port in the cylinder, with an outside guard tube to keep the flame steady; or a large flame may be used in contact with the port, as shown in the illustration of the economic gas engine, further on.

This form of igniter is also used on compression engines of the four-cycle type, with slide-valves enclosing ignition chambers, notably on European and American engines of the Otto slide-valve type.

Fig. 30 shows a section of a cylinder head with position of flame, guard chimney, and slide-valve at the moment of ignition.

Fig. 31 is a sectional view of the ports in the slide-valve and cylinder head of an Otto slide-valve engine, showing the position of the ports at different points in the stroke. No. 1, cylinder charging with air and gas, in which *a* is the air port, *g* the gas port, *b* the back port in the slide *s*, and *b'* the ignition port. No. 2, position of the slide during the return or compression stroke. No. 3, movement of the ignition port from the flame to the cylinder port. No. 4, reversal of the slide movement during the pressure stroke.

Fig. 32 illustrates the piston igniter as used on some of the Nash engines, where *e* is the gas jet, *d* opening through the valve shell, *g* the passage into the ignition chamber.

This igniter is based upon a new principle. The igniting jet of combustible mixture is caused to rotate in the circular chamber *r* in the piston, into which it enters through a passage tangentially placed. This forms a vortex of flame, which is positive in its action and simple. The piston valve is made of steel, and is hardened and ground to size. It moves in a reamed hole in the case, being so loosely fitted as to drop of its own weight, and yet making a gas-tight joint. Since the valve is perfectly balanced as to gas pressure, it moves without fric-

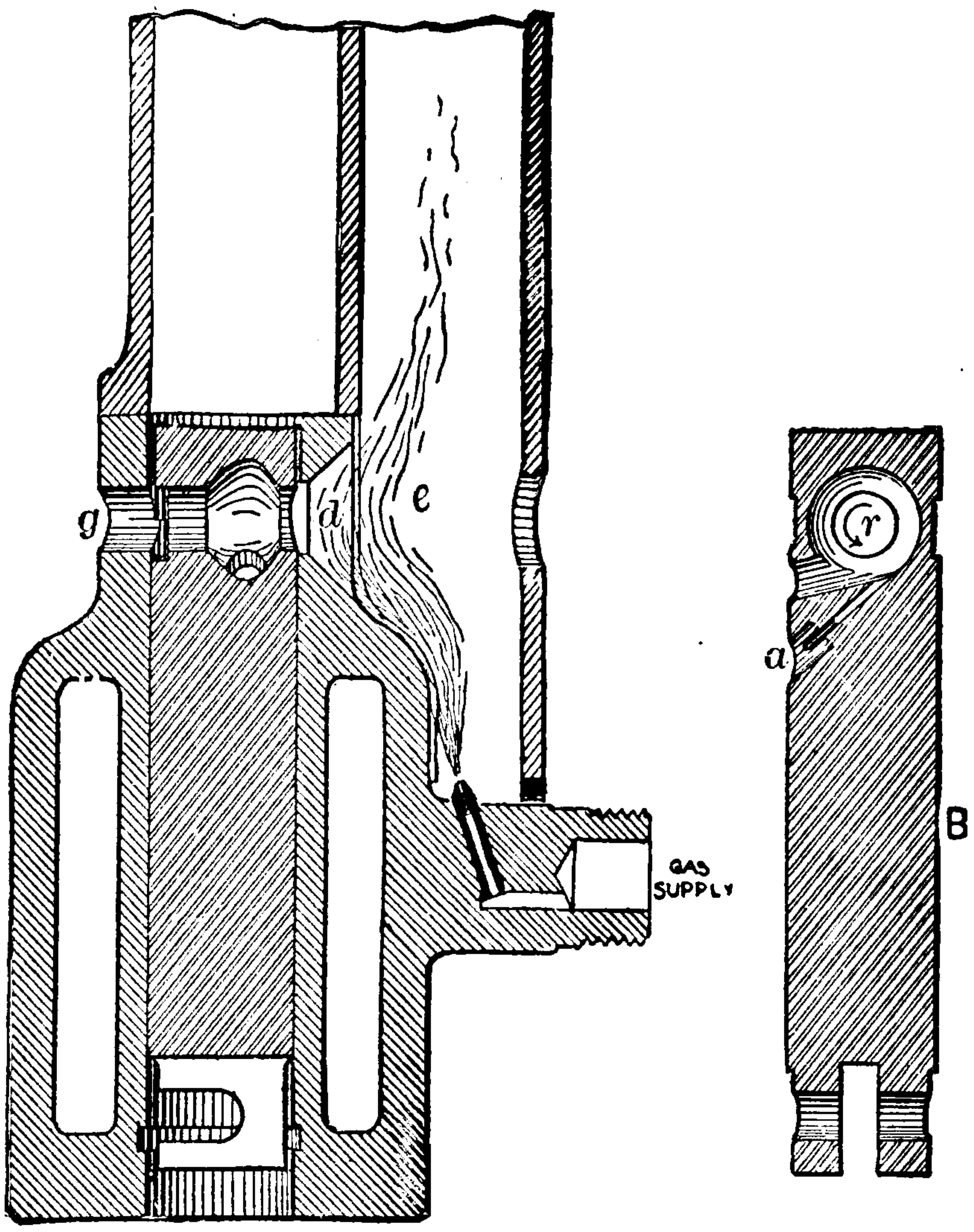


FIG. 32.—IGNITING VALVE.

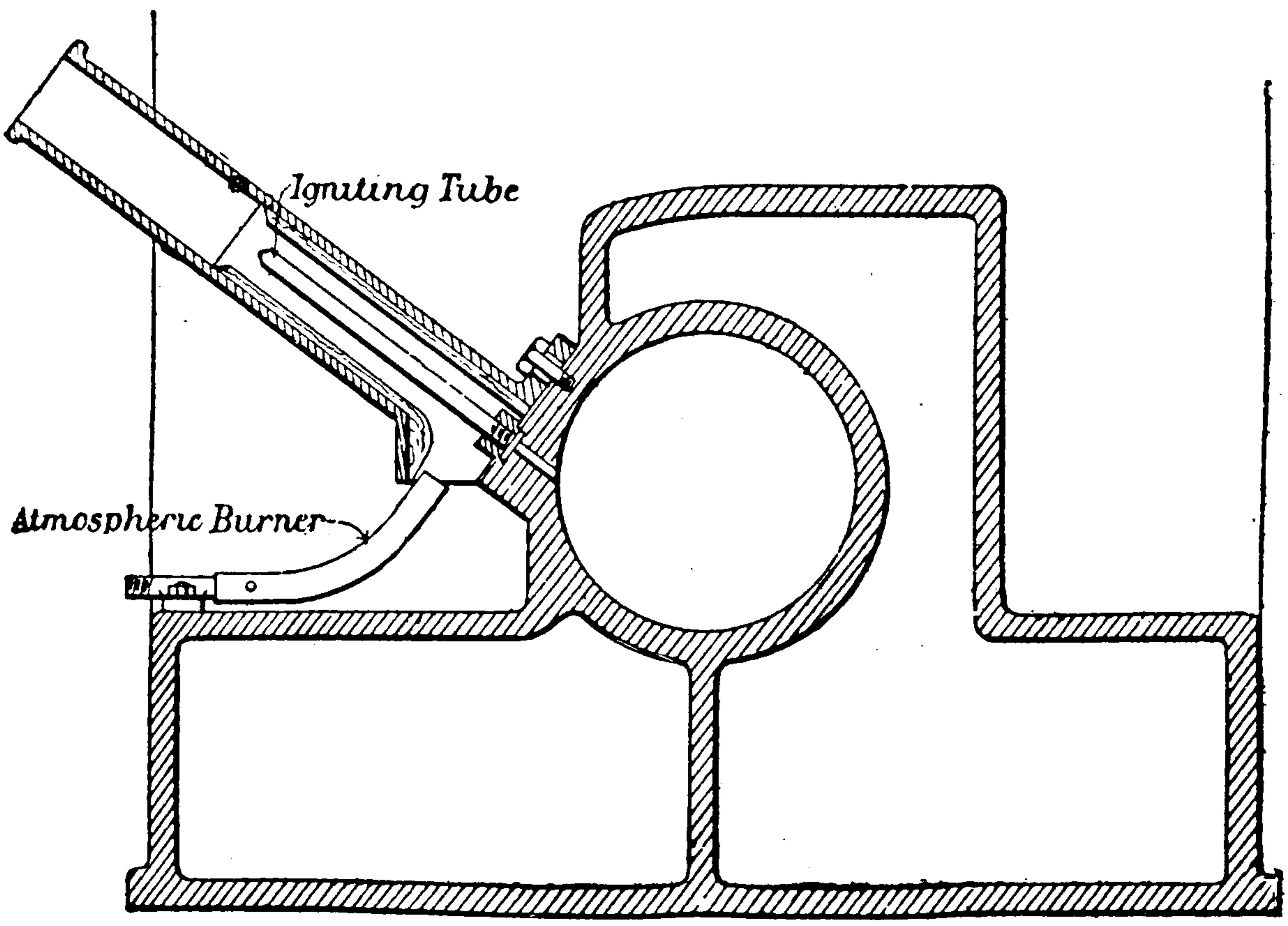


FIG. 33.—THE TUBE IGNITER.

The tube igniter, as shown in Fig. 33, has taken a wide range of usefulness and is well adapted to compression engines. As originally made, there is a deviation in the time of ignition from the uncertain condition of the explosive mixture and va-

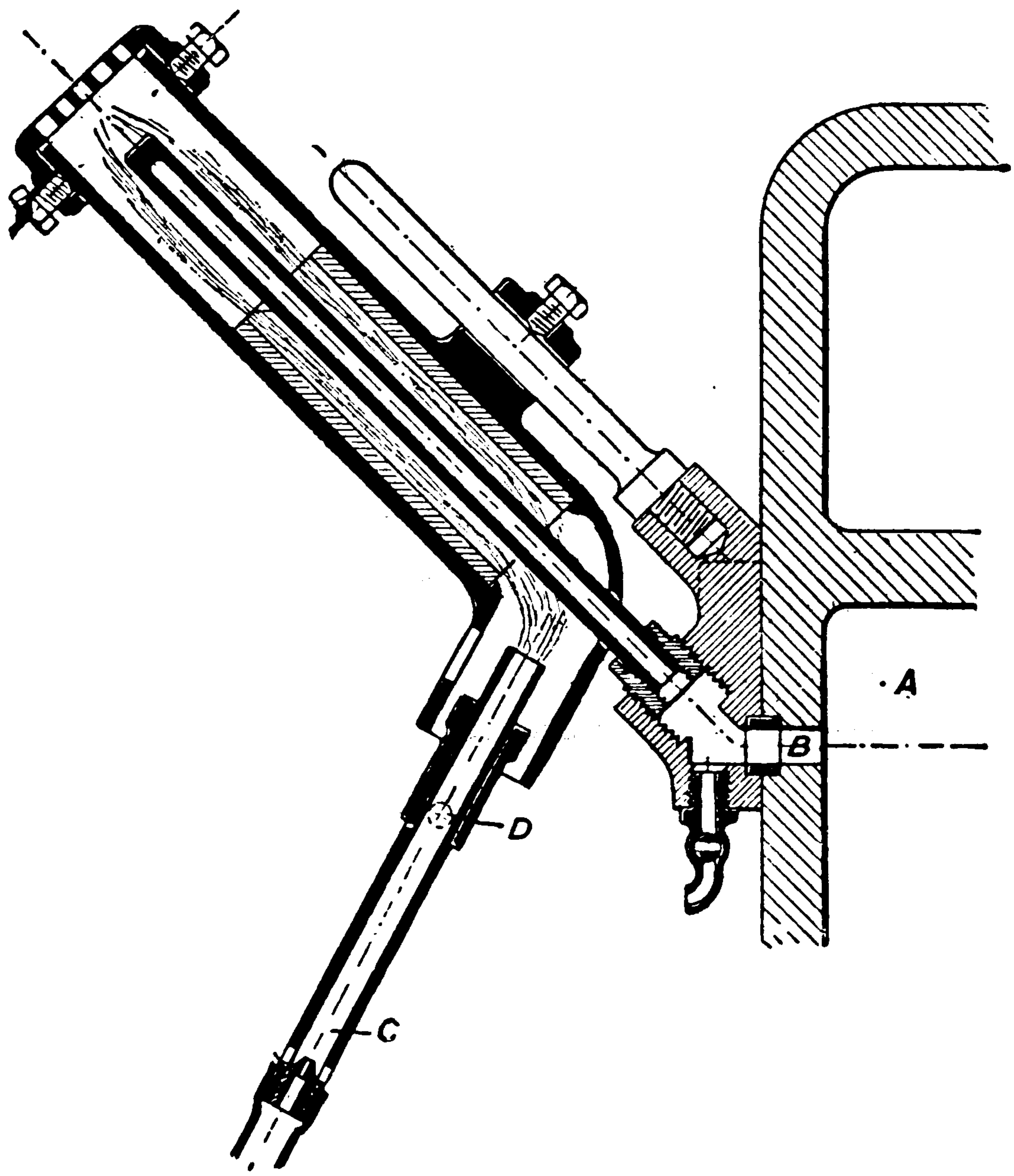


FIG. 35.—TUBE IGNITER.

riable heat of the tube. The adjustment of the length of the tube and position of the heating flame, so that ignition will take place at the maximum compression or end of the compression stroke, is a somewhat delicate matter, but has been found by experiment for the different designs of gas engines.

The degree of compression to just carry the fresh gas and air mixture to meet the firing temperature of the tube by pushing the products of the previous combustion before it, together with the adjustment of the Bunsen jet to a proper position in regard to the length of the tube, is a puzzling problem that has to be worked out experimentally for each style of engine.

In Fig. 34 is shown the form of slide igniters as used on

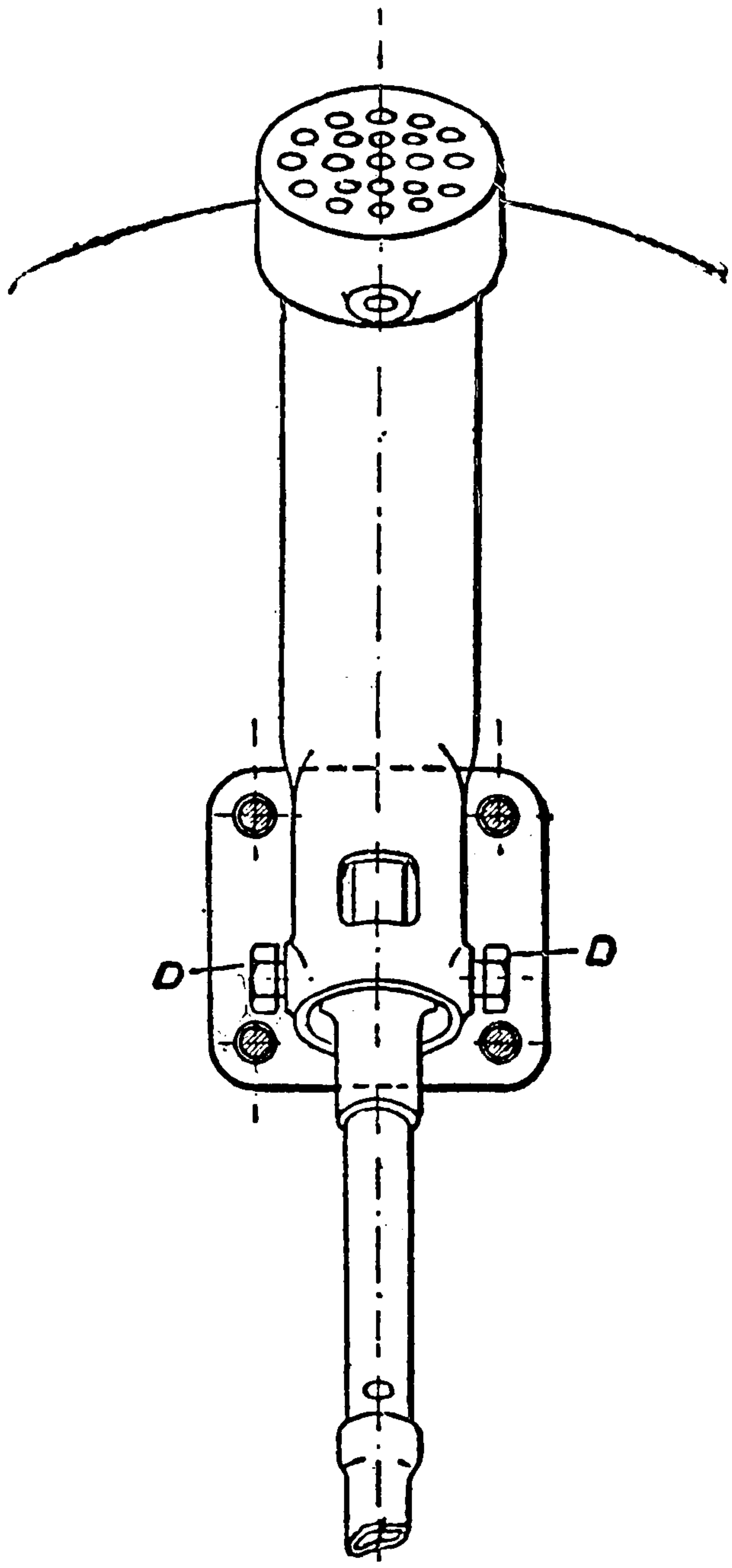


FIG. 36.—FRONT VIEW.

European engines using both tube and slide. This form acts as a time igniter, which regulates the time of ignition by the movement of the slide-valve or inlet piston, which opens communication with the hot tube through the inner tube by compression—the small vent tube and cock allowing of a free blowout of the igniting tube when accumulation of soot takes place.

In this plan the ignition tube is short, and may be made of platinum or porcelain.

The hot-tubs igniter (Figs. 35 and 36) shows two views of an ignition tube used on the Robey engines, which is adjustable for the position of the igniting surface of the tube as well as for the position of the Bunsen burner, A being the combustion chamber, B the igniter passage, C the Bunsen burner pivoted to the chimney frame at D, which allows the burner to be tilted slightly to regulate the distribution of the flame around the tube.

The set-screw in the chimney socket allows of a ready adjustment of the position of the chimney and burner for the time of ignition.

PRIMARY IGNITION BATTERIES.

The Edison Primary Battery, formerly known as the Edison-Lalande battery, and exclusively made by the Edison Manufacturing Company, of New York, Chicago, and Orange, N. J., is now the leading type for efficiency and lasting quality for primary battery ignition for all types of explosive motors. The batteries are made in varying sizes to meet the requirements for stationary, portable, launch and automobile services. In the construction of these batteries, a double zinc plate forms the negative element and a single plate of compressed oxide of copper forms the positive element of the battery. The fluid is a solution of caustic soda, which is sealed by a layer of paraffine oil to prevent evapora-

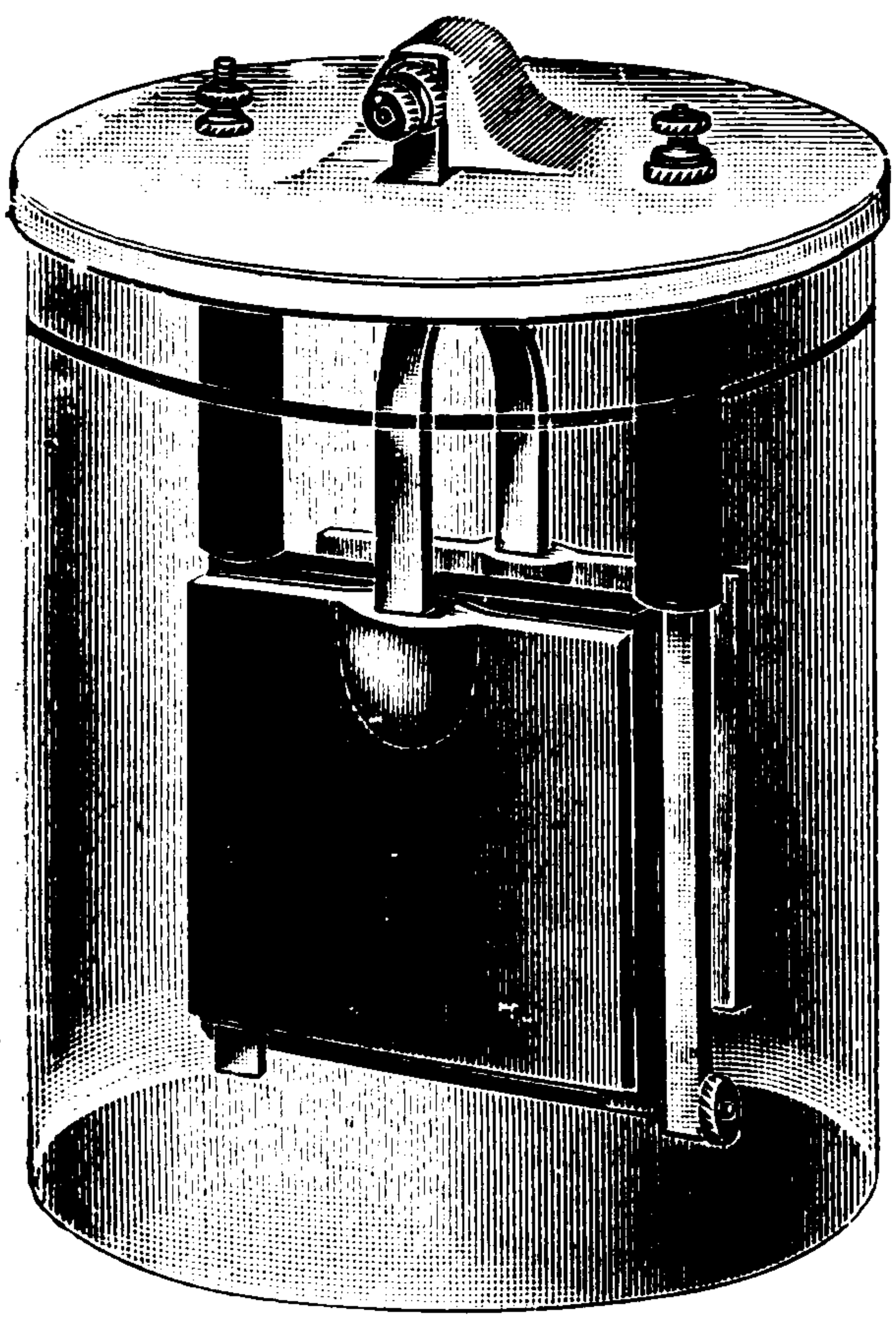


FIG. 37.—TYPE R R, 7¼ x 10½".

Several forms of internal circuit-breakers have been devised, in which is represented a reciprocating rod which may be operated by a connecting rod with a cam. The insulation is made within a sliding tube, which allows of considerable motion in order to allow the contact piece to slip off suddenly from the stud which is fixed in the cylinder head.

In Fig. 39 is represented a similar device, in which the insulated rod rotates by an outside gear driven from the valve

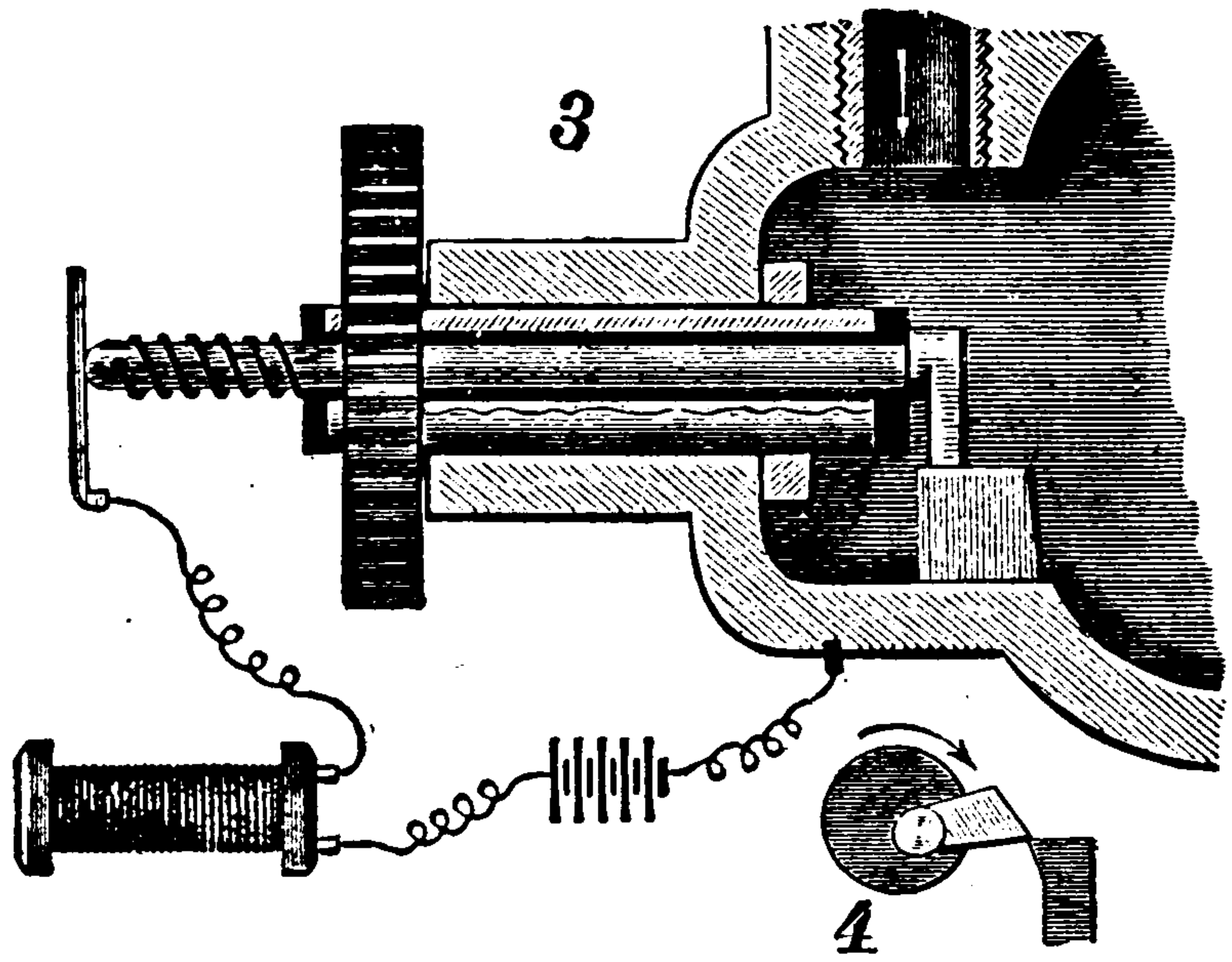


FIG. 39.—ROTATING SPARK-BRAKE.

shaft. The rotating spindle carries the insulated rod and break-piece eccentrically, so that its contact and break can be accurately regulated by rotating the position of the teeth of the gears.

The sparking coil used with this form of igniter is shown in Fig. 40. It consists of a bundle of iron wire, insulated and wrapped with insulated copper wire. It is a simpler device than the double or Ruhmkorff coil, but will not project a strong spark or at a great distance between the electrodes, as may be obtained from a Ruhmkorff coil—the breaking device being necessary in either case.

In Fig. 41 is represented the Pennington double igniter, in which the breaker is a loop piece attached to the end of the piston. The contact finger swings on a joint with a spring that keeps it in a straight line with the insulated rod. As the piston nears the end of its stroke, the loop pushes the finger over and breaks the contact at the end of the stroke; and as the piston recedes, the finger, having sprung back in line with the insulated rod, is caught by the loop, and a second break spark

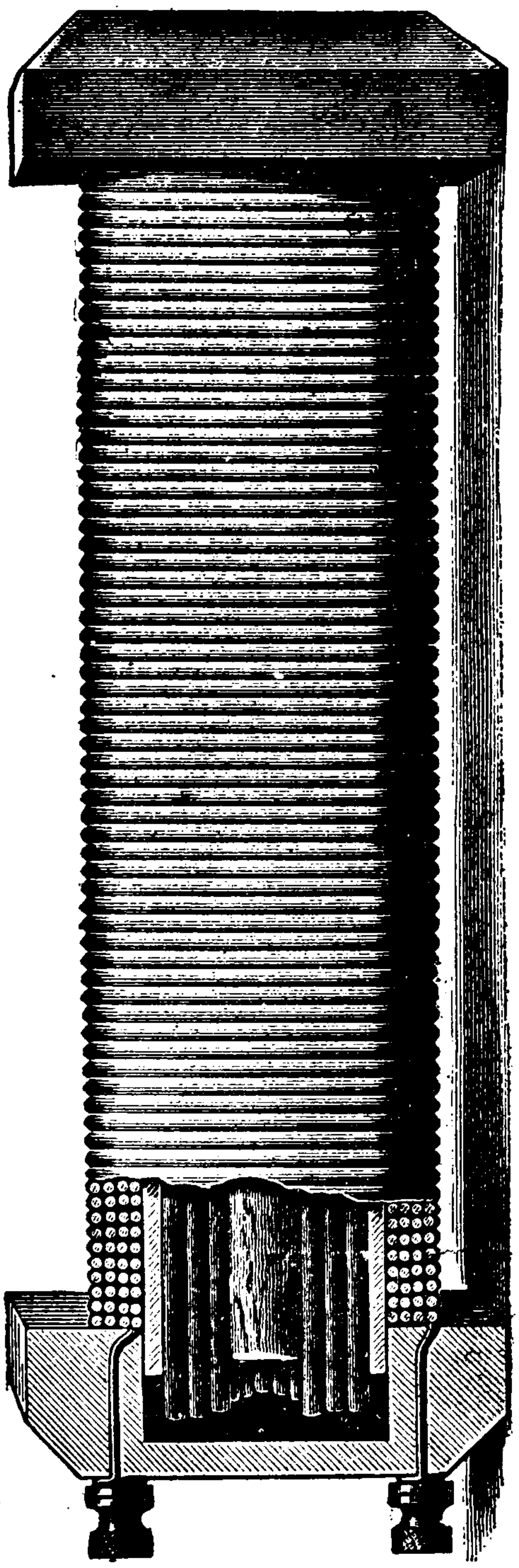


FIG. 40.—SPARKING COIL.

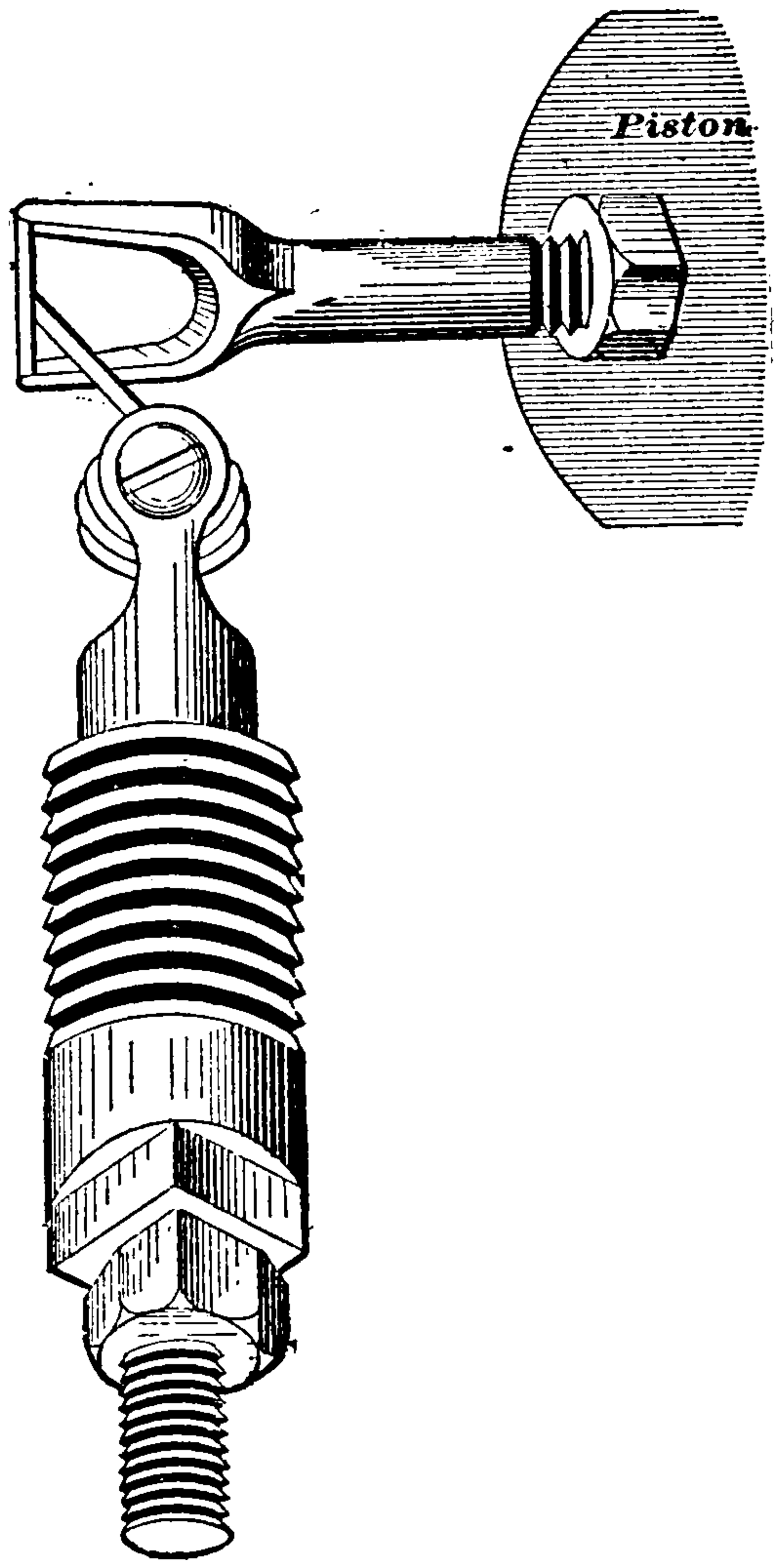


FIG. 41.—THE DOUBLE SPARK DEVICE.

takes place. The time of sparking can be varied by the length of the finger and by adjusting the position of the insulated plunger.

Ignition by direct current from a small dynamo with a current-breaker operated by the cam shaft is in favor with many gas-engine builders.

A current-breaker used on the Priestman engine is shown in Fig. 42, where an arm kept in position by a spring or weighted lever is made to touch a spud revolving on the sec-

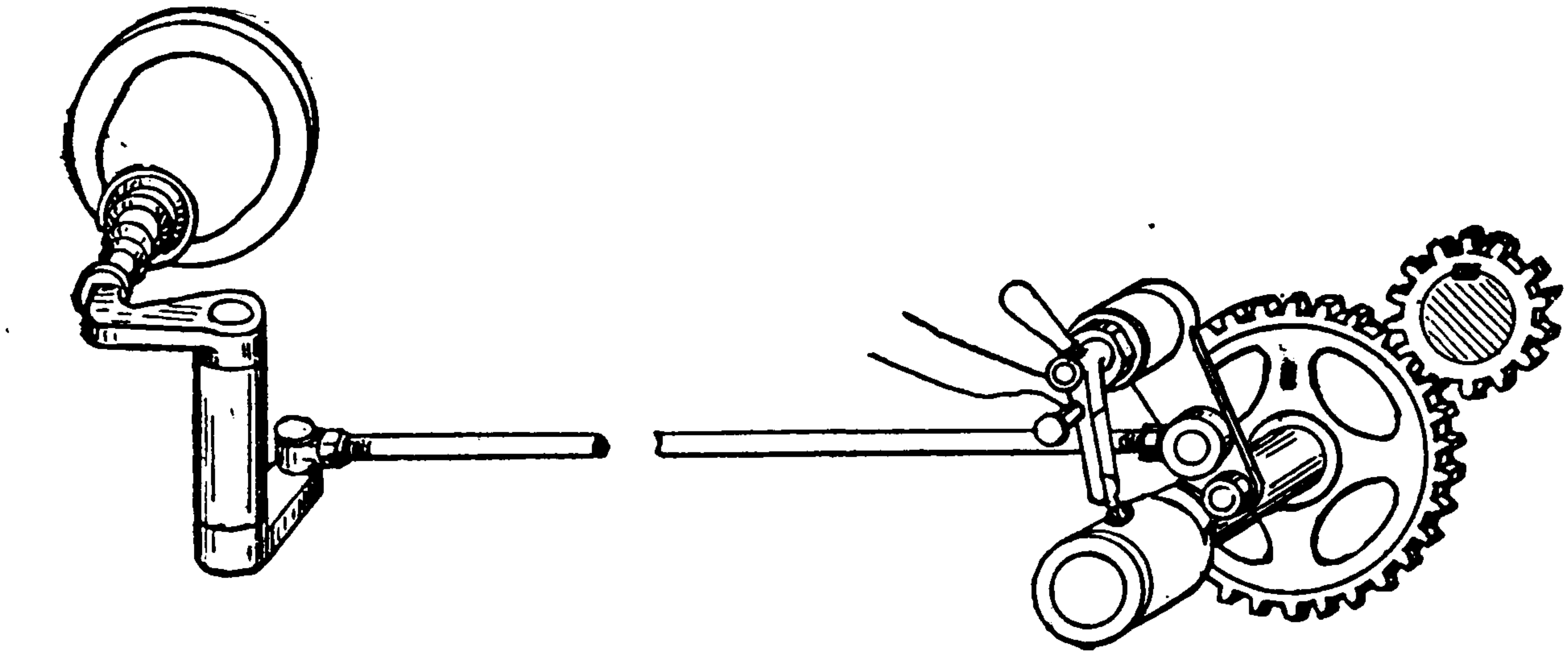


FIG. 42.—THE CURRENT-BREAKER.

ondary shaft. A movable sleeve on the shaft is set back or forward for time adjustment of the contact break.

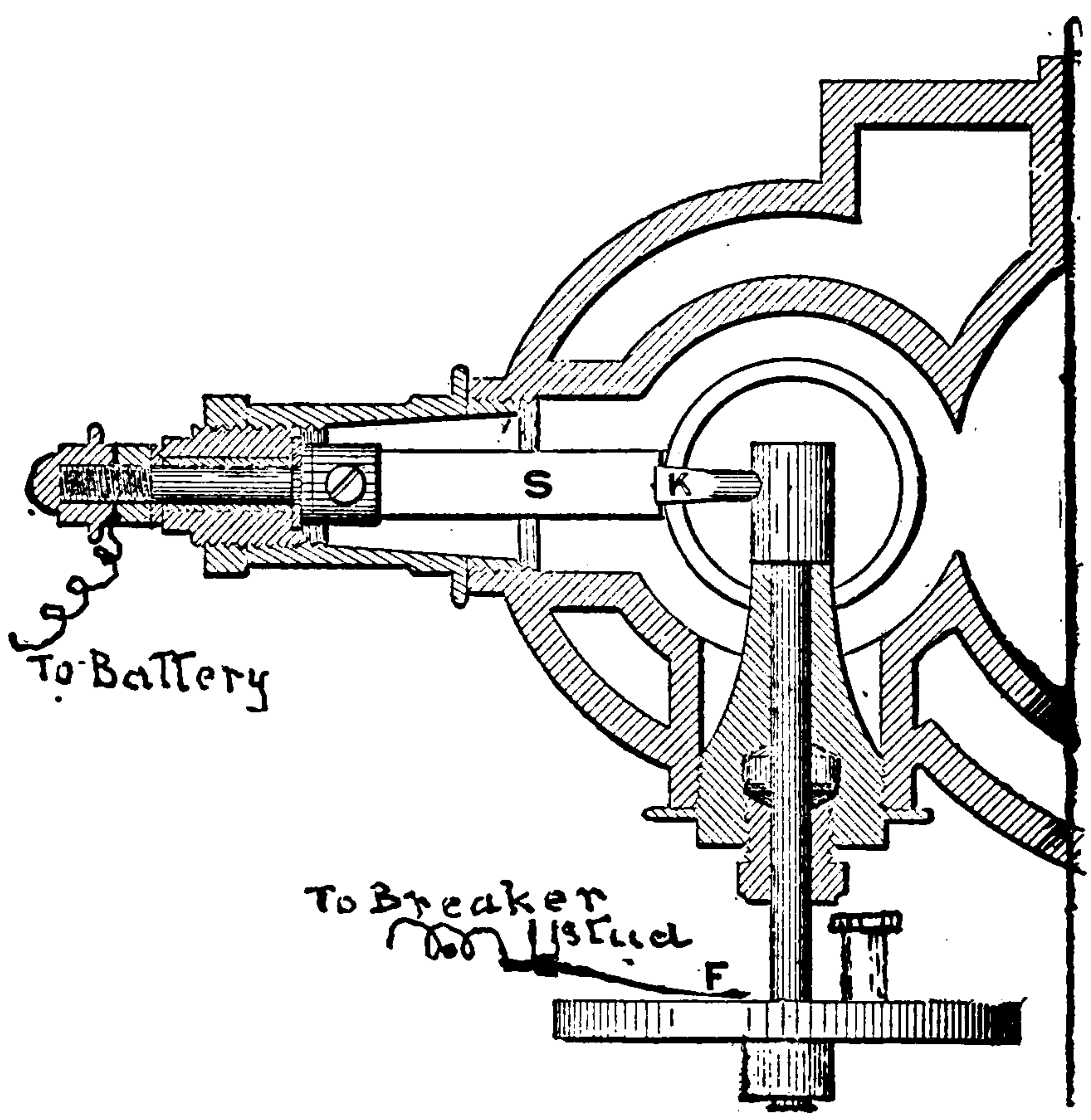


FIG. 43.—ROCKING SHAFT SPARKER.

Fig. 43 represents the sparking device used by the Union Gas Engine Company of San Francisco, and consists of a rocking shaft carrying a flattened pin, K, on the end inside of the

in successful use and does away with the care of a battery. This requires no induction coil, the spark being made directly through the break device and electrodes.

Fig. 45 represents a generator used on the Sumner gas and gasoline engines. The spark is produced by a plunger contact with the commutator operated from a cam on the secondary shaft.

IGNITING TIMING VALVES.

The value of an exact time of ignition for producing uniformity of speed in explosive engines is attested by the ex-

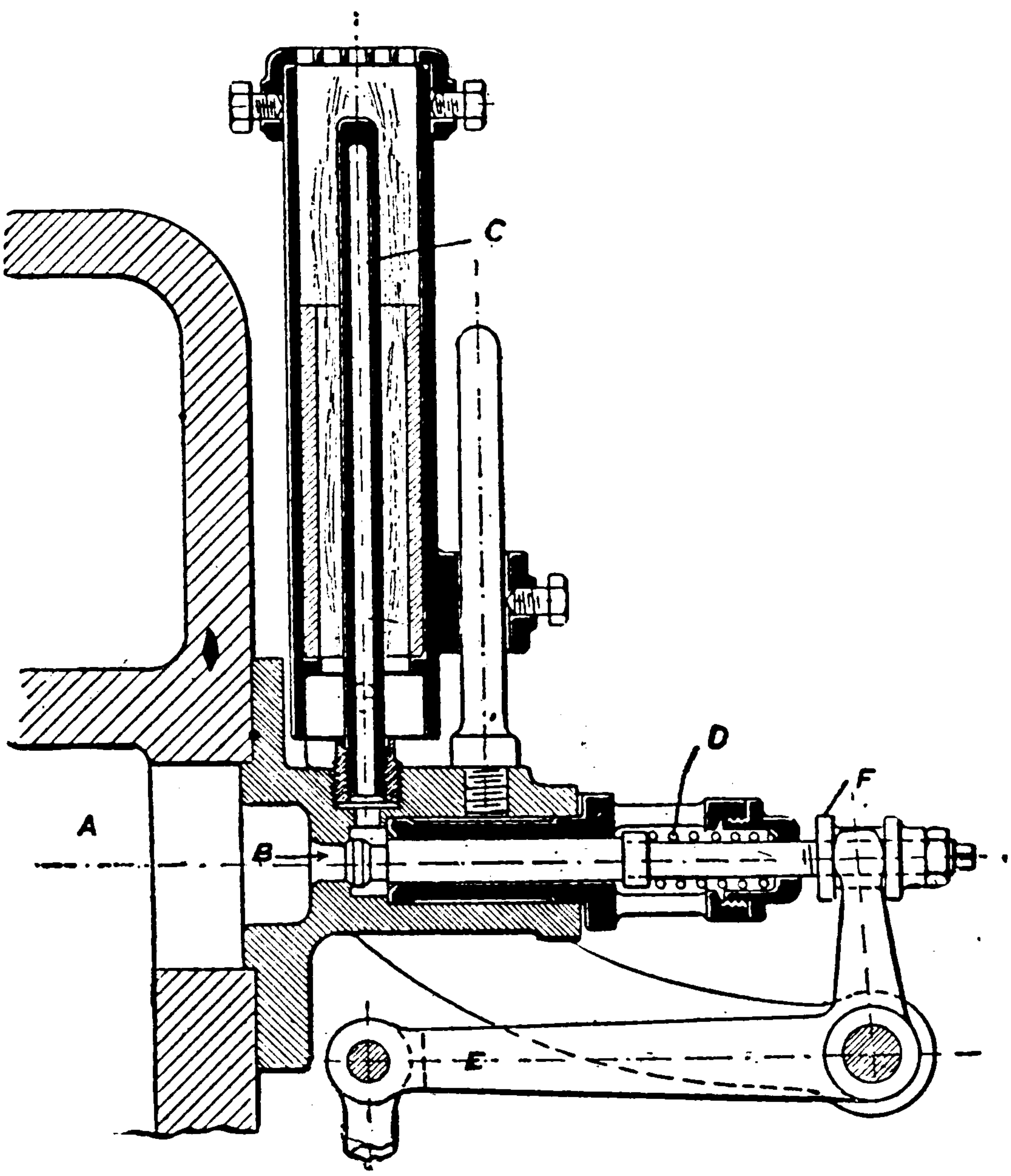


FIG. 46.—TIMING VALVE.

haustive experiments of years with the many devices made for the ordinary tube igniters, and the final recourse to electric ignition. A satisfactory result has been obtained in several designs for operating a valve at the mouth of the ignition tube that admits the compressed charge to the ignition tube at an exact point in the piston stroke.

In Fig. 46 is illustrated a timing valve used on the Robey

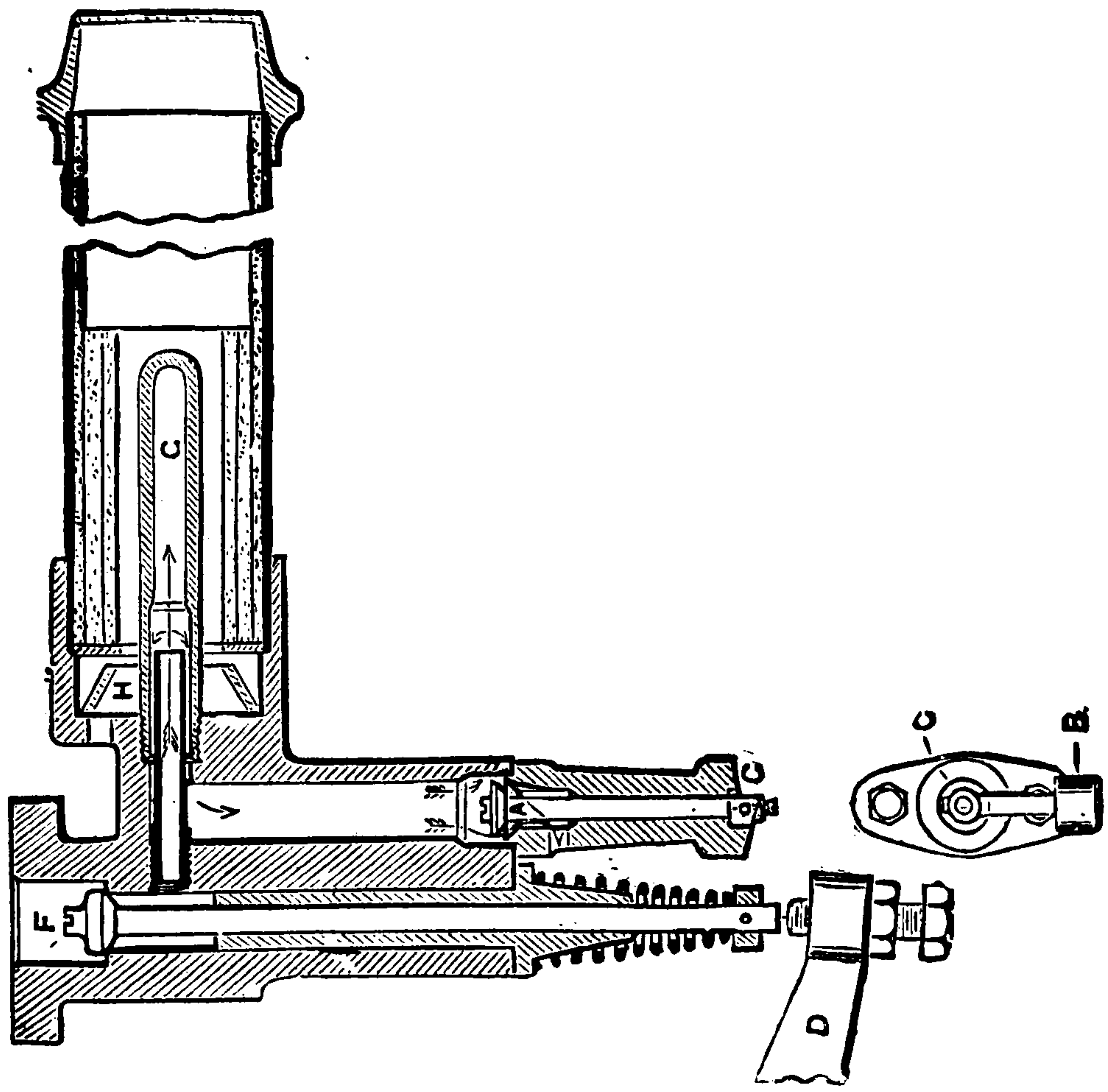


FIG. 47.—TIMING VALVE AND STARTER.

engine, in which A is the combustion chamber; B the passage leading to the hot tube, a double-seated valve and spindle held to its front seat by the spring D; E a lever operated from the cam shaft; F adjusting spool with set nuts. In action the valve is opened at or about the end of the compression stroke and kept open during the exhaust stroke, thus clearing the ignition tube uniformly and insuring exact time of ignition.

In Fig. 47 is illustrated a combined timing-valve igniter and starter, as used on the Stockport engines. In this arrangement a double tube is used, with an annular space between the inner tube and the hot tube, through which the products of combustion may be blown out, followed by the explosive mixture, into the hot tube, by compressing the timing valve and the starting valve at the same moment. Referring to the cut, F is the timing valve, operated by the lever D; A the starting-valve, with its waste outlet at V; H is a mantle to draw the flame closer to the igniting tube.

There are many variations in form and attachments for timing valves in use in Europe and the United States. They are fast coming into favor for hot-tube igniters for the larger gas and gasoline engines.

HOT TUBE IGNITERS.

Much of the difficulty in maintaining a constant and uniform explosive effect from the hot tubes used in the early or experimental period of the explosive motor was due to the inability to know or see what was the exact condition of the progress of combustion which was taking place within the tube and passage to the combustion chamber of the cylinder.

The want of a durable and inexpensive material for the ignition tubes was an unsatisfactory experience in the early days of the explosive motor. The use of iron, with its uncertain and perishable nature, under the intermittent high pressure and at the continual high temperature of the Bunsen burner, oxidized the tubes on the outside, making them thin, so as to burst in a month, a week, or a day; but only occasionally a tube would last a month, although by the use of extra strong iron pipe their life has somewhat lengthened. One of the principal causes for the short life of the iron tube may be found in the management of the Bunsen burner. A tube of iron or any other metal should not be used at a white heat even at any one spot. A uniform band at a full red heat all around the central or other part of the tube suitable for timing the ignition is the most desirable temperature for ignition, and for the lasting quality of the tube. In the construction and setting of the Bunsen burners, the point of greatest heat in the flame is too often made to impinge directly against the tube, heating it to a white heat at one spot.

should be hard and kept sharp. Use milk for lubricating the drill.

The running out of the drill will make a thin side to the tube, which will be liable to overheat, and by expansion and contraction, due to unequal temperature, will cause the thin side to bulge and finally rupture.

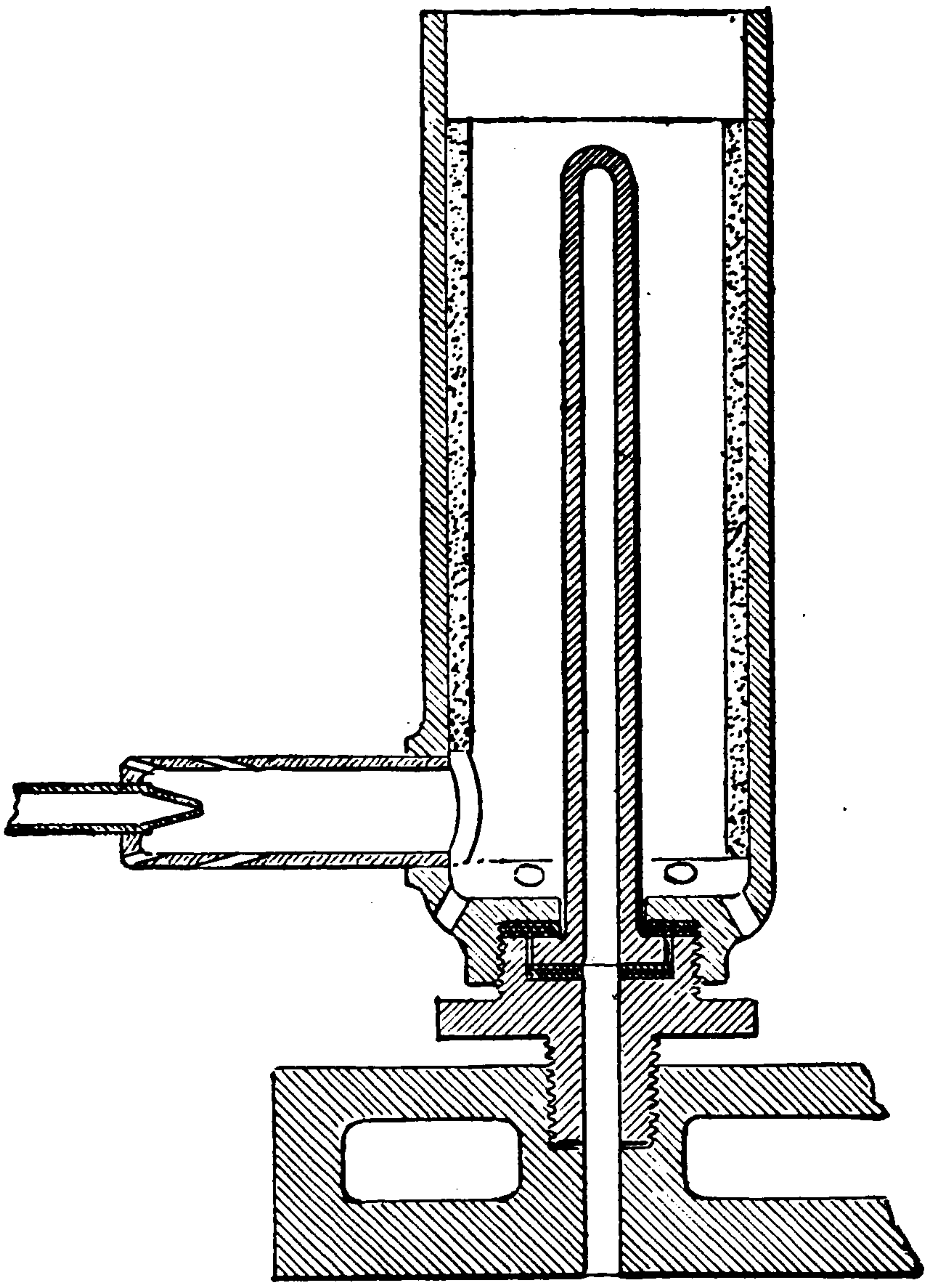


FIG. 47A.—PORCELAIN TUBE SETTING.

Platinum tubes have been used to considerable extent in Germany and a few in the United States; their cost will probably send them out of use in view of the lasting quality and cheapness of the nickel alloy and porcelain tubes.

In Fig. 47A is shown one of several methods for setting the porcelain tube in a socket to be screwed into the cylinder.

The packing may be asbestos washers, dry or moistened with wet clay.

The application of a new device in hot-tube ignition as used on the Mietz & Weiss engines, by which a short and plain porcelain or lava tube, open at both ends and set between sockets with asbestos packing, is a marked progress in simplifying the care and adjustment of tubes and time of firing.

A reinforcement of the combustion passage by an iron pipe extension enlarges the power of the small hot tube by prolonging the burning of the firing charge, and thus making a short tube available to meet the requirement for timing adjustment. Such tubes should last indefinitely; they are cheap, quickly changed, and easily cleaned.

ELECTRIC IGNITION PLUGS.

The ignition of the charge has undergone much change in the past five years in the various appliances and trials which have resulted in placing the electric jump spark in the lead for reliability and certainty of action. The form of the plug containing the electrodes has undergone many changes in order to eliminate the short circuit propensities of these simple devices by the carbonizing of the insulating surfaces and to obtain adjustment to meet the abrading propensities of the electric spark. In Fig. 47 B we give a section of an ignition plug of French design much

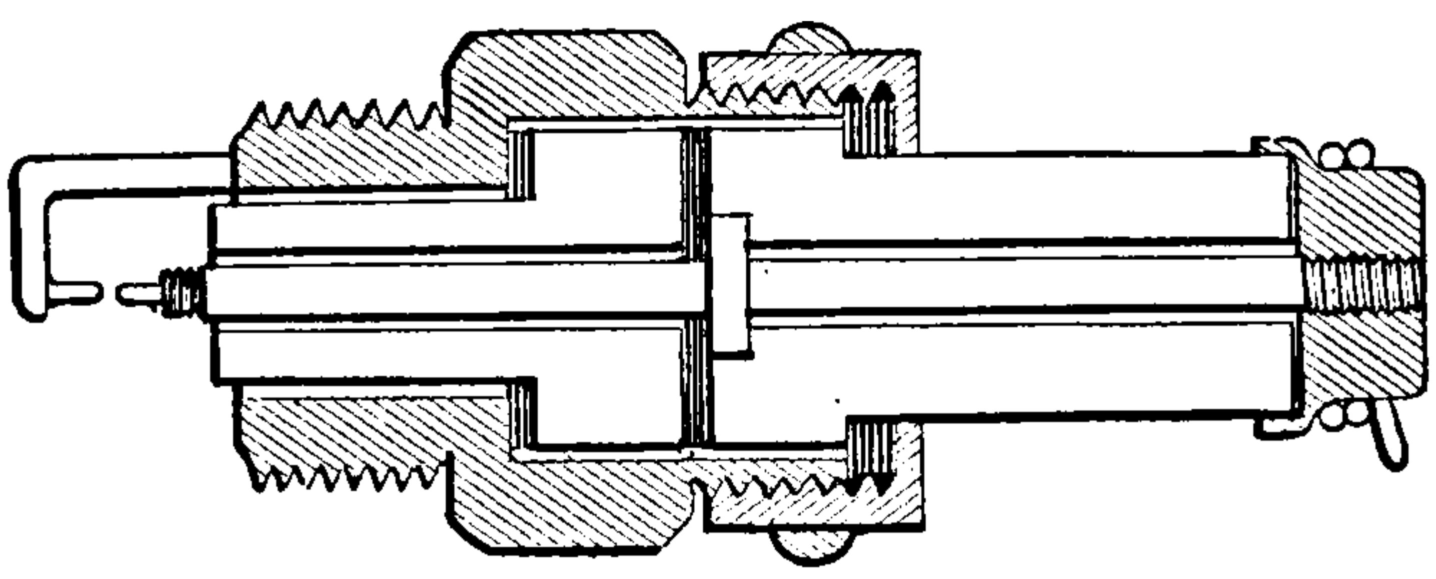


FIG. 47B.—FRENCH IGNITION PLUG.

in use on automobile motors. The plug and nut may be made of hard brass with an extension piece with an electrode of platinum. The spindle of copper with a fixed collar for adjustment and terminating in a platinum blunt point electrode. The insulation is porcelain or of lava in two pieces with a mica disk between, thick enough to allow of closing the electrodes by splitting off thin slices from the mica disk. The lava insulator can now be obtained from the makers, the D. M. Steward Manufacturing Company, Chattanooga, Tenn.

In Fig. 47 C is illustrated an ignition plug, the design of Mr.

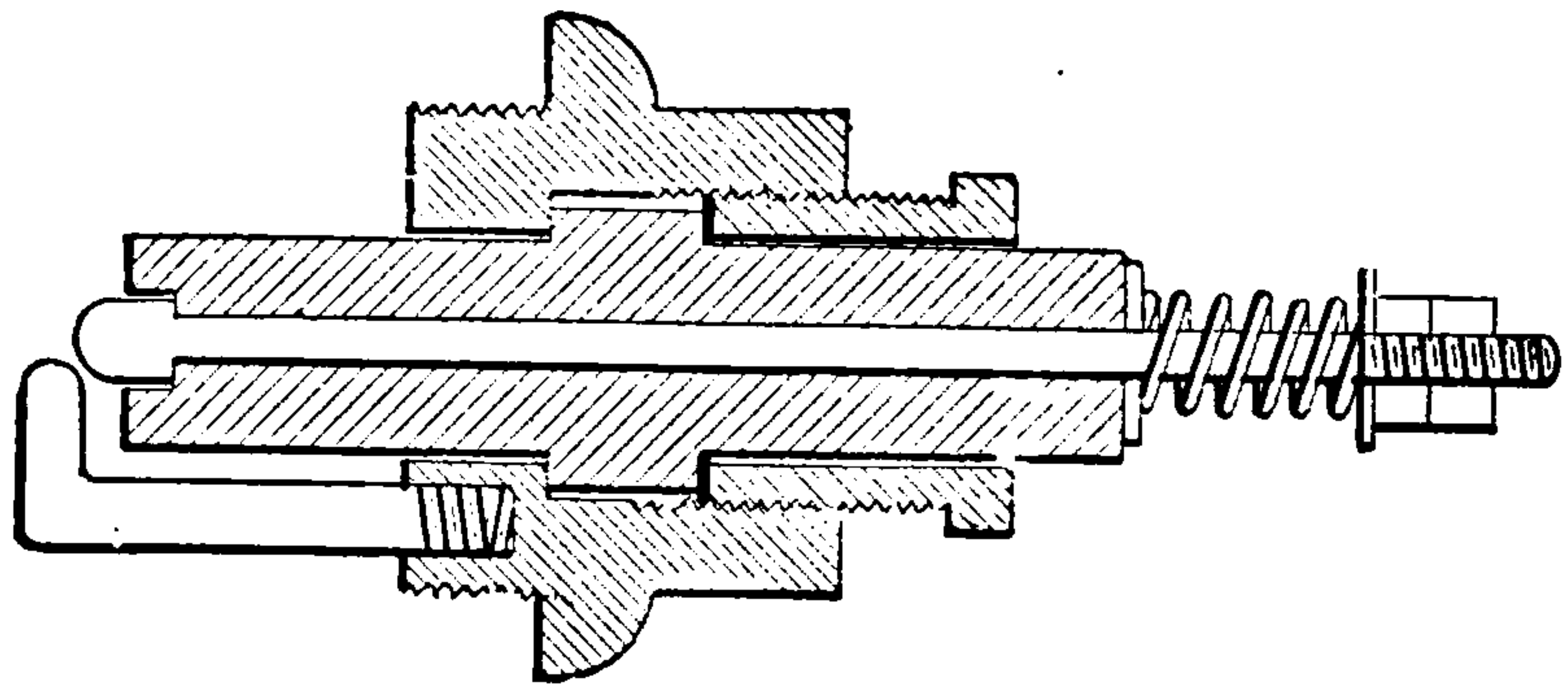


FIG. 47C.—MAXWELL IGNITION PLUG.

Harry B. Maxwell, Rome, N. Y., in which the terminals are blunt and spherical, which produce a more brilliant spark than plugs with small or thin terminals. In this design it is noted that the lava or porcelain insulating tube extends a distance beyond

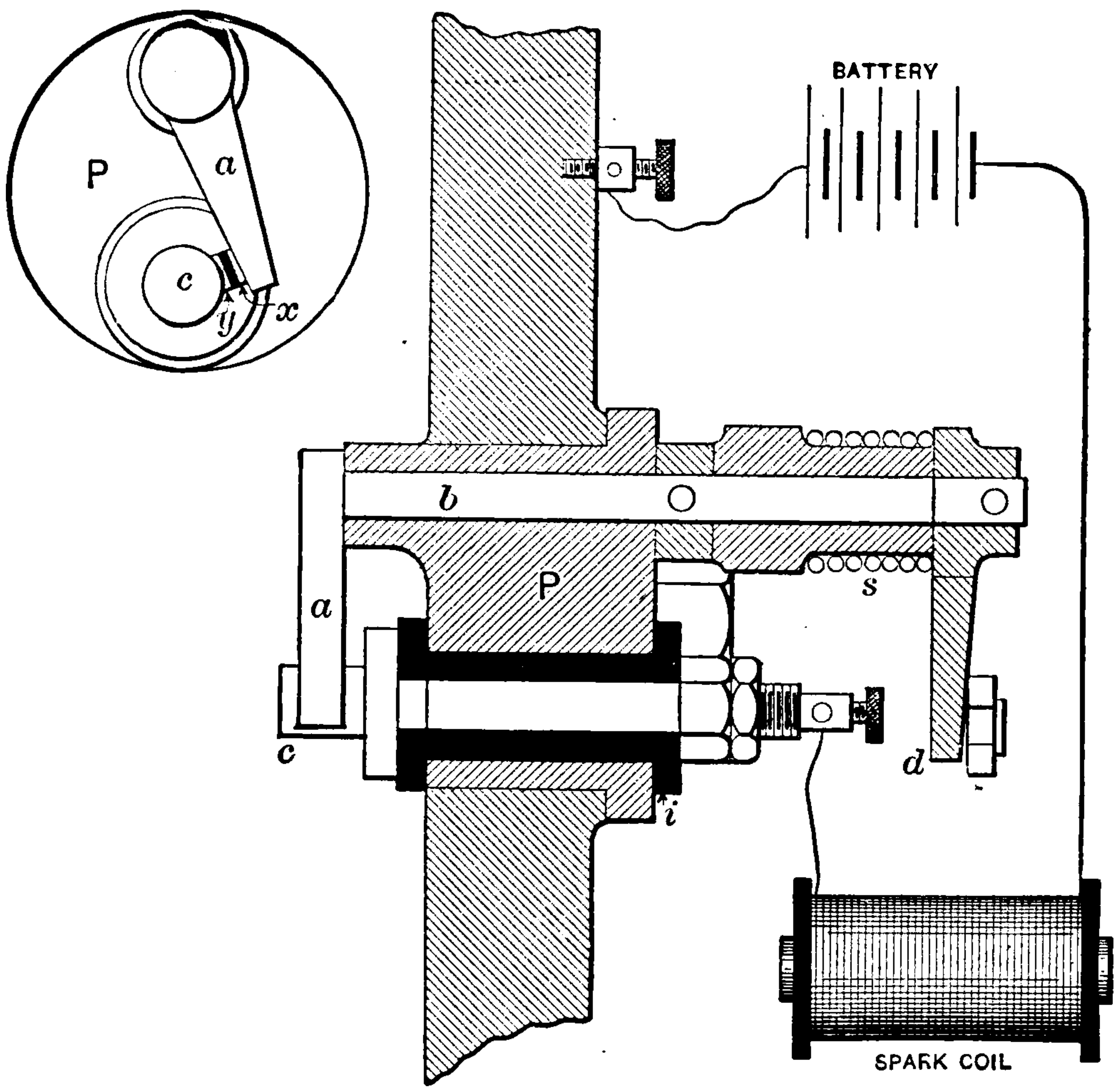


FIG. 47E.—HAMMER SPARK IGNITER.

a crossed wire electrode has been the subject of a recent patent, in which a double loop of two U-shaped platinum wires crossing each other at right angles at the sparking distance from the insulated electrode, is used in connection with the extended insulation plug, and so placed that the inlet charge sweeps across the wires and keeps them cool enough to prevent premature firing. The plug and valve positions are shown in Fig. 47D.

In Figs. 47F and 47G we illustrate the details of the mercurial sparker of Mr. J. V. Rice, Jr., Edgewater Park, N. J. It is well

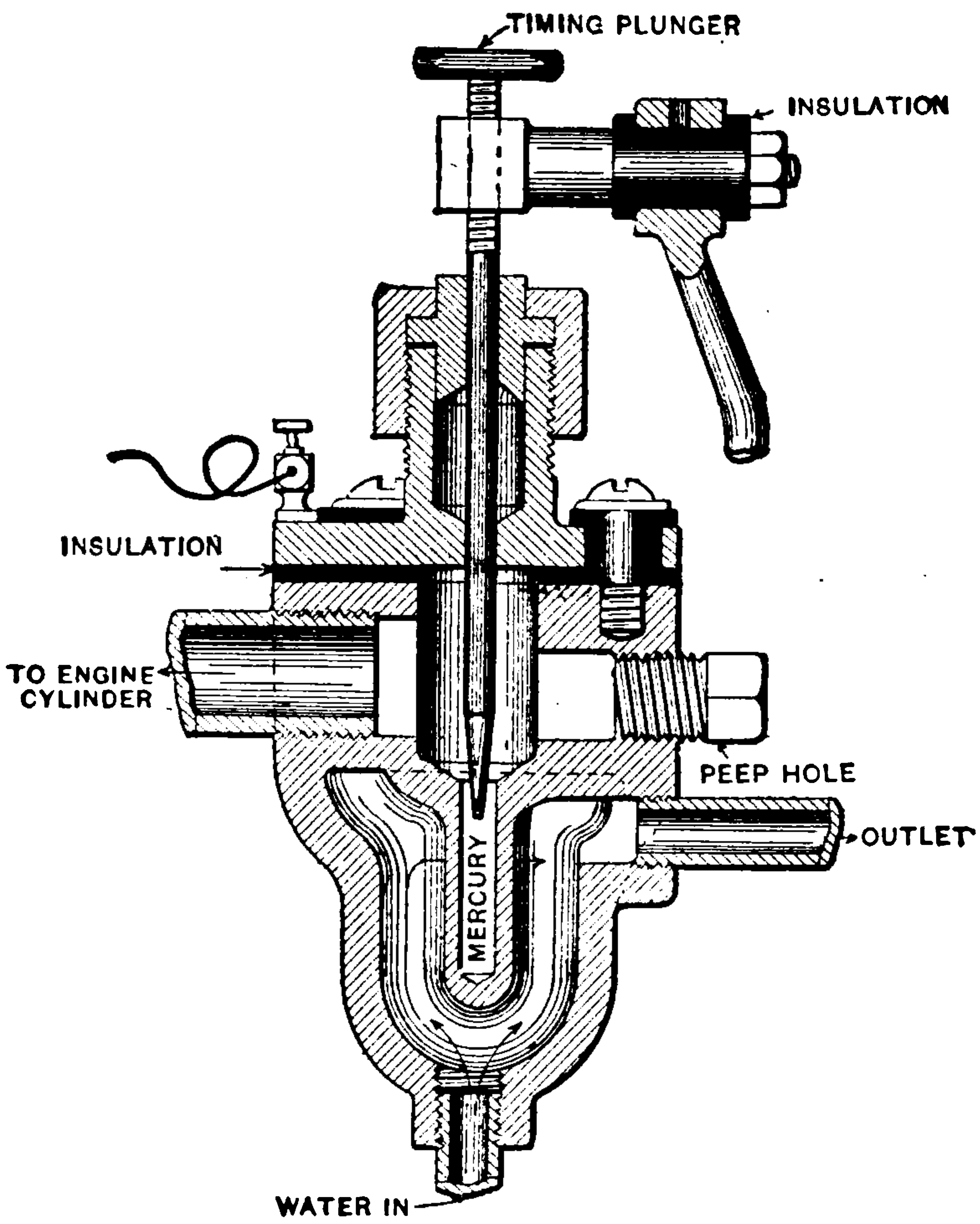


FIG. 47F.—RICE SPARKER.

known that the break of contact with mercury produces a brilliant spark from the electric current, or what is called in gas engine parlance a "fat spark." This idea has been found in practice to meet some of the faults of the hammer break devices and seems to insure a constant service in this important adjunct in explosive motor running.

The deep cup of mercury is enclosed in a small water chamber forming part of the cooling circulation of the cylinder, and make-and-break contact is made by the movement of an insulated spindle operated direct from a cam in a two-cycle engine or the reducing shaft in a four-cycle type.

The timing is regulated by screwing the spindle up or down, as shown in the cuts. The connections with a sparking coil and battery, or with a dynamo, are made in the same manner as with other break-contact sparking devices.

The sparker has been in use for many months on a gasoline

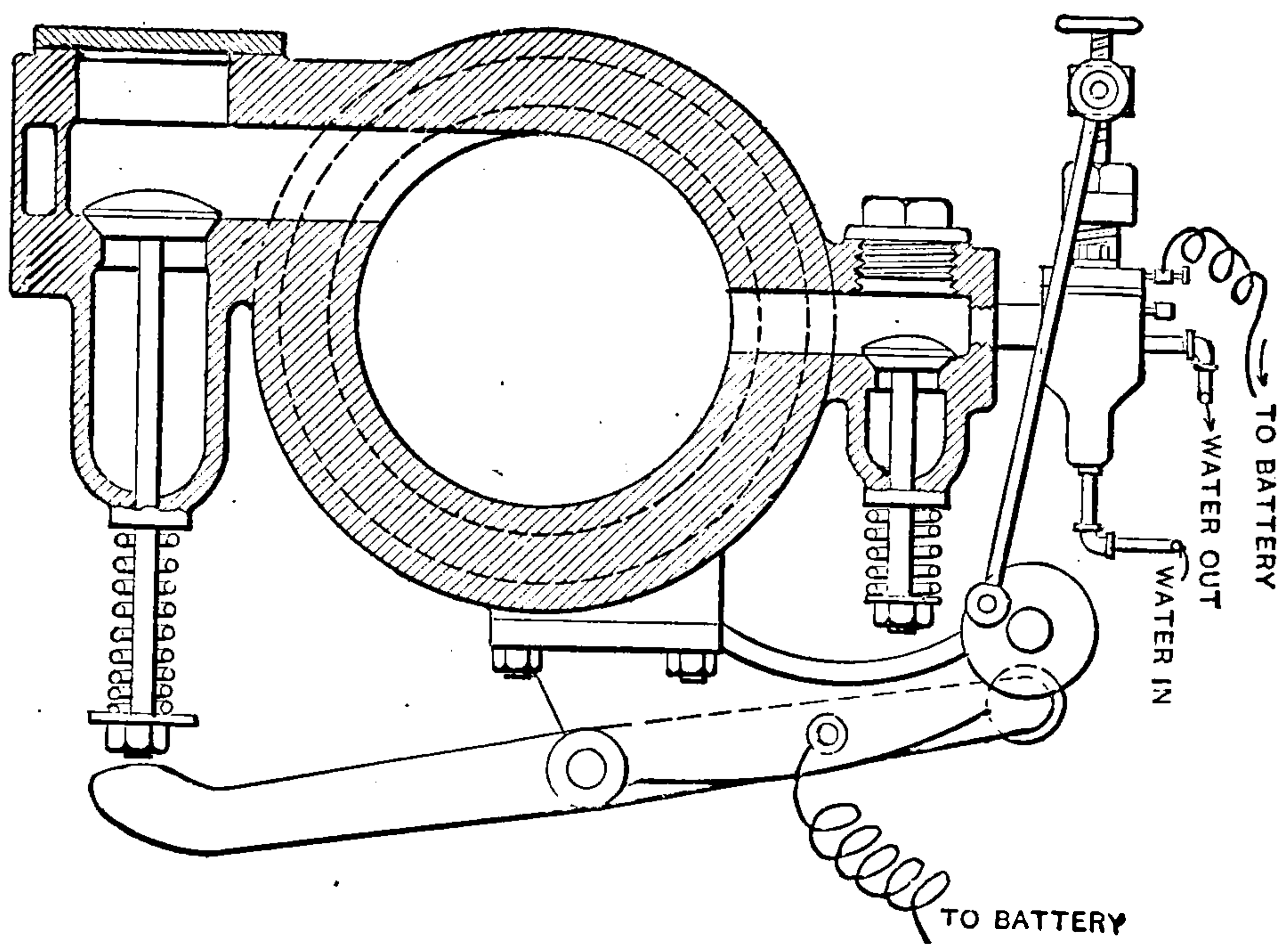


FIG. 47G.—RICE VALVE GEAR.

engine driving a machine shop motive plant, a launch and a high-speed tricycle, without misfires except by control.

The evaporation of mercury from the cell is exceptionally small and does not spill by the jar of the motor. The amount of mercury actually lost in a year's run of a 12-H.P. motor does not exceed 35 cents in cost. High speed, which sometimes interferes with the perfect operation of igniters, in a test of this device by the writer, has been found to give a perfect ignition at all speeds up to more than 2,300 revolutions per minute.

A simple primary sparking coil may be made with a core of iron wire (No. 16) 10 inches long and one inch in diameter. Fasten heads for the spool on this, and cover the core with a few turns of brown paper. Wind No. 14 single cotton-covered magnet wire on this to a depth of about ⅝ inch, insulating each layer from the next by a layer of paper. Give each layer a coat of shellac also. The coil is used in series with a battery, and the spark is obtained when the circuit is broken. With six or eight strong cells a thick spark will be given. This coil is illustrated in Fig. 40, only instead of four windings make six to eight windings.

THE JUMP SPARK COIL.

For a better understanding of the detail of construction of an induction coil of suitable size for the ignition of the explosive charge of a gas, gasoline or oil engine. We therefore illustrate in Fig. 47 H the details of such a coil without a vibrator, and in

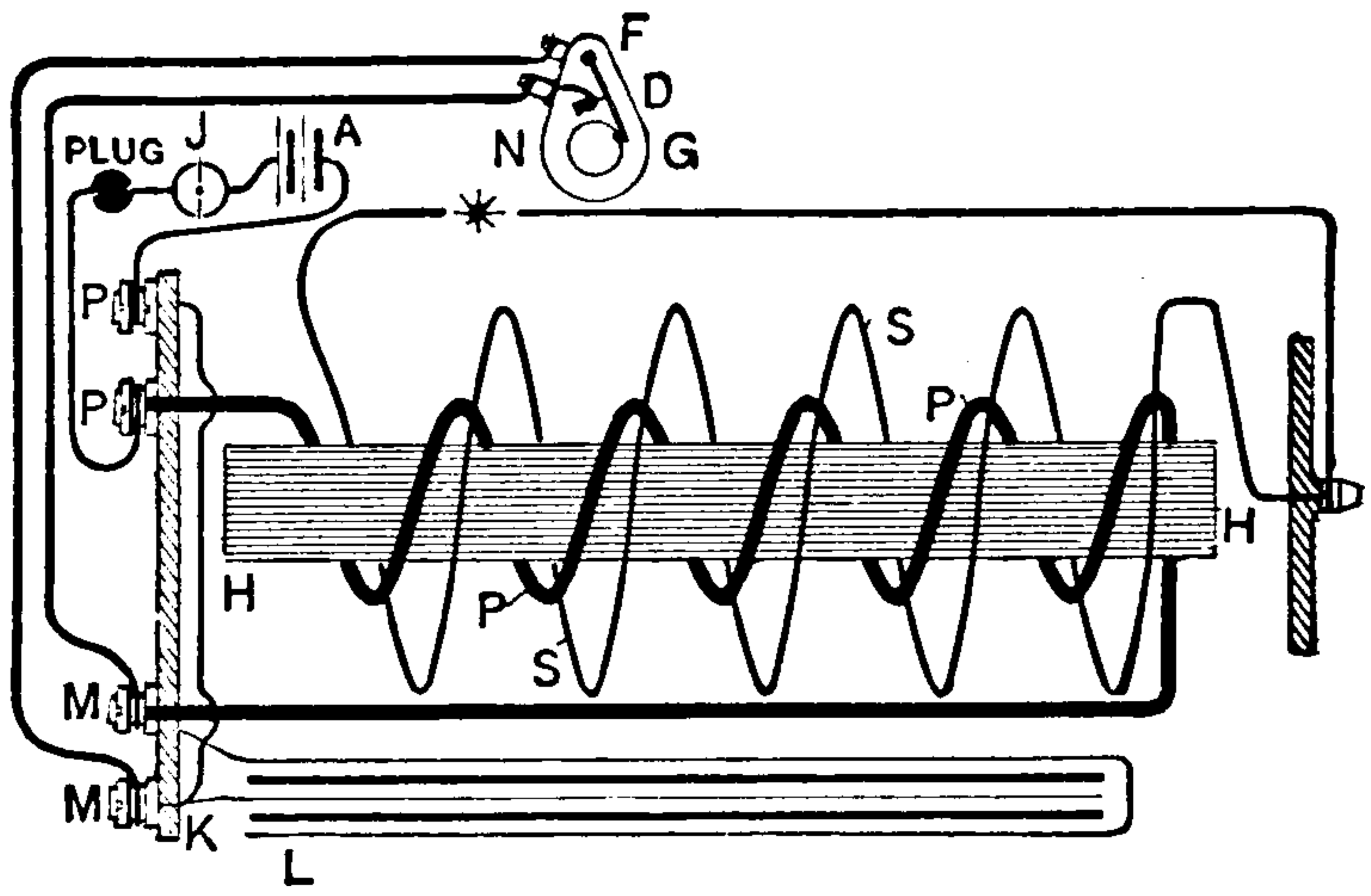


FIG. 47H.—JUMP SPARK COIL.

Fig. 47 I the same coil with the vibrator. A coil of the size here given and detailed should give a full and hot spark for any ordinary engine across a 1-16 to 3-32-inch space between the electrodes. Its full-length spark should be equal to a jump of from ½ to ⅝ of an inch between wire terminals. The iron core H H is made up of annealed wire, No. 20 wire gauge, 5¾ inches long, as many pieces as can be pushed into a ⅝-inch paper tube, 5½ inches long, made by wrapping paper on a ⅝ rod with shellac varnish between the layers, say, a half-dozen layers, and shellac the outside. Push onto each end of the paper tube a square wooden flange, ½ inch thick, 4 inches diameter, even

ends of the layers where the difference in potential is greatest with a liability of sparking from layer to layer of the coil and the ruin of the work.

Such a coil may be used without a vibrator, and referring to Fig. 47H, in which the leading principles of construction are shown, P P M M are the primary binding posts. The upper posts P and P are connected through the battery and switch. The lower posts, M and M are connected through the breaker on the reducing gear from the crank shaft represented at N F D G. The upper post, P and the lower post M are directly connected, making a complete primary circuit from the battery A through the switch J and post P around the core and post M to the breaker at D and through the lower post M and across by the upper post P to the battery. The condenser L is composed of strips of tinfoil separated by paraffined paper in series and are connected at M M as a shunt across the contact breaker for the purpose of absorbing an extra current induced in the primary coil by the break of the circuit, which would tend to prolong the magnetization of the core beyond the desired limit in a high-speed engine.

The condenser may be made of a size to be enclosed in the hollow base upon which the coil is to be fixed, and made up of about 71 sheets of plain uncalendered writing paper, say 5 by 8 inches, dipped in melted paraffine or varnished with shellac on each side; interleaved with 70 sheets of tinfoil, cut 4 by 7 inches with an ear at one corner of each sheet to project beyond the paper sufficient to allow of the alternate sheets to be connected together on opposite corners. The pile may then be clamped together with two pieces of board well shellacked. The ears of each set of 35 sheets may then be pressed together and clamped for connecting to the binding posts M M. Condensers are not absolutely necessary and many jump-spark coils are in use without them. The theory is that the electro-magnetic force of self-induction in the primary, which is principally instrumental in causing the spark at break contact, will expend most of its energy in charging the condenser, causing the break spark of the primary to be less and the current to become zero with greater rapidity. The practical effect of the condenser on the spark volume of the secondary is very great, or what is commonly called a fat spark.

The vibrating coil Fig. 47 I is of the same general construction as described with the addition of a spring vibrator shown at F G. The steel spring G F may be 1½ inches in length and ½ inch in width, fastened to a post at F and fixed to a small armature of soft iron at G with a platinum or, what is better, an alloy of platinum and iridium contact piece at E. D is a brass post with a platinum iridium point adjusting screw, and connected to the breaker N and to the condenser K L, completing the primary circuit through the post F, the switch J and the breaker B.

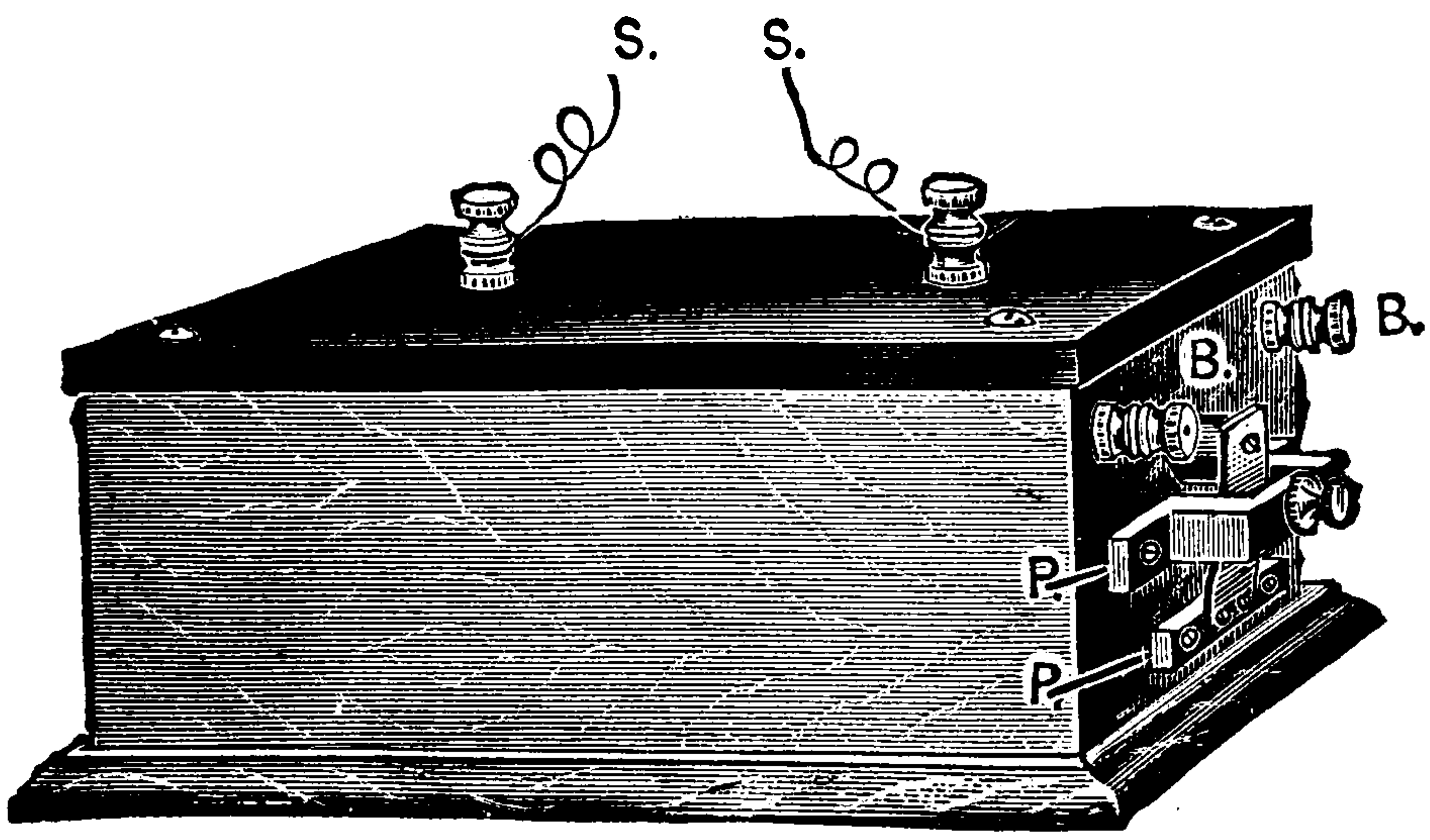


FIG. 47J.—THE INDUCTION COIL CASE.

The office of the vibrator is to give a rapid intermission of the primary current while the commutator bar C is in contact with the spring B. By this means the induced secondary current also becomes intermittent and so secures a succession of sparks at the electrodes that insures a positive ignition.

The complete induction coil may then be enclosed in a box as shown in Fig. 47 J, which illustrates a jump-spark ignition apparatus as made and sold by C. F. Splitdorf, 25 Vandewater Street, New York City, who also makes an up-to-date sparking plug.

In Fig. 47 K is illustrated an ignition battery plant, in which the batteries may be from three to four in series, connecting with the binding post *p* of the primary winding of the induction coil T and continued through the other binding post p^1 to the breaker at *k*, which is operated by a break contact arm or cam on the reducing gear or shaft.

The secondary winding of the induction coil is connected to the ignition plug P by the wires *e e* and continued through separate insulating sleeves, *i i*, terminating in the platinum points or preferably small knobs, *c c*. The distance apart of these electrodes should be in proportion to the strength of the current. With an induction coil and battery of size to produce a half-inch

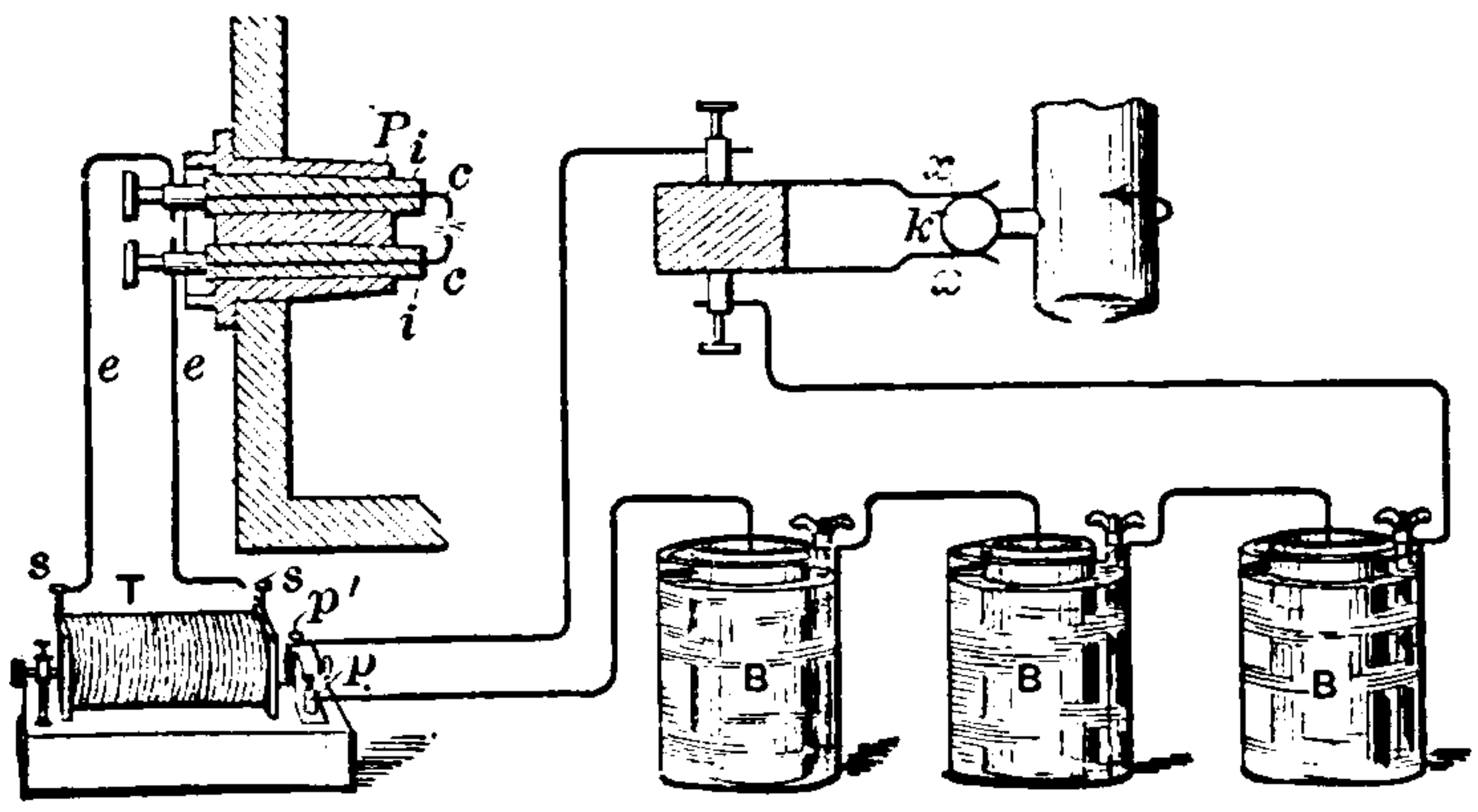


FIG. 47K.—ELECTRIC IGNITER.

open jump spark, one-sixteenth to three-thirty-seconds of an inch should be the limit. With ¾ to 1 inch open jump spark the limit may be one-eighth inch between the electrodes. The primary circuit is made and broken by the passage of the contact piece *k*, between the spring clips *x x*, at the moment required for firing the charge.

DYNAMO-ELECTRIC IGNITION.

The permanent field dynamo or magneto for producing the ignition current are coming into favor and are made in a variety of styles. They have a drum armature, enclosed so as to be proof against dirt, oil and moisture. They can be run by belt or by contact with the fly-wheel with a band of rubber stretched tightly and cemented upon the dynamo pulley. They are made

brush should be soaked in oil from time to time to prevent cutting the commutator. Carbon brushes will not cut the commutator, but occasionally may become glazed and fail to give reliable contact; when this occurs their ends should be filed off to a new surface, when they will operate as well as new brushes.

Fig 47 O represents the magneto dynamo of the Carlisle & Finch Company, Cincinnati, O.

The distinctive feature of this magneto is the method of sup-

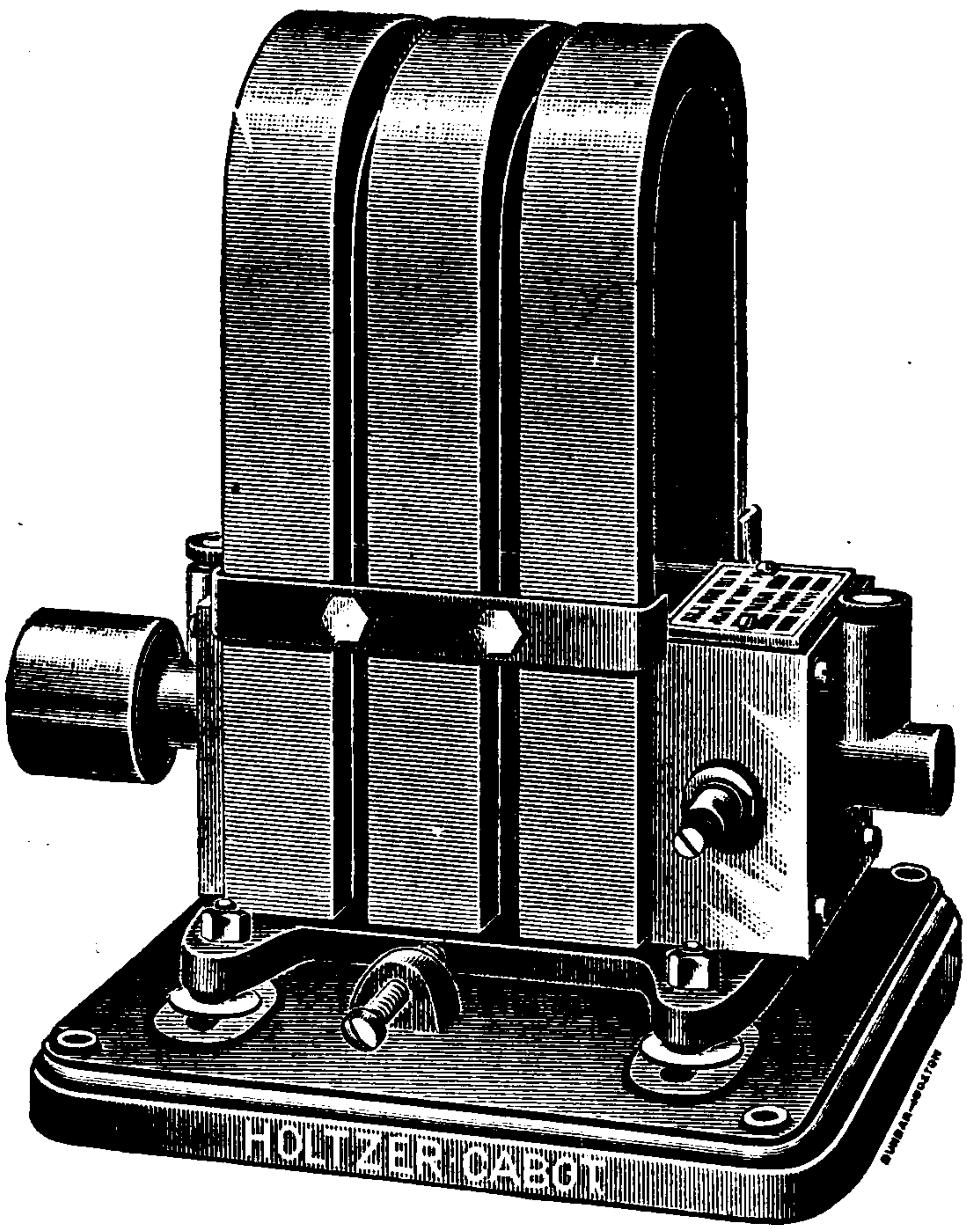


FIG. 47N.—VERTICAL MAGNETO.

porting it. It is mounted on a strong pin on which it rocks. This permits of the belt being tightened if it becomes loose, and an adjusting screw is provided for this purpose. The square base or pedestal is to be fastened to the floor, and the tightening screw inserted in the hole on the side toward the engine. This will allow the dynamo to be pushed away from the engine, so as to tighten the belt as it becomes loose.

If it is desired to run the magneto by a friction pulley, a spring may be attached to the bottom of the magneto, so as to draw it toward the fly-wheel of the engine. In this case, the tightening screw will be omitted. Friction pulleys are furnished.

The armature is completely enclosed, and the magneto may be sprinkled with water without damage.

For small engines, when the fly-wheel can be turned by hand, it is not necessary to use a battery for starting; but when the

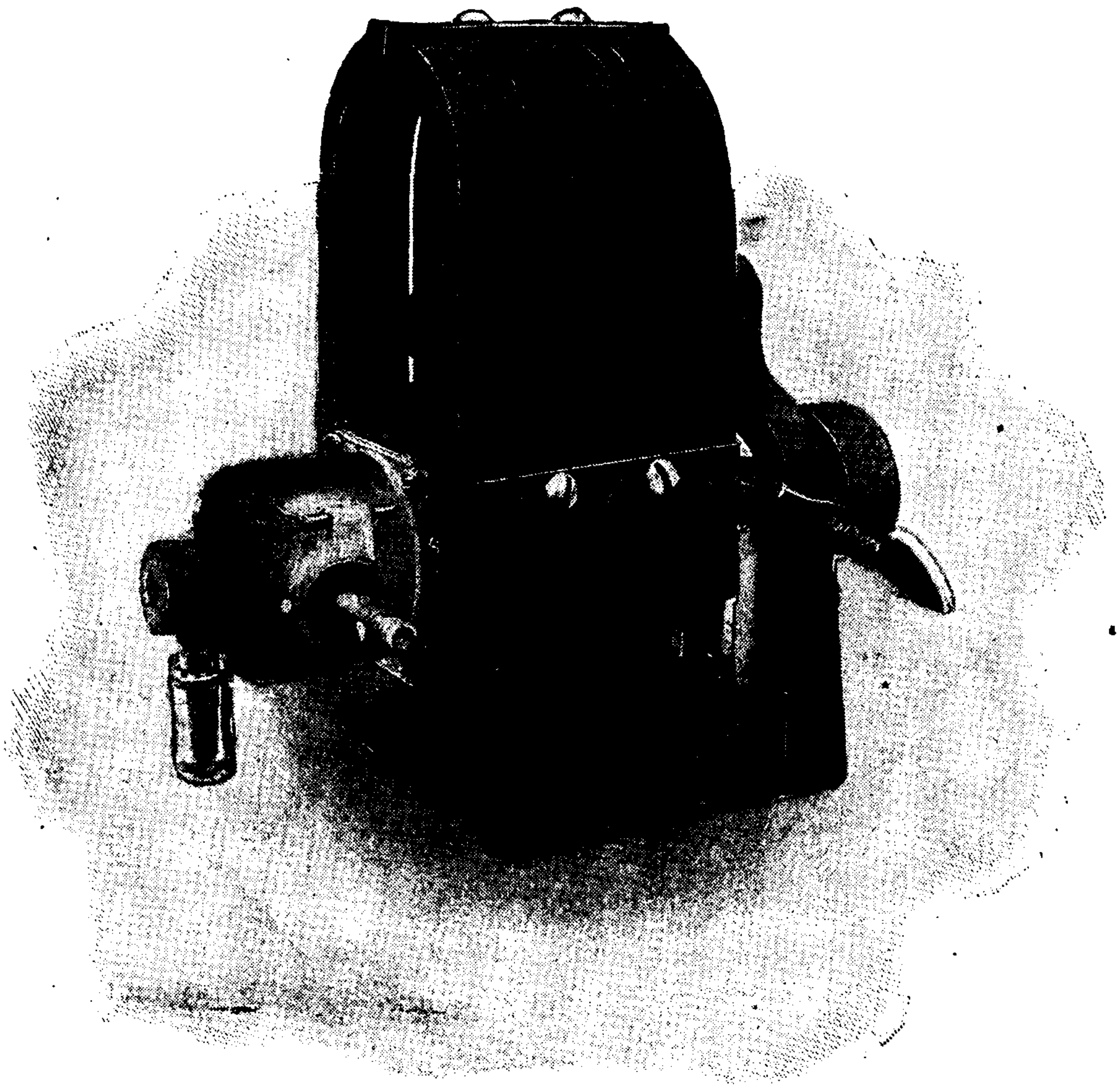


FIG. 47 O.—VERTICAL MAGNETO.

engine is so large that it can be turned but slowly, it is necessary to have 6 or 8 cells of open-circuit battery for furnishing the initial spark. Any good type of Leclanche battery will answer. Dry batteries may be used if the magneto is to be used on an automobile where the available space is small.

To meet the wishes of those who have individual preferences for the dynamo type of igniter, and to meet conditions which demand an igniter that will deliver a large amount of energy continuously, as for instance multiple cylinder engines, the Holtzer-

Cabot Electric Company have brought out a dynamo type of igniter which is shown in Fig. 47 P. This new igniter will work through a range of speed from 1,000 R.P.M. to 2,500 R.P.M.; it may be used to advantage in automobile work, it being unnecessary to use any governor whatever. It will deliver a continuous output of 50 watts and will serve under the most severe and exacting conditions. The igniter is pivoted on a sub-base and the belt is tightened or the pressure of the friction pulley regu-

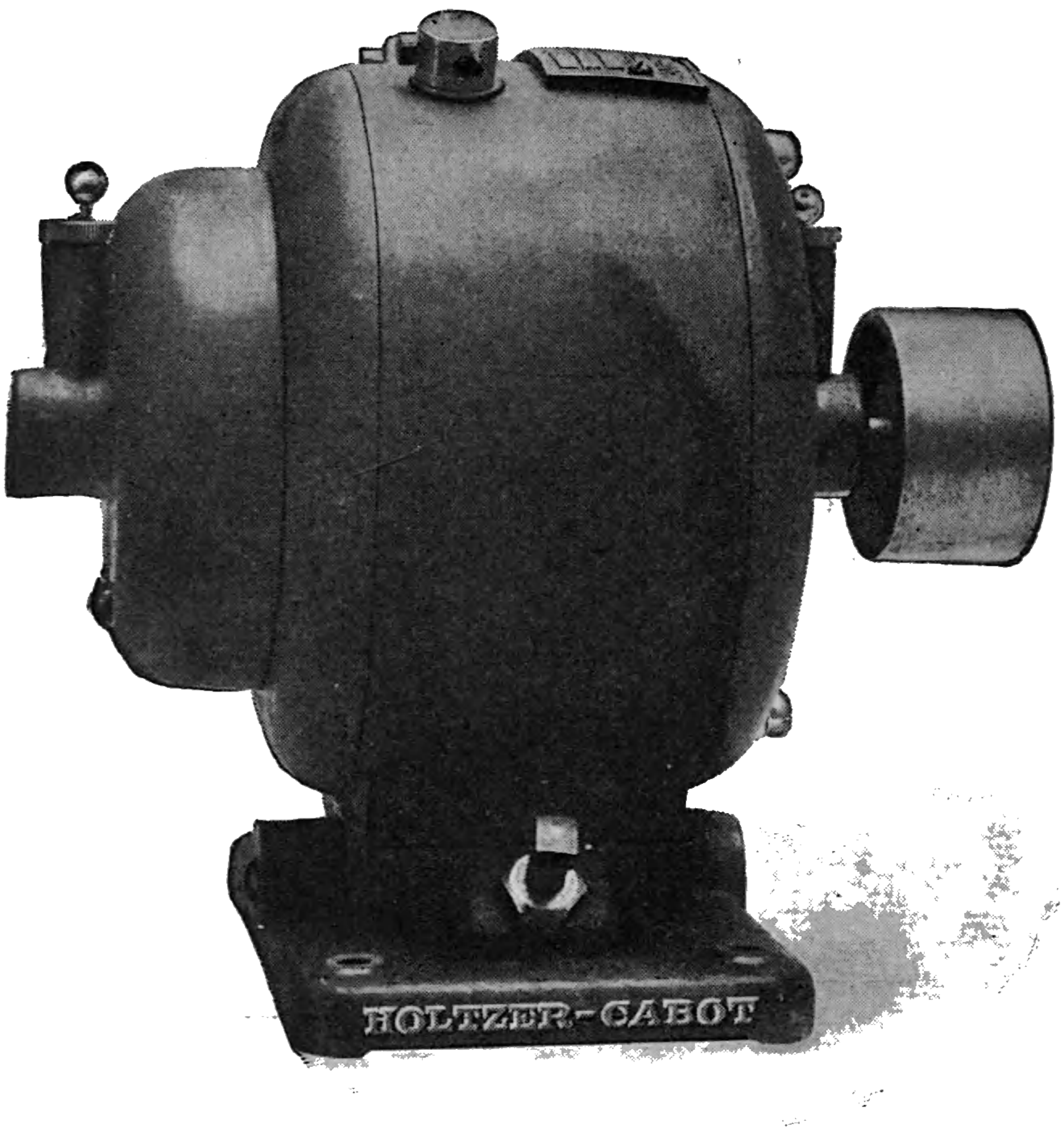


FIG. 47P.—DYNAMO IGNITER.

lated by means of two butt-screws which rock the machine forward or backward as the case may be.

Fig. 47Q represents an igniting dynamo with belt tightener, made by the Carlisle & Finch Company, Cincinnati, O. This dynamo, like their magneto, is made to swing on a pin support, in order to tighten the belt, or to permit of its being driven by a friction pulley. An improvement in this dynamo is the means for shifting the brushes by rotating the brass cover at the commutator end a few degrees in either direction and a change of

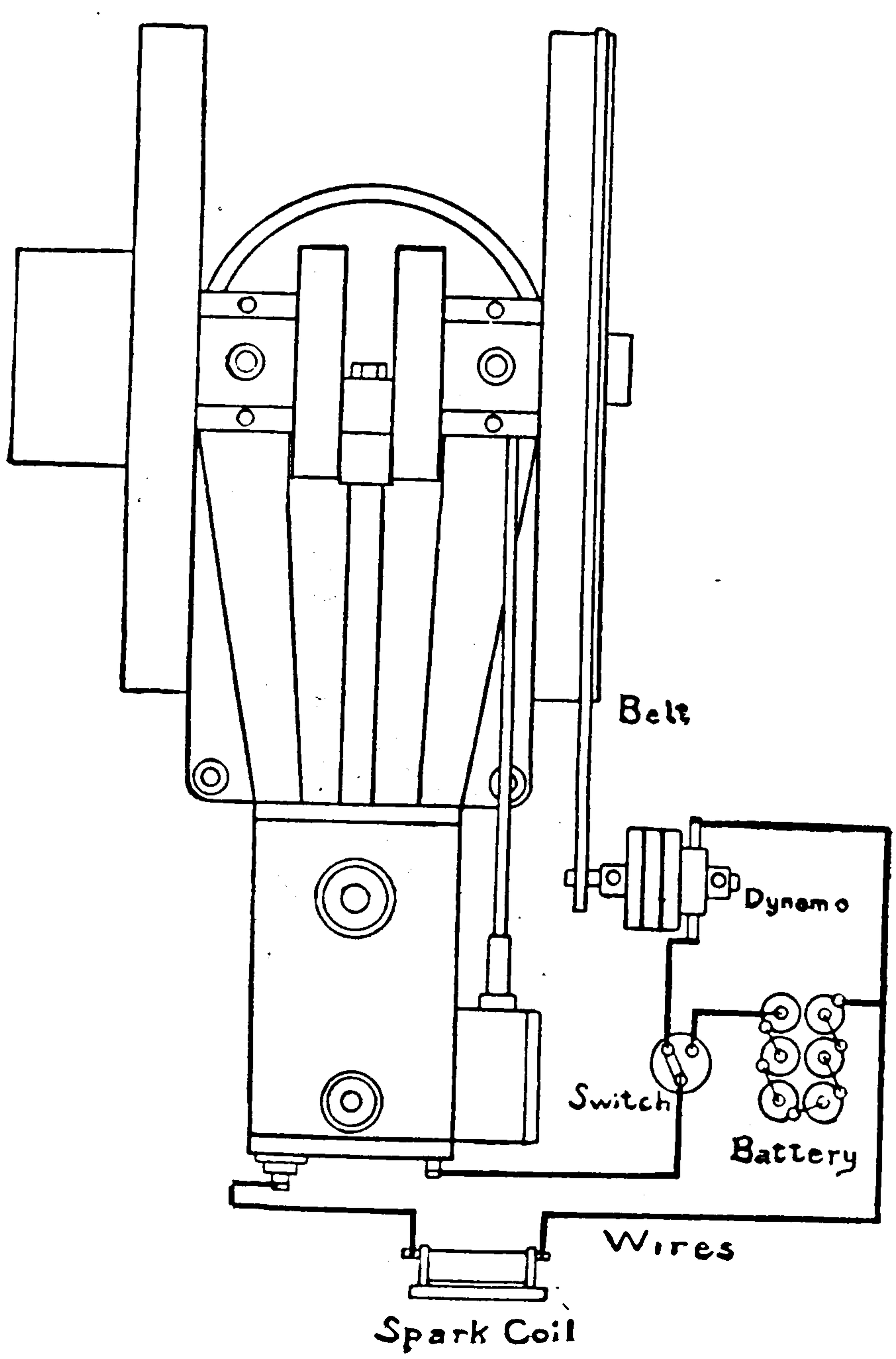


FIG. 47R.—DYNAMO WIRING.

POINTERS ON VALVES AND IGNITION.

Although the general designs of explosive motors, so far as their power-moving parts are concerned, are so much alike that, excepting their ignition devices, any explosive motor may be made interchangeable or readily convertible to the use of either of the explosive materials for power, for each requires an equal strength in all the parts of the motor as well as an equal treatment in the regulation of cylinder temperature.

The value of the materials of explosive power has been as fully discussed under the head of "materials of power" as is consistent with our present knowledge of the experimental details in regard to the explosive values of such materials. Their study becomes an essential feature in motor design, especially in regard to cylinder volume to meet specified power.

The details of valve gear may be made variable to meet the fancy of designers or their judgment of fitness; but there are a few points in its operating principle which must be made to meet the requirements not only of each form of explosive element to be used; but also the varied values of gases in gas engines from acetylene to producer gas and of the volatility of the variable grades of gasoline, kerosene and the cruder oils, and which dominate the sizes and relative proportions of the inlet and exhaust valves.

The forms of the faces and seats of valves seem to have been varied to meet the fancy of designers in a great measure and even the crudity of a spindle riveted to the valve disk has been used and published as a desirable makeshift. The flat-faced valve is also in use, but from the author's experience, is unreliable and makes an imperfect seat by use. Conical seated valves with faces at from thirty-five to forty-five degrees from the axis of the spindle are giving good service. A flatter cone of from fifty to sixty degrees is in use with apparent wearable properties and with slightly less lift for its full area than with the deeper seated valves.

Spindle valves with stems one-fifth to one-quarter the outside diameter of the valves, well filleted under the disks give general satisfaction for ordinary speeds; but for very high speed motors the valve stems should be somewhat larger. The general valve arrangements are well shown in their various modifications as illustrated in this work.

The relative size of these valves has been a subject of enquiry and discussion with so far no fixed general rule applicable to the required conditions of each element. Some designated speed should first be assigned for any given sized cylinder volume from which the size of the valves may be computed for the full flow of the inlet charge and for the discharge of the exhaust without undue back pressure during the times of the inlet and exhaust strokes. This means larger valves for high speed than for low speed motors—a practice too often ignored to the detriment of motor efficiency by making these valves too small for the motor's best work; while if made to meet the requirements for highest speed capacity their efficiency action will be best for all lower speeds. This should be made a study with the designers of explosive motors.

The present practice with builders in regard to the size of the valves seems to vary the extreme diameter of the exhaust valve from a quarter to four-tenths of the diameter of the cylinder and the charging valve a little less, sometimes but one-fifth diameter of the cylinder.

Indicator cards taken from motors with small valves, if properly done, plainly show the effect of back pressure from both the exhaust and charging strokes. Good practice suggests the larger valves with full lift of one-quarter their diameter for developing the full power of the motor.

The ignition devices have been a puzzle to motor builders and operators during the decades of explosive motor development, and so-called improvements are still in vogue. For gas engines, tube ignition has had its day for want of a better way and is still in use to a considerable extent, probably because it is simple and cheap to make; but the short life of the tubes when made of iron

its cylinder terminals, which places the intermittent action on the outside of the cylinder, thereby allowing of ready observation and adjustment without stopping the motor. In the early form of the jump-spark igniter with both terminals passing through a single insulation in the plug, the space on the insulated face of the plug was made so short that by the fouling of the surface the electric current was short-circuited and no spark was produced; this gave much trouble from the necessity of frequently removing the plug for cleaning the insulating surface. Its construction has been modified so as to increase the distance between the terminals by an extension of one of the terminals from the body of the plug, which was an improvement, but still defective. A later improvement has been made by extending the porcelain insulator beyond the face of the plug from a half to three-quarters of an inch and extending the opposite terminal from the face of the plug with a hooked end and clearing the insulator by a quarter inch, thus giving more than three-quarters of an inch of insulating surface between the electrodes. In some motors the plug terminal is a single positive electrode, while the negative electrode is fixed to the cylinder head away from the plug, making a greater distance in which short-circuiting has to pass, but this is a mistake, for the insulated part of the plug is the limitation of short-circuit possibilities.

The jump spark system of ignition requires a secondary or induction coil, and, for further efficiency, a condenser with a breaking device operated from the valve gear shaft to open the otherwise closed primary coil from which the secondary or jump spark is generated at the moment of closure for timing the spark.

There are two methods of operating the jump spark ignition; in one a magnetic vibrator is employed which makes and breaks the primary circuit many times during the open contact of the time switch on the secondary shaft, during which moment a series of sparks is sent across the terminal electrodes in the combustion chambers, thus ensuring ignition by repeated sparking.

In the use of the induction coil without the vibrator, but a single weak spark is produced at the opening and a single strong spark again at the closing of the timing switch, thus giving two sparks; but the first is not considered available, except from a more powerful induction coil than needed for the vibrating attachment.

The distance or opening between the terminals of a sparking plug is of greater importance than generally considered, as much hidden trouble has arisen from the form and spacing of this important adjunct in the operation of explosive motors.

For a satisfactory effect a four element battery in series and an induction coil for sure ignition should give a spark of maximum range from three-eighths to half an inch, for which the terminals of the sparking plug should be set at from three to four thirty-seconds of an inch apart, or one-quarter of the extreme length of the spark. The voltage for a reliable spark need not exceed one and a quarter volts in each of a four-battery series, equal to five volts, acting through an induction coil consisting of a soft iron wire core five-eighths of an inch diameter, No. 12 gauge, insulated by a paper tube spool five inches in length between the shoulders, on which is wound two layers of cotton-covered copper wire, No. 12, B. & S. gauge, well insulated with paper and shellac varnish. For the secondary coil, wind 10 ounces of No. 36 B. & S. gauge cotton-covered copper wire, shellacking and covering each winding with a layer of uncallendered writing paper.

A vibrating hammer and condenser adds to the efficiency of the jump spark igniter—see these devices in other parts of this book.

THE APPLE IGNITION DYNAMO.

In Fig. 47S and following we illustrate a neat and compact ignition dynamo made by the Dayton Electrical Manufacturing Company, Dayton, Ohio. It is entirely enclosed in a case, prac-

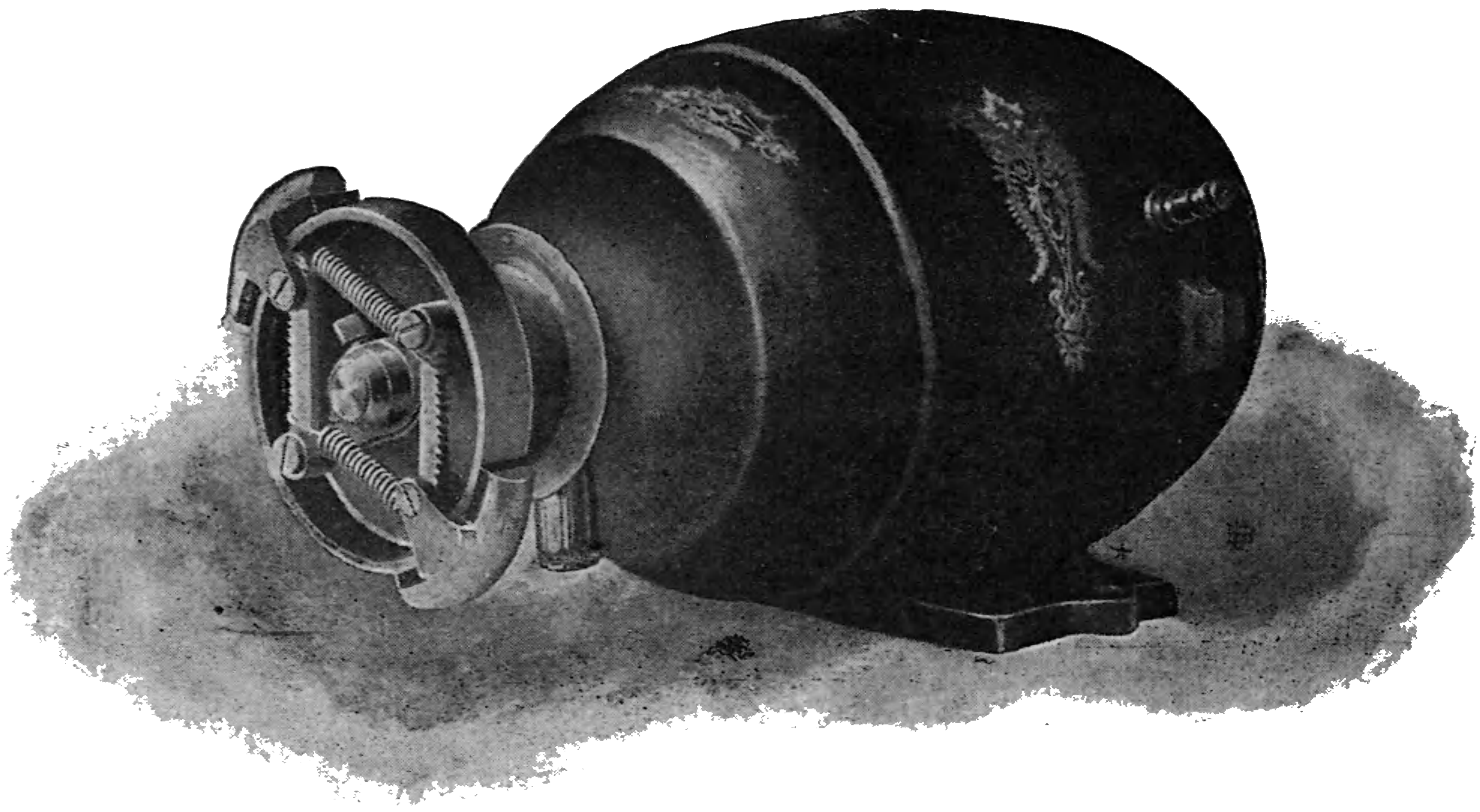


FIG. 47S.—THE APPLE IGNITION DYNAMO.

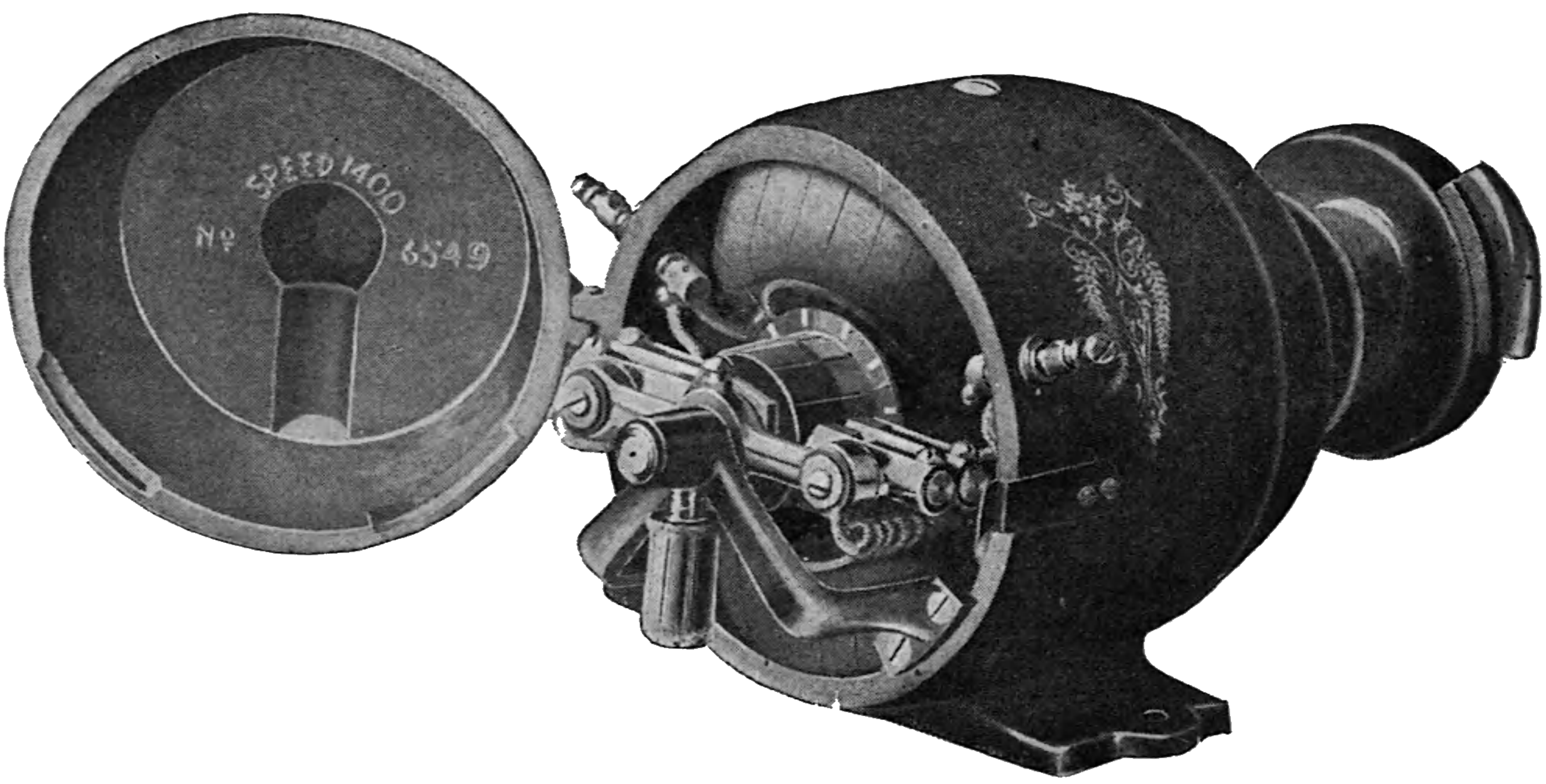


FIG. 47T.—OPEN END SHOWING COMMUTATOR AND CONNECTIONS.

tically water and dust proof. The pulley has a friction clutch governor acting on the rim of the pulley and attached to the spindle of the armature. The clutch shoes of the governor are

This company also make and attach to these dynamos a storage battery with two cells of three plates each and of four volts; so arranged that by moving a switch after the motor is started from the storage battery, the dynamo furnishes the re-

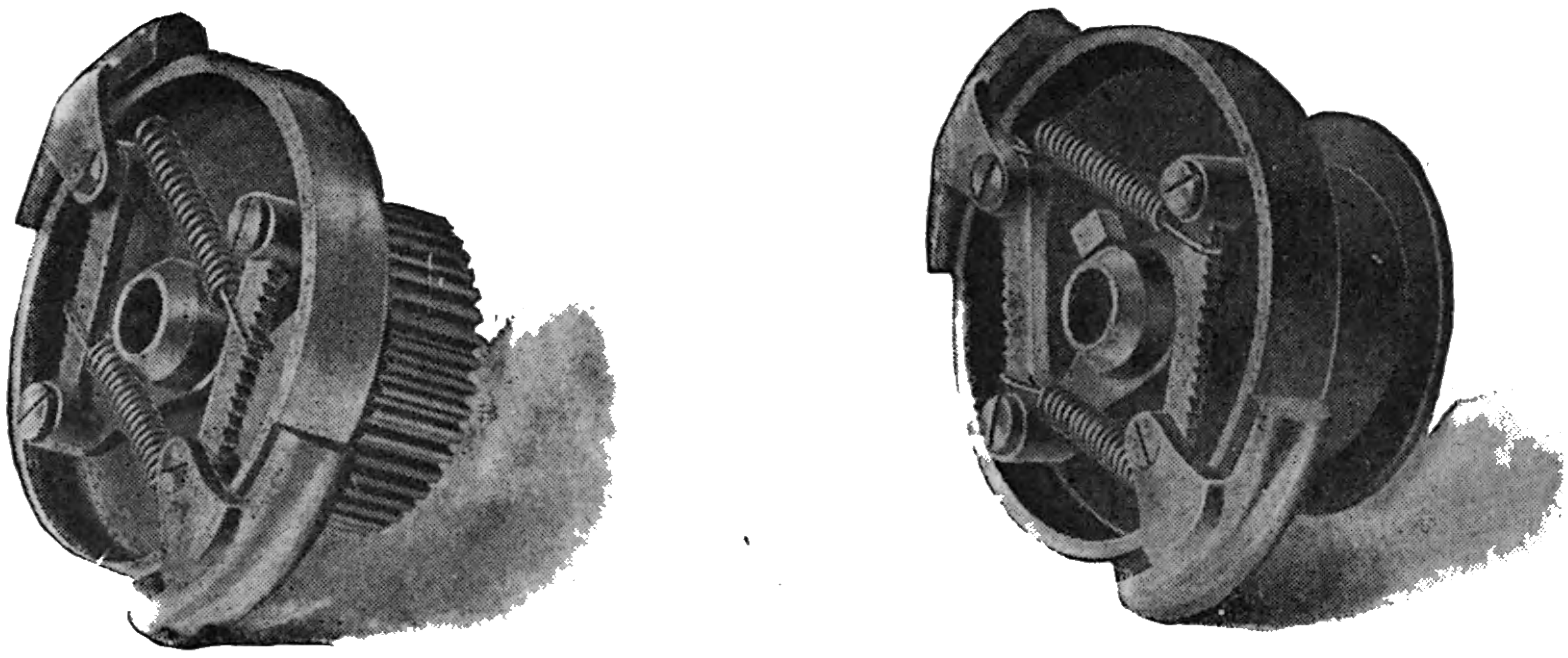


FIG. 47V.—GEAR AND PULLEY CENTRIFUGAL CLUTCH GOVERNORS.

quired current for ignition with a surplus for recharging the battery.

These dynamos are made for both break and jump spark

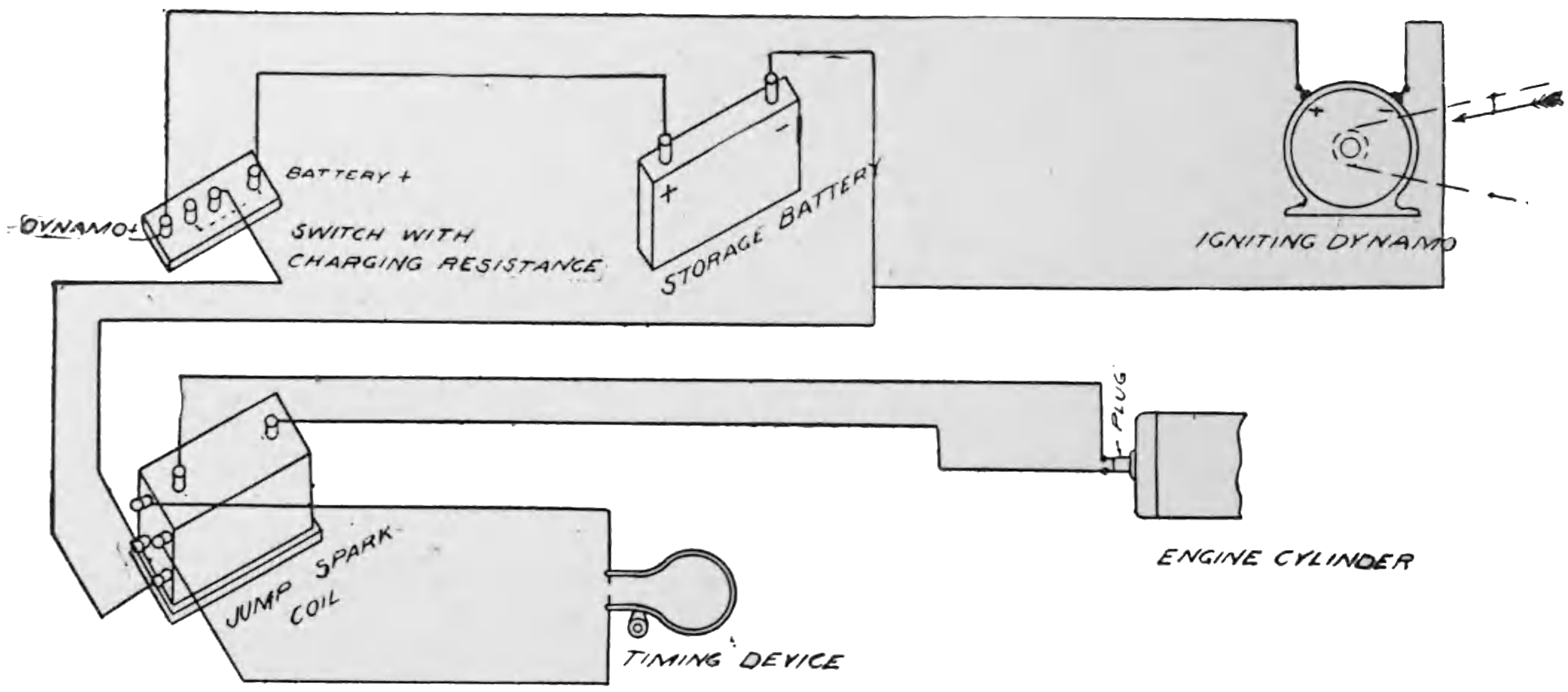


FIG. 47W.—WIRING SYSTEM FOR IGNITION DYNAMO WITH STORAGE BATTERY, JUMP SPARK COIL AND TIMING DEVICE.

ignition as desired, giving a constant current of about 4½ volts at from 1,000 to 1,200 revolutions per minute.

A wiring system suitable for these dynamos is shown in Fig. 47w, in which the dynamo is directly connected with the storage battery through a resistance switch, and also to the primary circuit of the induction coil, and to the timing break device, the secondary coil being in direct connection with the sparking plug. By the throw of the switch the full current from the battery leads to the primary winding of the induction coil and is interrupted in its circuit by the break device, and at another position of the switch nearly the full current of the dynamo is in use for sparking, with a resistance shunt through the storage battery that restores its lost charge in a short time.

There is much to be said in favor of this system of ignition, and as engineers and others in charge of explosive motors become more familiar with their apparent complication, the more they will become assured of their reliability and certainty of operation. The jump spark or induction coil with a storage battery reservation supplied by a current from a dynamo will no doubt soon become the universal means of explosive motor ignition.

CHAPTER XIII.

CYLINDER LUBRICATION.

THE lubrication of cylinders of explosive motors is a matter of great importance, as the intensely hot gases in immediate contact with the lubricating oil, although the oil is in contact with a comparatively cool metallic surface, has an evaporative

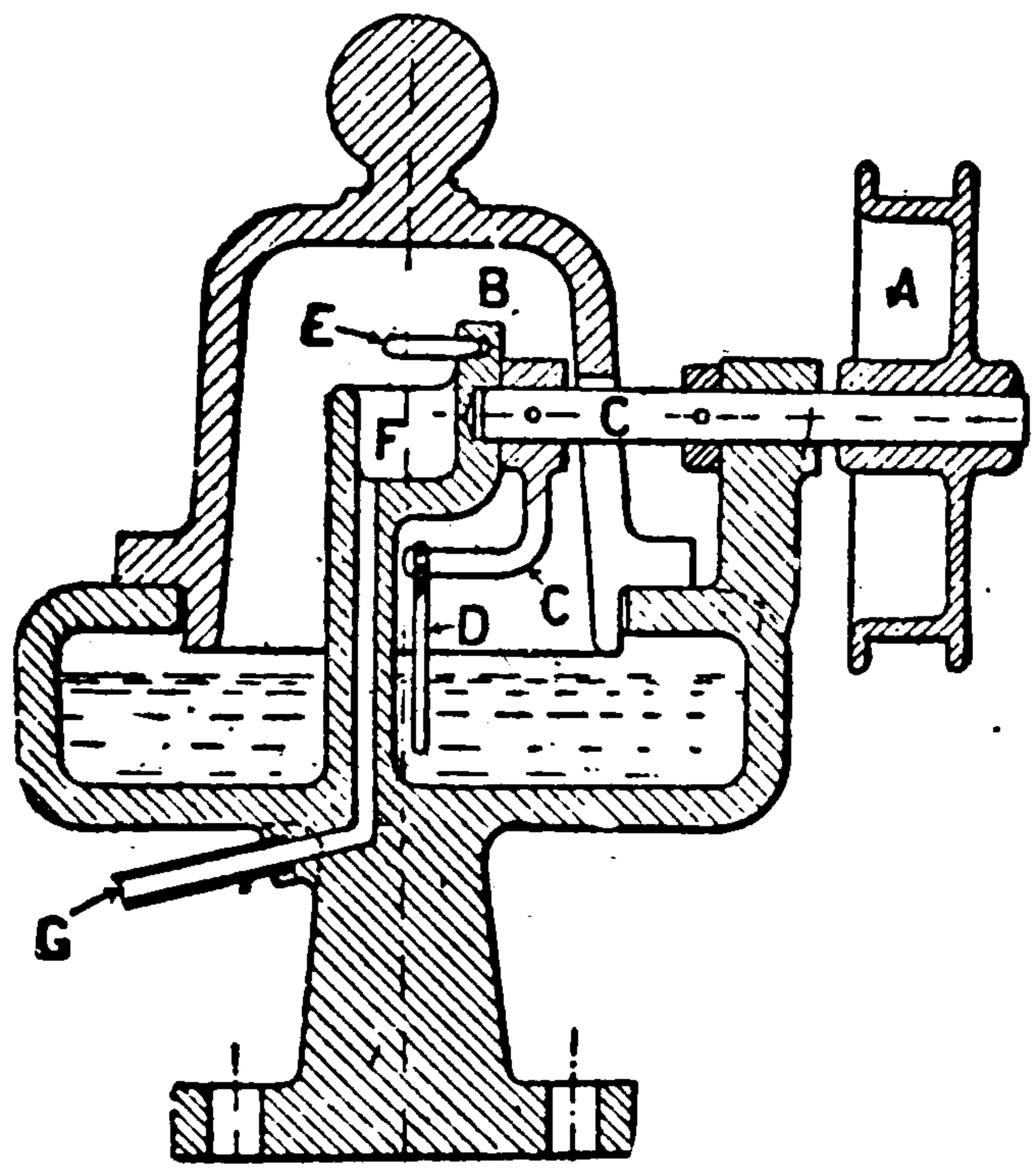


FIG. 48.—THE MECHANICAL LUBRICATOR.

effect, tending to thicken the oil into a gummy lining on the surface of the cylinder. To avoid this and keep a perfect lubrication, an oil that is adapted to this severe heat trial should be used and fed to the cylinder walls and piston in constant flow, and not too much or too little, but just enough so that the oil cannot be pushed into the combustion chamber in excess, so as to be blown through the exhaust valve to clog the passages with oily soot.

The sight feed and capillary drop-oil feeders have been perfected to such an extent in the United States that they are al-

the spindle and crank C C, to which is loosely attached a wire D, that dips into the oil and carries a minute portion to the wiper E, from which the oil drops into the passage to the cylinder.

In Figs. 49 and 50 is shown a section and plan of a lubricator used on the Robey engines, which is an improvement over the previous one, in that it has a small receptacle above the level of the main oil cistern, which is fed by a revolving shaft and crank arm with drop wire reaching to the bottom of the cistern and wiping the oil on a fixed wiper over the receptacle, from which a second crank arm and drop wire lifts the oil to the wiper that feeds the passage to the cylinder. By this arrangement the oil for the cylinder is drawn from a fixed level, and the feed is therefore perfectly uniform at any level of the oil in the cistern.

Strict attention should be given to the quality of the oil used in the cylinder. Such oil is now made and sold as *gas engine cylinder oil* of a less density and viscosity than the ordinary cylinder oil and more fluid, so that it flows readily over the surface of the piston. Such oil does not readily gum in the cylinder and on the piston. It evaporates more readily than heavy oil and in a measure mixes with the explosive charge, is burned and discharged with the gases of the exhaust, thus avoiding the sooty oil that lodges in the muffler and exhaust pipe from the heavier oils. A very small quantity of finely pulverized graphite used with this oil, occasionally, gives good results as a cylinder lubricant and imparts a smooth and glossy surface to both cylinder and piston. For all other parts of the engine the best engine oil is none too good. The poorer grades of machinery oil are not economical at their price.

CHAPTER XIV.

ON THE MANAGEMENT OF EXPLOSIVE MOTORS.

THE drift of constructive practice in the United States seems generally to be in the line of simplicity and least number of parts, in order to conform to the needs of the people that have the care of such motive power. The explosive motor now appeals to no experience as an engineer for its care and running; yet it does seem to require some common sense as to cleanliness and the propriety of things that may assume a menacing or dangerous habit by neglect of some of the few points of attention required in persons having the charge of this rising prime mover. The ability to discover leakage of gas or oil vapors or the products of combustion in the pipe connections, through valves, or by a defective or worn piston; the thumping in journal boxes, looseness of pins and piston thump is easily acquired when a person assumes the care of an engine. The regulation of the explosive mixtures are fully explained in the instruction pamphlets and display sheets of the builders, and from the completeness of instructions furnished there seems nothing to fear in the first start of an explosive motor by any person of ordinary intelligence.

Cleanliness being of the first order, due attention should be given to the cleaning of the cylinder, valves, and exhaust pipe at stated intervals; in some motors at least once a month, in other motors several months may elapse without internal cleaning being necessary, apparently without detriment. But we apprehend that the quality of the fuel has much to do with the fouling of the combustion chamber and exhaust pipe, and therefore the quality of the fuel should be suggestive of the times indicated for internal cleaning. The outside surfaces should be wiped off before starting or at the close of work every day, especially where the location is in a room with working-people, as the odor of the lubricating oil is not agreeable when the oil is spread in excess over an engine.

In workshops or rooms where dust prevails it is most desirable to enclose the motor in a small room by itself, well ventilated from without, for motor cylinders are mostly open and gather dust on their oily surfaces, and dust in the ingoing air of combustion leaves grit and ashes in the cylinder. The oil for lubricating the cylinder should be of the best "cylinder oil" of the trade, and is sold by many dealers as "gas-engine cylinder oil." It is not so expensive as to preclude its use for all the moving parts of an explosive motor, although a poorer quality is in general use.

Automatic oil feeders are almost universally furnished with these engines, so that there should be very little waste of oil. In cleaning the internal parts from carbon and oil crust, no sharp scrapers should be used on any rubbing parts or the bearings of valves. If unable to remove the crust with a cloth and kerosene oil, a hardwood stick and oil will generally remove the incrustation down to the metal, while the valves, if not cut, only need rubbing on their seats with finely pulverized pumice or other polishing powder. Emery is not recommended, as valves often get too much grinding to their detriment by the use of this material.

In starting a motor it should always be turned over in its running direction, and when compression makes this difficult the relief valve (most motors have one) or the exhaust or air valve may be opened to clear the cylinder, if an overcharge of gas or a failure has been made at the first turn.

In most cases turning the fly-wheel two or three revolutions will clear and charge the cylinder under the usual conditions for starting. With most of the large motors a starting device is provided, which is described in Fig. 47, and in the special exhibit of the American explosive motors further on.

The water should be drawn off occasionally from the muffler pot by a cock. Gas motors running with electric igniters sometimes do not start at first trial from the accumulation of air in the gas-pipe. Testing by a gas-burner or a second trial will show where the difficulty lies and its remedy. And finally, much caution should be observed in examining the interior of valve chambers and the electric exploders by taking off caps or plugs and using a light near them until assured that fuel inlets are closed and the motor has been turned over several times to clear it of all explosive mixture. The consequences of explosion from peepholes are obvious. Even when a motor has been idle for a time it should be opened with the above caution.

The adjustment of governors only require care and a careful study of the directions for operating the engines, as there are too many variations in the designs and methods of adjustment for definite instructions under this head. Much care is required in renewing the ignition tubes, especially after the spare tubes furnished with the engine have been all used. The same size gas-pipe and of the same length as the tubes furnished with the engine should be made and the end welded up or capped, so that they may contain the same volume as the original tubes. This caution will insure the uniform adjustment of the time of ignition by change of tubes; otherwise tinkering with the position of the Bunsen burner will not enable an attendant not experienced in regulating the time of ignition to regulate it with any degree of certainty. The regulation when once lost can be properly tested only by an indicator card.

With a timing valve and the amount of lead for the return fire from the tube being known, the adjustment of the timing-valve throw can be made from the position of the dead centre of the crank at the end of the forward stroke. The timing lead is the time that is required for the mixture to pass the valve and become compressed in the igniting tube and the flame to return to the combustion chamber, as measured on the circumference of the timing-valve cam.

Other than iron tubes are used, such as nickel, aluminum bronze, and porcelain, with satisfactory results. The porcelain tubes are made short and require a special fitting to adapt them to a chimney, or the chimney should be of special design (as shown in Fig. 34), for a cross impact of the flame of the Bunsen burner.

There are many points in the management of explosive motors that cannot be discussed in a general treatise, arising from the varied details of design, in which special reference to the methods of operating the valve gears of igniters and governors of each individual design is required. The special instructions furnished by builders are ample for the operation of their motors, and if carefully studied lead to success in their operation by any person of ordinary intelligence or tact in handling moving machinery.

Another year's experience with gas, gasoline, and oil vapor engines has brought out more strongly the good qualities of well-made explosive motors, and placed them far ahead as a reliable, cheap and easily managed motive power, even up to several hundred horse-power in a single installation. The application of power from explosive motors for the generation of electricity for lighting and the transmission of power is no longer a mooted point of economy, but has become a fixed principle in the application of prime moving power. The governing devices have been improved and applied in the line of uniform motion from intermittent impulse. An electric gas governing device for controlling the flow of gas to correspond with the required amperage is a new governing application that seems to break the last objection to the use of explosive motors for generating the electric current for lighting purposes.

The hot tube ignition seems to hold its own with increased power and life by the use of the nickel alloy and porcelain tubes as described in the article on Hot Tubes; for while the electric spark has its advantages in some respects, it has likewise its annoyances. When the spark or ignition fails, much detention may follow the search for the fault. The hidden contact points, fouling of sparking insulation, battery faults and connections are to be looked after; or if a generator is used, the chances for faults in a constant current generator are no less, but also become a cause of watchfulness.

As it is now well known that the full firing of an explosive charge is not instantaneous from the moment of ignition in the hot tube, and that the greatest mean pressure on the piston results from perfect ignition of the whole charge at the moment of the passage of the crank over the center, it becomes a matter of considerable importance that the hot tube and Bunsen burner shall be adjusted so as to allow the compressed fresh charge to reach the part of the hot tube at which the temperature is high enough to cause ignition of the charge at a moment just before the crank reaches its center. The variable mixture of the charge either from misfiring of a previous charge or from the action of an over-sensitive governor has made this adjustment heretofore somewhat difficult, especially where short-lived tubes were in use, for a change of tube usually varies the moment of ignition. Since the advent of the nickel alloy and porcelain tubes this difficulty has been greatly overcome, and the ignition tube has been restored to favor with many engine builders who had adopted the electric system for its positive timing. The marine engine, however, will probably hold to electric ignition from the obvious difficulty in managing a gasoline burner for such service.

Many minor improvements of the past year have conduced to a general economy in running expense and to ease of management, among which may be noted a new device on the White & Middleton engines, by the turning of which the time of sparking is retarded at starting, and the engine prevented from the

POINTERS ON EXPLOSIVE MOTORS.

The explosive motor now appeals to no experience and responsibility of a professional engineer for its care and running, yet it does require much common sense as to cleanliness and the propriety of things that may assume a menacing or dangerous habit by neglect of some of the few points of attention absolutely essential.

The ability to discover and locate leakage of gas or oil vapors or the products of combustion in the pipe connections, through valves or by a defective or worn piston; the thumping in journals, looseness of pins and piston thump, is easily acquired when a person assumes the care of an explosive motor. The regulation of the explosive mixtures is so fully explained in the instructions now sent out with the motors that there seems nothing to fear in their first starting by any person of ordinary intelligence.

In the operation of these motors, cleanliness is of the first order, and due attention should be given to the cleaning of the cylinder, valves and exhaust pipe at stated intervals, according to the kind of fuel used. The highly carbonaceous gases and vapors require more attention in internal cleaning than those containing an excess of hydrogen and nitrogen constituent.

In using highly carbonaceous gases and vapors, cylinders, valves and exhaust pipes need cleaning at least once a month, while with the cleaner fuels, several months may elapse without cleaning.

The outer surfaces, boxes and parts bespattered with oil should be kept clean, as well as the floor, which should have a zinc lining around the motor. Wiping up twice a day is none too much for cleanliness and the welfare of people working in the same room with a motor.

It is better to enclose the motor in a small room by itself, well ventilated from without; it keeps dust from the cylinder and foul odors from the workrooms. It pays to use the best cylinder oil for all parts of a motor, as it requires less of the good oil than of the poor quality for lubricating any surface and is inducive of efficiency. In cleaning the internal parts, avoid the use of a sharp scraper on rubbing surfaces and valve seats. A hardwood stick and kerosene oil will generally do this work and save much after trouble.

For regrinding valves, emery should not be used; pulverized pumice stone and oil do the work well without over grinding.

Some of the troubles met with in the operation of explosive motors are severe explosions after one or several misfires, by which the cylinder becomes overcharged with combustible mixture and on firing produces an excessive explosion and kick in the motor. This is due to irregular work of the motor or misfiring of the igniter. Other interruptions sometimes occur, such as the sticking of the exhaust valve open by gumming of the spindle. From this may also arise the back firing in the muffler pot and exhaust pipe, which although not pleasant to the ear, are not considered dangerous, because the motors and all their parts subject to this explosive force are made equal in working strength to the greatest pressure from such explosions.

One possible evil is the rupture of a weak muffler pot from the choking of the exhaust pipe by soot—a suggestion to make the exhaust pipe from the muffler pot two pipe sizes larger than the usually assigned size for the motor.

In examining the interior of an explosive motor, care should be taken to remove any gas or vapor from all chambers and recesses by closing their inlets and turning over the fly-wheel several times with the air inlet open. This is most essential for safety in removing plugs for examining the sparking electrodes. A few accidents have happened when looking at the sparking device through a plug hole.

An accumulation of air in the gas pipe is sometimes the cause of failure in starting with an electric igniter, and often attributed to the failure of the spark. A search in both directions will find the true cause of failure.

On purchasing a motor, the one who is to operate it should carefully study the mechanism and the instructions, as the detail in operating the three kinds of fuel, gas, gasoline and kerosene or crude oil vary enough to require special inquiry for the operation of each kind.

The method of ignition is also peculiar and requires special instruction in either of the kinds of devices by which the motor is operated. Whether tube, hammer spark or jump spark is selected, they are each so different in detail as to need special instruction.

One of the annoyances in explosive motor service is the incrustation of the water jacket by lime. Hard water or such as contains a considerable amount of carbonate or sulphate of lime when used as a free running stream, has been found to choke a water jacket in a few months so as to render the jacket almost useless as a cooling device. To obviate this difficulty a cooling tank of about twenty gallons per horse-power should be used, set above the cylinder and of such form as to give large surface to the air with a free circulation on all sides. A round tank gives the least air cooling surface, while a long tank of galvanized sheet iron with vertical corrugated sides has given the most satisfactory service.

By the use of a cooling tank charged with the best water attainable, preferably rain water and a pound of caustic soda to each five gallons, an encrusted jacket can soon be cleaned or the incrustation so loosened that it can be easily scraped and washed out through the core openings. Acid and water has been recommended and used; but such treatment is not as convenient as the soda circulation.

The manufacturer, if he understands his interests, usually furnishes sufficient explanatory matter to enable the operator to understand all details. Often this has been a failure to the detriment of both maker and purchaser; but if the seller thinks he can afford to be careless about this, the buyer need not, for all shut-downs and interruptions caused by failure to operate a motor satisfactorily are more or less expensive.

CHAPTER XV.

THE MEASUREMENT OF POWER.

THE methods of measuring power are of but two general forms or principles, although the individual machines or instruments for accomplishing the measurement are of many kinds and of a variety of construction.

The one form is especially adapted for the measurement of the available power of prime movers under the various conditions of the application of their elementary constituents, by the absorption of their whole output of power at the point of delivery and there record the value of its force and velocity. Its representative is the brake dynamometer, or Prony's brake, in the various details of construction that it has assumed as designed and applied to meet the views or fancies of mechanical engineers.

The second form is a marked departure from the structural form of the first, and with the principle in view of placing as little obstruction as possible to the transmission of power from the prime mover to the receiver of power, to measure the actual net or differential tension of a belt or gear, and with its velocity indicate the exact amount of power delivered to a line of shafting or a machine. These are called transmitting dynamometers in distinction from the absorption dynamometers of the Prony type. They are of two kinds, one with a dial and index pointer, by which the hand on the dial must be constantly watched and recorded for a length of time and a mean pressure obtained from the varying record. The other carries a self-marking register moved by clockwork, by which the actual pressure is a constant record for any desired time, or a full day's work, the only personal observation required being the speed of the pulley or belt or its average throughout the time or day

In Fig. 51 we illustrate the first form, a simple absorption

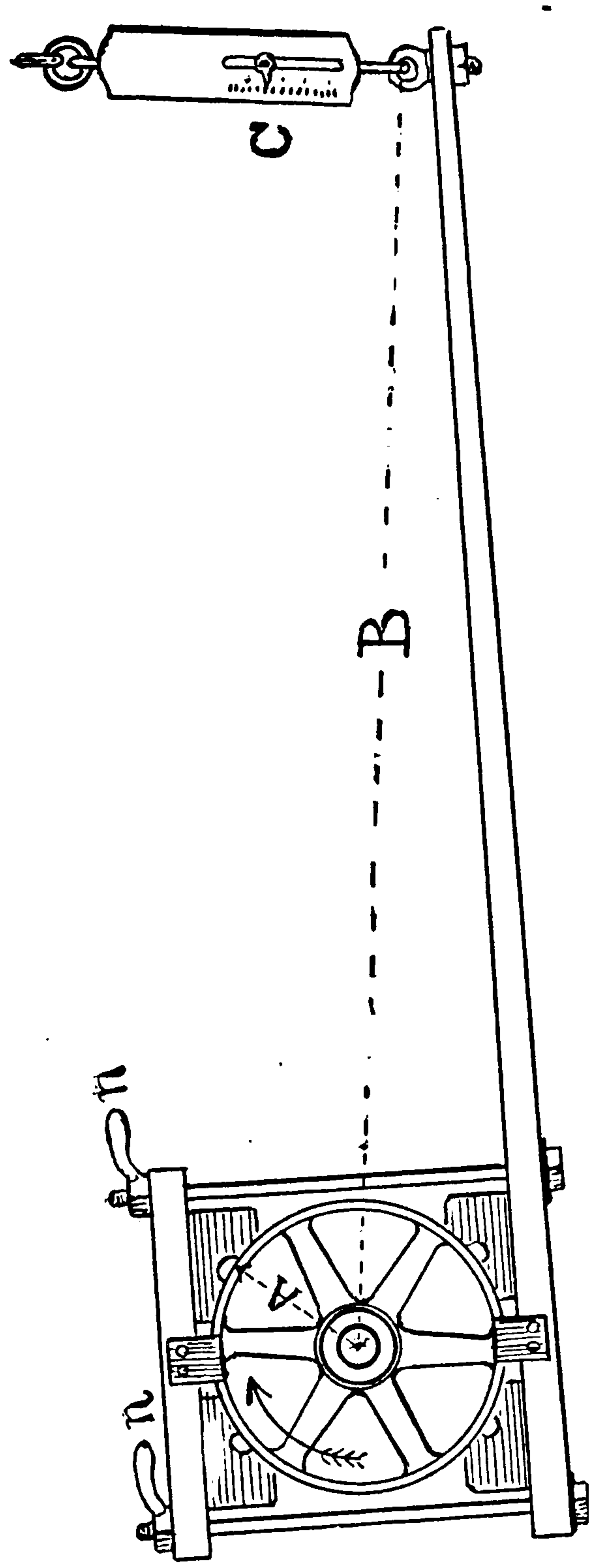


Fig. 51.—The Prony Brake.

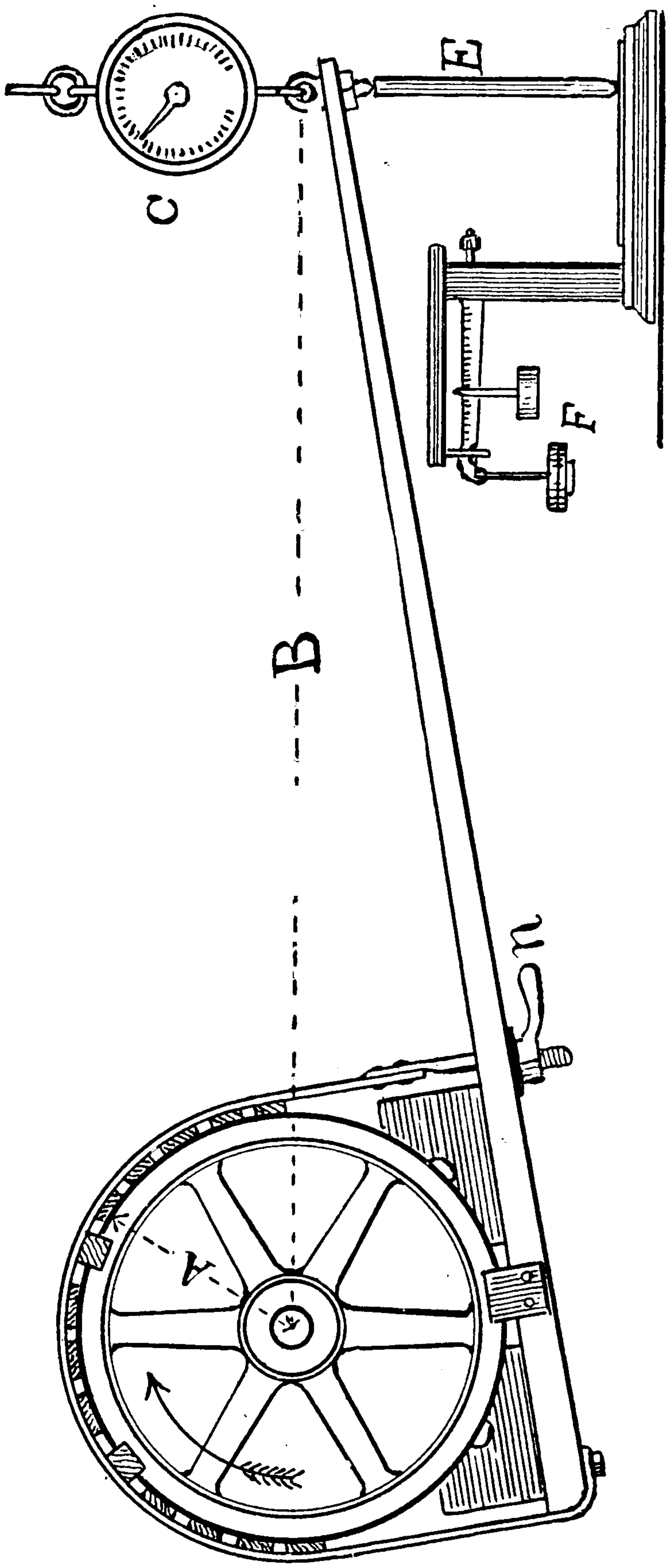


Fig. 52.—The Prony Strap Brake.

dynamometer or Prony's brake, named after its inventor, in which A is the radius of the pulley drum or shaft to which resistance may be applied; B the length of the lever from the centre of the shaft to the point of attachment of the spring scale or other means of measuring the tension of the lever; C a spring scale, which is preferable for light woık within its range; and N N lever nuts for quick control of the pressure.

In Fig. 52 is presented a simple and inexpensive arrangemen of a power-absorbing brake for a large driving-pulley or finished fly-wheel, in which a belt is lined with blocks of wood spaced and fastened to the belt with screws or nails, a few of the blocks projecting over the edge with shoulders to prevent the belt from running off the pulley.

Spring scales may be purchased of the straight and dial pattern up to one or two hundred pounds capacity at reasonable figures, and are a source of satisfaction in showing the amount of vibration due to irregular pulsations of the motive element and crank motion. Where the measurement of power beyond the range of a spring balance is required, the use of a platform scale or any other weighing device may be made available. With a platform scale the light wooden strut, E, Fig. 52, may be adjusted to any length and vertically reaching from the platform to the horizon line, B, from the centre of the shaft; lanyards or any convenient means being used to keep the end of the lever from swaying.

Water from a squirt can is the best lubricant for this class of dynamometers, as it can be easily thrown upon the face of the pulley at the interstices of the blocks and lagging, and by its quick evaporation carries off the heat generated by friction. Soapy water has been used to good effect in preventing irregular pressure or stickiness of the friction surfaces.

It matters not in what direction the brake lever is placed to suit the convenience of observation, so long as the pull of the scale is made at right angles to the radial line from the shaft center. Its weight, as indicated on the scale, with the friction blocks or strap loosened in any position that it may be set, should be noted and a record made of the amount, which must be deducted from the total observed weight of the trial.

$D \times 3.1416 \times R =$ the velocity of the face of the pulley or of the belt that it is to carry.

In Fig. 53 is represented a simple and easily arranged differential strap brake or dynamometer for small motors of less than two horse-power. It consists of a piece of belting held

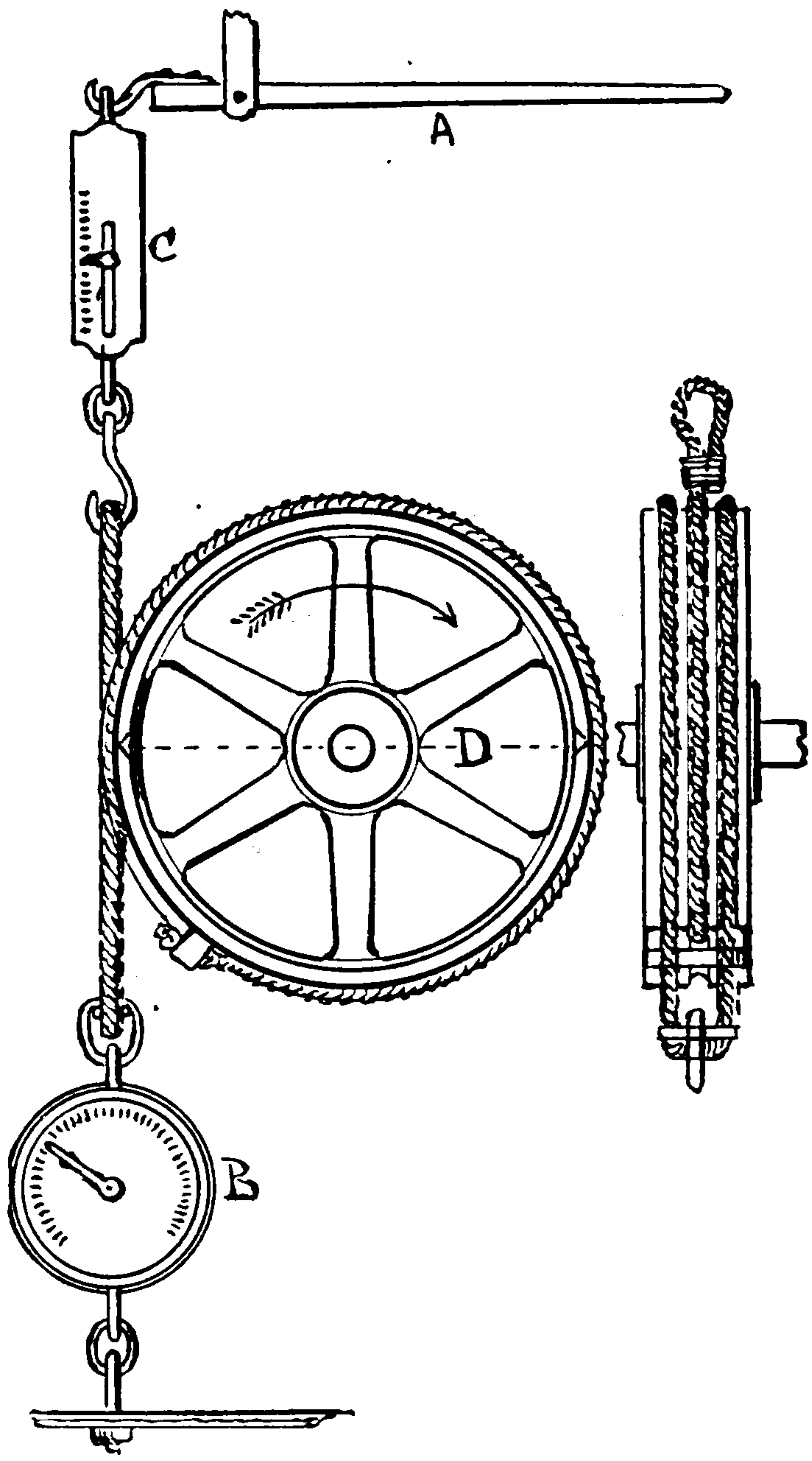


FIG. 54.—DIFFERENTIAL ROPE BRAKE.

in place on the pulley by clips or only strings fastened parallel with the shaft to keep the belt from slipping off; two spring scales, one of which is anchored and the other attached to a hand lever to regulate the compression of the belt upon the surface of the pulley, when the differential weight, B – C, on the scales may be noted simultaneously with the revolutions of the pulley. The simple formula

$$\frac{D \times 3.1416 \times R \times \text{differential weight}}{33,000} = \text{horse-power.}$$

Fig. 54 illustrates a rope absorption dynamometer or brake with a complete wrap on the surface of the pulley, very suitable for grooved pulleys or fly-wheels used for rope transmission. In this form the friction tension may be regulated with a lever as at A. The weight (W) in the formula is the differential of the opposite tensions of the two scales, or B—C=W, Fig. 54. and the formula will then be: $\frac{D \times 3.1416 \times R \times W}{33,000}$ = horse-power, as in the notation, Fig. 53.

Thus it may readily be seen that the difference of the pull in a rope or belt on the two sides of a pulley, multiplied by the velocity of the rim in feet per minute, and the product divided by 33,000, gives the horse-power either absorbed or transmitted by the rope.

The Measurement of Speed.

The revolutions of a motor may be readily obtained by an ordinary hand counter with watch in hand to mark the time; but for accurate work and to show the variations in the fly-wheel speed by the intervals of revolution between impulses, and especially the effect of mischarges or impulses due to governing the speed, there is no more accurate method than by the use of the centrifugal counter or tachometer.

These instruments are designed to show at a glance a continuous indication of the actual speed and its variation within 2 per cent. by careful handling of the instrument. The tachometer (Fig. 55) with a single dial scale 3 inches in diameter, reading from 100 to 1,000 revolutions per minute, and by changing the gear for the range of gas-engine indication the actual revolutions will be one-half the indicated revolutions, and each divided by 2 will represent the actual speed. In this manner a very delicate reading of the variation in speed may be obtained. For testing the variation of speed in electric-lighting

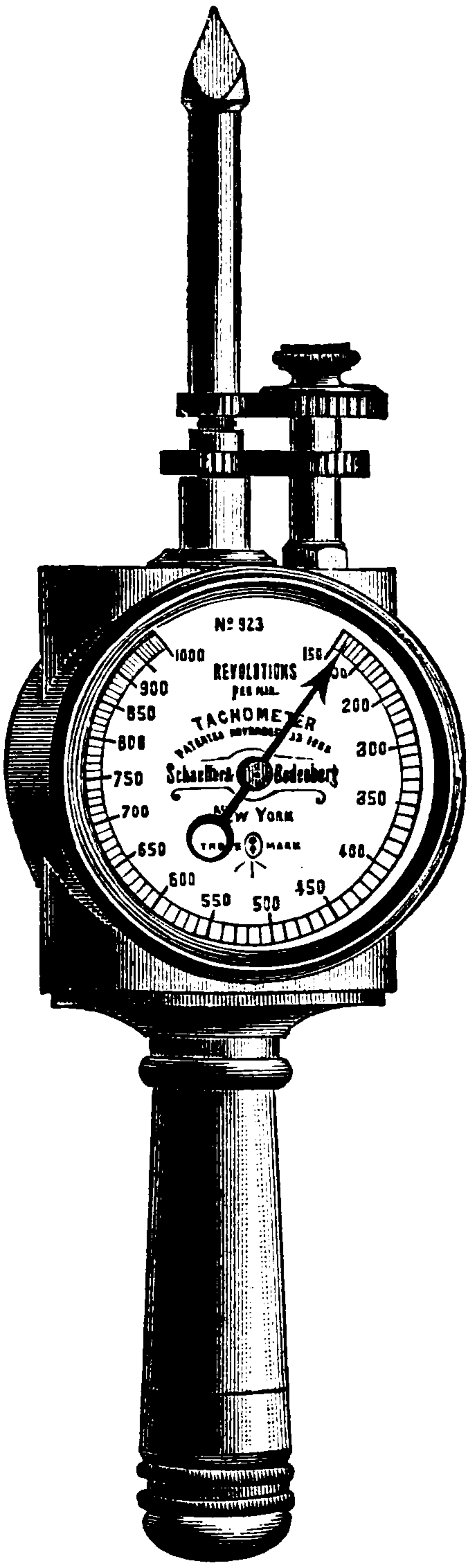


FIG. 55.—THE TACHOMETER.

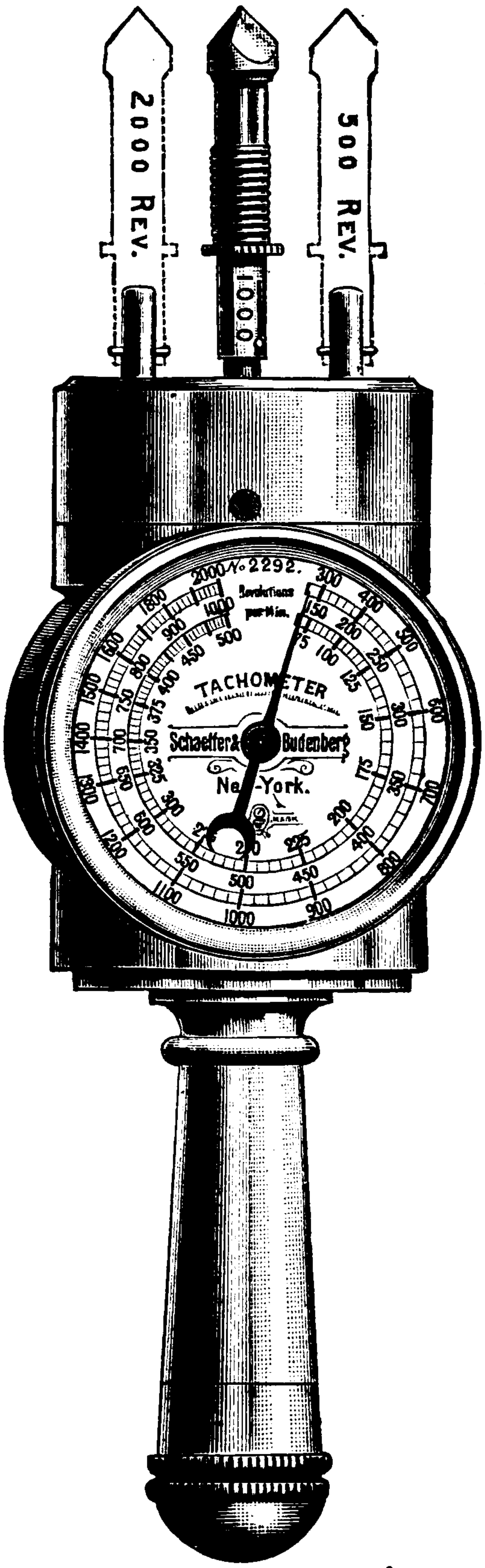


FIG. 55A.—THE TRIPLE INDEXED TACHOMETRE.

plants operated by gas or gasoline engines, there is no method so satisfactory as by the use of the tachometer.

The triple indexed tachometer (Fig. 55A), is a most con-

Schaeffer & Budenberg, New York, and illustrated in Figs. 56 and 57, is a light and sensitive instrument with absolute rectilinear motion of the pencil with its cylinder and piston, made of a specially hard alloy which prevents the possibility of sur-

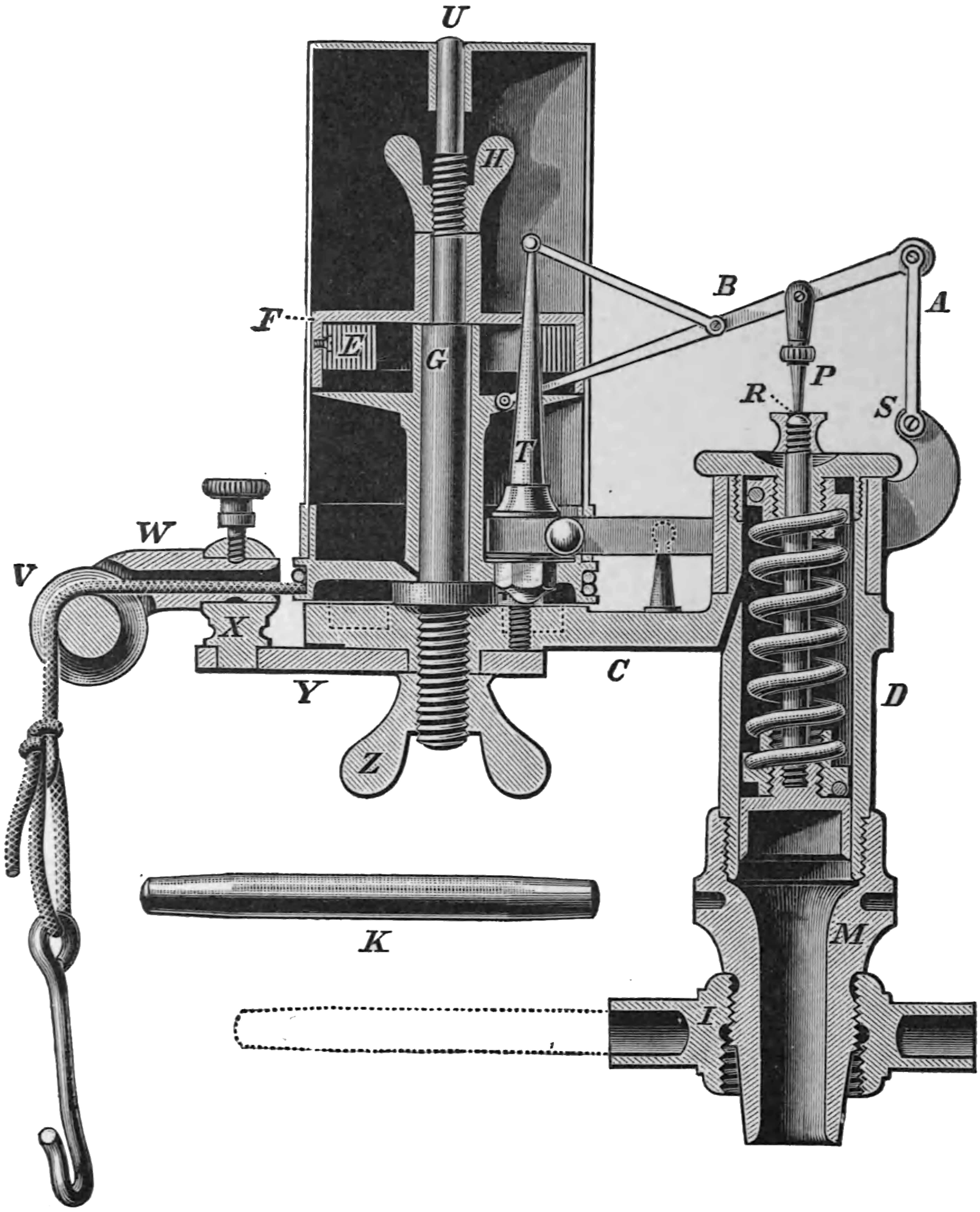


FIG. 57.—SECTION OF INDICATOR.

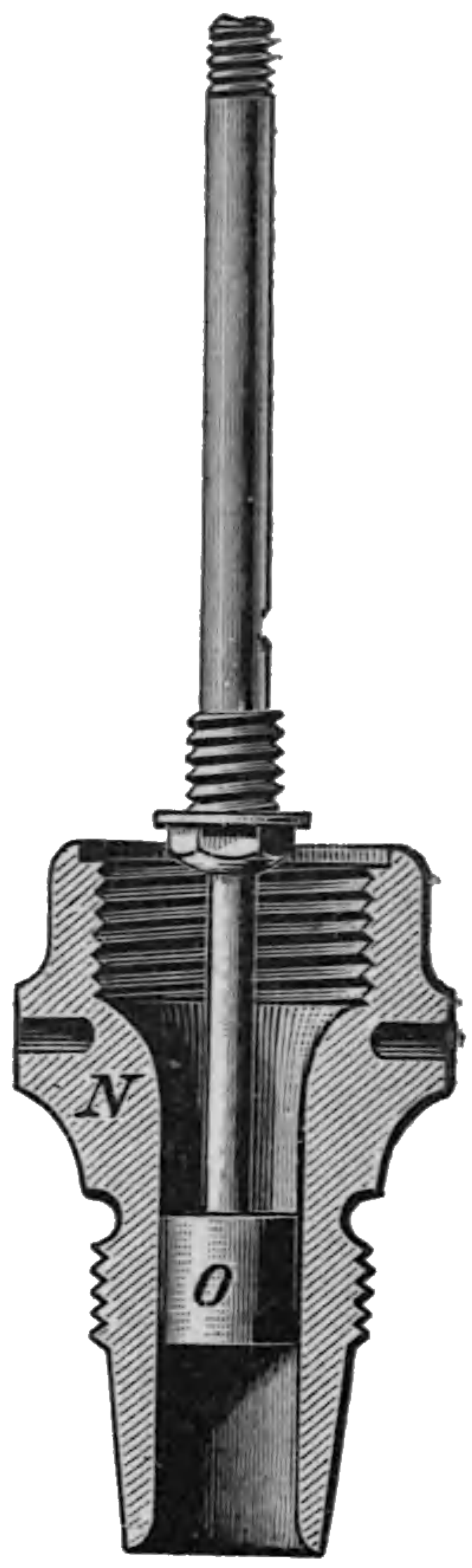


FIG. 58.—SMALL PISTON

face abrasion and insures a uniform frictionless motion of the piston. It is provided with an extra and smaller-sized cylinder and piston, suitable with a light spring for testing the suction and exhaust curves of explosive motors, so useful in showing the condition and proportion of valve ports.

The large piston of the standard size is 0 798 inch in diameter and equal to ½ square inch area. The small piston (Fig. 58) is 0.590 inch in diameter and equal to 0.274 square inch area, so that a 50 or 60 spring may be used in indicating explosive engines with the small piston, which will give cards within the range of the paper for low-explosive pressure but full enough to show the variations in all the lines. With the 100 spring and ½ inch area of piston 250 lbs. pressure is about the limit of the card, but with this size piston a 120 or 160 spring is more generally used.

The pulley V is carried by the swivel W and works freely in the post X; it can be locked in any position by the small set screw. The swivel plate Y can be swung in any direction in its plane and held firmly by the thumb-screw Z. Thus with the combination the cord can be directed in all possible directions. The link A is made as short as possible with long double bearings at both ends to give a firm and steady support to the lever B, making it less liable to cause irregularities in the diagram when indicating high-speed motors.

The paper drum is made with a closed top to preserve its accurate cylindrical form, and the top, having a journal bearing at U in the centre, compells a true concentric movement to its surface.

The spring E and the spring case F are secured to the rod G by screwing the case F to a shoulder on G by means of a thumb-screw H.

To adjust the tension of the drum spring, the drum can be easily removed, and, by holding on to the spring case E and loosening screw H, the tension can readily be varied and adapted to any speed, to follow precisely the motion of the engine piston.

The bars of the nut I are made hollow, so as to insert a small short rod K, which is a great convenience in unscrewing the indicator when hot.

The reducing pulley (Fig. 59) is a most important adjunct of the indicator. The revolving parts should be as light as possible and are now made of aluminum for high-speed motors with pulleys proportioned for short-stroke motors. In the use of indicators for high-compression motors it is advisable to have a stop-tube inserted in the cap-piece that holds the spring and extending down and inside the spring so as to stop the motion of the piston at the limit of the pencil motion below the top of

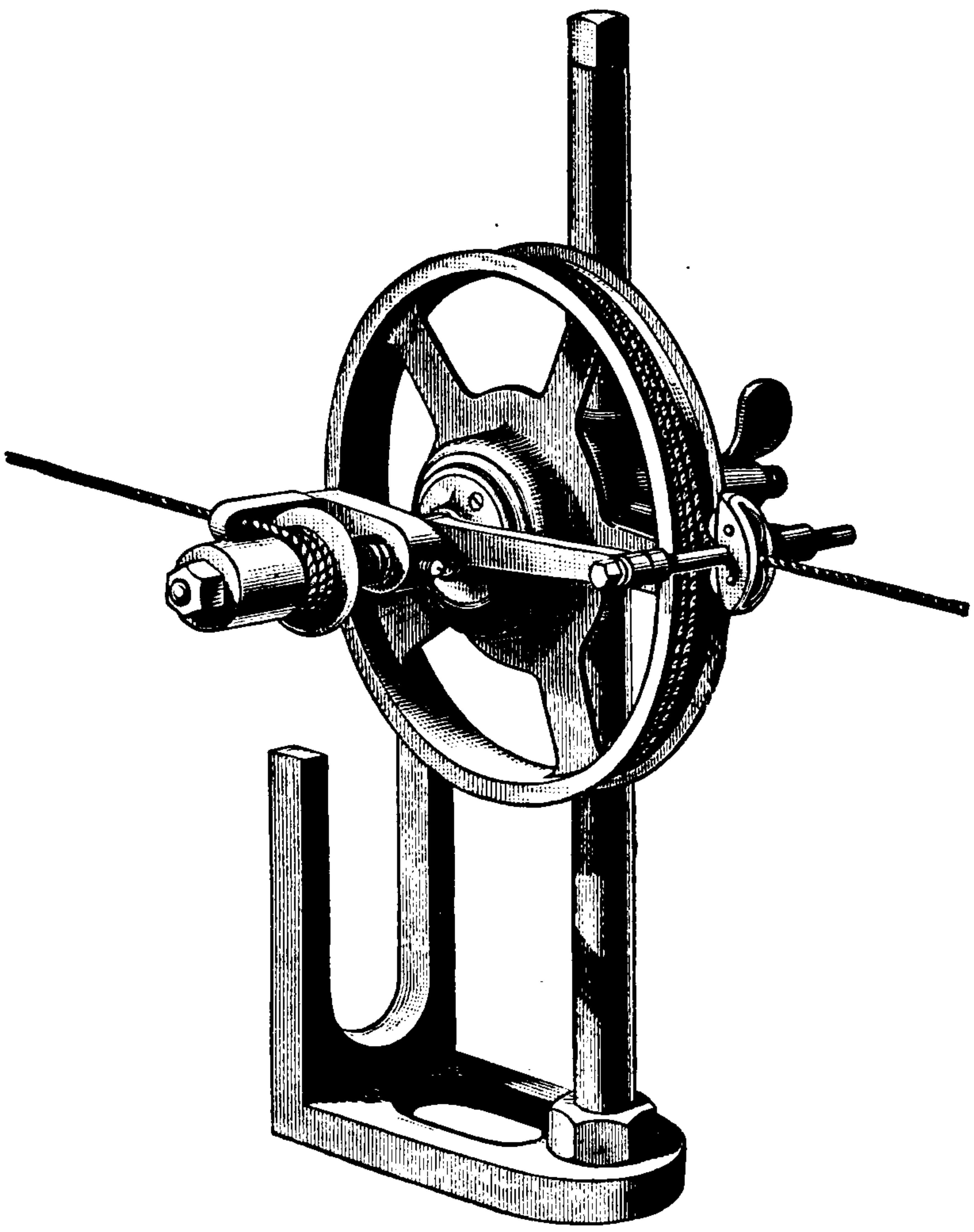


FIG. 59.—THE REDUCING PULLEY.

the card. This will prevent undue stress on the spring and extreme throw of the pencil when by misfires an unusual charge is fired. With the smaller piston and the usual 100 or 120 spring any possible explosive pressure may be properly recorded.

The proximity of the indicator to the combustion chamber is of importance in making a true record of the explosive action of the combustible gases on the card. The time of transmission of the wave of compression and expansion through a tube of one, two, or three feet in length is quite noticeable in the distortion of the diagram. It shows a delay in compression and

post be placed between the engine floor and floor beams above, as it only communicates the vibrations to any floor in unison with the vibrations of the engine floor.

A system of diagonal posts extending from near the centre of a vibrating floor to a point near the walls or supporting columns of the floors above or below, or a pair of iron suspenders placed diagonally from the overhead beams near their wall bearings to a point near the location of an engine and strongly bolted to the floor beams, will greatly modify the vibration and in many cases abate a nuisance.

In the installation of reciprocating machinery on the upper floors of a building in which the reciprocating parts of the motor, as a horizontal engine, are in the same direction as the reciprocating parts of the machines (as in printing pressrooms) the trouble from the horizontal vibration has been often found a serious one. It may be somewhat modified by making the number of the strokes of the engine an odd number of the strokes of the reciprocating parts of the machine.

It is well known to engine builders that explosive motors, like high-speed steam engines, cannot be absolutely balanced, but their heavy fly-wheels and bases go far toward it by absorption, and the best that can be done with the balance is to make as perfect a compromise of the values of the longitudinal and lateral forces as possible by inequality in the fly-wheel rims.

The jar caused by excessive explosions after misfires and muffler-pot explosions is of the unusual kind that cannot be easily provided with a remedy where the transmitted power is not uniform, for where it is uniform there is ample regulation from the governor to make the charges regular, and if the igniter is well adjusted there should be no cause for "kicking," as our European cousins call it. A good practice in setting motors is to locate them near a beam-bearing wall or column that extends to the foundation of the building. Many motors so placed are found to be free from the nuisance of tremor.

CHAPTER XVI.

EXPLOSIVE ENGINE TESTING.

For the reason that elaborate and complicated tests have been made and exploited in other works on the gas engine, which may be referred to for the details of expert work, the author of this work has decided to reduce the practice of testing explosive motors to a commercial basis on which purchasers can comprehend their value as a business investment for power. The disposition of builders of explosive engines to follow the economics in construction in regard to least wall surface in contact with the heat of combustion, and of maintaining the wall surface at the highest practical temperature for economical running by the rapid circulation of warm water from a tank or cooling coil, leaves but little to accomplish, save the proper size and adjustment of the valves and igniters for the engines, in order that they may properly perform their functions. The indicator card, if made through a series of varying proportions of gas or gasoline and air mixtures, will show the condition of the adjustments for economic working. The difference between the indicated power for the gas used by the card and the power delivered to the dynamometer or brake shows the mechanical efficiency of the engine. The best working card of the engine should be a satisfactory test to a purchaser that the principles of construction are correct. A brake-trial certificate or observation should satisfy as to frictional economy, and the price and quantity of gas per horse-power hour should settle the comparative cost for running. The variation in the heating power of illuminating gas in the various parts of the United States is much less than its variation in price. Producer gas is a specialty for local consumption, and its cost drops with its heating power.

Apart from the actual cost of gas in any locality and the quantity required per brake horse-power, durability of a motor is one of the principal items in the purchase of power.

In the use of gasoline, kerosene, and crude petroleum in explosive engines, their heating values are uniform for each kind, and as motors are generally adjusted for the use of one of the above hydrocarbons only, the difference of cost between these various fuels is the best indication as to the relative cost of power.

No instruments have yet been contrived for giving the temperatures of combustion, either initial or exhaust, in an internal combustion motor; for at the proper working speed the changes of temperature are so rapid that no reliable observation can be made even with the electric thermostat, as has been tried in Europe. The computed temperatures are unreliable and at best only approximate; hence the indicator card becomes the only reliable source of information as to the action of combustion and expansion in the cylinder, as well as to the adjustment of the valves and their proper action.

The temperature of combustion as indicated by the fuel constituents, and computed from their known heat values, gives at best but misleading results as indicating the real temperature of combustion in an explosive engine. There is no doubt that the computed temperatures could be obtained if the contaminating influence of the neutral elements that are mixed with the fuel of combustion, as well as the large proportion of the inert gases of previous explosions, could be excluded from the cylinder, when the radiation and absorption of heat by the cylinder would be the only retarding influences in the development of heat due to the union of the pure elements of combustion.

For obtaining the indicated horse-power of a gas, gasoline, or oil engine, the mean effective pressure as shown by the card

It is assumed that the taking of an indicator card must be done when the engine is running steady and at full load. During the moment that the pencil is on the card there should be no misfires recorded, in order that the card may represent the true indicated horse-power of the engine. The record of the speed of the engine should be taken at the same time as the card, but the measurement of the quantity of gas used cannot be accurately observed on the dial of an ordinary gas meter during the few moments' interval of the card record and speed count. For the gas record, the engines should be run at least five minutes at the same speed and load and an exact count of the explosions made. The misfires or rather mischarges in an engine running with a constant load are of no importance in the computation for power because they are properly caused by overspeed, and the overspeed and underspeed should make a fair balance for the average of the run as indicated by the speed counter.

The number of cubic feet of gas indicated by the meter for a few minutes' run, multiplied by its hour exponent and divided by the indicated power by the card or the actual horse-power by the brake, will give the required commercial rating of the engine as to its economic power. The difference as between the cost of gas for the igniter and the cost of electric ignition is too small to be worthy of consideration.

In testing with gasoline or oil the detail of operation is the same as for gas, with the only difference of an exact measure of the fluid actually consumed in an hour's run of the engine under a full load. The loading of an engine for the purpose of testing to its full power is not always an easy matter; although, when driving a large amount of shafting and steady-running machines, a brake may be conveniently applied to increase the work of the engine. In trials with a brake alone, a continual run involves some difficulties on account of the intense friction and heat produced, which makes the brake power vary considerably and cause a like variation in the ignitions.

Probably the most satisfactory method of testing the power of a motor is by its application to generate an electric current, which, if properly arranged in detail, allows the test trial to be continued for a length of time and makes the test a perfectly reliable one. For this purpose the motor may be belted to a generating dynamo of the same or a little higher rating than that of the motor. A short wiring system with a volt and ampere meter and a sufficient number of 16 candle-power lamps in circuit, of a standard voltage and known amperage, will indicate the power generated in kilowatts, to which should be added the loss of efficiency in the dynamo.

From this data the actual horse-power of the motor may be computed, which with the fuel measurement and the speed of the motor during test trial is all that is needed for a commercial rating.

In testing motors with ordinary illuminating gas under street pressure as used for lighting purposes, the ordinary meter measurement will be found correct, but with natural or other gas supplied at high pressures the pressure should be reduced by a pressure regulator, or by drawing the gas from a properly weighted gas holder. A one-inch water pressure in a glass inverted siphon gives the proper pressure for meter measurement. The details for the finer tests of explosive motors have but little commercial value and require much expert experience in the details of such tests; so that for ordinary purposes in testing for best effect the cylinder cooling water should be run long enough and with the engine running at full load to establish an overflow temperature of 175° Fah., which has been found to give a good working efficiency in the cylinder temperature. This may be readily obtained by regulating the quantity of flowing water. Then the actual measurement of the gas or other fuel and its cost as compared with the brake horse-power may be said to give a fairly just measure of its fuel economy. The test of endurance is a strictly mechanical one due to design and quality of construction, which may be obtained first by inspection or detailed examination of the motor, and further from guarantee of the builder.

CHAPTER XVII.

TYPES OF THE EXPLOSIVE MOTOR.

The leading feature of two-cycle engines are essentially an embodiment of the Day model as first made in England, and noted for the absence of valves for inlet and exhaust, and for a compression initial charge from a closed crank chamber, made by the impulse stroke of the piston and a final compression and explosion of the charge at every revolution of the crank shaft. The air and gas or vapor are drawn into the crank chamber by the

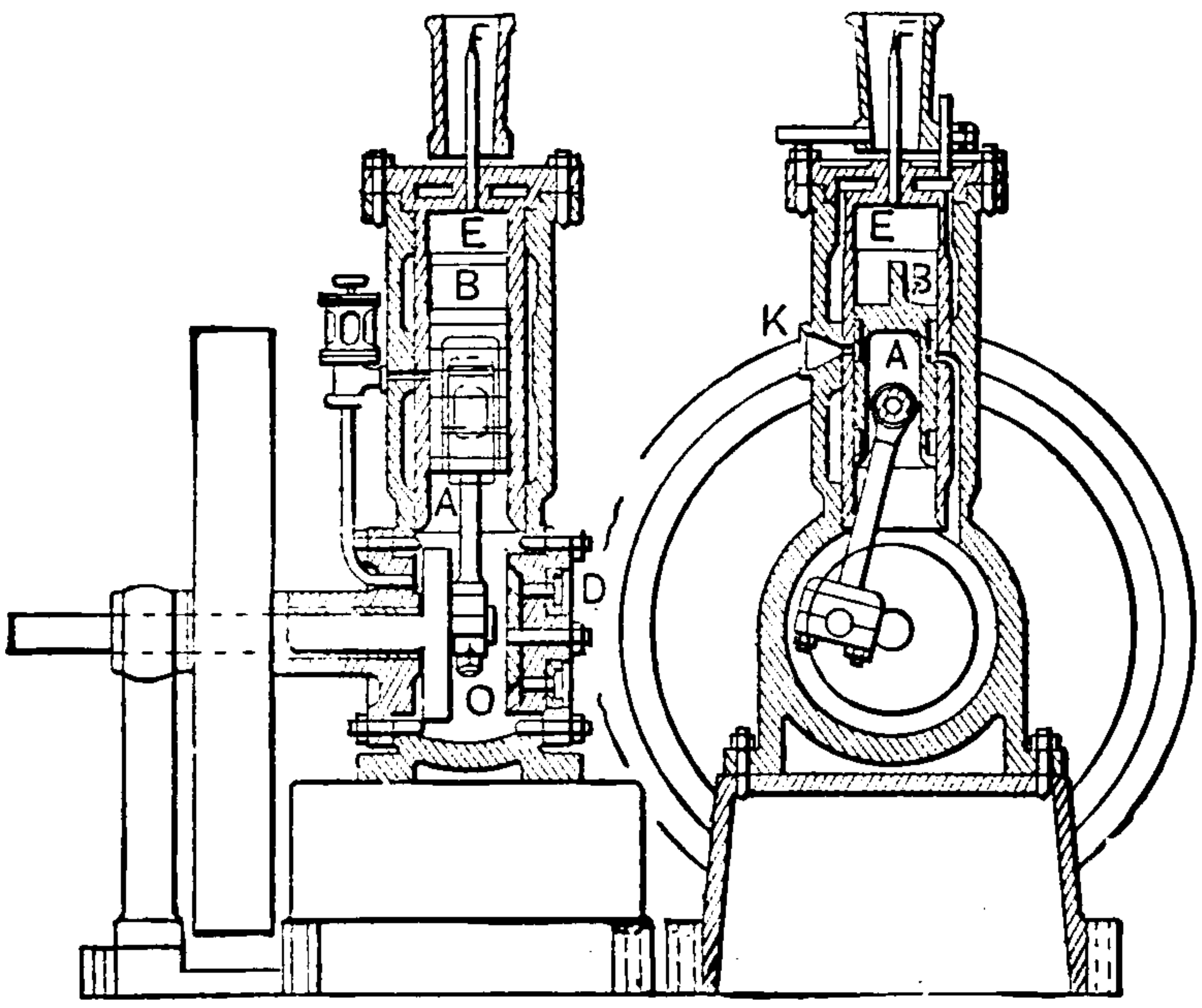


FIG. 61A.—THE DAY MODEL.

action of the piston and the mixture completed by the motion of the crank. From the absence of cylinder valves and valve gear this type of explosive engine has the peculiar advantage that it can be run in either direction by merely starting it in the direction required. This type of motors receive their charge and exhaust through cylinder ports at the end of the impulse stroke of the piston. In some modifications of the Day model a supplementary exhaust is provided for by the use of a valve in the cyl-

thus almost entirely eliminating vibration, or ignition may be made alternately with a two-cycle effect. The radial ribs on the motors of suitable size for light vehicles are found efficient and

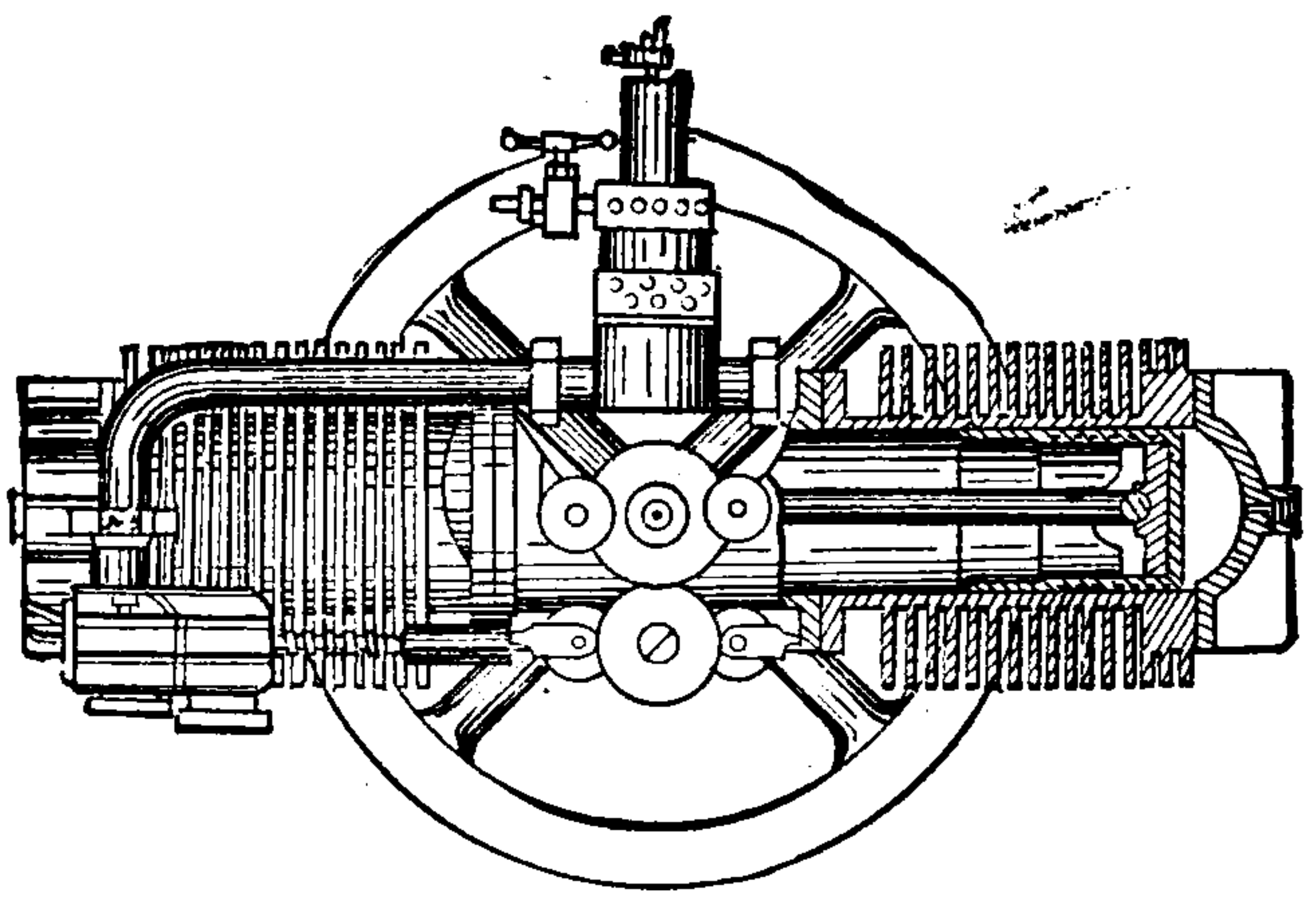


FIG. 61C.—NON-VIBRATING MOTOR.

most convenient in eliminating one of the troubles of explosive motor power—the water jacket. The Crest Manufacturing Co., Dorchester, Mass., are building motors similar to this type.

A compact gasoline motor, rib jacketed, and designed for an automobile, Fig. 61D, is of French origin. It has a special combustion chamber and attached valve chamber for facilitating ignition by tube or spark, the tube being shown in the sketch.

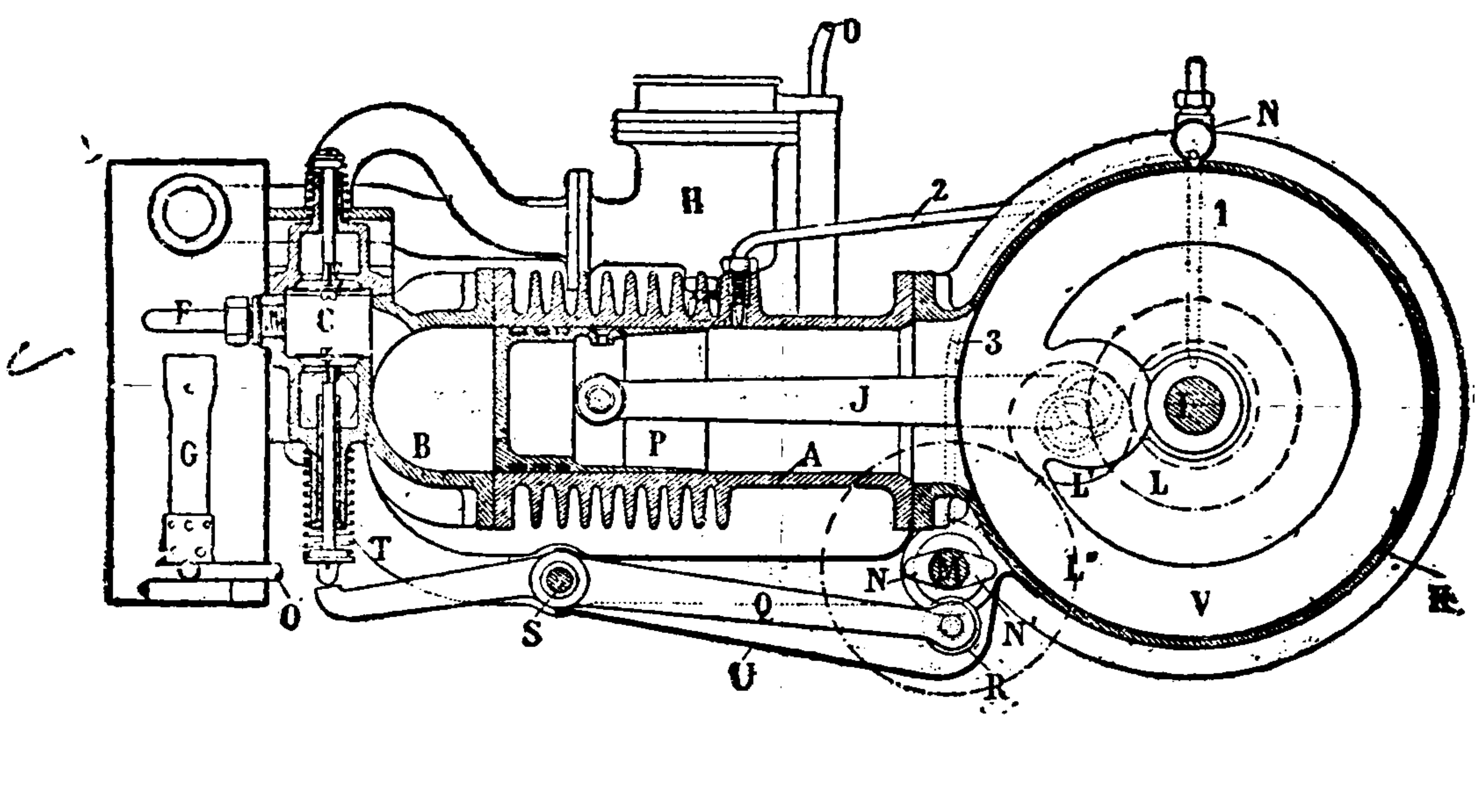


FIG. 61D.—GASOLINE AUTOMOBILE MOTOR.

P is a short platinum tube directly over the Bunsen burner G operated by gasoline vapor generated in the burner. H is the carburetter, which receives its charge through an automatic valve where it is vaporized by warm air from over the burner. The vapor charge with its air mixture is drawn in through the valve E. A reducing gear, cam and lever, operates the exhaust valve, and speed is regulated by varying the charge of gasoline vapor, which is controlled by an index cock. The crank end and fly-wheel are enclosed in a light iron case, which holds the oil for lubricating the journals and gearing. The other lettered parts are self-explanatory.

We illustrate the special construction of the Lewis gas and gasoline motor in Fig. 61 E and 61 F, built by J. Thompson &

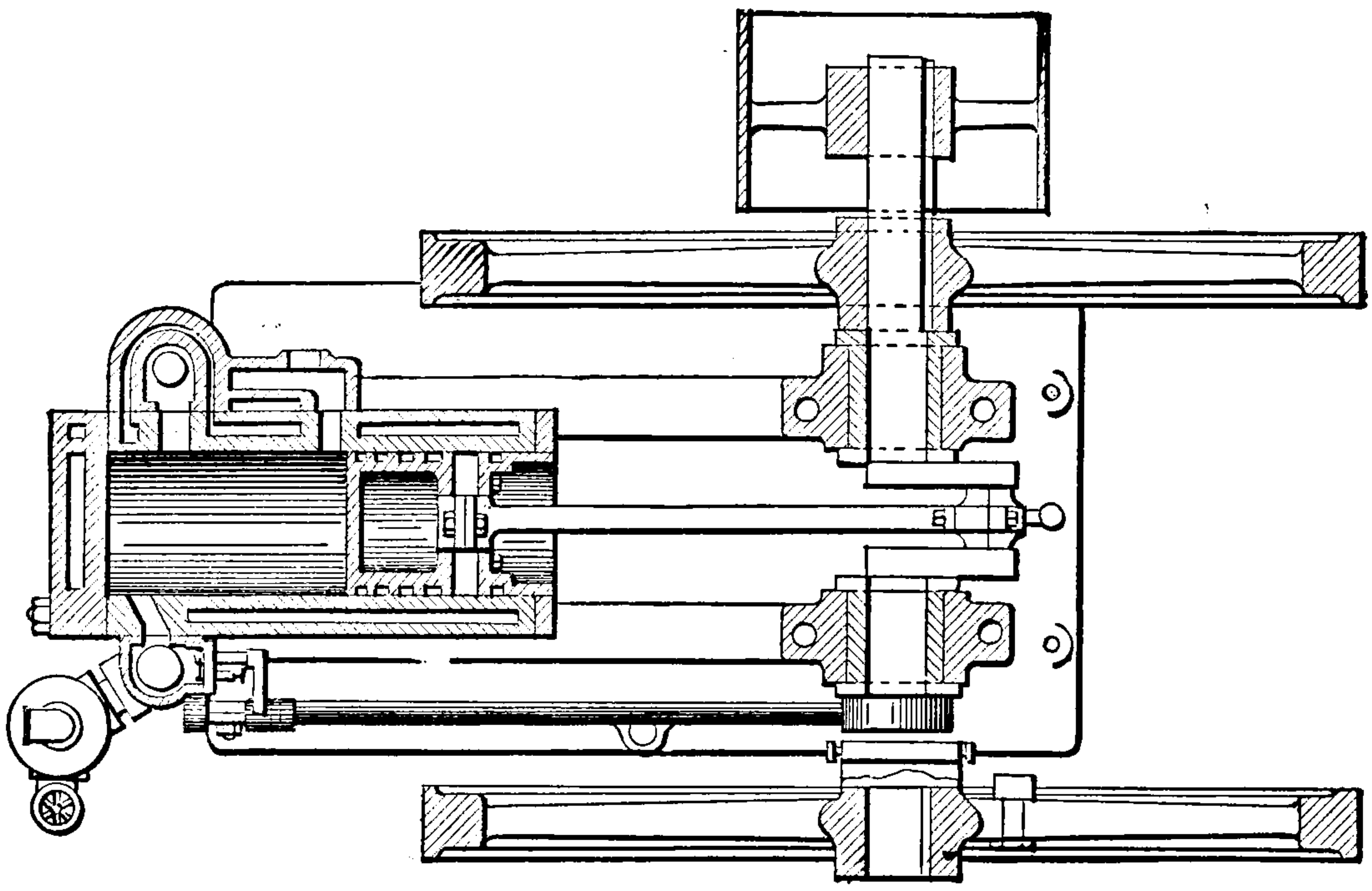


FIG. 61E.—LEWIS MOTOR.

Sons Manufacturing Company, Beloit, Wis. The principal feature of this motor is the addition of the cylinder port exhaust as an auxiliary to the regular exhaust valve, which is now a conceded measure of economy in reduced exhaust back pressure and in the saving of wear on the exhaust valve.

The vaporizer is shown in section in Fig. 61 F, which consists of a chamber M, with an air pipe A, by which the mixture of gasoline and air is regulated by drawing the air pipe to or from the surface of the gasoline constant level, which is regulated by the overflow pipe at M. A further regulation of the charge mixture is made by the valve at the right of the vaporizing chamber.

The gasoline pump is operated from the arm of the exhaust valve lever. The igniter is of the hammer break type and is attached by

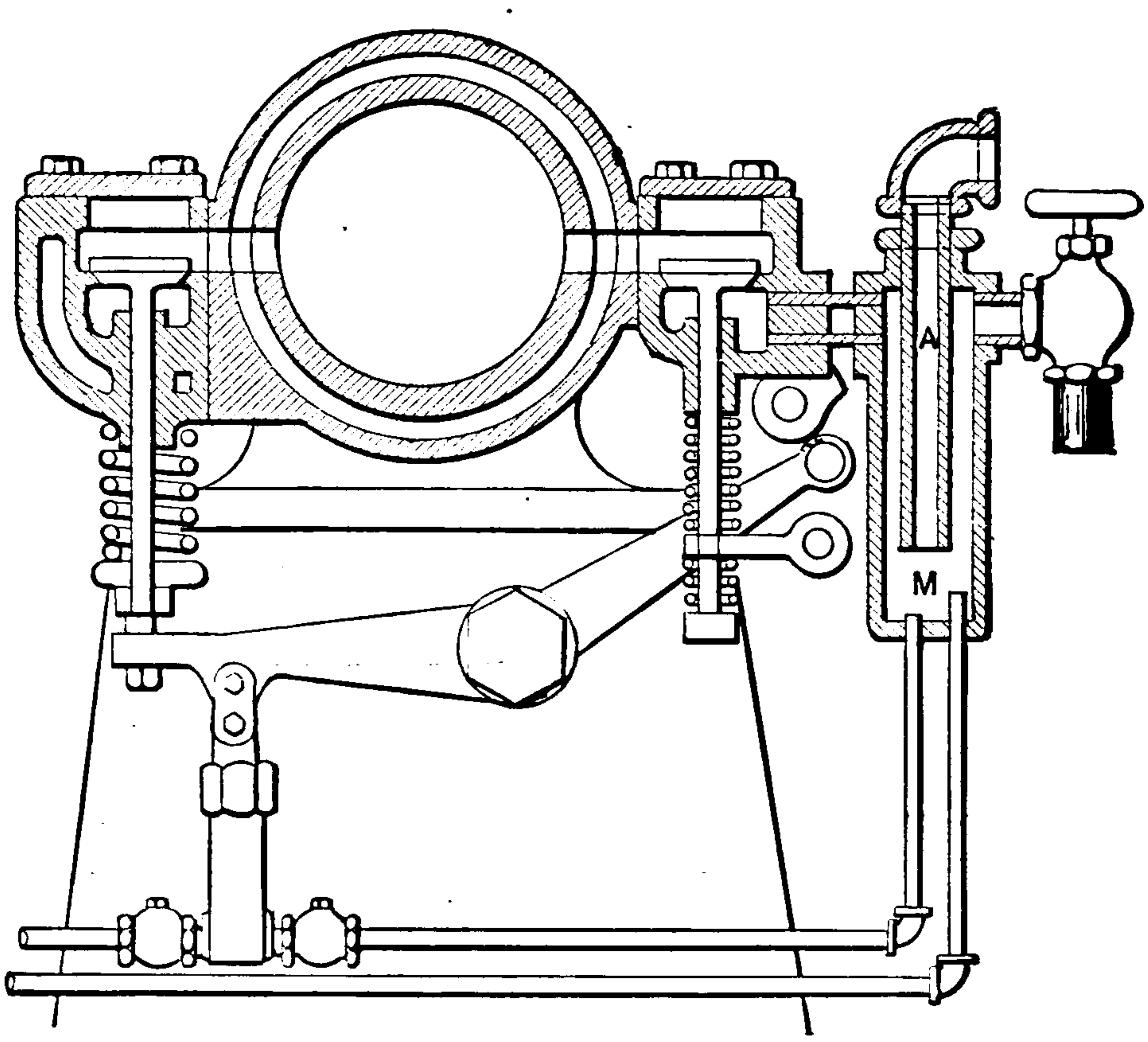


FIG. 61F.—VERTICAL SECTION.

a flange to the side of the inlet chamber and operated directly from a snap cam on the reducing shaft. The governor limits the lift of the inlet valve through the arm on its spindle.

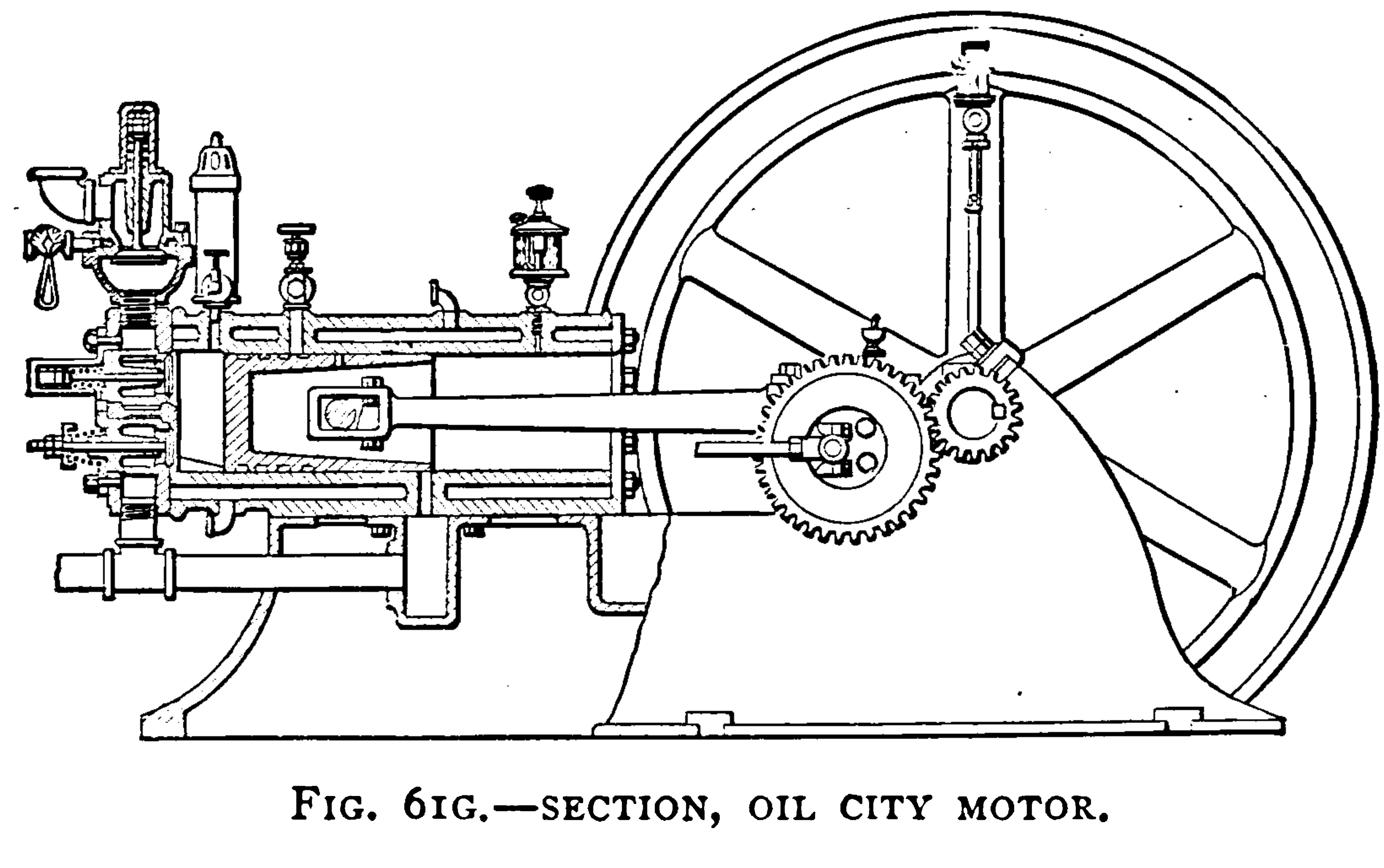


FIG. 61G.—SECTION, OIL CITY MOTOR.

In Fig. 61 G we illustrate in a vertical sectional view the "Oil City Motor," built by the Oil City Boiler Works, Oil City, Pa.

is by holding open of the exhaust valve by a stop lever that catches the push rod when the valve is open and holding it until released by the governor. A single eccentric actuates the four-cycle principle by a pick blade that makes a miss push at every other revolution.

In Fig. 61 I are shown some of the details of the "Wayne

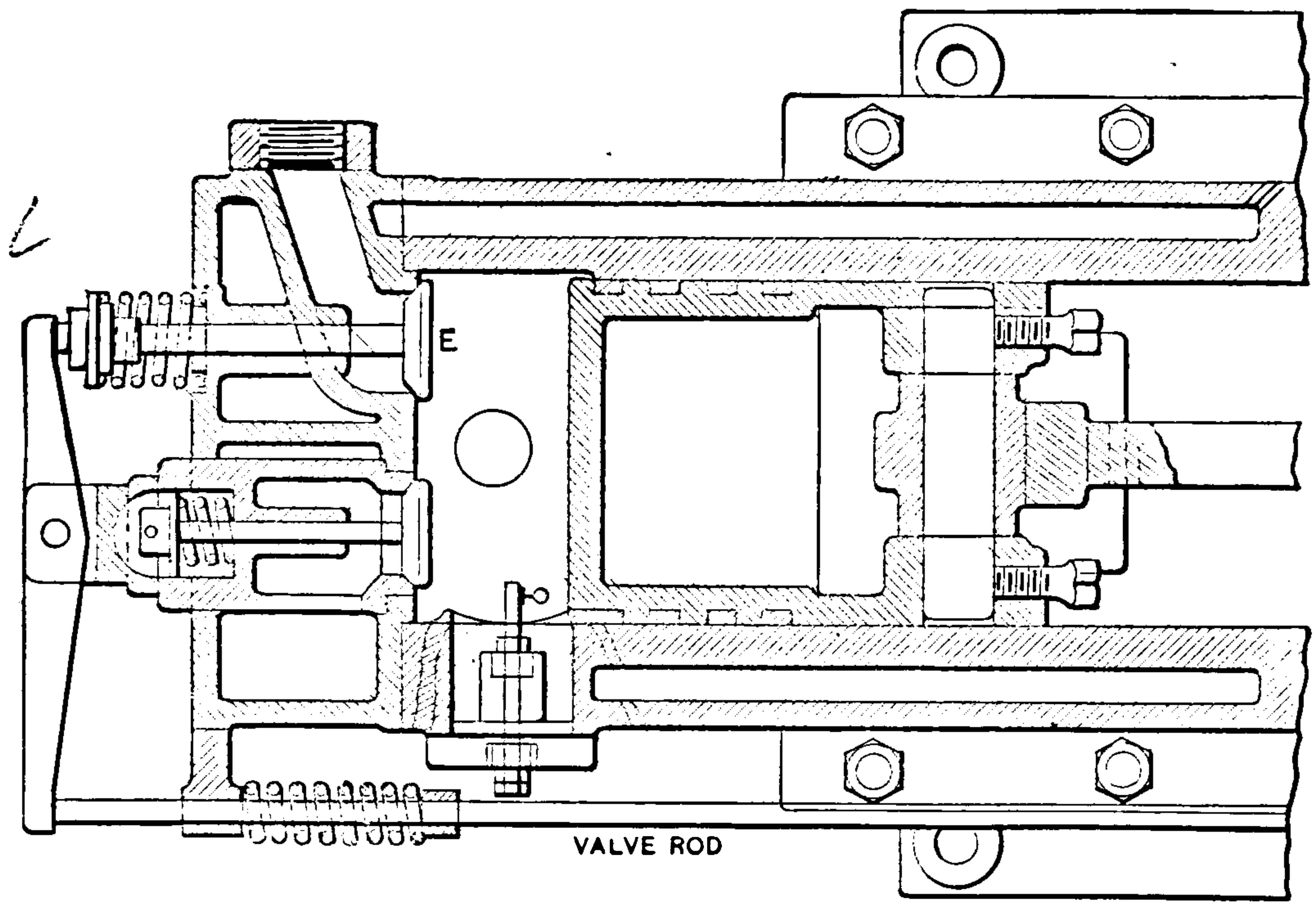


FIG. 61 I—SECTION, WAYNE MOTOR.

Motor," built by the Fort Wayne Foundry and Machine Company, Fort Wayne, Ind. A double cam on the reducing gear shaft operates the exhaust valve E through a push rod and lever across the cylinder head and also a supplementary gas valve, independent from the free opening inlet valve. The igniter of the make-and-break type is operated by a pick blade on the end of the firing rod which engages with the arm of the igniter spindle. The throw of the firing rod is controlled by the governor.

The motors of the Lazier Gas Engine Company, Buffalo, N. Y., have a peculiar valve arrangement, which we illustrate in Figs. 61 J, 61 K, 61 L. The design is of the four-cycle type, with the hit-and-miss governing gear, but is peculiar in the fact that its exhaust valve is the only one mechanically operated, and is so constructed that when the engine needs to miss an explosion it is held open, telescoping over the seat of the air suction valve, cutting off all fuel supply and allowing the piston to travel in the cylinder without compensation, during which time the valves re-

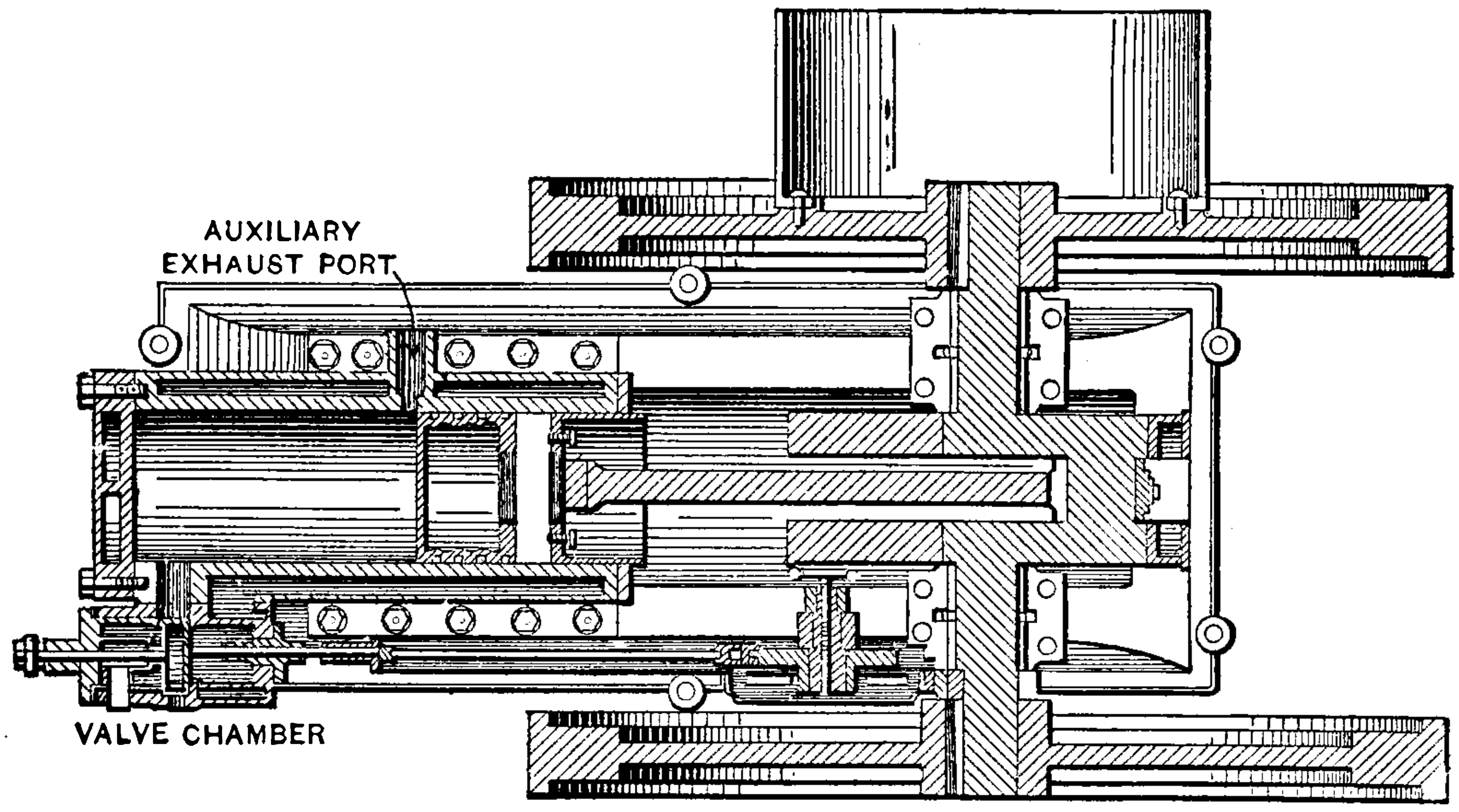


FIG. 61 J.—THE LAZIER MOTOR.

main in a state of rest. Fig. 61 J shows a plan in section of the cylinder, while Fig. 61K is a horizontal and vertical section,

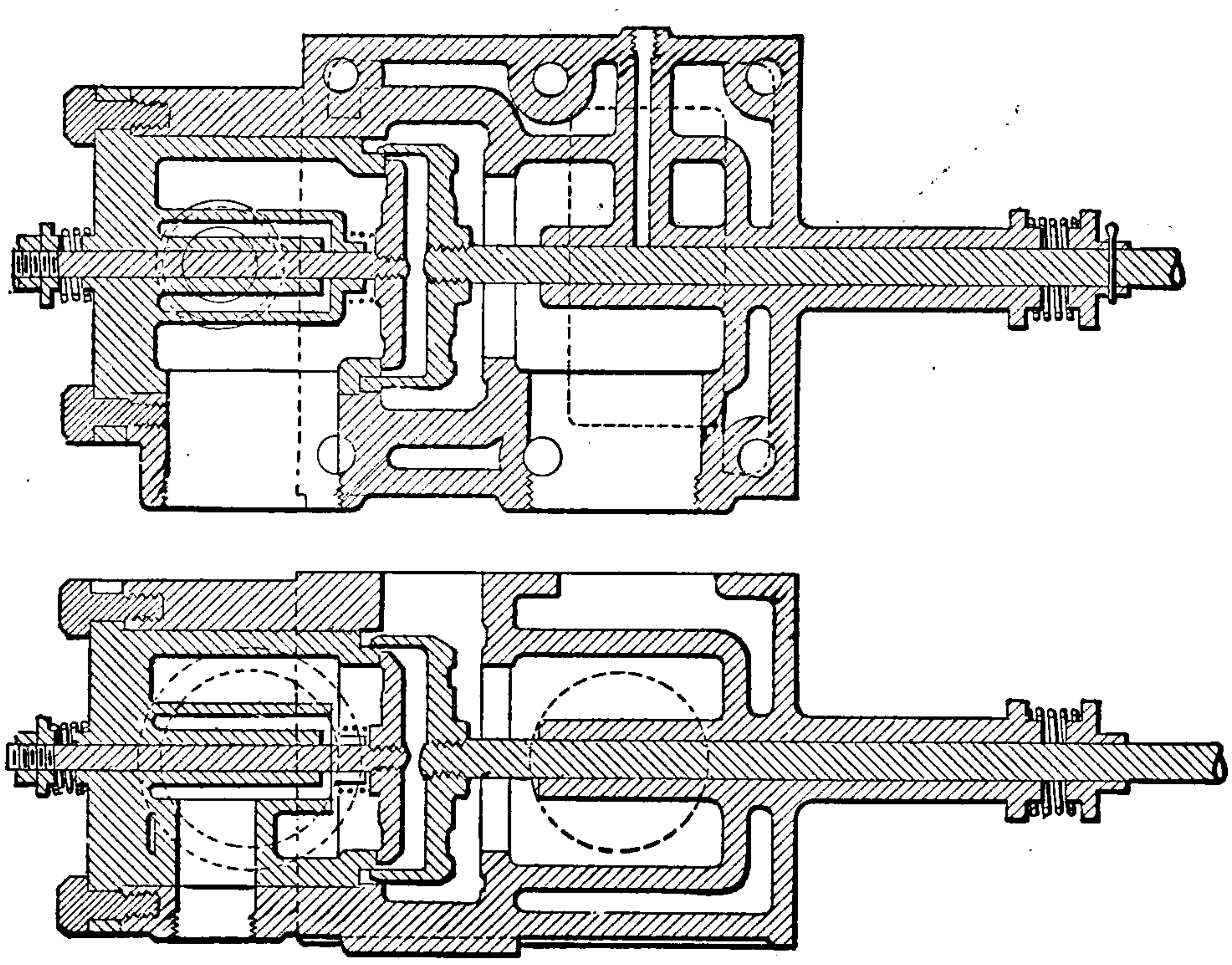


FIG. 61K.—SECTION, VALVES.

showing the valve mechanism upon a larger scale. Fig. 61 L shows the position of the valves during a suction stroke, the admission valves *a A*, being drawn open by suction, the explosive charge entering as shown by the arrows, and the exhaust *E* being seated. On the next stroke the charge is compressed; the next is the explosion or working stroke. At the end of the power stroke the piston uncovers the automatic port in the side of the cylinder, which allows the high terminal pressure to be reduced, thus permitting the main exhaust valve to open at atmospheric pressure, at which time the piston sweeps back, clearing the residue gas from the cylinder, and is then ready to take in a new mixture if governor permits, and on the next the exhaust valve is held open, allowing the products of combustion to escape. All

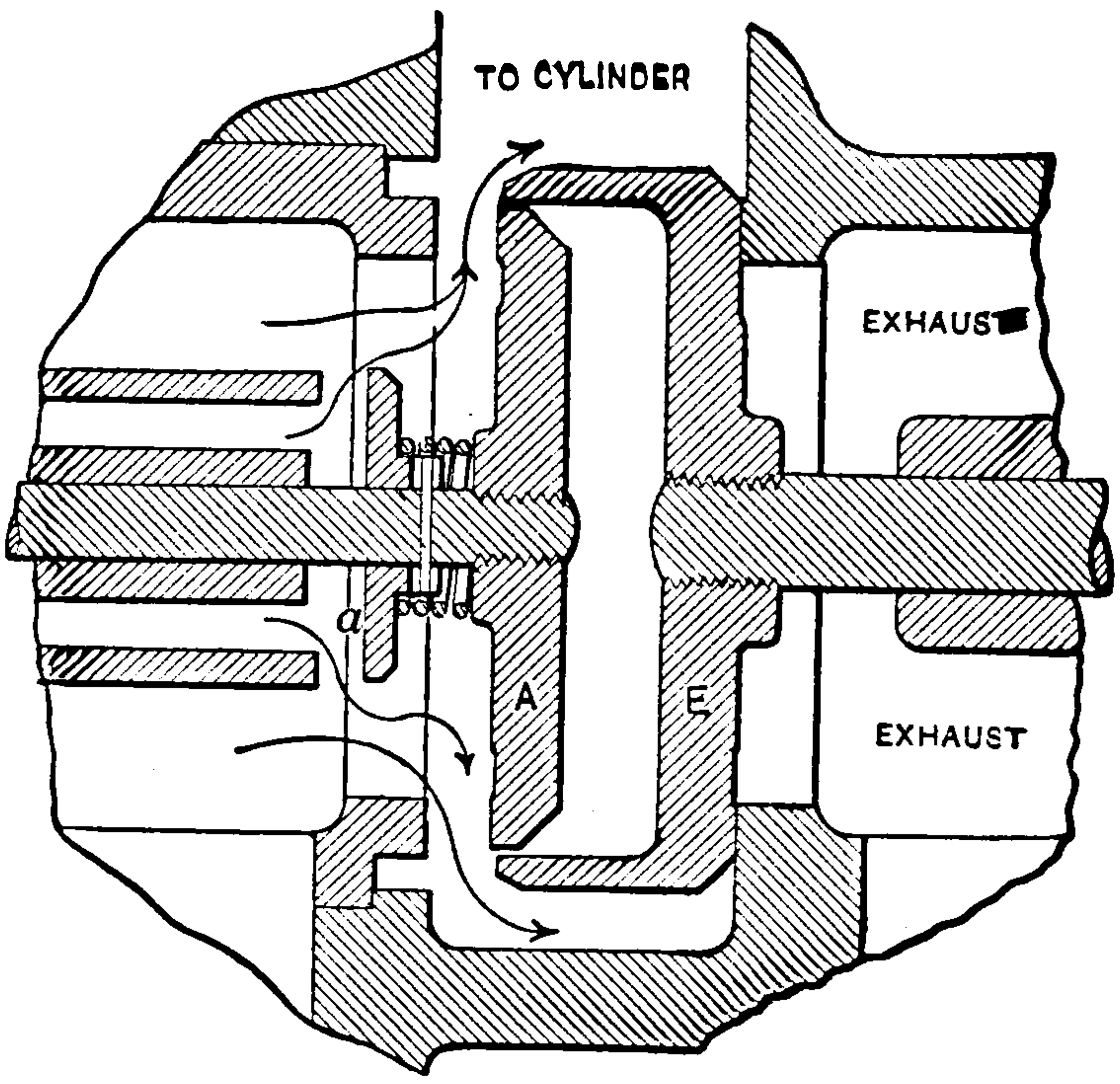


FIG. 61L.—INLET VALVE OPEN.

this time the pressure on the cylinder has been greater than the outside of the admission valve, and there has been no tendency for the latter to open. In fact, during the exhaust stroke the valve is in the position shown in Fig. 61 K, completely covering the admission valve. When the speed exceeds the normal, the exhaust valve remains in this position, so that on the suction stroke there is no vacuum created, the exhaust passage being open, and even if there were the admission valve is effectively closed by the telescoping of the exhaust valve. Neither is there any useless compression, the exhaust remaining open and the valve remaining motionless until another admission is required.

cylinder is overhung and bolted to the bedpiece and made in two pieces. The jacket and cylinder-head are cast in a single piece and the liner made of a specially hard mixture of iron for wearing quality and easy replacement when worn out. The valve casings are all contained in the cylinder-head, which is spherical and water-jacketed. All valves are contained in casings with flanges and shoulder joints, easily removed for cleaning or repairs. Ignition is of the hot-tube type, as shown at J I, and the gas inlet is regulated by an index cock at V (Fig. 61 o).

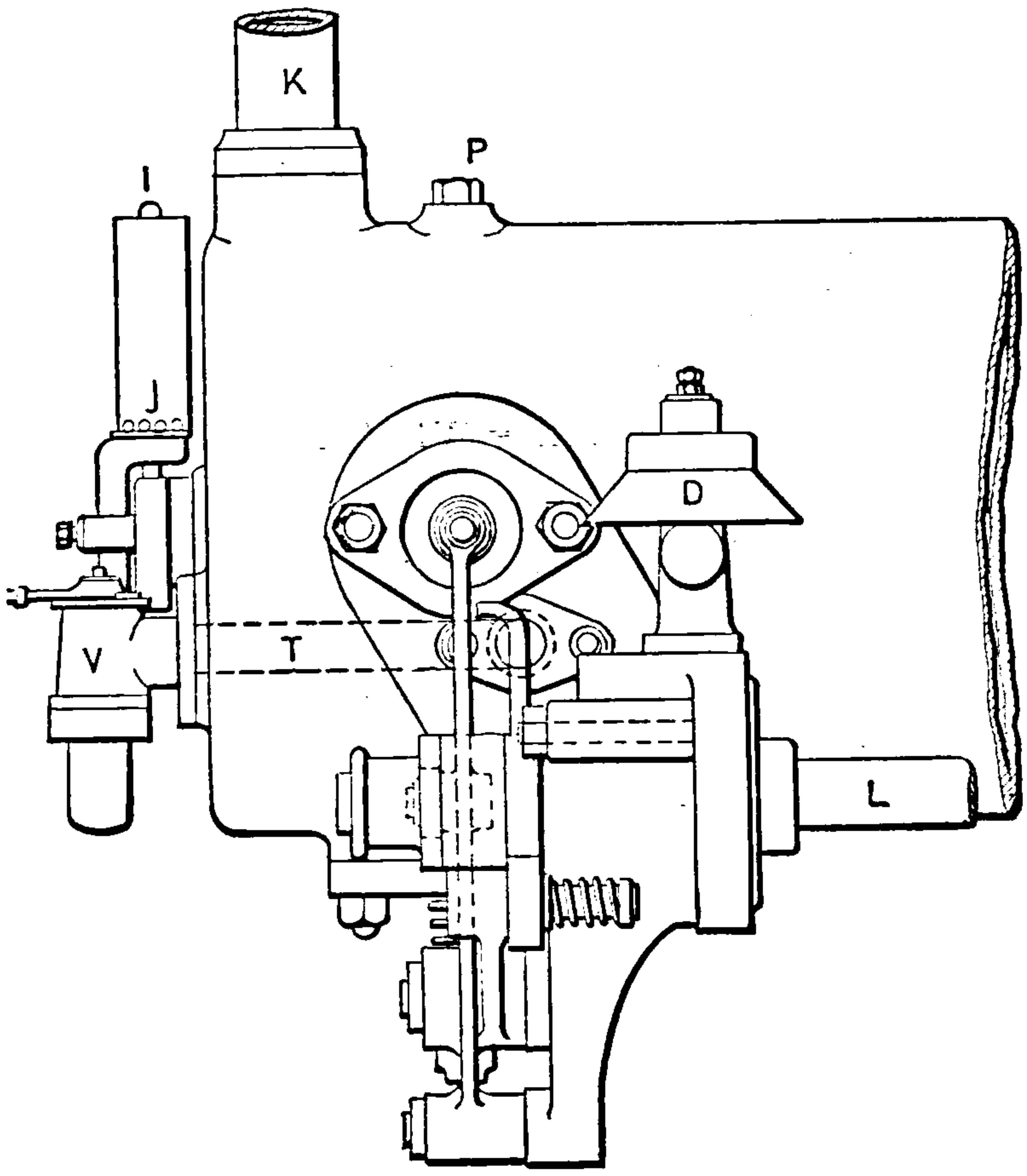


FIG. 61 O.—GOVERNOR.

The governor, as will be seen by reference to the various illustrations, is of the fly-ball type, controlling the engine on the hit-and-miss principle.

The construction of the valve-gear may be more readily understood by reference to the figures. All valves are worked from the reducing-shaft L, which is driven from the crank-shaft by means of helical gears. F and G are air and gas valves respectively, valve G opening directly into the air inlet H. The exhaust valve E opens directly into the exhaust outlet O. The air valve F is driven through the lever *f* by means of the cam *c*. The exhaust valve is controlled by the lever *e* operated by the cam *d*. The gas valve is opened by means of a small arm B and the striker-blade A attached to the air-lever arm. Small arm B also carries a striker which is met by the striker-arm A as it moves toward the cylinder to open the air-valve. Arm B is under control of the governor through the arm C, and so connected that, as the governor rises, lever B is lifted and the striker *b* is lifted out of the path of A. In this manner, when the speed rises above the limit, the gas valve G is not opened, and the cylinder takes in a charge of pure air, thus missing impulses and developing less power. The speed of the engine may be increased by putting on extra weights as shown at D, or the speed may be decreased by removing weights.

In Fig. 61 P is shown the sectional detail of a vehicle motor lately brought out in France. The engraving has been made on a scale of 3-16 inch to 1 inch, the diameter of the cylinder being 3⅞ inch, with 4-inch stroke. It is rated at 4 horse-power at full speed.

A novel arrangement for cooling the motor by means of a mechanical ventilator has been adopted, and is one of the most successful features of this motor. Motors with the ordinary type of cooling wings, of which the De Dion is a good example, offer great advantages of simplicity which make them preferred for the smaller powers, but unfortunately they do not always give entire satisfaction on account of the insufficient cooling when the vehicle moves slowly and the current of air is small; this is especially noticed in hill-climbing. To remedy this the motor runs a small fan which is mounted on ball-bearings and consequently takes but little power. It is set in motion by a friction roller in contact with the fly-wheel of the motor. This ventilator blows a current of air against the motor cylinder, and thus the cooling is independent of the speed of the vehicle. This motor drives by a shifting belt on tight and loose pulleys with separate speed and reversing gear. It is noticed that the crank shaft bearing is six times longer than its diameter, which makes the balanced crank self-supporting, the pin of which carries freely a secondary gear-crank (45) and pinion, gearing into a spur-wheel on the cam

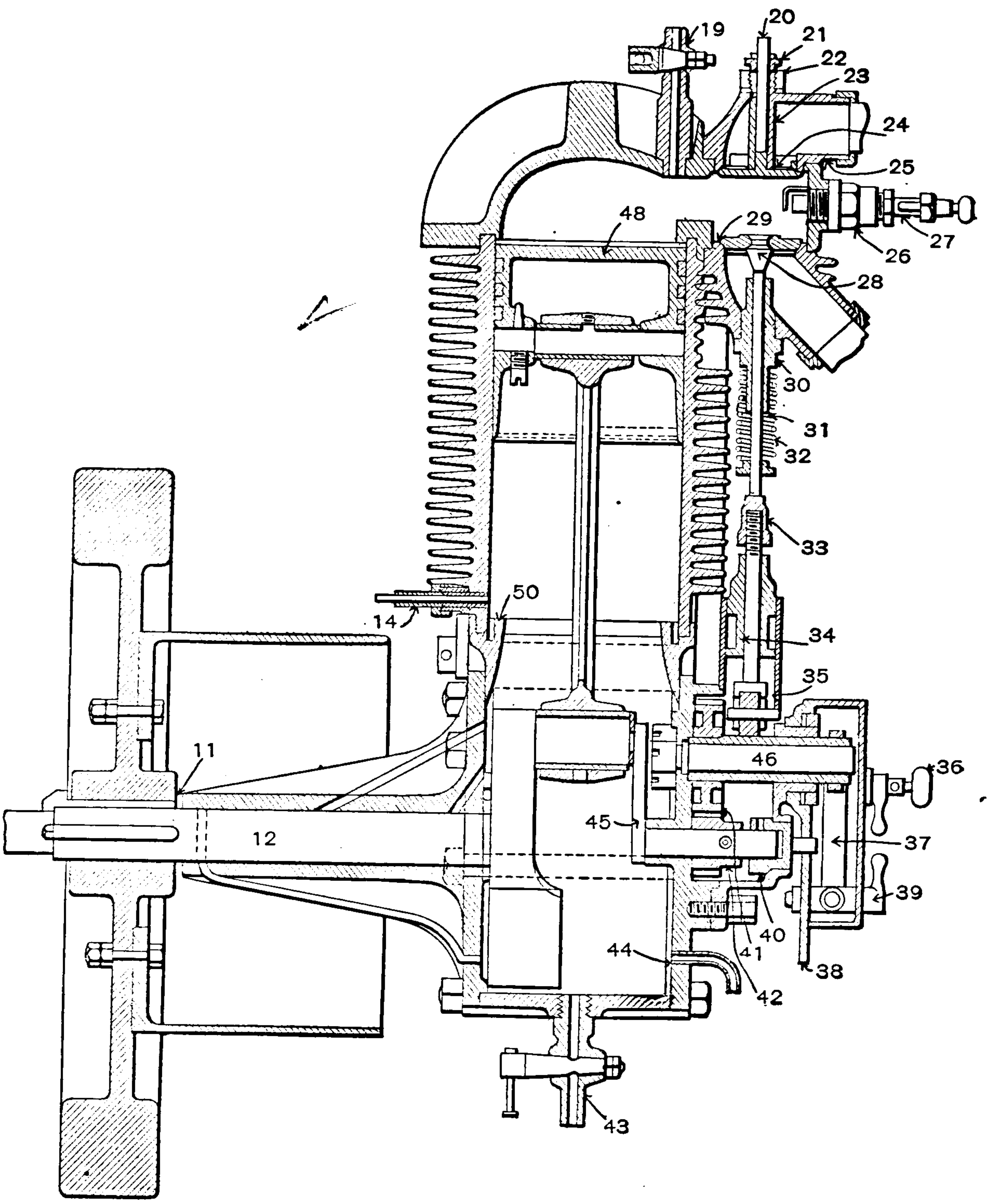


FIG 61P.—SECTION OF AIR-COOLED MOTOR.

Figured Parts of the Motor.—12, Crank-shaft. 13, Oil-cooling tube 14, Oil-duct. 19, Pet cock. 20, Key. 21, Washer. 22, Spring. 23, Valve-guide. 24, Admission-valve. 25, Valve-seat. 26, Igniter. 27, Porcelain. 28, Exhaust-valve. 29, Exhaust-valve seat. 30, Exhaust-valve stem guide. 31, Exhaust-valve stem. 32, Spring. 33, Collar. 34, Exhaust-valve operating rod. 35, Cam-roller controlling exhaust. 36, Thumb-screw. 37, Contact. 38, Platinum contact. 39, Screw-controlling platinum contact. 40, Distributing-crank bearing. 41, Distributing-gear wheel. 42, Distributing pinion. 43, Drain-cock. 44, Waste-pipe. 45, Distributing-crank. 46, Cam-shaft for exhaust. 48, Piston. 49, Pin of piston-rod. 50, Oil-groove in frame.

or three vertical cylinders. The speed is controlled through the governor by missed charges.

The air chest surrounds the passage by which gas enters and is drawn with the air into the mixing chamber A. The admission valve B is open during each suction stroke and the mixture passes through that valve to the cylinder to be compressed upon the succeeding stroke and then exploded. The toe which lifts the gas valve is carried upon the stem of the admission valve and is kept from engaging with the latch upon the gas valve stem when explosion is not required. The admission is operated by a positive cam upon the side shaft in an obvious manner, and the fact that it is opened every fourth stroke insures an indraft of fresh air, even when no gas is admitted, scavenging the cylinder of any products of combustion remaining. The exhaust valve is similar to the admission valve, but its roller can be thrown to a cam, relieving the compression when starting up. The igniter is at *l* and is operated by an eccentric upon a side shaft on the opposite side of the engine, this side shaft being operated by a cross shaft geared to the other side shaft, which in turn is geared to the main shaft with two-to-one spur gears. The governor is driven from the first side shaft and simply regulates the position of the latch upon the gas valve stem.

The Diesel oil engine has come to the front for economy and as a motor in which any of the fuel oils of commerce give most satisfactory results. It is of German origin and with the late improvements obtained from American suggestions in design and with the modifications brought out from its extensive use in Germany, its details have been much simplified, and in the hands of the Diesel Motor Company of America, whose office is at No. 11 Broadway, New York City, and factory at Worcester, Mass., it is now taking the lead for the larger powers and is especially adapted for operating electric plants. It is a two-cycle type and with duplex cylinders for driving electric generators brings the variation in light effect within one per cent. The points of difference from other explosive motors are a small clearance of about seven per cent. of the piston sweep, high compression to about 500 pounds per square inch, sudden injection of liquid fuel at a still higher pressure, and its spontaneous ignition by the heat of compression. Apparently there is no sudden explosion, but rather a gradual combustion of the charge of the sprayed oil and the oxygen of the hot compressed air during part of the stroke. The motor is of the four-cycle construction, operated on the two-cycle impulse, and is represented in its essential parts in the section Fig. 61R. The steel reservoir T is the high pressure air reserve,

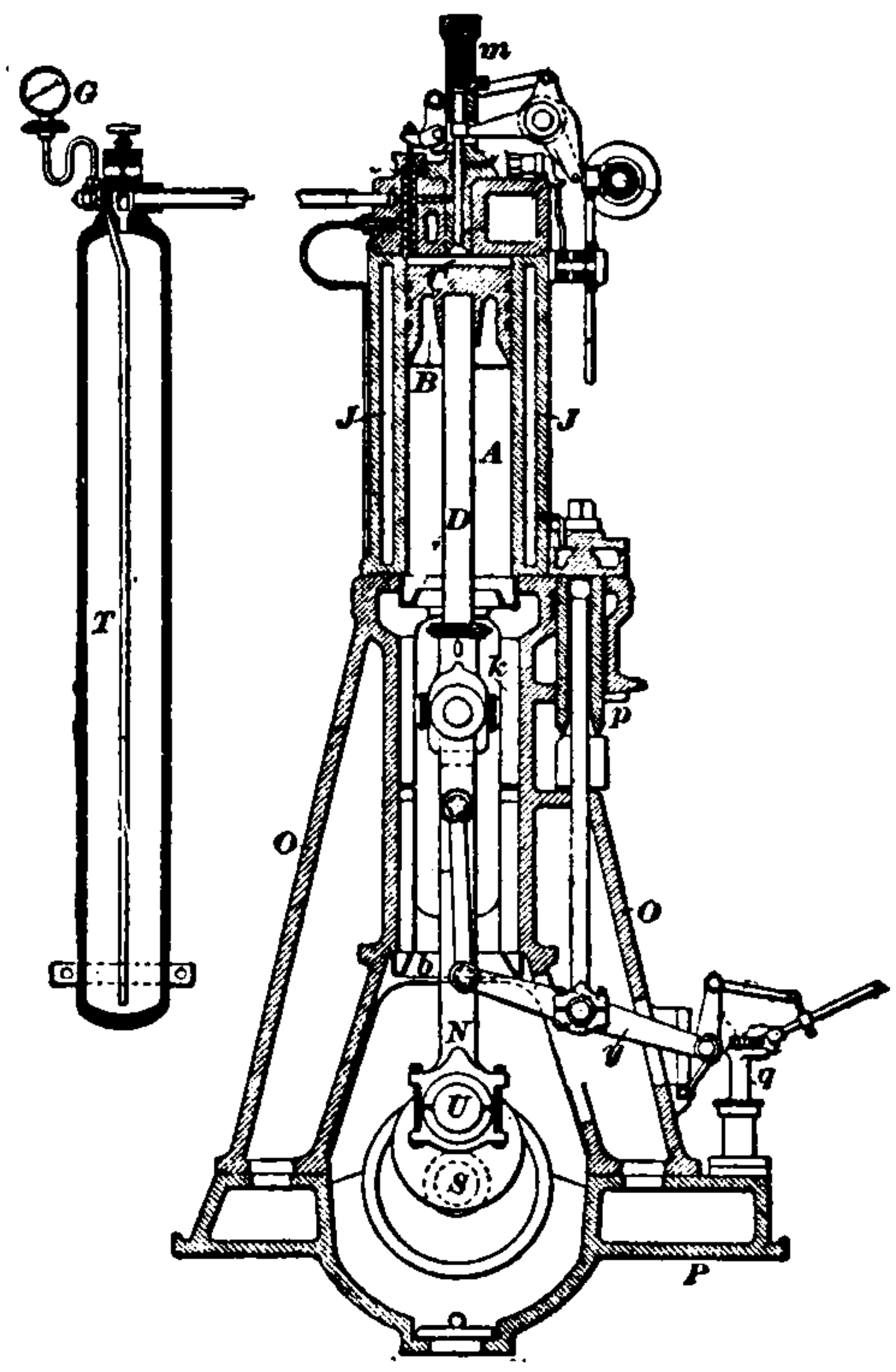


FIG. 61R.—THE DIESEL ENGINE.

supplied by an air pump P, driven by the motor through the rocker arm *y*, while the small pump *q*, also operated from the same arm, supplies the fuel oil at the required pressure to be injected with the high pressure air used for spraying the charge. Further details are given in the general description of explosive motors. Also see indicator card, page 37.

Of explosive motors of the larger units now in the market, we detail in the following table some of their most salient features as a study of the progress of this class of prime movers for large power instalments:

Builders.	Diameter, inches.	Stroke, inches.	R. P. M.	Brake H P.	Clearance, per cent.	System of Governing.	Type of Engine.	Weight: Engine complete, including Fly Wheels.	Weight: Per rated H. P.	Fly Wheel. Weight, lbs. Total.
Struthers, Wells & Co (Warren)...	21	24	180	300	20	Throttling.	Ver. 2-cyl., 4 cy.	75,000	250	12,000
National Meter Co. (Nash)..	13 5	16	225	125	19	Hit and miss.	Ver. 3-cyl., 4 cy.	28,500	228	3.600 2,400
The Bessemer Gas Eng. Co.... ..	13.5	20	180	100	14	Throttling.	Hor. 2 cyl., 2 cy.	23,000	230	5,800
Marinette Iron Wks (Walrath).	14	14	250	125	23	Throttling.	Ver. 3-cyl., 4 cy.	23,000	184	6,600
The Alberger Co	17	19	200	125	21	Auto cut-off.	Hor. 2-cyl., 4 cy.	25,000	200	7,000
Lazier Gas Eng. Co..	15	21	160	50	20	Hit and miss.	Hor. 1-cyl., 4 cy.	14 000	280	4,000
National Meter Co. (Nash)	9	11	270	50	22	Hit and miss.	Ver. 3-cyl., 4 cy.	11,000	220	3,600
Westinghouse Machine Co	18	22	200	300	21	Throttling.	Ver. 3-cyl., 4 cy.	95,000	316	8,600
Westinghouse Machine Co...	8	10	325	38	21	Throttling.	Ver. 3-cyl, 4 cy.	10,500	276	1,750 1,150

A novelty in the make-up of large vertical motors has been adopted by Struther, Wells & Co., of Warren, Pa., in their "Warren Motor." The connecting rods are made in two parts, as shown in Fig. 61s, joined by a heavy bolted flange near the

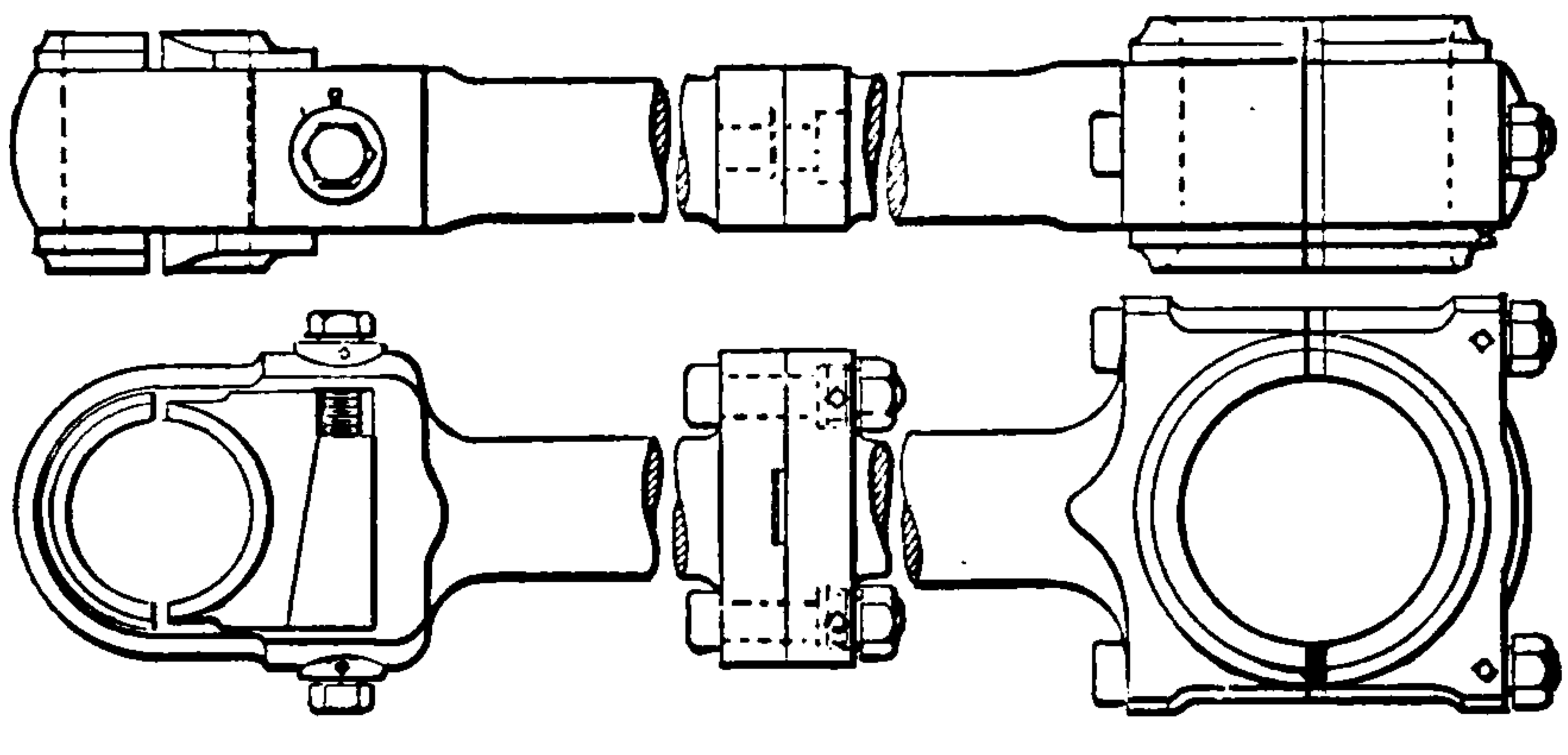


FIG. 61S.—THE TWO-PART CONNECTING ROD.

center of the rod, which allows the piston to be taken down through the bottom of the cylinder for inspection and repairs without disturbing the cylinder head and valve gear, which is attached to the cylinder head.

CHAPTER XVIII.

VARIOUS TYPES OF ENGINES AND MOTORS.

The Royal.

The Royal gas and gasoline engine, made by the Monarch Gas Engine Company, Indianapolis, Ind., has been designed on the lines of experience in the modern practice of gas engine building.

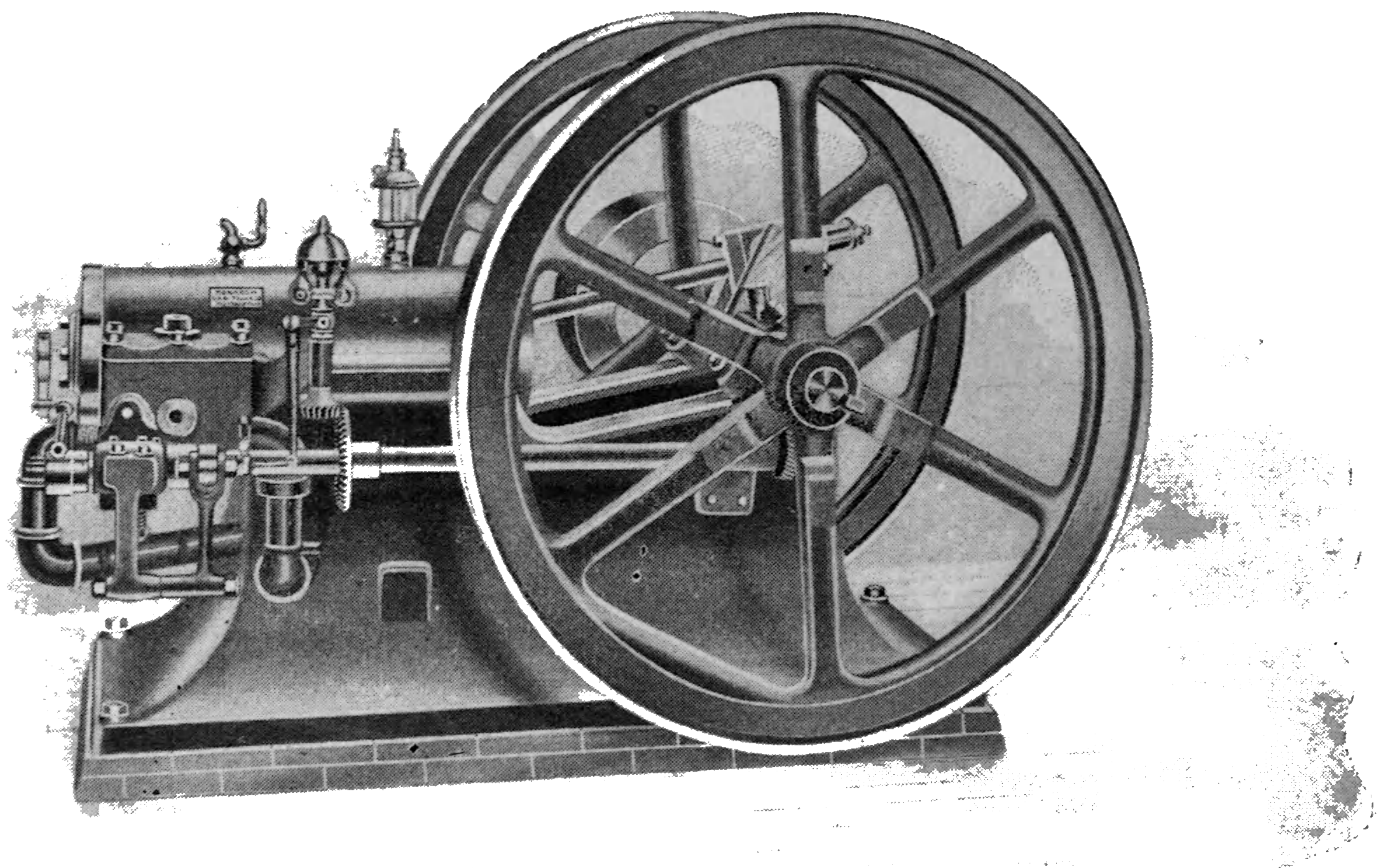


FIG. 62.—THE ROYAL GAS AND GASOLINE ENGINE.

The working parts are well on one side, a most convenient arrangement for setting the engine close to a wall. It is of the four-cycle type with an auxiliary exhaust from a cylinder port opened by the piston at the end of its impulse stroke. The valves are of the broad seat poppet type in a vertical position, the exhaust valve being operated by a bell crank lever from a cam on the side rod. The gas or gasoline charge enters through a number of small holes in the seat of the intake valve which is wide enough to entirely close the gas or gasoline inlet except during the charging stroke.

The cylinder head is cast solid upon the cylinders and is water jacketed. A hole in the center of the head receives the igniter plug, which is ground to a seat in the cylinder head and fixed by bolts. The sparking device is of the break or hammer type with platinum contact points and operated by a push rod and eccentric pin on the side rod. The governor is of the fly ball

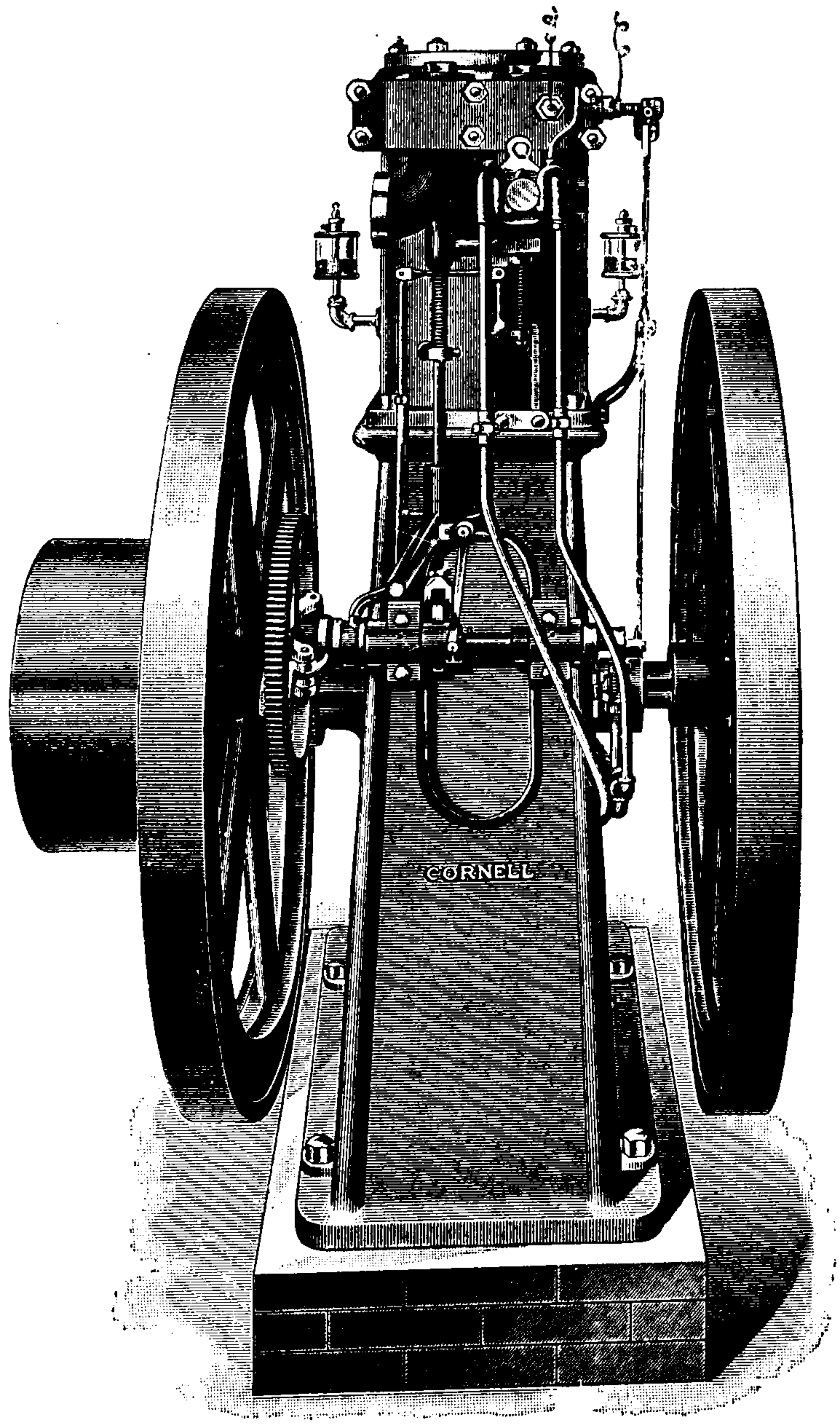


FIG. 63.—CORNELL VERTICAL

type of high speed, driven by a bevel gear from the side rod and governs by holding the exhaust valve open with a locking device. The company build this type of motor in vertical, single and double horizontal cylinders and from 1½ to 100 horse power.

The Cornell Motor.

Gas and Gasoline Engines of the Ellington Manufacturing

Company, Quincy, Ill. These engines have been designated as the "Cornell," and are made in the vertical type with single and double cylinders as shown in Figs. 63 and 64.

They operate on the four-cycle principle with the cylinder fixed upon an enclosed pedestal base. The valves are of the vertical type with a hit and miss regulation from a centrifugal governor in the reducing spur gear which throws the exhaust push rod roller off or on to the cam sleeve on the secondary

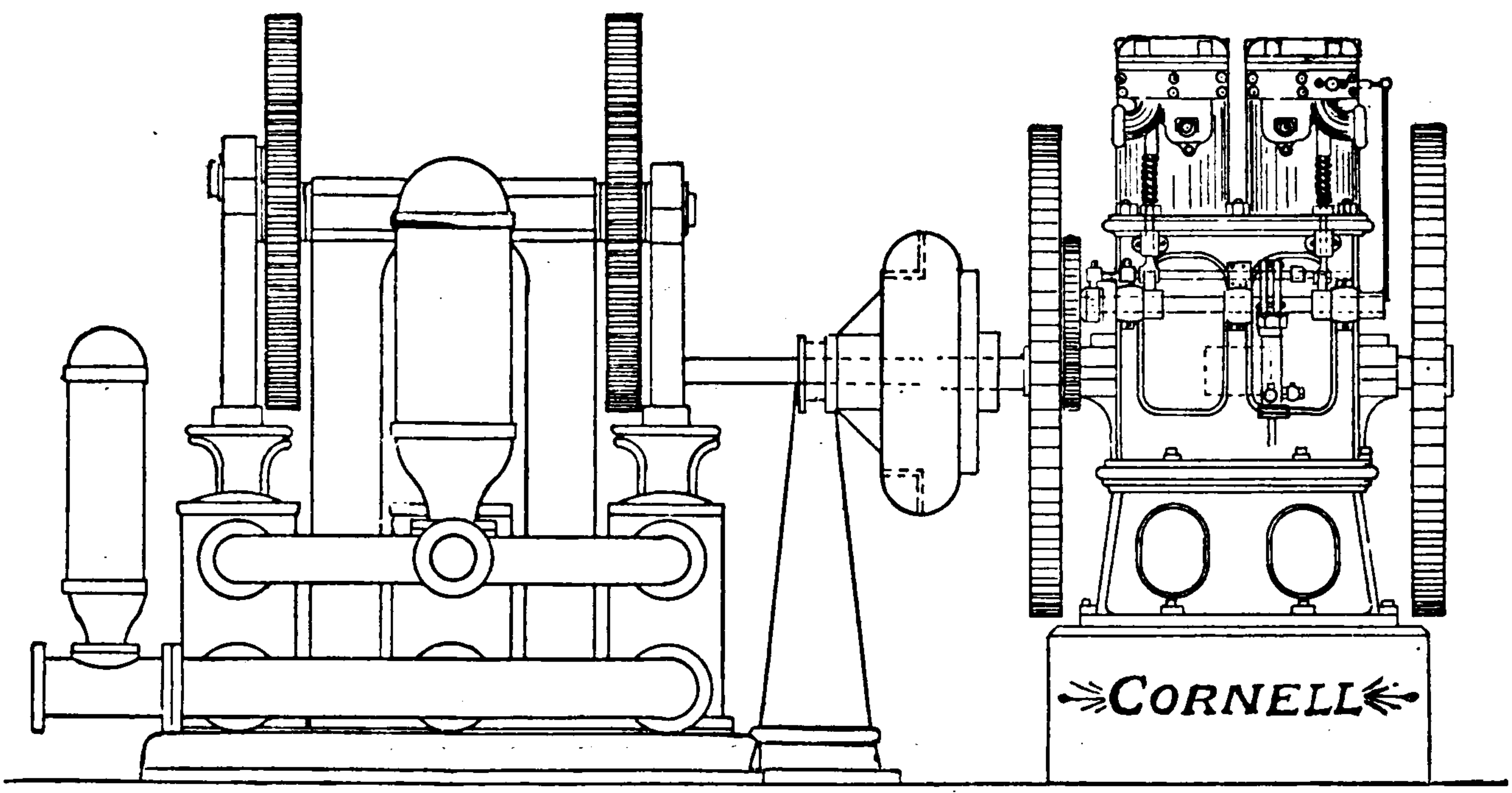


FIG. 64—DOUBLE CORNELL PUMPING PLANT.

shaft. Electric ignition by break contact in the inlet chamber; the break arm being operated by a small rock shaft and arm with a direct rod to an eccentric on the end of the reducing gear shaft. They are built in nine sizes from 1½ to 16 horse power with single cylinder and in six sizes with double cylinders from 20 to 50 horse power.

The New Era Gas Engine

is of the four-cycle compression type with a heavy and substantial base. The valve-gear shaft being driven by a worm

valve-gear shaft is fast growing in favor, and is now largely in use.

The valves are of the poppet type, operated by cams on the secondary shaft, which also drives the governor through bevel-

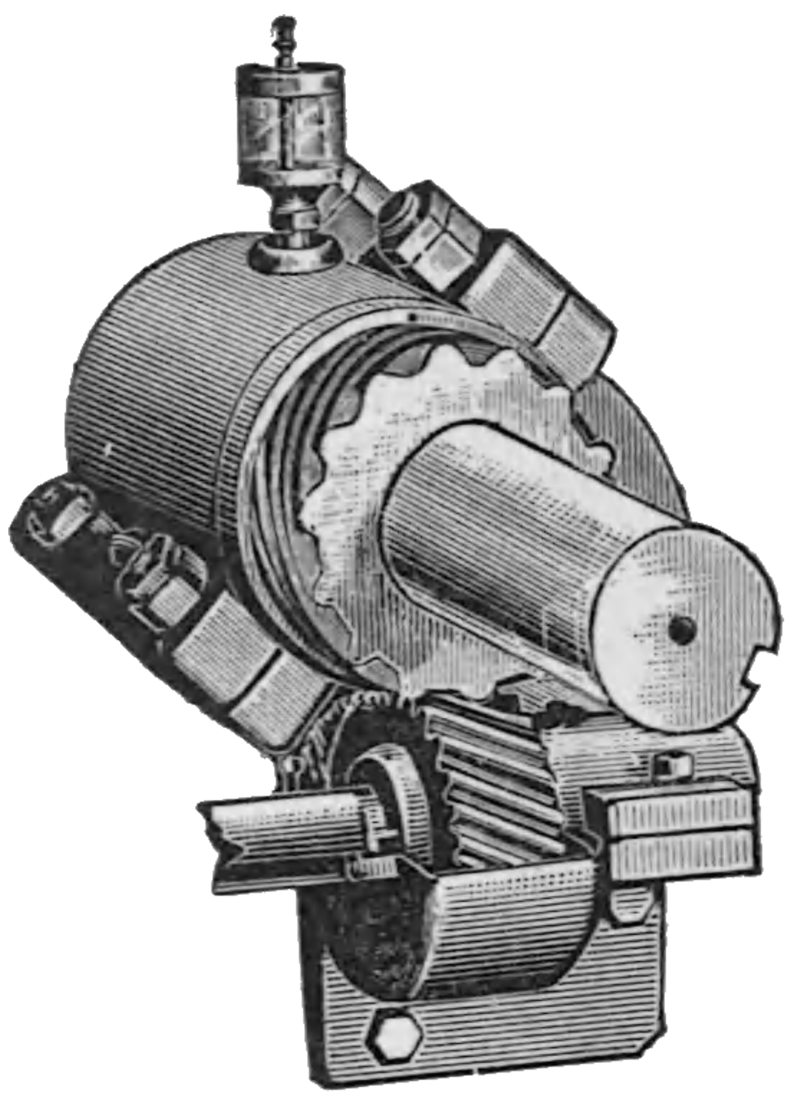


FIG. 67.—THE WORM GEAR.

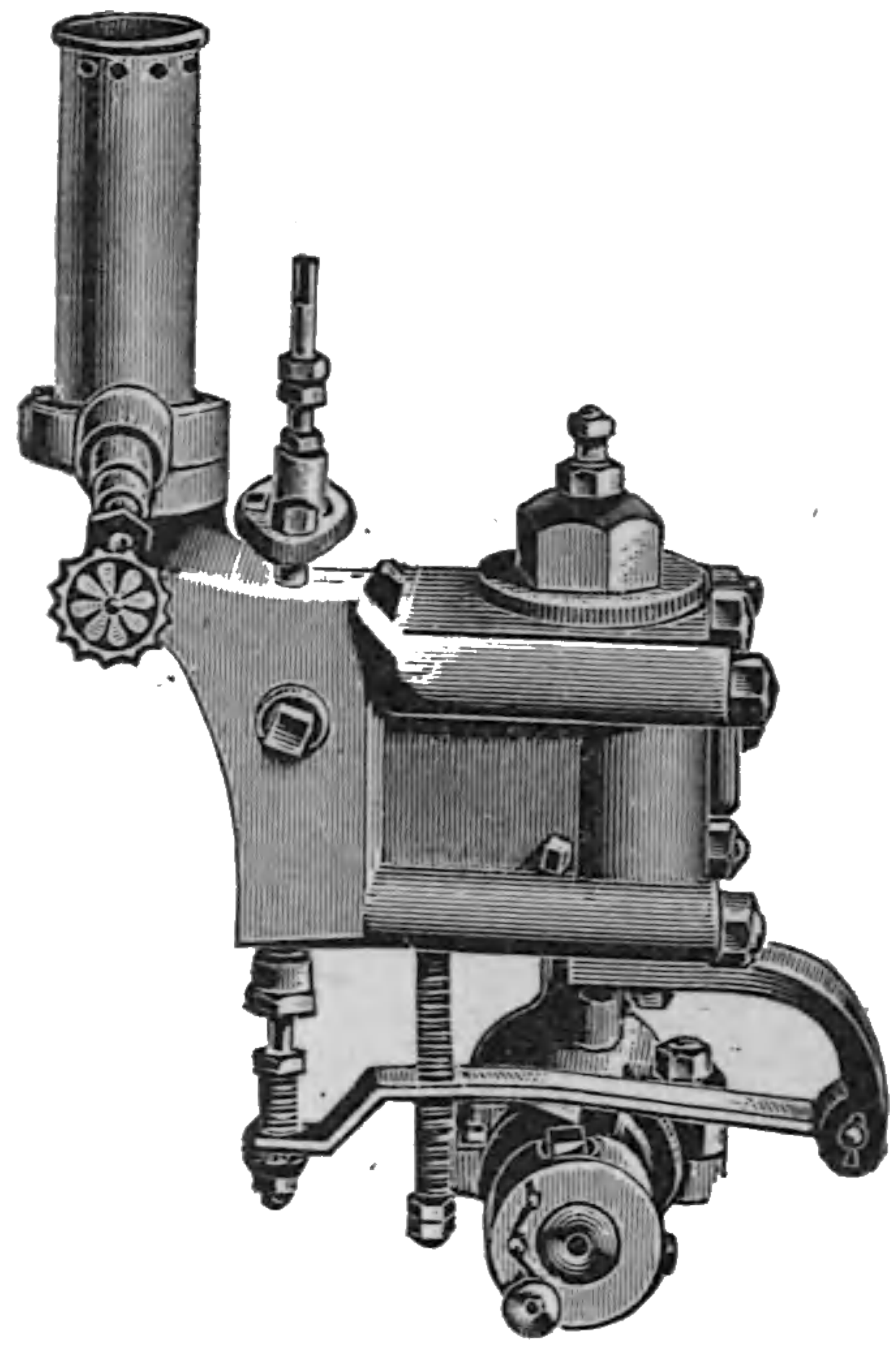


FIG. 68.—VALVE CHEST.

speed gear. All the valve chambers have flanged plugs for facilitating the removal and cleansing of the valves.

The end view of the lateral shaft and valve chest with the

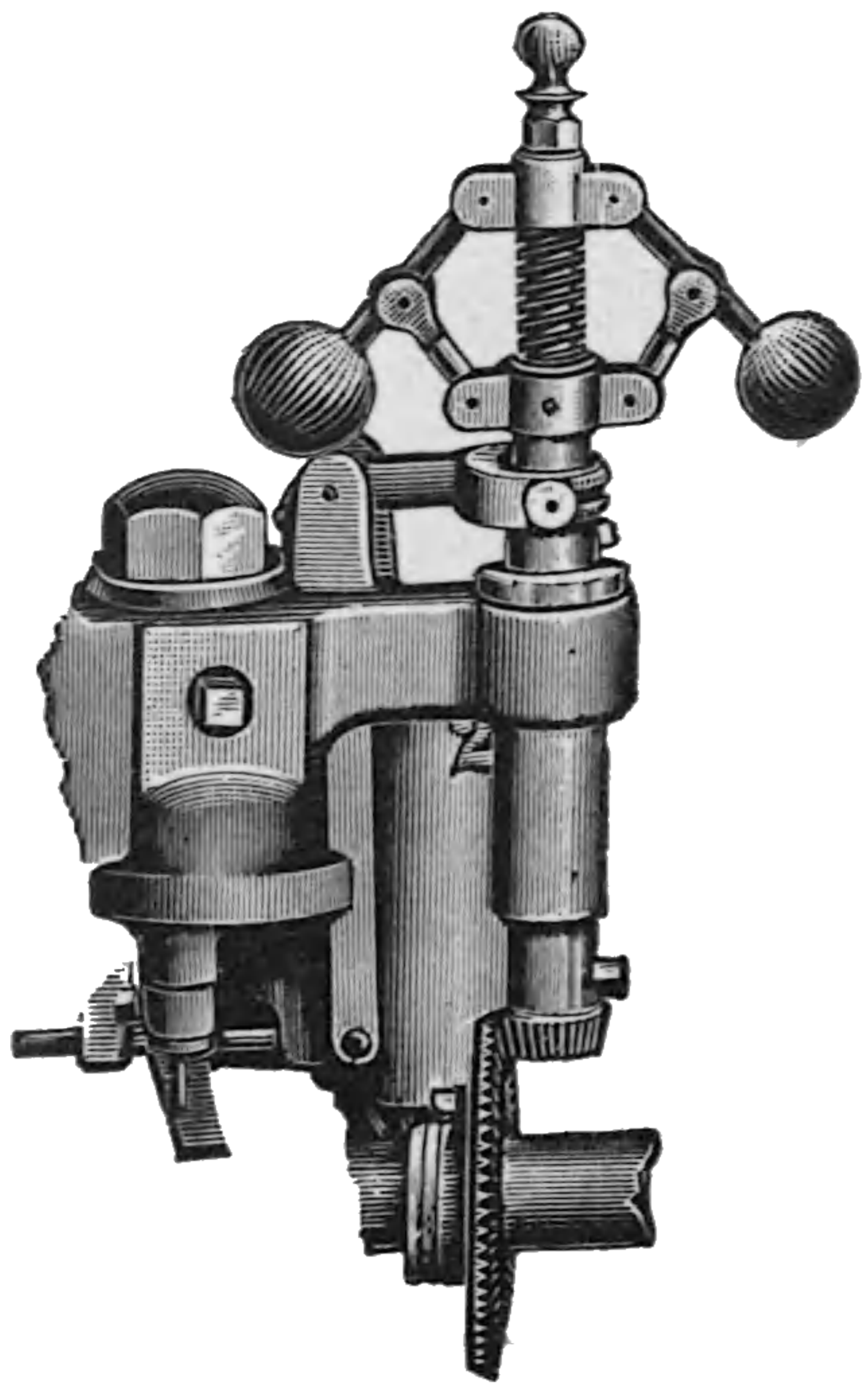


FIG. 69.—THE GOVERNOR.

attachment of the tube igniter is shown in Fig. 68. The electric igniter is applied at the same opening in the valve chest as used for the tube igniter.

The governor is of the ball type, running direct from the secondary shaft by a bevel gear, and through a bell-crank lever and arm controls the gas-inlet valve. Fig. 69 shows the arrangement more in detail and also the great convenience in gas engines, a cap plug for quickly removing the valve and an inspection plug at the side of the valve chest.

The fuel for these engines may be illuminating gas, producer gas, natural gas, or gasoline. The cost for running can be gauged only by the quantity, say 15 to 20 cubic feet illuminating gas or one-tenth of a gallon of gasoline per indicated horse-power per hour.

In using gasoline a small pump (Fig. 70) is attached to the

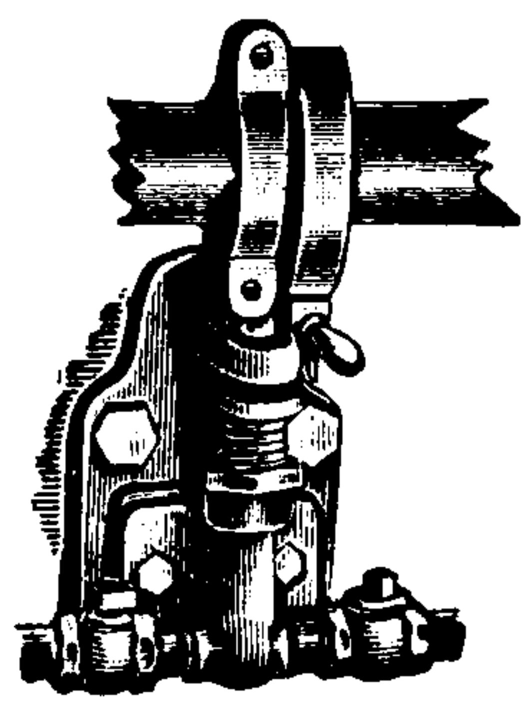


FIG. 70.—THE PUMP.

engine bed and driven by a cam on the lateral shaft. The pump draws from a tank set in a safe place, underground if possible and draws a few drops of gasoline at a stroke, forcing it into the air chamber, where it is vaporized and mixed with the incoming air. The surplus, if any, is returned to the tank. These engines are made in sizes from 10 to 50 B.H.P.

The Pierce Gas and Gasoline Engine.

This engine is built on the four-cycle compression type, as shown in the illustrations of both sides of the 1 to 5 H.P. engines (Figs. 71 and 72). This company also build engines of 6, 8, 10, 12, 15 and 20 H.P. These figures represent the brake or actual horse-power.

The valve motion is taken from the main shaft with spur gears and secondary shaft upon which there is a cam that operates the valves through a connecting rod. On the face of the cam is a wrist pin, carrying a connecting rod, which operates both the governor and the electrical firing device.

The poppet valves never require oil; they lift squarely from

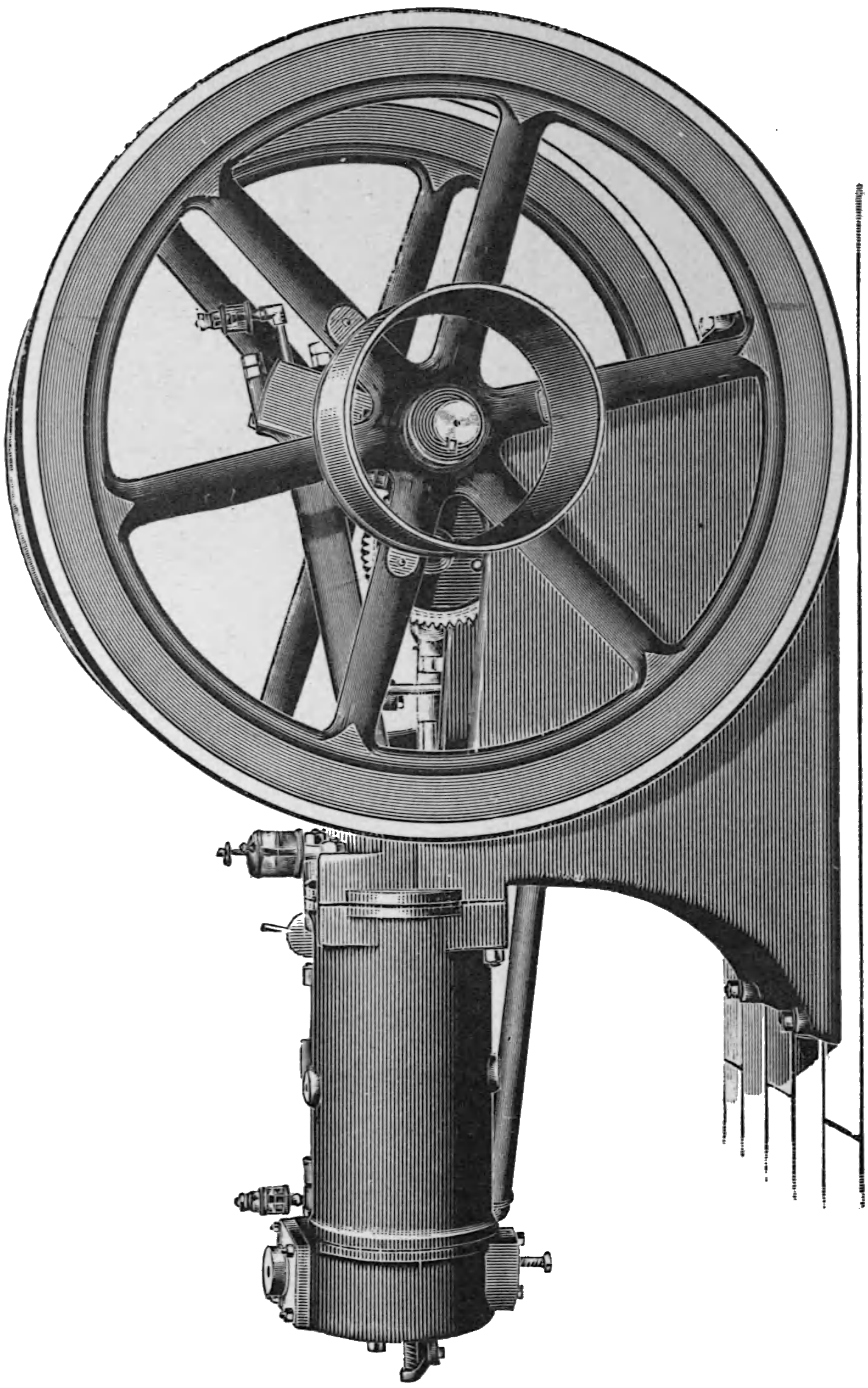


FIG. 71.—THE PIERCE GAS AND GASOLINE ENGINE—RIGHT SIDE.

their seats. They wear smooth and bright and are easily uncovered for regrinding when necessary. The entire operating mechanism is in plain sight and all wearing parts can be readily examined and adjusted without removing or taking the engine apart. The governor is very simple and sensitive. It is composed of three pieces: a hardened steel finger, weighted and

of two electrodes, one a flat piece of steel $\frac{1}{4}$ inch wide by $\frac{5}{8}$ inch long and $\frac{1}{16}$ inch thick. The other is a piece of No. 16 wire. One is insulated from the engine and the other in circuit with it. A make-and-break spring at the side of engine (also insulated from the frame) forms the circuit when the electrodes come together. In parting the spark is made which fires the charge. The electrodes never corrode, as they clean themselves every time they pass each other, and they will remain clean until they are worn out. A four-cell battery is used and will run these engines 1,800 hours without recharging.

Cost of Operation.—These engines run with a consumption of illuminating gas of 16 cubic feet per actual horse-power per hour; with gasoline, $\frac{1}{10}$ of a gallon per actual horse-power per hour.

For the use of gasoline, a small pump is attached to the engine, which pumps the gasoline to a small cup from a tank placed underground or in a safe place; from the cup the gasoline is fed directly to the cylinder air inlet. If more gasoline is pumped than required, the excess runs back to the tank; 0.74 gravity gasoline is used.

The Charter Gas and Gasoline Engine.

The Charter is a representative of one of the earliest types of American gas engines. It has gone through its evolution of improvement, and claims to be a model of simplicity. It is of the four-cycle compression type. It runs equally well with illuminating gas, natural gas, and gasoline. It is built in nine sizes, from $1\frac{1}{4}$ to 35 B.H.P. The cut (Fig. 73) represents five sizes, and Fig. 74 represents the smallest size, No. 00, which is vertical and of $1\frac{1}{4}$ B.H.P. Both tube and electric ignition are used with these engines. In the horizontal engine the mixing chamber is attached to the head of the cylinder, into which the gas or gasoline is injected by the operation of the small pump G (Fig. 75), driven by a rod and levers operated by a cam on the secondary shaft. The nozzle H (Fig. 75) projects upward so that the indraught from the air pipe N supplies the required quantity, while the overplus is returned to the tank when placed below the engine. When the gasoline tank is placed above the engine so that there is a gravity flow to the engine, the flow is regulated by two valves

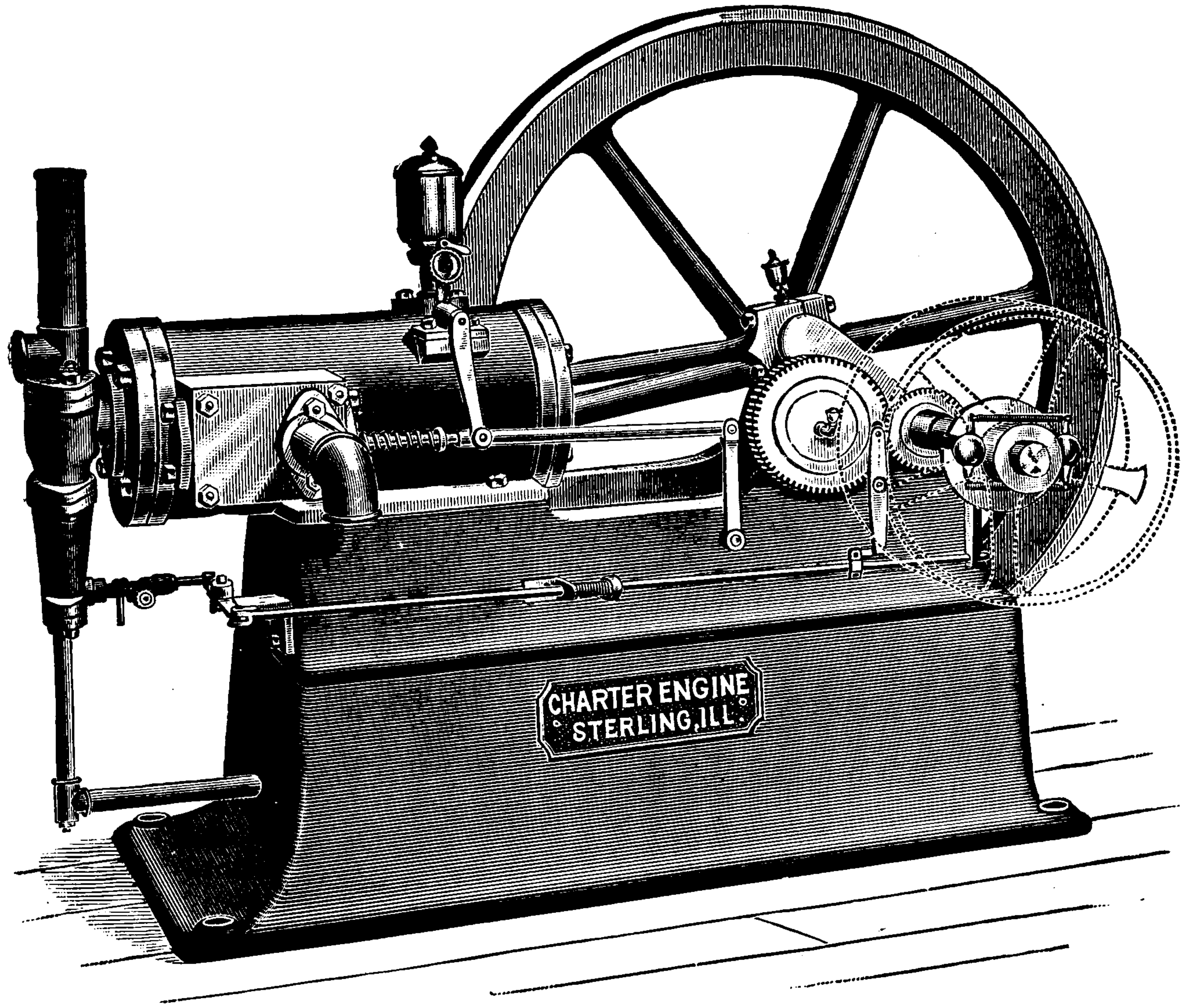


FIG. 73.—THE CHARTER GAS AND GASOLINE ENGINE.

in the flow pipe, a throttle valve at the pump, and by the operation of the plunger of the pump, which in this case does not force a specific quantity of gasoline, but only opens the way for an instant of time to a flow produced by gravity and the suction of the cylinder. In this arrangement, any stoppage of the engine other than by closing the gasoline valves will stop the flow of gasoline by the covering of the pump ports by the plunger. The governor is of the centrifugal type, mounted on the pulley, and consists of two balls held in tension by springs, which operate a sleeve on the main shaft through a bell-crank movement. The movement of the sleeve throws the injector-rod roller on to or off the cam on the secondary shaft, thus making a "hit or miss" injection from the pump.

Communication between the mixing chamber and the cyl-

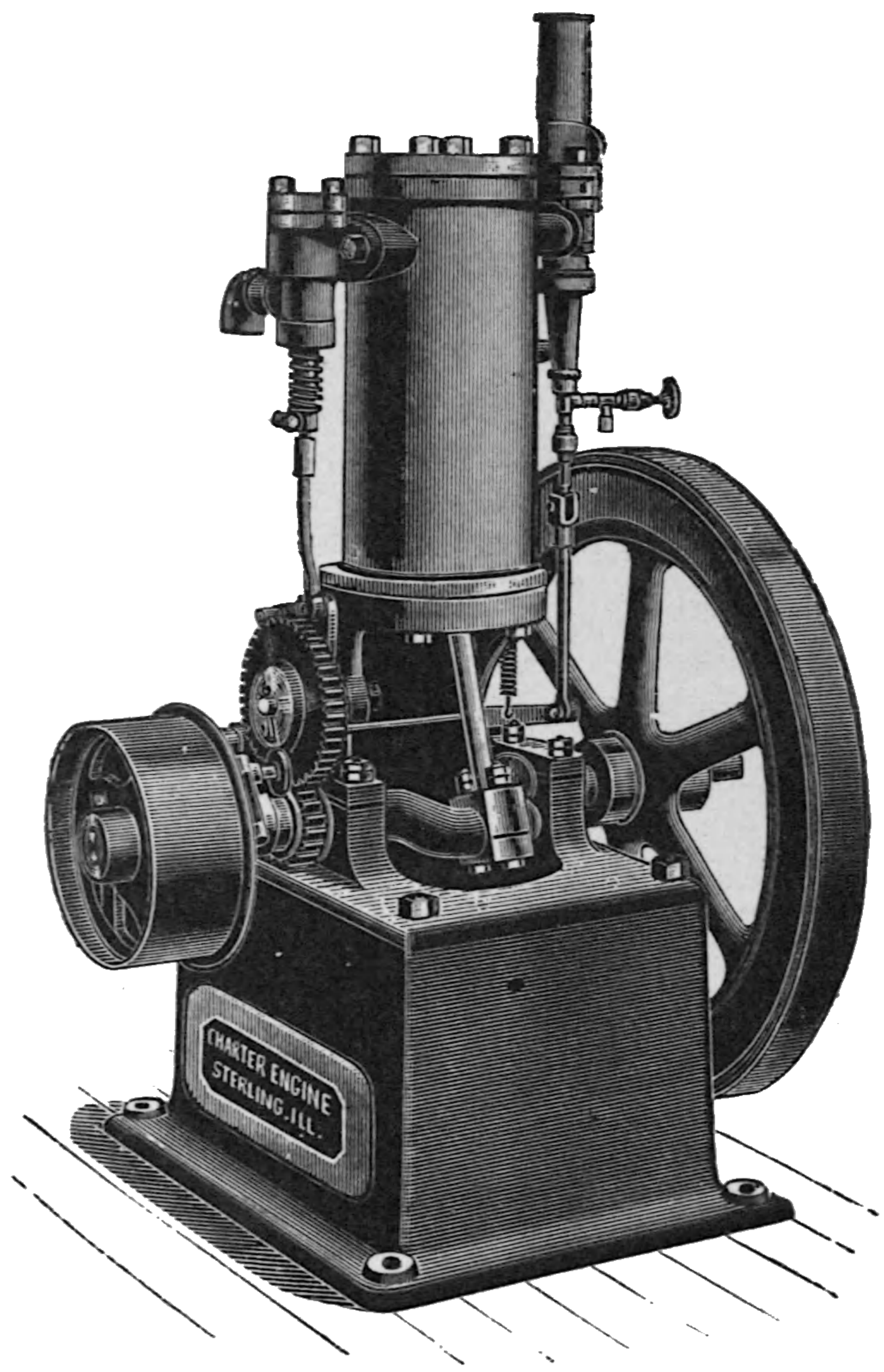


FIG. 74.—THE VERTICAL CHARTER.

inder is cut off, at the moment the charge to the cylinder is completed and compression commenced, by a gravity-poppet valve at B (Fig. 75). The operation of the pump plunger is the same for gas as for gasoline: the plunger only opening a way for the flow of the gas at the proper moment, and being governed in its operation the same as when gasoline is used. The exhaust valve is of the poppet type, operated by a cam on the secondary shaft, the movement of which also operates the oil cup on the cylinder by the levers and small-rock shaft, as shown in Fig. 75. The detail of the operating parts are well

shown in the skeleton cuts of the horizontal and vertical engines (Fig. 76 and Fig. 77). A relief valve for easy starting is placed on the cylinder of No. 2 and larger engines. The No. 6 and No. 7 engines are furnished with a perfect and practical starter. The ignition-tube burner is shown in the different illustrations, consisting of a gas or gasoline jet in a

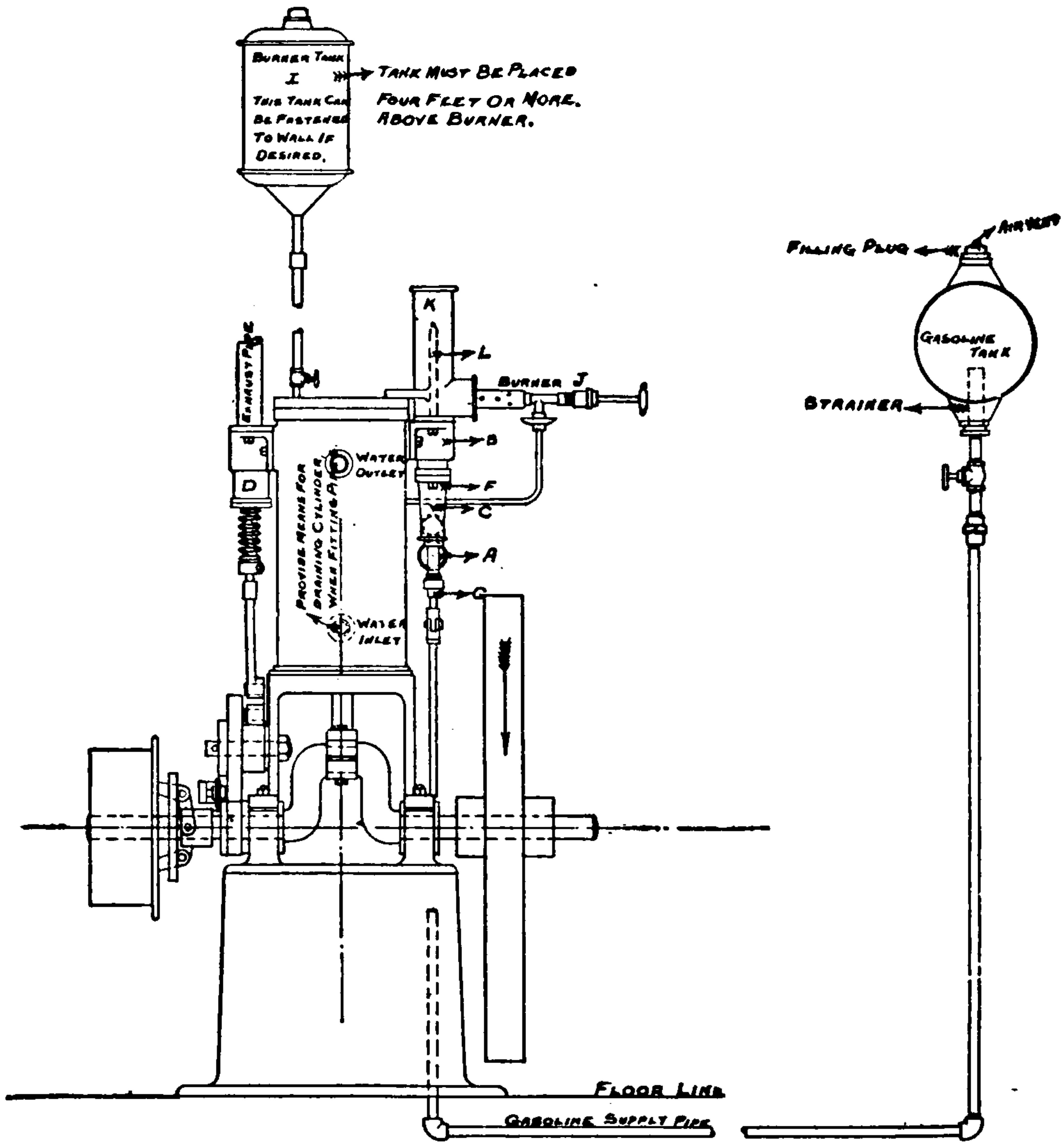


FIG. 76.—THE VERTICAL CHARTER FOR GASOLINE.

perforated sleeve, acting as a Bunsen burner upon the compression tube contained in the asbestos-lined chimney.

For electric ignition a pair of insulated electrodes in a plug are screwed into the place of the tube igniter and operated by a spark breaker.

The Charter Gasoline Pumping Engine.

Fig. 79 shows an engraving of the Charter gasoline engine and pump combined. This combination was designed for any kind of service that piston pumps are capable of. It is compactly built, a feature which, in places where floor space is valuable, is especially desirable. It is easily operated. When

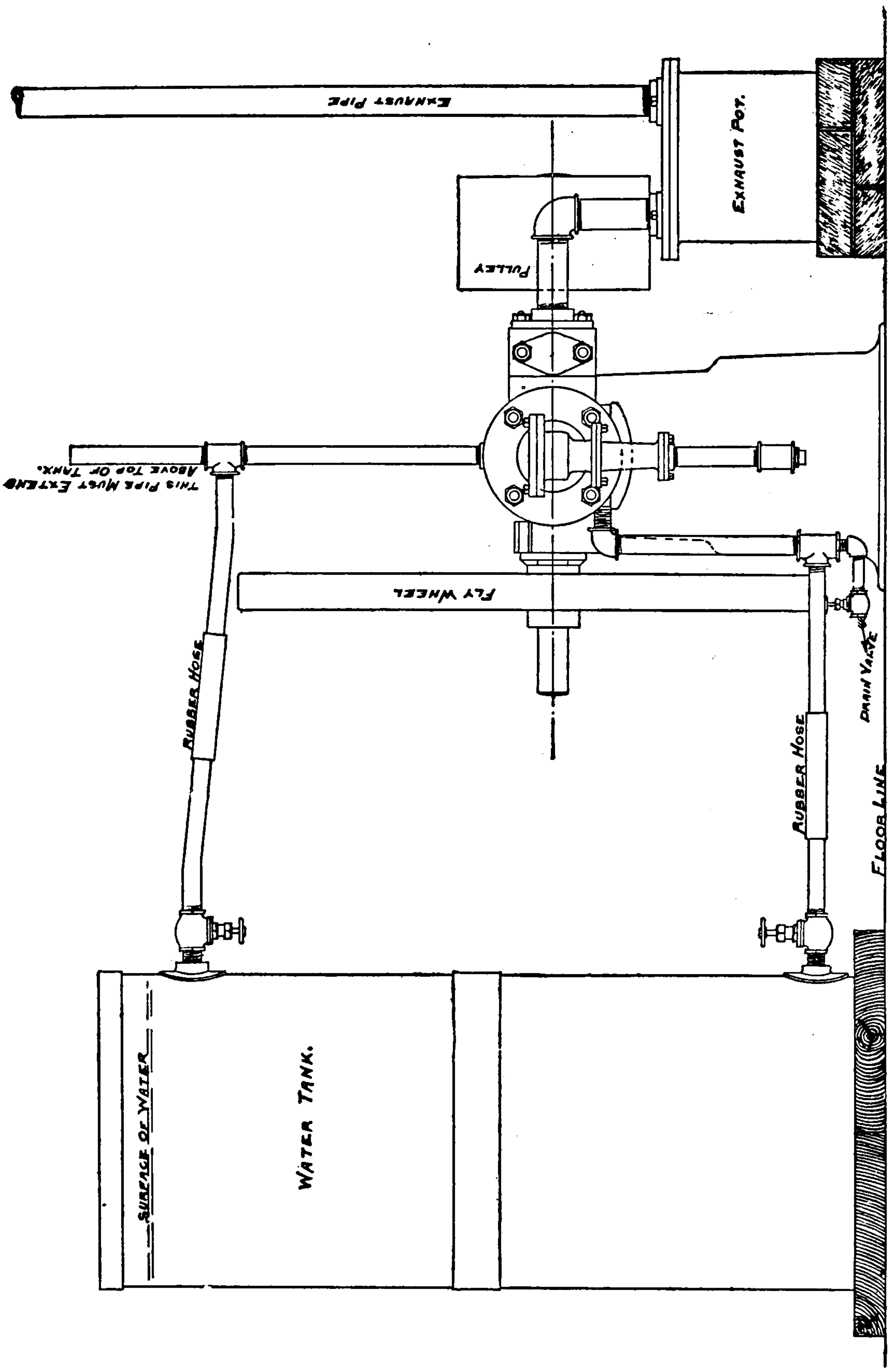


FIG. 77.—THE CHARTER WATER TANK AND CONNECTIONS.

through pumping, nothing remains to do but shut off the gasoline. As no special attendant is required, it is especially desirable for filling railroad tanks, as the station agent or his assistant can take care of the engine and see that the pumping is done without interfering with their regular duties, thus saving the expense of employing a man to go from station to station

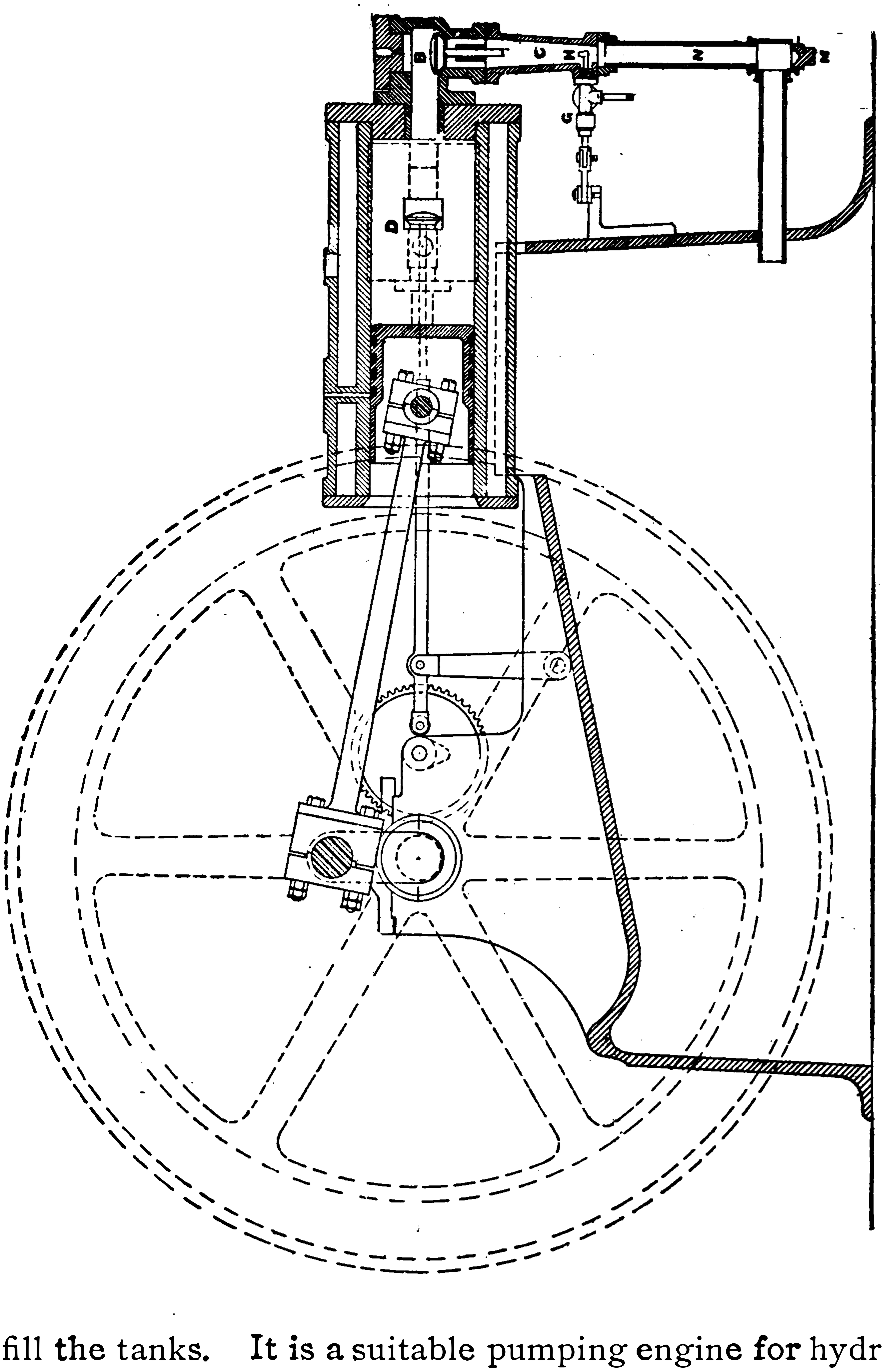


FIG. 78.—SECTION OF THE CHARTER ENGINE.

to fill the tanks. It is a suitable pumping engine for hydraulic elevators. The gears are all machine cut, the pump cylinder is brass lined, and everything about the engine and pump is built on the interchangeable plan. The cut illustrates an en-

The Raymond Gas and Gasoline Engines.

These engines are built in three styles, all in the vertical four-cycle compression type. The quadruple engine (Fig. 80), in

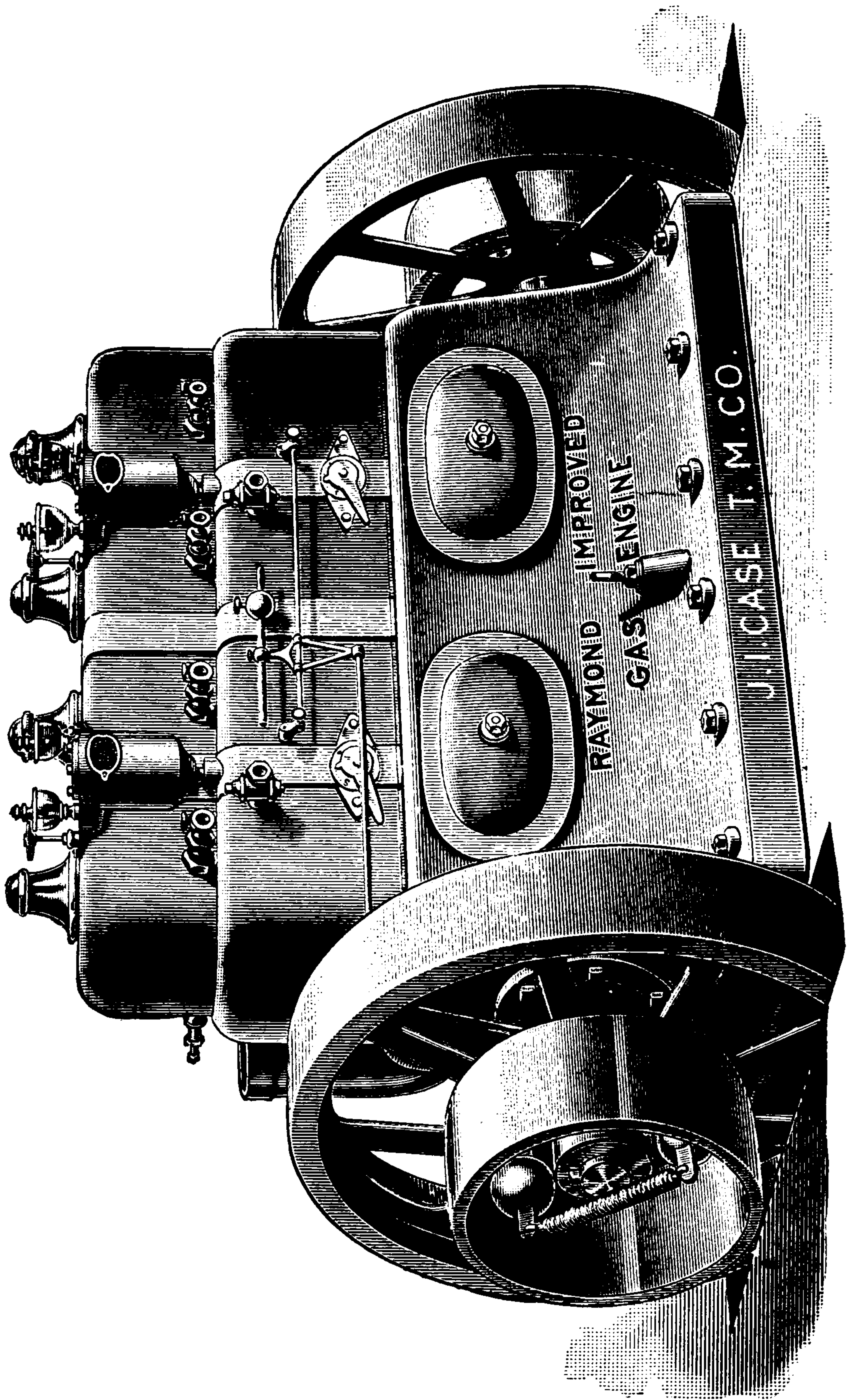


FIG. 80.—THE RAYMOND QUADRUPLE GAS ENGINE.

which there are two impulses during each revolution of the shaft, are made in three sizes: 60, 85, and 100 H.P. (actual).

The duplex (Fig. 81) with a section view (Fig. 82), in which one impulse is made for each revolution, are made in ten sizes, from 4 to 50 H.P. (actual).

The details of construction are similar in all the styles and

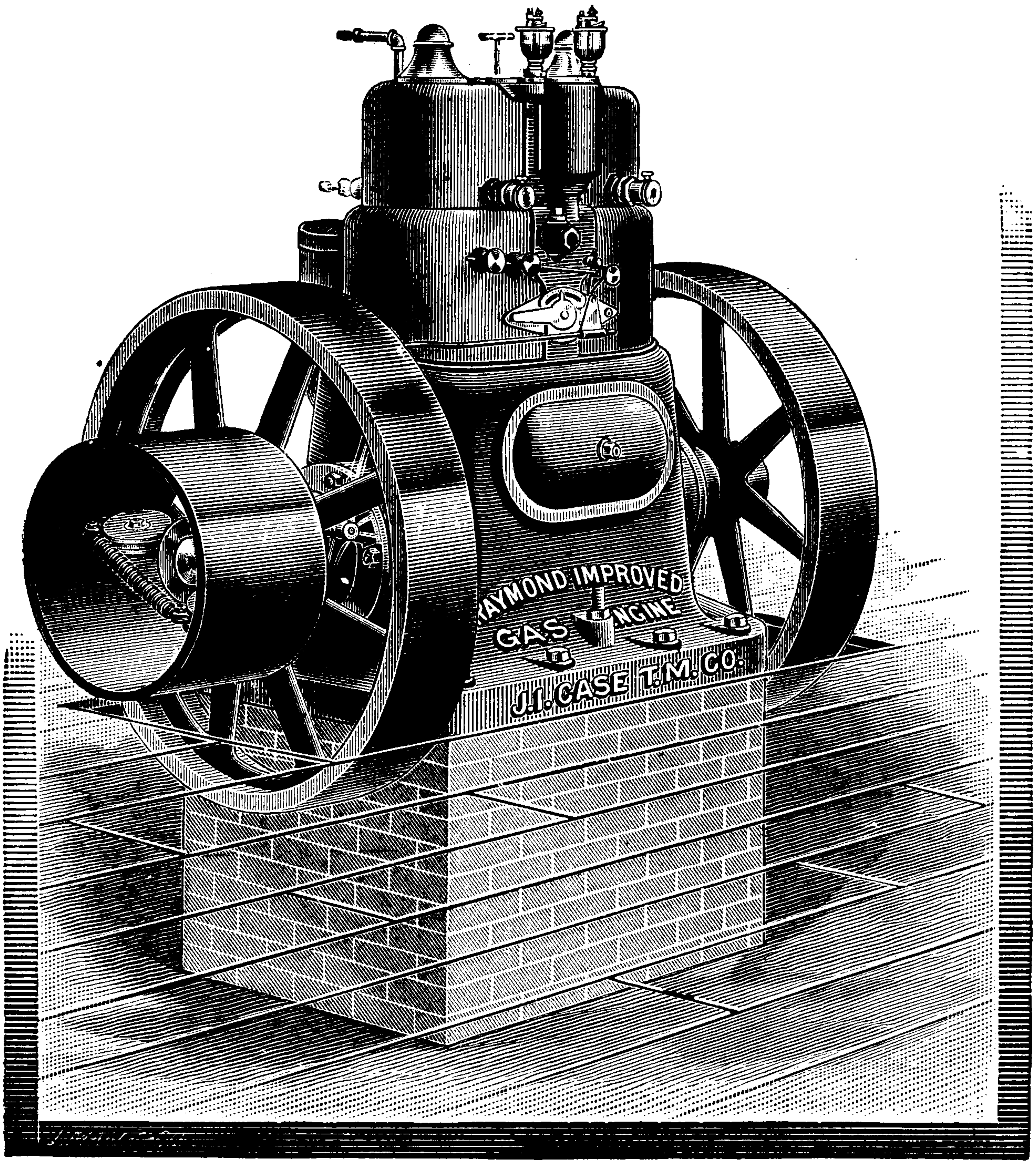


FIG. 81.—THE DUPLEX RAYMOND.

sizes. They are entirely enclosed in a base with a vent pipe at the back to prevent cushioning by the pistons, and, with the large flange on the front of the base, are removable for easy feed-oil access to the moving parts within.

The valves are of the rotating type and are operated directly from the crank shaft by a set of bevel and spur gear;

they are held to their seats by spiral springs and are supplied with steel ball bearings. The valves are lubricated from sight feed oil-cups.

Fig. 82 shows a section of one of the cylinders of a duplex

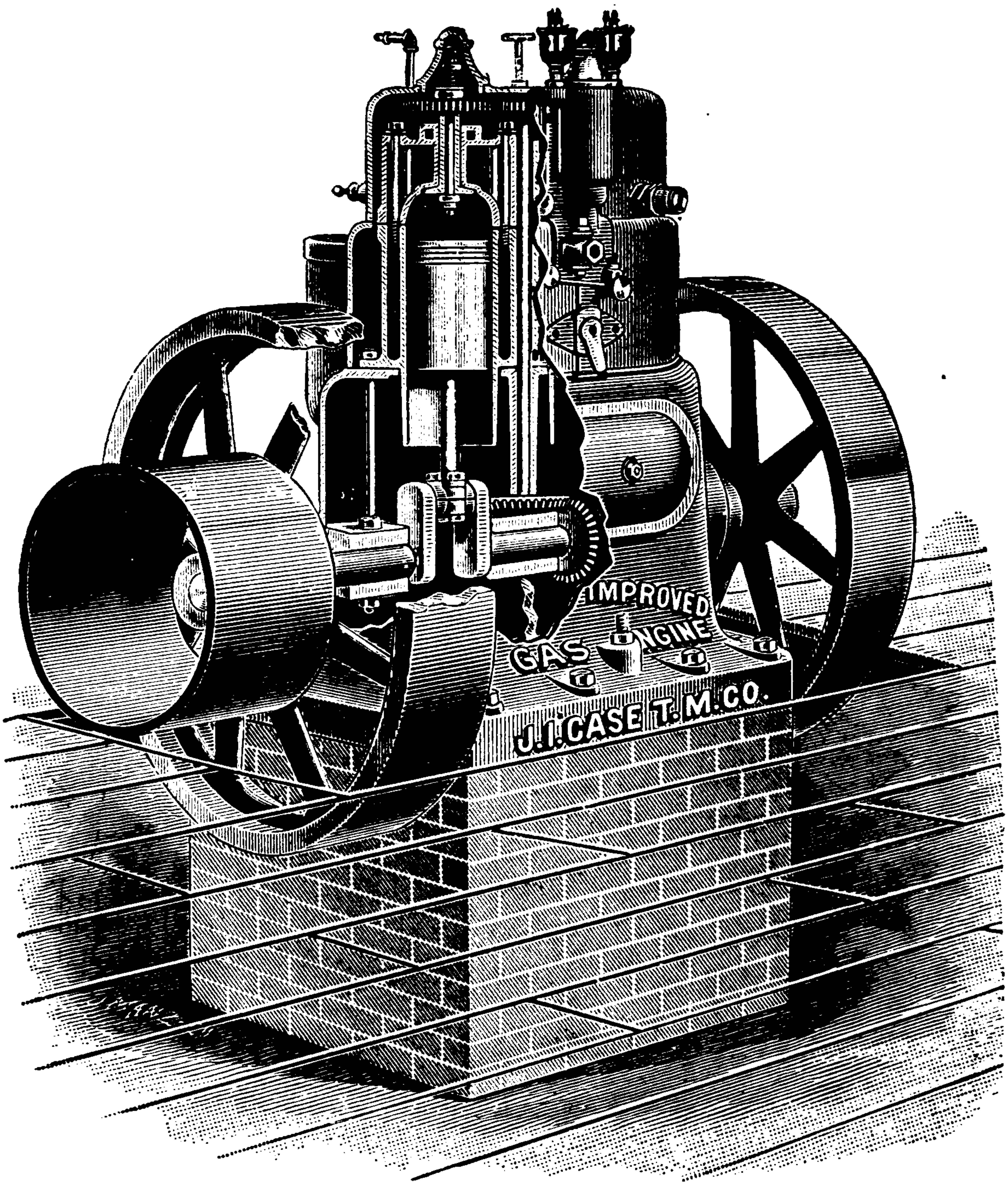


FIG. 82.—SECTION OF THE DUPLEX RAYMOND.

with the bevel gear, secondary shaft, and spur wheels of the valve gear.

The governor is placed on the fly-wheels, and is of the centrifugal type, and regulates through piston valves the exact amount of gas or gasoline mixture required for each impulse to maintain a perfectly steady speed of engine under all conditions and variations of load.

gas, gasoline, or light oil, showing the cover removed to expose the valve gear and adjustable spring for tightening the rotating valve. It is made in ten sizes, from 1 H.P. (actual) to 20 H.P. (actual).

It is claimed that an economy of 12 cubic feet of natural gas per actual horse-power has been attained, and a guaranty of 15 cubic feet per actual horse-power is made.

The Sintz Gas Engine.

This engine is of the two-cycle compression type, taking an impulse at every revolution, yet it is different from the usual

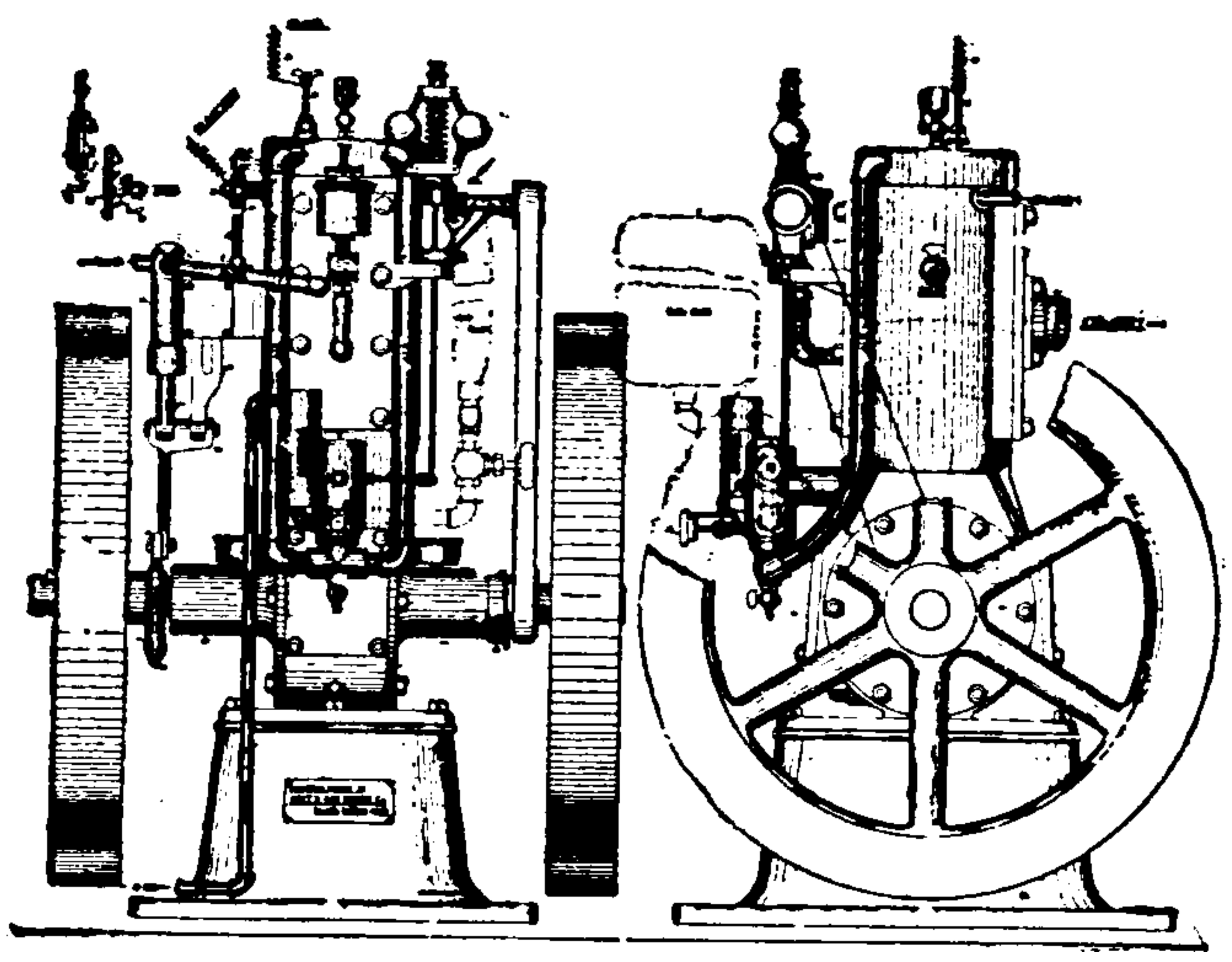


FIG. 84.—THE SINTZ ENGINE.

action of the ordinary two-cycle non-compression type, for it is a compression engine with enclosed crank and piston connections, so that with the up-stroke of the piston air is drawn into the crank casing and by the return stroke the air is slightly compressed. When the down-stroke of the piston nears the terminal, it opens an exhaust port in one side of the cylinder, and at a little farther advance of the piston opens an inlet port on the other side of the cylinder, through which the compressed air in the crank chamber rushes to charge the cylinder, at the same time the gas valve is opened by the eccentric; or if gasoline is used, the pump injects a charge of gasoline in a fine spray at the proper moment. By means of a deflector on the inlet side of the piston, the incoming charge is thrown upward toward the top of the cylinder, thus separating the discharging products of the previous explosion from the fresh charge and by this means obtaining a purer mixture for the next explosion.

The ascension of the piston gives a full compression and time for the mixture to become uniform for ignition by tube or electric igniter. It may be called a valveless engine, as the piston itself opens both the exhaust and inlet ports. A light check valve only is used to check the return of the air drawn into the crank chamber by the upward movement of the piston.

In Fig. 84 is represented the stationary Sintz engine, front and side view. The governor is of the centrifugal type, lo-

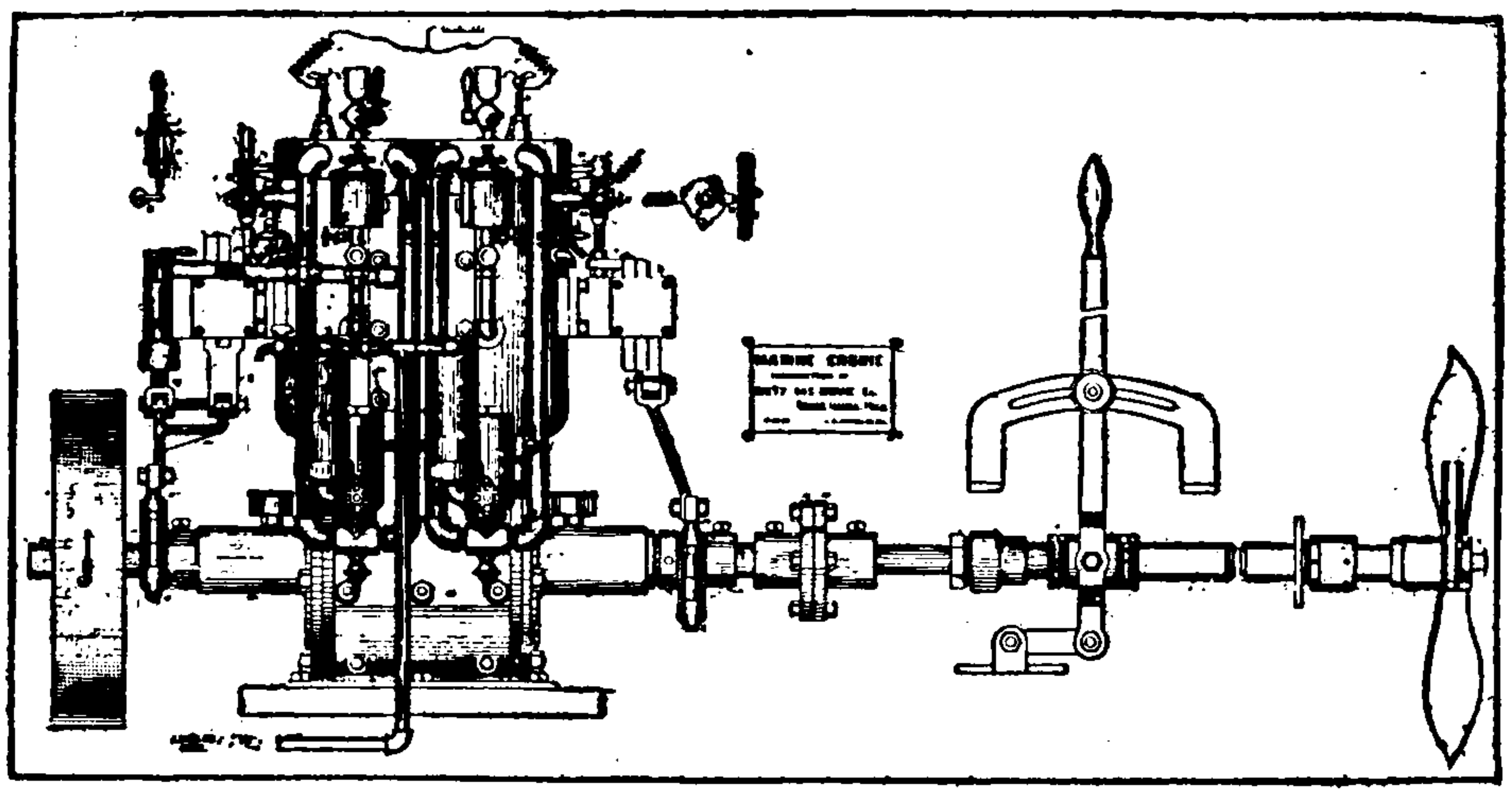


FIG. 85.—THE SINTZ DUPLEX MARINE ENGINE.

cated in the fly-wheel, where two balls held by springs operate through bell-cranks the movement of a sleeve on the main shaft carrying a cam, which by the position of the sleeve determines the operation of the cam on the gas valve, or on the gasoline pump when gasoline is used. The cam is so constructed as to regulate the flow of gas or gasoline to modify the explosive mixture, and not by the entire suspension of an explosion.

Fig. 85 shows the duplex marine engine with its reversing propeller. The reversing gear operated by the lever contains all the movements required for full head, slowing, dead centre, slow backing, and full back—one of the neatest arrangements yet made for the management of boats driven by gas engines. Other arrangements of the reversing lever are made so as to place it in the forward part of the boat with the steering gear.

A section of the Sintz cylinder (Fig. 86) shows somewhat in detail the inlet and exhaust ports with the deflector on the piston opposite the inlet port. The compressed air port in a recess in the lower part of the cylinder shuts off a portion of

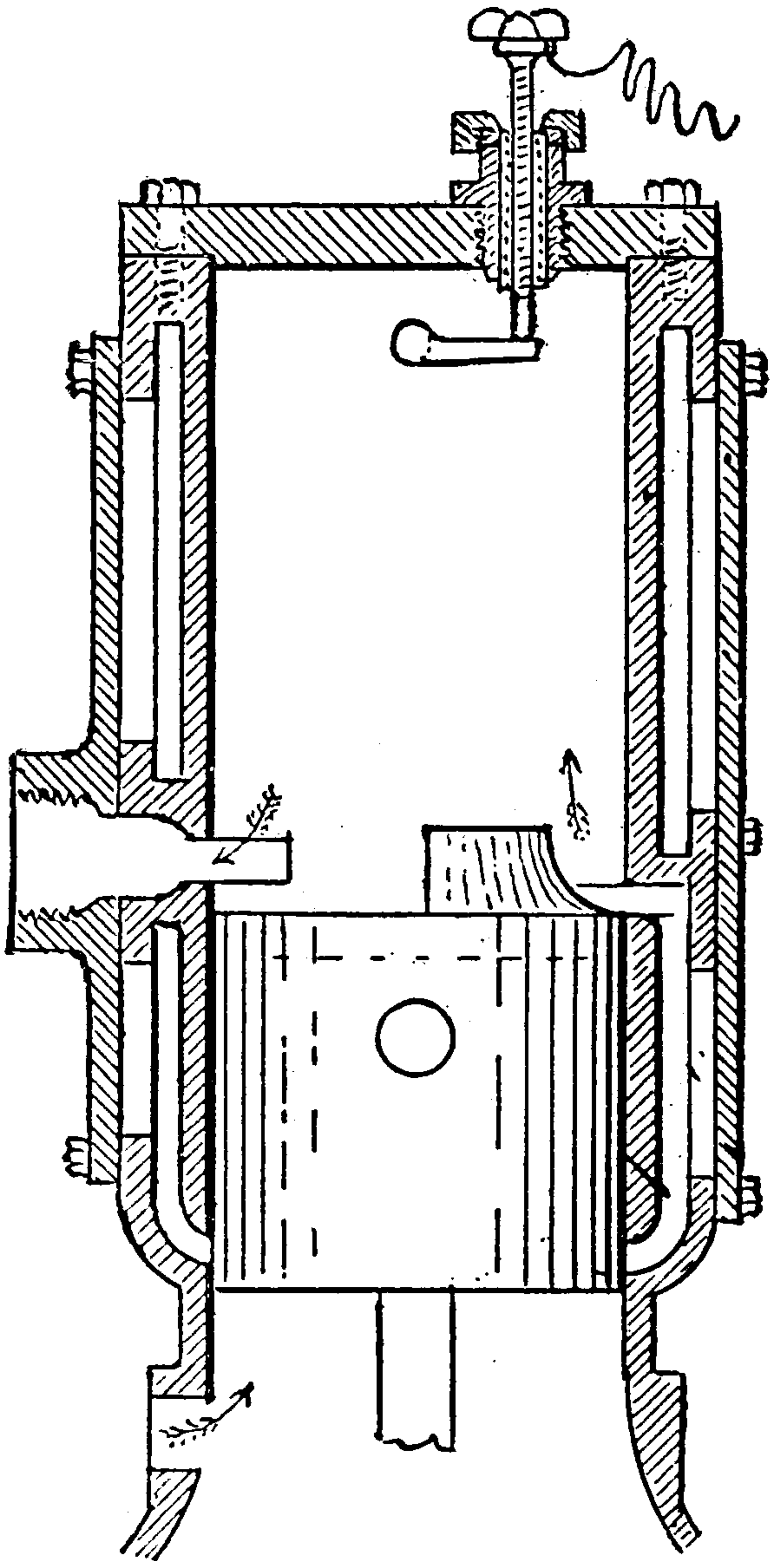


FIG. 86.—THE CYLINDER.

the compressed air at the moment that the inlet port opens, by which means a measured charge of fresh air is forced into the cylinder at every revolution of the shaft. The slight compression by the down-stroke of the piston is sufficient to charge the air chamber in the cylinder for an explosion charge by its expansion through the inlet port during the part of the crank revolution due to the amount of port opening.

The electrode entering at the top through the cylinder cover makes contact and spark break by the rocking arm on a spindle passing through the side of the cylinder. The time

the chamber B, preparatory to starting. The air inlet valve and the exhaust valve are actuated by cams in the ordinary manner on a secondary shaft, the engine being of the four-cycle type. The injection of oil is accomplished by the pump D, actuated by

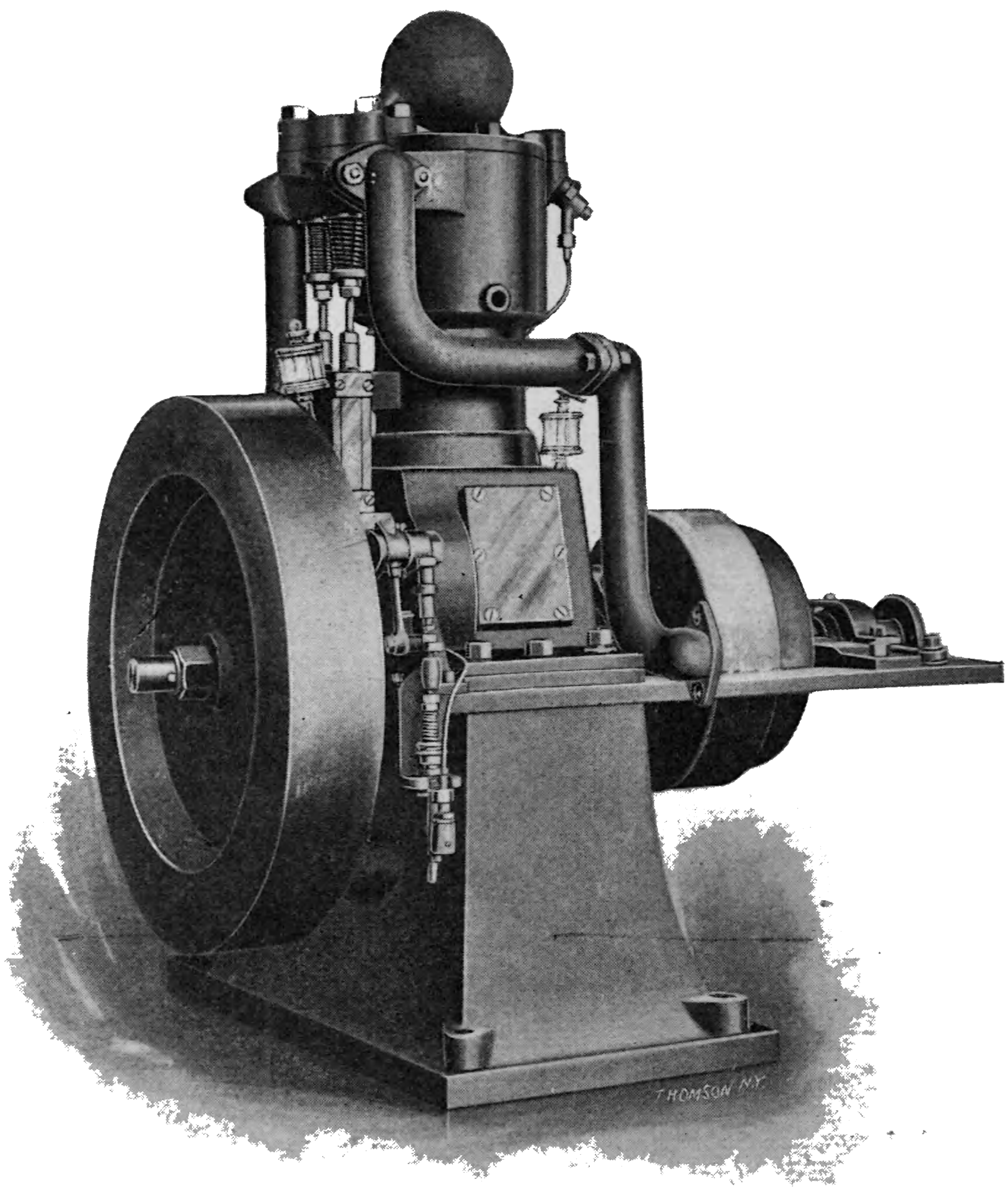


FIG. 88.—MARINE MOTOR AND BASE.

one arm of a rock-lever, which is oscillated by a cam on the secondary shaft.

The charge of kerosene is regulated by the stroke of the pump, which is controlled by a lever in the marine motors and by a governor in stationary motors.

The injection of the oil is in a very fine stream under considerable force by which it is atomized in the hot chamber B. The blow pipe lamp L is made permanent in the stationary engines with an air pressure combination for gas or gasoline. In the marine motors a tank air-pressure kerosene torch is used which heats the combustion chamber ready for starting the motor in about five minutes. The clearance is so adjusted that the compression is carried to 85 pounds, at which point or just before the piston reaches the dead center, the charge of oil is suddenly injected and vaporized by the heat of compression and the walls of the vaporizing chamber. By the late injection of the oil, preignition is impossible and the atomizing of the oil being instantaneous is followed by its perfect vaporization in its mixture with the hot air. The firing of the charge of partially mixed oil vapor and air is exact and instantaneous as to time and owing to the small volume of the clearance space carries the pressure up to about 190 pounds, and by continuous combustion during the impulse stroke gives a higher expansion curve than is due to the adiabatic line and showing by the indicator card a mean effective pressure of 74 pounds. This exceeds the usual mean pressure in gas and gasoline explosive motors. These motors are built in sizes of 2, 5, 10, and 20 h.p., with one, two and four cylinders.

Marine Gasoline Engines of the Two-Cycle Type.

We illustrate in Fig. 89 and following the two-cycle marine engines of Smalley Bros. & Co., Bay City, Mich. The manufacturers of these engines believe that simplicity in the construction of gasoline engines of the two-cycle type can be carried too far and at the expense of efficiency, and have therefore discarded the valveless type and adopted an inlet valve to take in the charge at the head of the cylinder and a peculiar arrangement for transferring the charge from the crank case to the head of the cylinder through a port in the side of the piston near its head.

This arrangement seems to insure the charge entering the cylinder near the igniting device and so separating the fresh charge from the products of the previous explosion.

A special atomizing device is shown with a needle valve to regulate the flow of gasoline with a check valve on the air passage into the crank chamber. A lever operating on the inlet valve

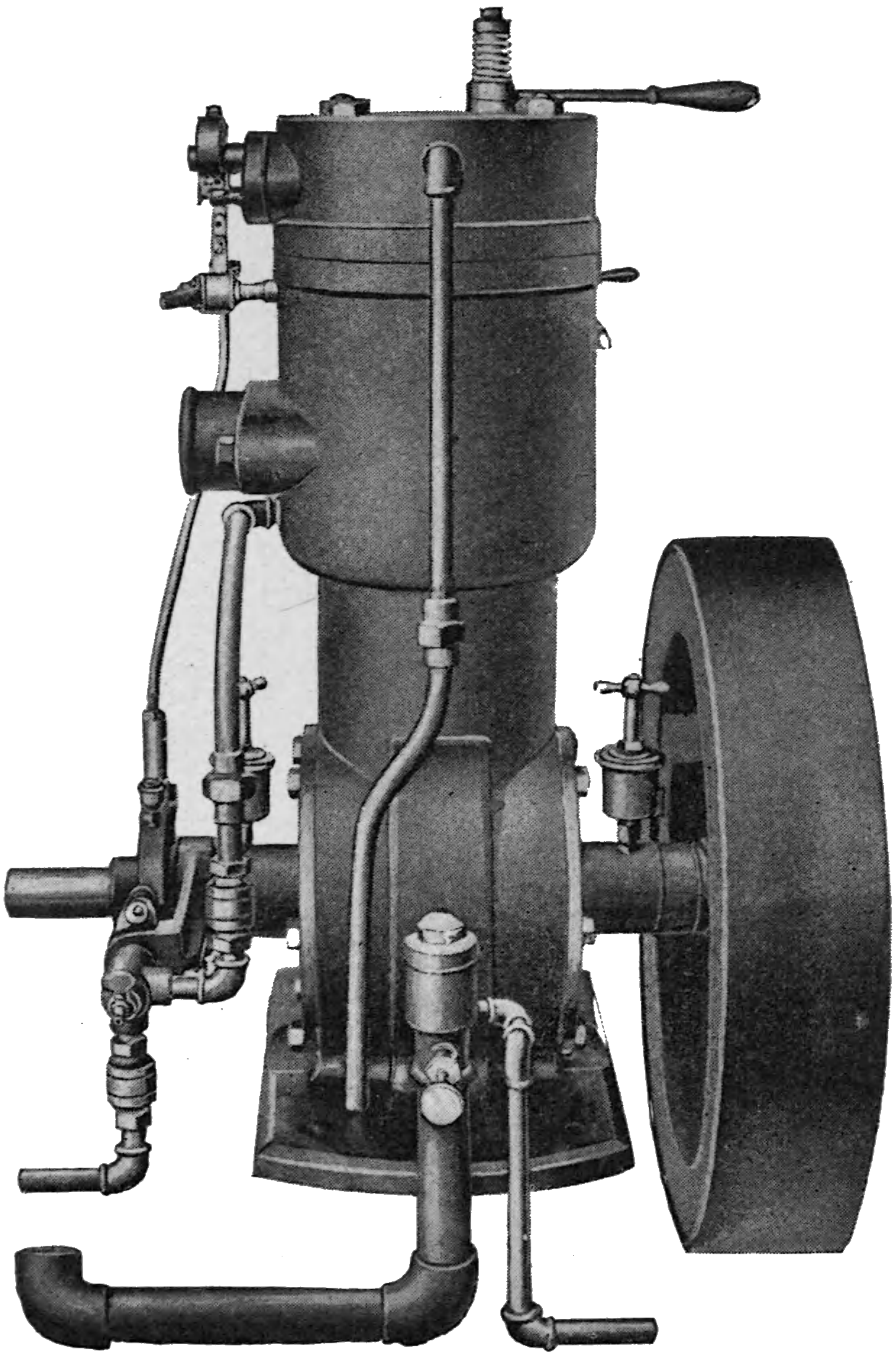


FIG. 89.—TWO-CYCLE MARINE MOTOR.

spring tension on top of the cylinder head, by a wedge movement, regulates the quantity of the charge. It will be seen that the charge passes through the hollow part of the piston, around the pin bearings and through the port *d*, and into the passage *e*, during a small section of the crank revolution at the lower part of the stroke. This imparts warmth to the charge and cools the

The motors of this company are made in single cylinder design of 1½, 2½, 4 and 6 horse power and in duplex cylinder design to twice the above named power. It will be seen that in the duplex motor the ignition gear for both cylinders is con-

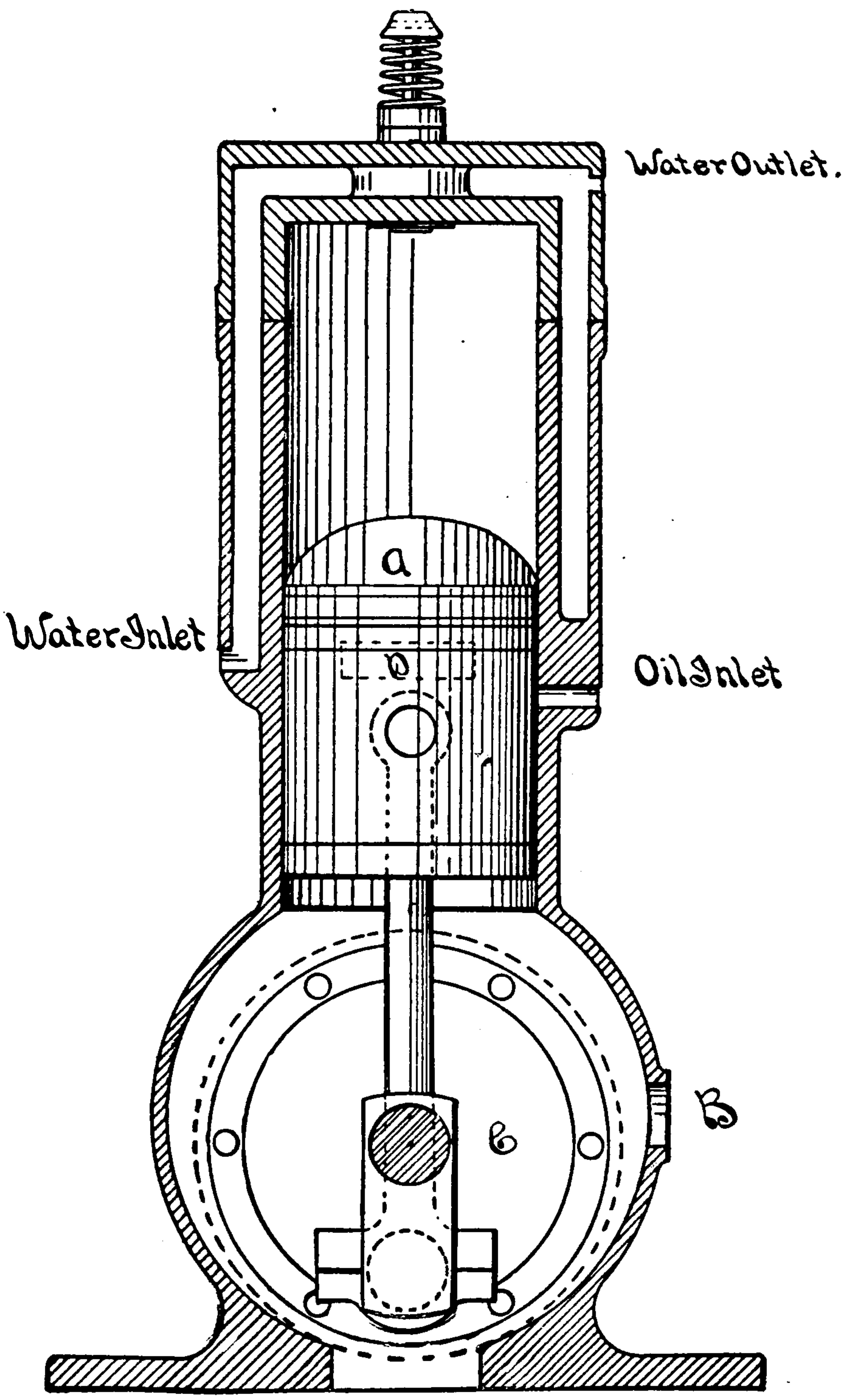


FIG. 89B.—CROSS SECTION.

trolled by a single lever connecting the trip device on each cylinder, so that ignition takes place in each cylinder at alternate strokes or half revolutions of the shaft, thus requiring but one eccentric with a rock shaft.

Fig. 89D shows the eccentric and igniter gearing. The igniter hook A is operated by the eccentric rod B, which is attached to the eccentric C. The sparking points or electrodes in the ignition chamber are brought together and separated by the action of igniter hook A upon the igniter latch 2 which is attached to a rock arm, which passes through the ignition chamber cover D.

The sparking points are easily accessible, as it is only neces-

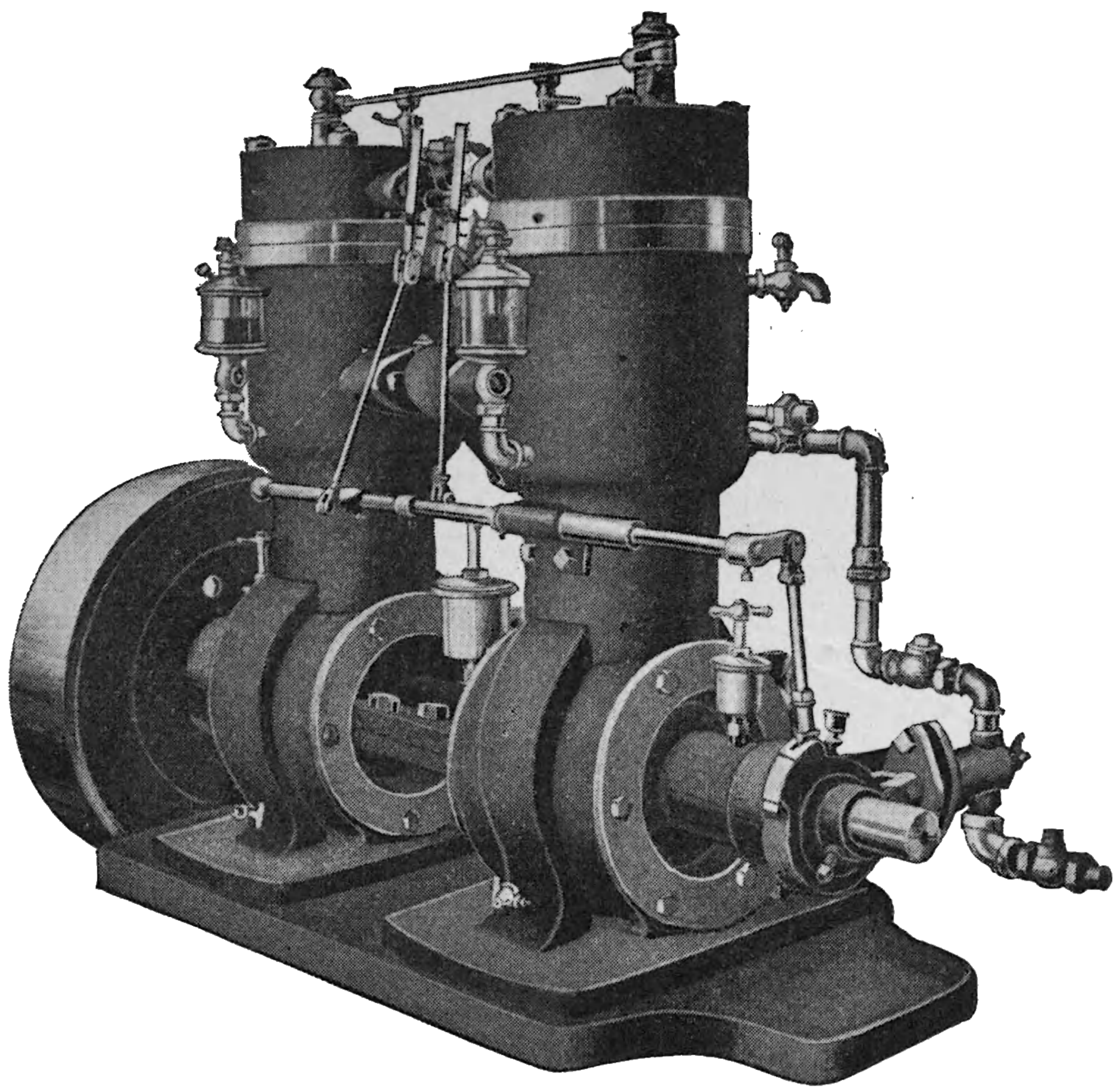


FIG. 89C.—DUPLEX MARINE MOTOR.

sary to remove the two screws when the whole igniter may be removed from the engine, and the spark examined while holding igniter in the hand.

One of the important features of the Smalley engine is the device for changing the time of ignition. This can be done when engine is running, by simply throwing the lever H up or down, and the adjustment is so fine that the point of ignition can be varied to the smallest fraction of an inch.

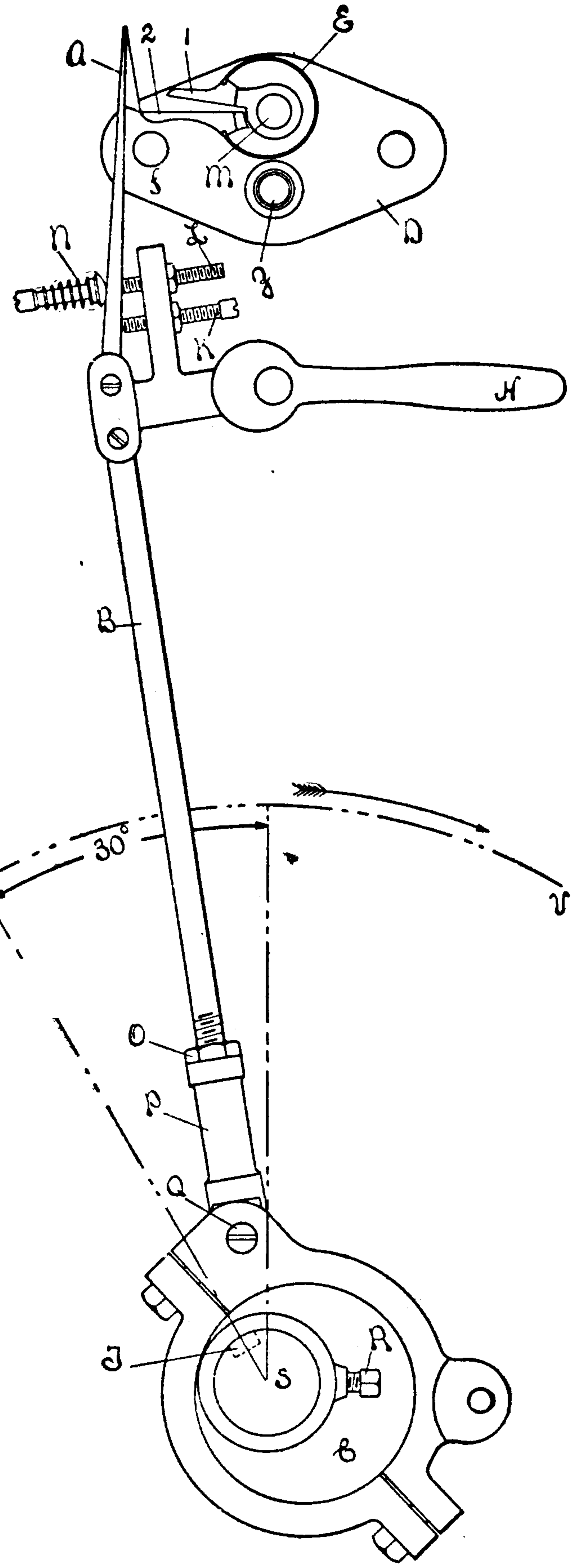


FIG. 89D.—SMALLEY IGNITION GEAR.

tical gas and gasoline engine, with its connections with the gasoline supply, cooling tank, and muffler. The gasoline for the burner runs by gravity from a small tank on the wall. The vertical engines are made of 2 H.P. for power and pumping.

In Fig. 91 is represented the horizontal gasoline engine of this company. It is of the compression four-cycle type, with

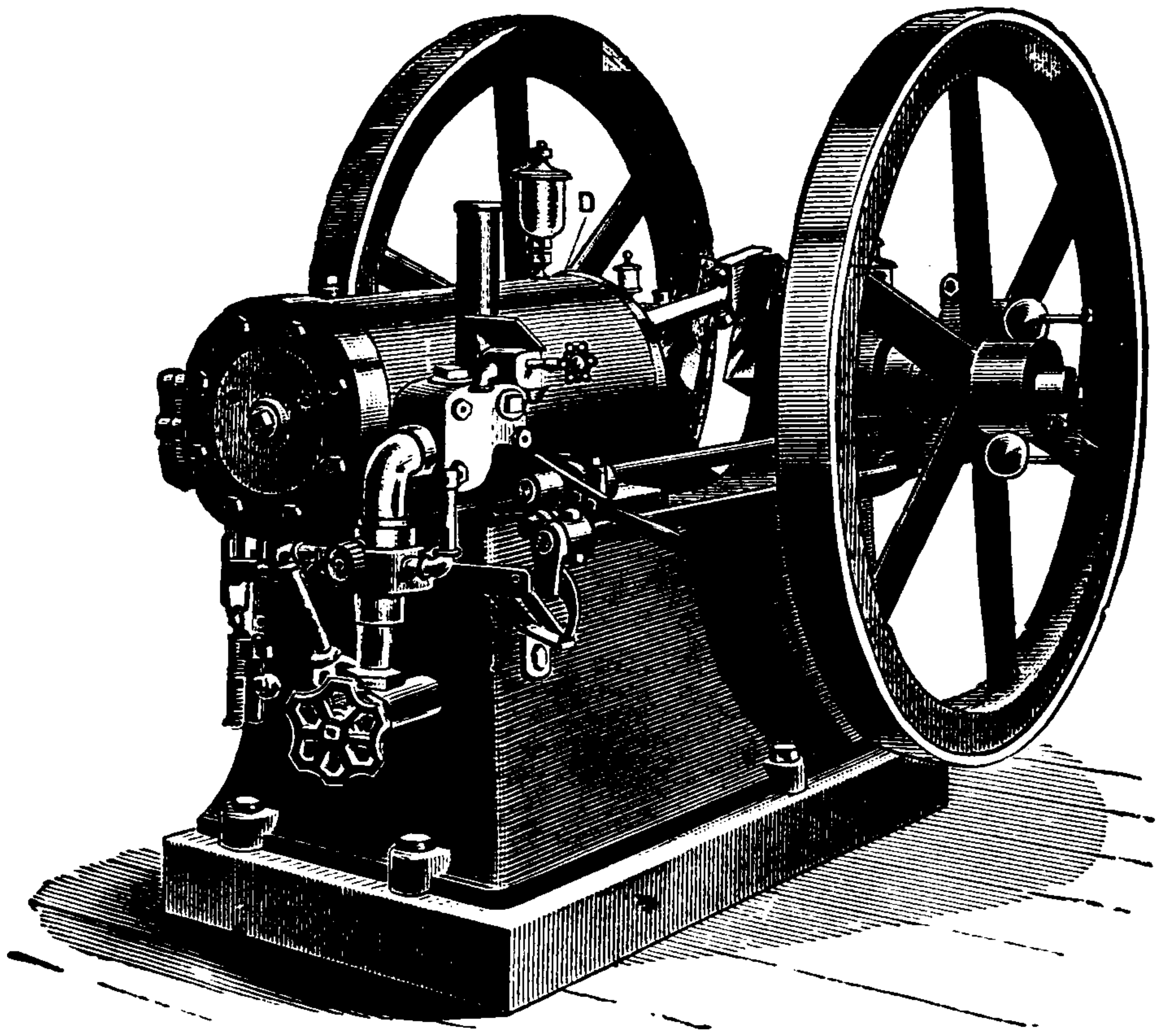


FIG. 91.—THE WEBSTER GAS ENGINE.

poppet valves, tube igniter, gasoline pump, and regulating valves for both gasoline and air inlet, independent of the governor, which is of the centrifugal ball type, attached to the main shaft, and operates a regulating cam. The reducing gear from the main shaft, through a secondary shaft, operates the exhaust valve and gasoline pump through the lever across the front of the bed piece.

In operation, the air charge is drawn in through the pipe and regulator valve from the hollow bed piece and vaporizing chamber to the valve chest, the inlet valve opening by the suction of the piston.

When running light the governor shaft causes the exhaust valve to miss its lift, as also the gasoline pump to miss its stroke, and thus the gasoline supply is cut off until released by the governor. A small lever serves to open the exhaust valve and relieve the pressure in starting the engine.

A self-starting mechanism is furnished for the larger size engines, a novel and simple arrangement, consisting of a valve screwed into the top of the cylinder, in which is inserted an ordinary explosive match. By screwing the valve disc down to make tight, the head of the match comes in contact with the seat of the valve, which produces a flash and thus ignites the charge, which has been slightly compressed by turning back the fly-wheel with one hand, while with the other hand the operator turns the valve to its seat.

The sizes of engines made by this company are of 4, 6½, 10, 15, and 20 B.H.P., and adapted for the use of gas, natural gas, and gasoline.

The Springfield Gas Engine.

The engines of the Springfield Gas Engine Company are of the four-cycle compression type, adapted to the use of illuminating gas, natural gas, producer gas, gasoline gas, and gasoline fluid by injection.

The inlet and exhaust valves are of the poppet type, actuated by cams on a cross shaft over the cylinder head, the cross shaft being driven by a longitudinal shaft and two pairs of bevel gears.

The cams Nos. 18 and 19 on the cross shaft (Fig. 93) operate the inlet and exhaust valves by depression against internal pressure, the valves being also held to their seats by springs.

The governor is of the horizontal, centrifugal type, running free on the end of the cross shaft and driven by a small belt from the main shaft. Fig. 93 shows an end view of the engine as fitted for gas. An air valve No. 8 and the gas valve No. 35 are on a vertical spindle, which is operated by a cam, rotating with the cross shaft and controlled in its longitudinal

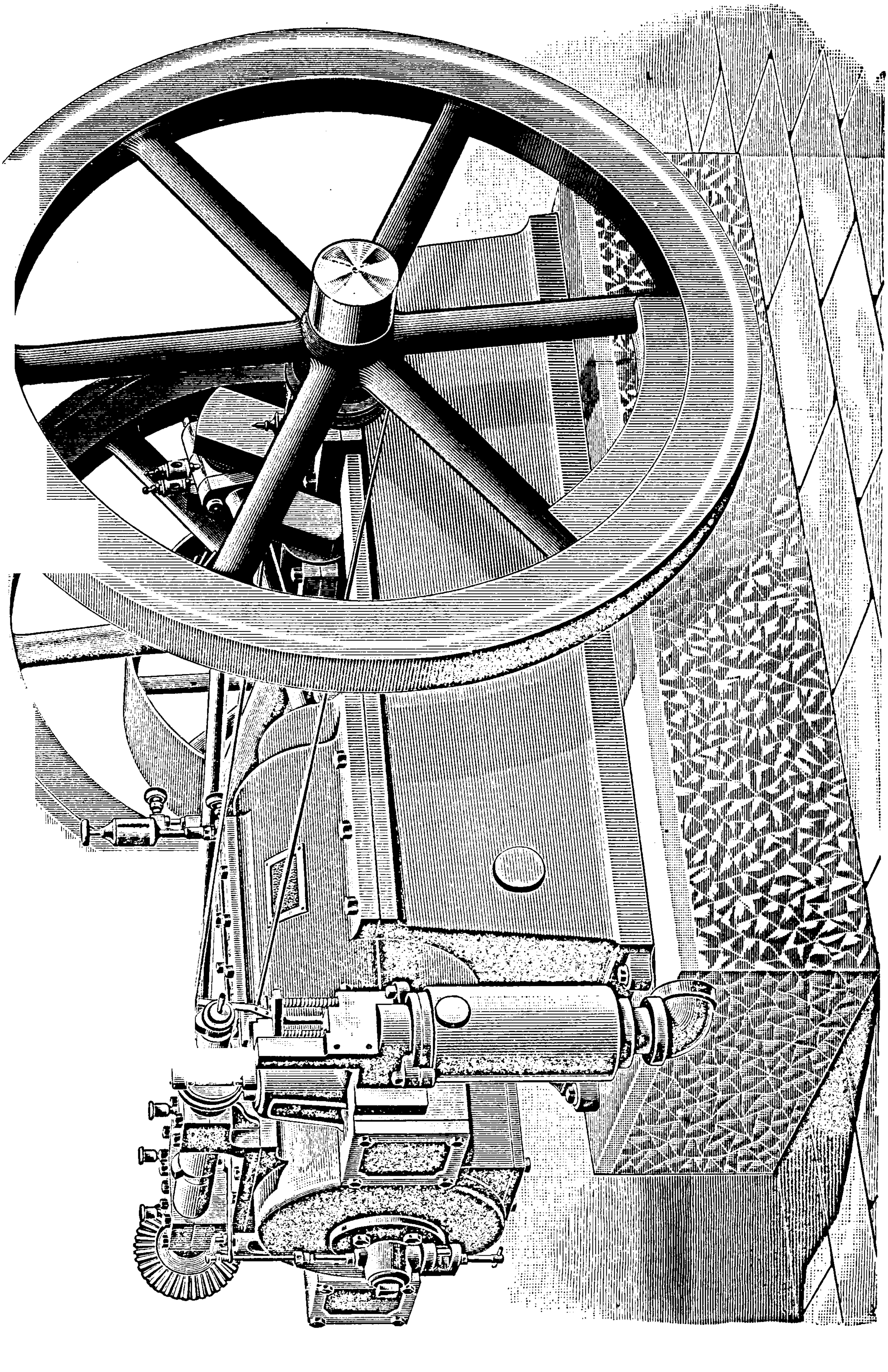


FIG. 92.—THE SPRINGFIE

the gas valve, which is set by raising or lowering the gas-inlet pipe No. 6 in the mixer No. 10 by means of the set-screws No. 7.

For the use of gasoline a small supply pump, driven from a cam on the longitudinal shaft, supplies the fluid to the injection plunger with an overflow to return the surplus to the gasoline tank.

Fig. 94 is a side view of the engine as arranged for control-

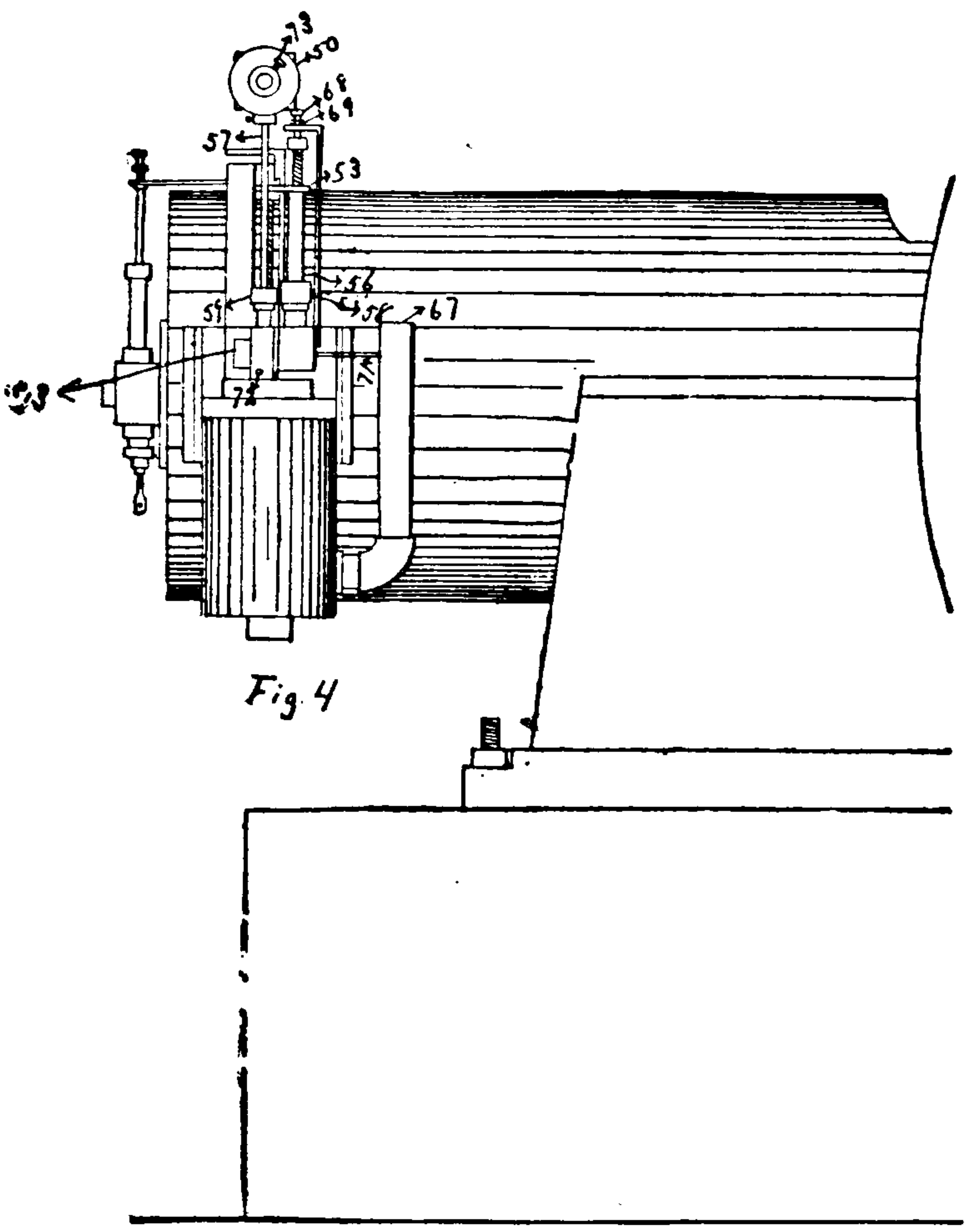


FIG. 94.—GASOLINE REGULATOR.

ling the fluid injection. The air-inlet pipe is attached to the side of the mixing tank ; the gasoline pipe from the supply pump enters at No. 72. No. 56 is the injector plunger, and No. 57 the air-valve stem.

With a gravity feed the supply pump is dispensed with. Electric ignition is used. The device is embodied in a flanged chamber bolted to the head of the cylinder, as shown in Figs 93 and 94, and the construction is detailed in Fig. 95. The upper electrode No. 34 vibrates as a current breaker, and is operated by a snap cam and spring lever at No. 20 in Fig. 93. The lower electrode is insulated and has a screw movement for adjusting the separation of the electrodes.

The battery connections are made on the head of the cylin-

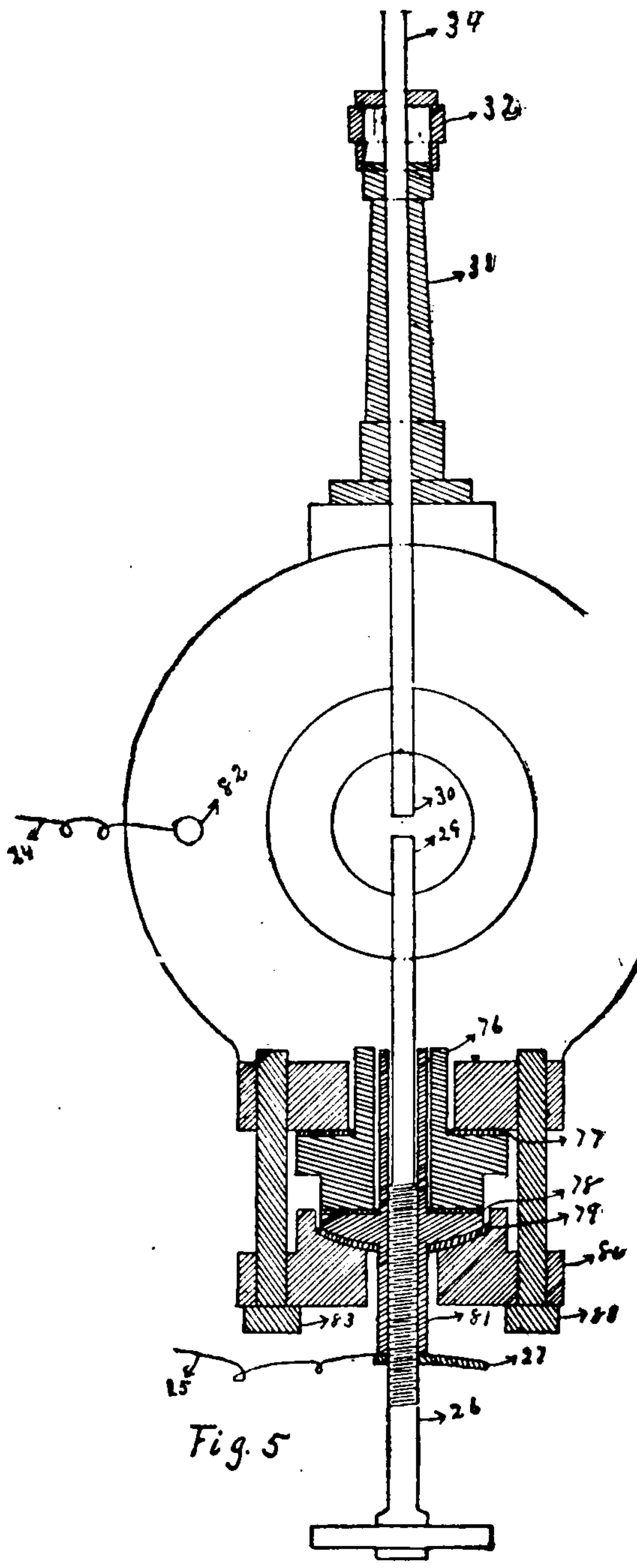


FIG. 95.—THE IGNITER.

der at the binding post 82, and to the insulated electrode at 25.

The battery plant consists of four (more or less) Edison-Lelande cells in series, a sparking-coil, and switch, as shown in Fig. 96. The sparking-coil is more fully described on page 75, in the chapter on ignition devices. The switch should always be turned off when the engine is not running, to save battery waste

The Springfield Gas Engine Company builds eleven sizes of gas and gasoline engines, from 1 to 40 B. H. P. Full details for running these engines, with reference and key to the parts as figured, are given in their book of instructions.

The Foos Gas and Gasoline Engine.

The engines of the Foos Company are built in the horizontal and vertical styles, and of 16 sizes, from 2½ to 100 B. H. P.

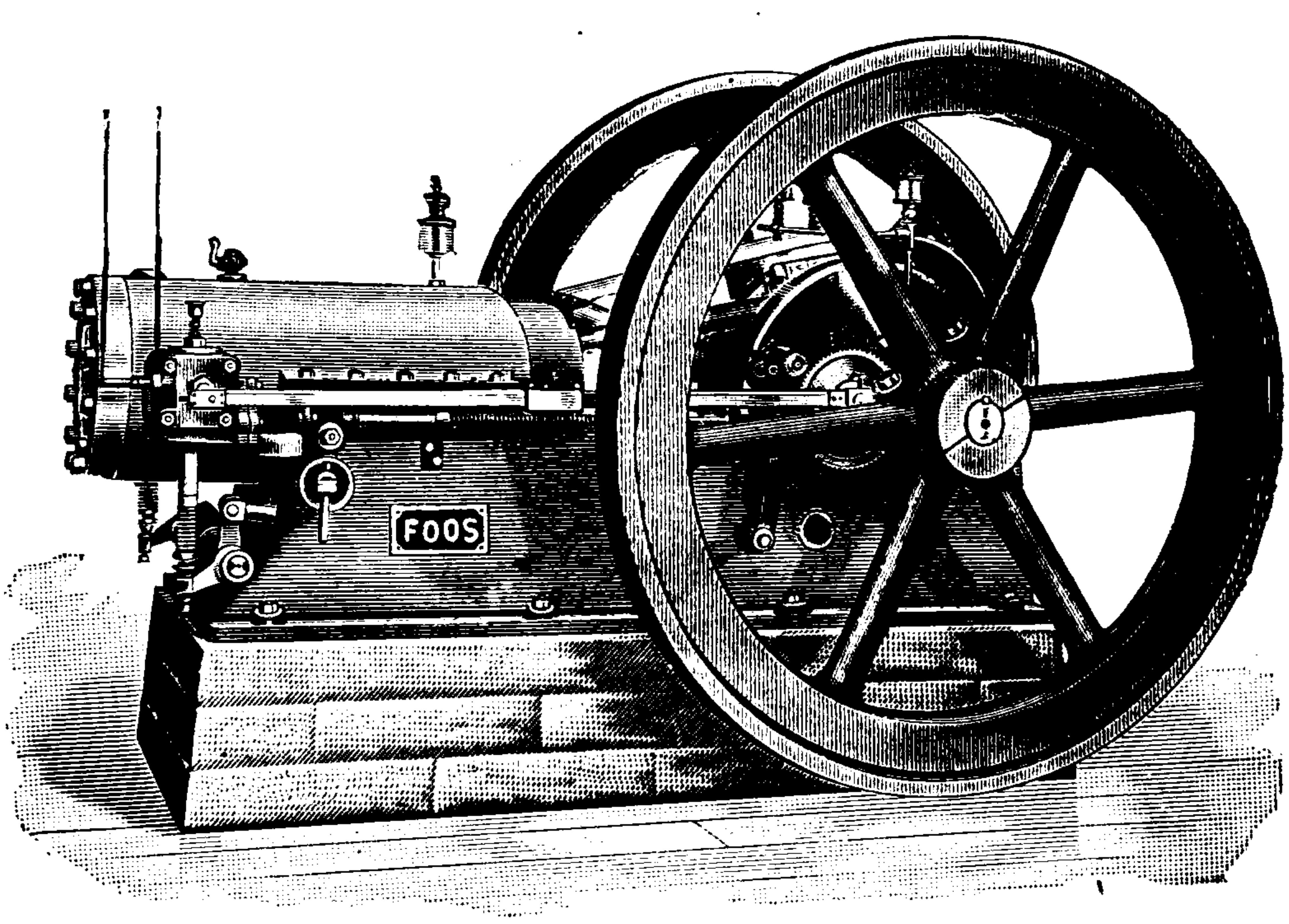


FIG. 96 —THE FOOS GAS ENGINE.

They are all of the four-cycle compression type, with poppet valves. Fig. 97 represents the horizontal engine as connected for the use of gasoline.

The exhaust valve on the opposite side of the cylinder in the cut is lifted by a rock shaft and arms operated by a connecting-rod inside of the engine base, leading to a cam on the reducing-gear. The adjustable spring closes the exhaust valve. The regulation is made by mischarges of gas or gasoline by an interrupter device on the charge push-rod leading from a cam on the secondary gear. The governor L is of the

horizontal centrifugal type, driven by a band from a pulley on the main shaft. The movement of the governor operates a lever, which makes a hit-or-miss contact between the push rod and the pump rod, as may be traced by inspection of the cut (Fig. 97).

When gas is used, the pump is removed and a lever attachment made in place of the pump rod, which operates a gas

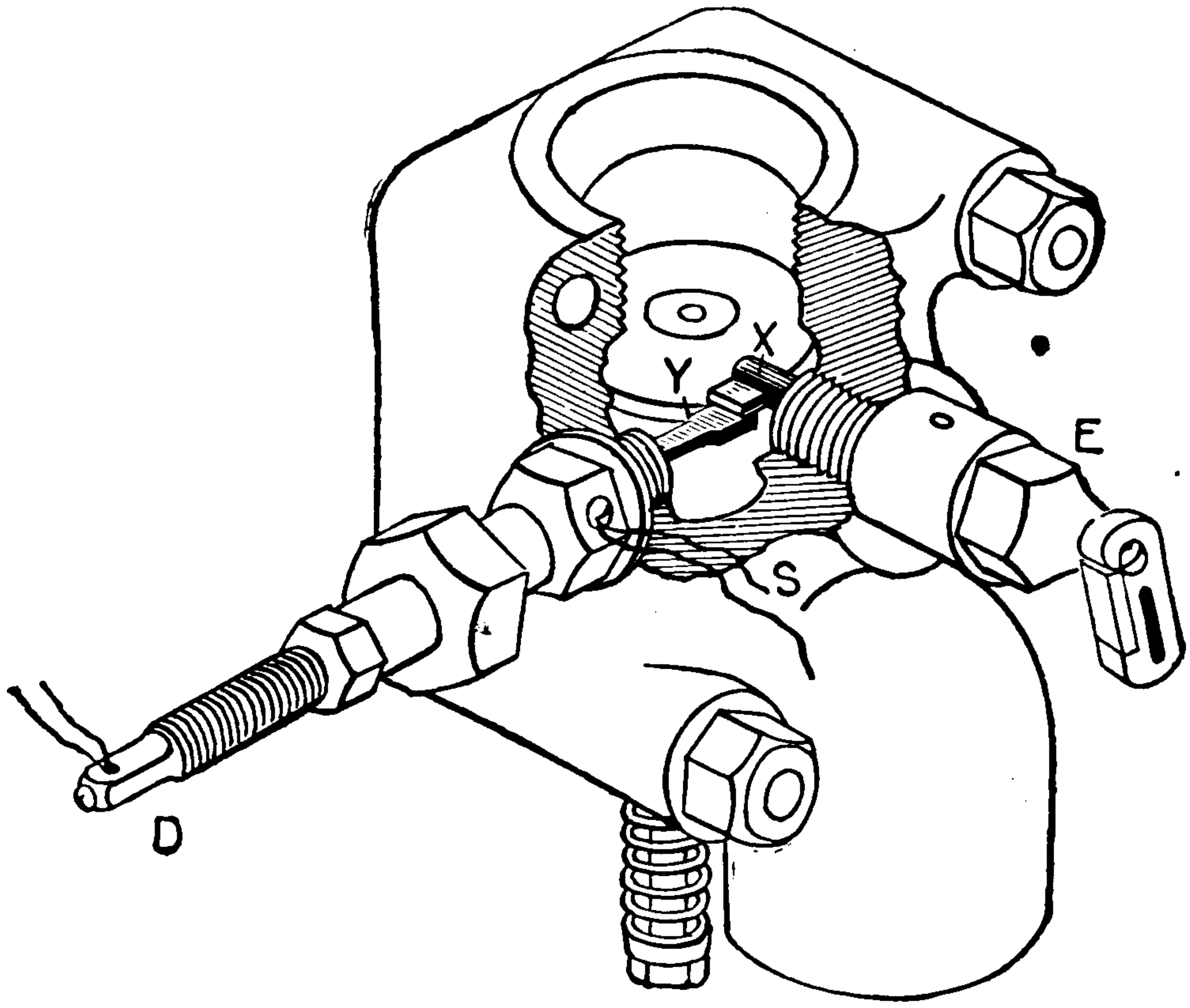


FIG. 98.—THE ELECTRODES.

valve for intermittent discharges into the air-inlet pipe, in the same manner that the gasoline injection is made, and controlled in the same way.

The charging and exploding chamber is shown at B (Fig. 97), and the details of its operation are shown in Fig. 98. The air is drawn in by the suction of the piston through the valve shown at X Y, the spindle of which passes through a subchamber connecting with the air pipe, and is regulated in its tension by a spiral spring and adjusting nut. The electrodes are shown at D and E, D being an insulated spring with its battery connection at D, and the opposite electrode is connected to the plug at S. The electrode E is revolved by the oscillating and sliding bar F, Fig. 97, one end of which is connected to an adjustable crank pin on the secondary gear, and the other to the crank of the electrode E. The slide pivot, as observed near the middle of the bar, enables the bar to transmit a circular motion to the electrode in an opposite direction from the motion of the pin on the secondary gear wheel. The time of sparking is regulated by moving the driving-pin in its circumferential position by turning the slotted plate K, in which the pin is set. The proper moment is at the end of the forward stroke of charge compression. A relief valve G is provided for relieving the pressure in the cylinder when turning over the fly-wheel for starting.

The speed of the engine may also be controlled by compressing or loosening the governor springs, by means of the nuts at each end of the springs.

The electric batteries are of the Edison-Lelande type in series.

The Dayton Gas and Gasoline Engine.

The engines of the Dayton Gas Engine and Manufacturing Company are built in the vertical and horizontal style, and also mounted as a portable engine on a wagon for agricultural purposes. They are of the four-cycle compression type, with the valve chamber on the top of the cylinder in the horizontal style, with poppet valves operated by straight-line push-rods from cams on the secondary shaft. The exhaust-valve rod with a back spring is on one side, and the admission valve with a positive cam motion and back spring is on the other side of the valve chamber, while between is the igniter rod, also operated by a cam—all having straight-line motions. The gas or gasoline valve is also operated by a rod and push-point, which is controlled by the governor.

The governor is of the horizontal, centrifugal style, mounted on the main shaft, adjusted by springs, and so arranged that the engine speed is regulated by hit-and-miss charges of gas or gasoline. The ignition is electric. The spark is produced by the end of the push-rod passing an insulated stem in the mixing-chamber, and made adjustable by a movable collar and handle between spiral springs. The handle on the igniter rod allows the electrodes to be readily cleaned

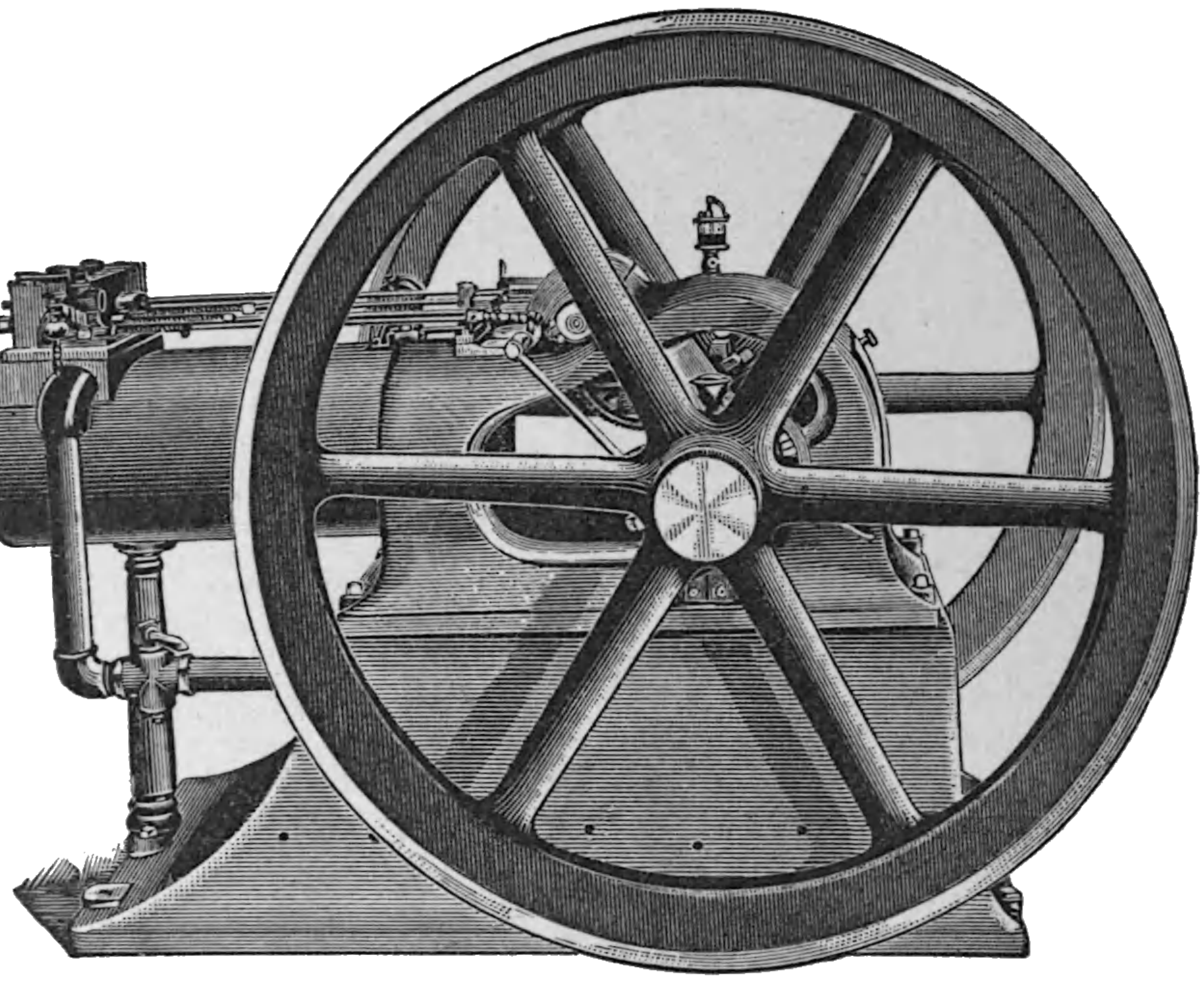


FIG. 99.—THE DAYTON ENGINE.

by vibrating the rod. The battery and sparking-coil is similar to those described with other engines. A match igniter for starting is also provided.

The Dayton is built in eleven sizes, from ½ to 50 H.P., and arranged for using natural and producer gas, illuminating gas, and gasoline.

The Victor Vapor Engine.

The engines of Thomas Kane & Co., are of the four-cycle compression type, with poppet valves, ignition by hot tubes or electric battery and double sparking-coil

Fig. 100 is a view of the engine as fitted for gasoline with hot-tube igniter, with one fly-wheel off to show the arrangement of the valve gear. A cam on the secondary gear drives the push-rod lever of the exhaust valve, which is held back by a spiral spring. The governor is of the horizontal centrifugal type, revolving on the main shaft, and by overspeed carries

the roller of the push-rod lever on to the governor eccentric, holding the exhaust valve open.

The gasoline pump forces the gasoline into a small cup over the vaporizer, with an overflow back to the gasoline tank. The gasoline is fed to the vaporizer by a small valve and sight-feed cup, and comes in contact with the hot air drawn from the exhaust heater, which is a casing placed around the exhaust pipe and connected with the vaporizer by a side neck at the top of the vaporizer.

Thus the gasoline coming in contact with the hot air from the heater on extended surfaces inside of the vaporizer is completely vaporized and mixed with the air to saturation before it enters the admission valve, which opens by the suction of the piston.

Any accidental surplus of gasoline that may enter the vaporizer will drop into an extension of the vaporizer below the engine feed pipe, and flow back to the gasoline tank. An indexed regulating valve in the vapor pipe near the admission valve serves to regulate the flow of saturated vapor to the admission valve, where it is mixed with a further portion of air drawn in by the piston to make a proper explosive mixture.

The electric igniter is entered through the walls of the exhaust-valve chamber, which is directly connected with the inlet-valve chamber. It makes a double spark by a revolving mechanism driven from the secondary gear wheel and is adjustable, so that a spark takes place, one just before and one just after final compression—this being one of the peculiar features of this engine, from which a high efficiency is claimed; the other being the thin cylinder walls, as devised by Mr. Pennington.

In Fig. 101 the same engine is shown ready for gas connection, the operation of which is the same as for gasoline, as far as the valve action and regulation is concerned.

The sizes of the "Victor" are at present of 2, 3¾, and 5 B. H. P.

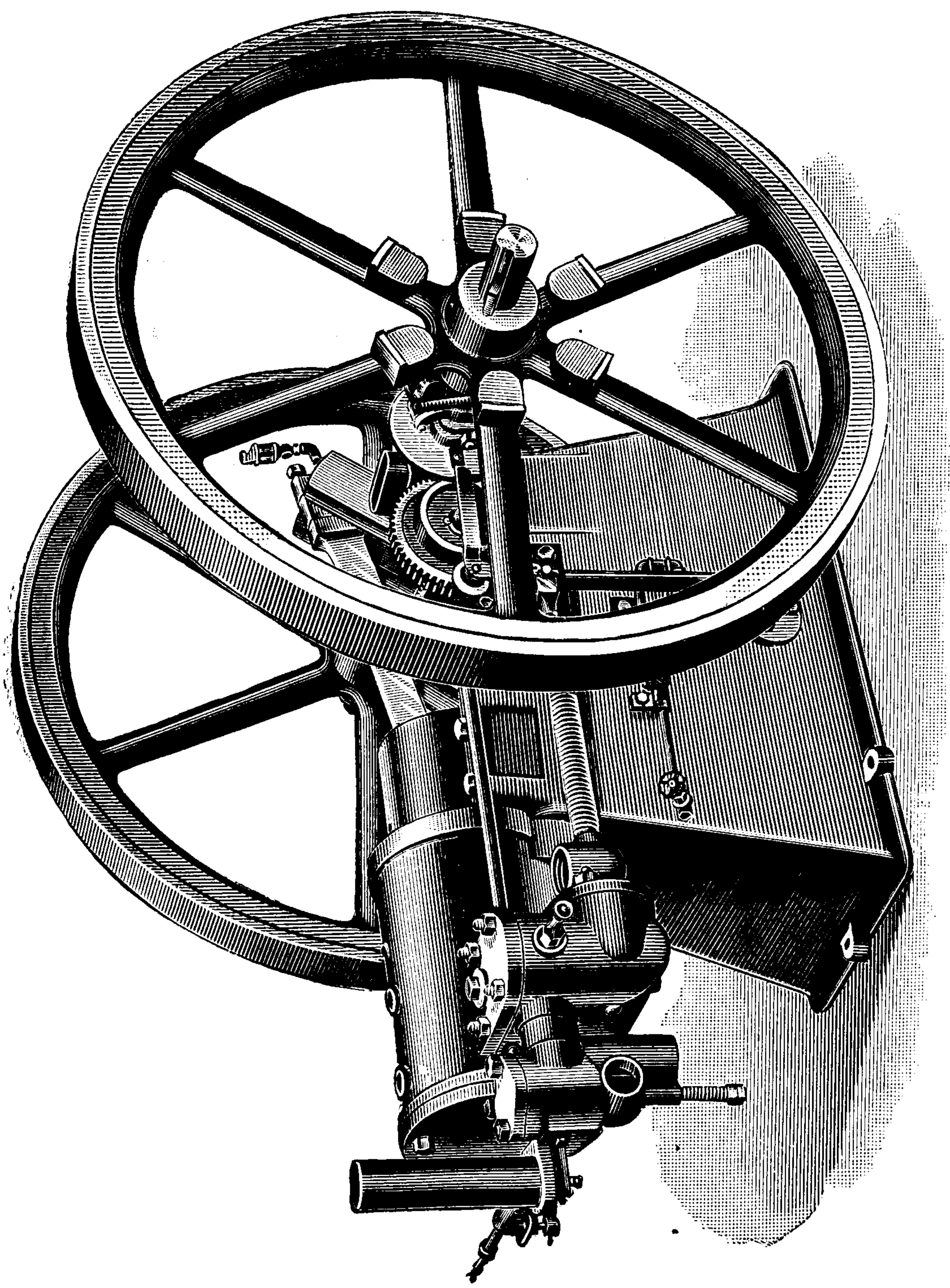


FIG. 101.—THE VICTOR VAPOR ENGINE AS ARRANGED FOR GAS.

The Wolverine Motor.

The engines of the Wolverine Motor Works are in the vertical style, for both stationary and marine power, as also for car-motor service. They are of the two-cycle and four-cycle compression type, with poppet and cylinder port valves. The stationary engines are for gas or gasoline of any grade from

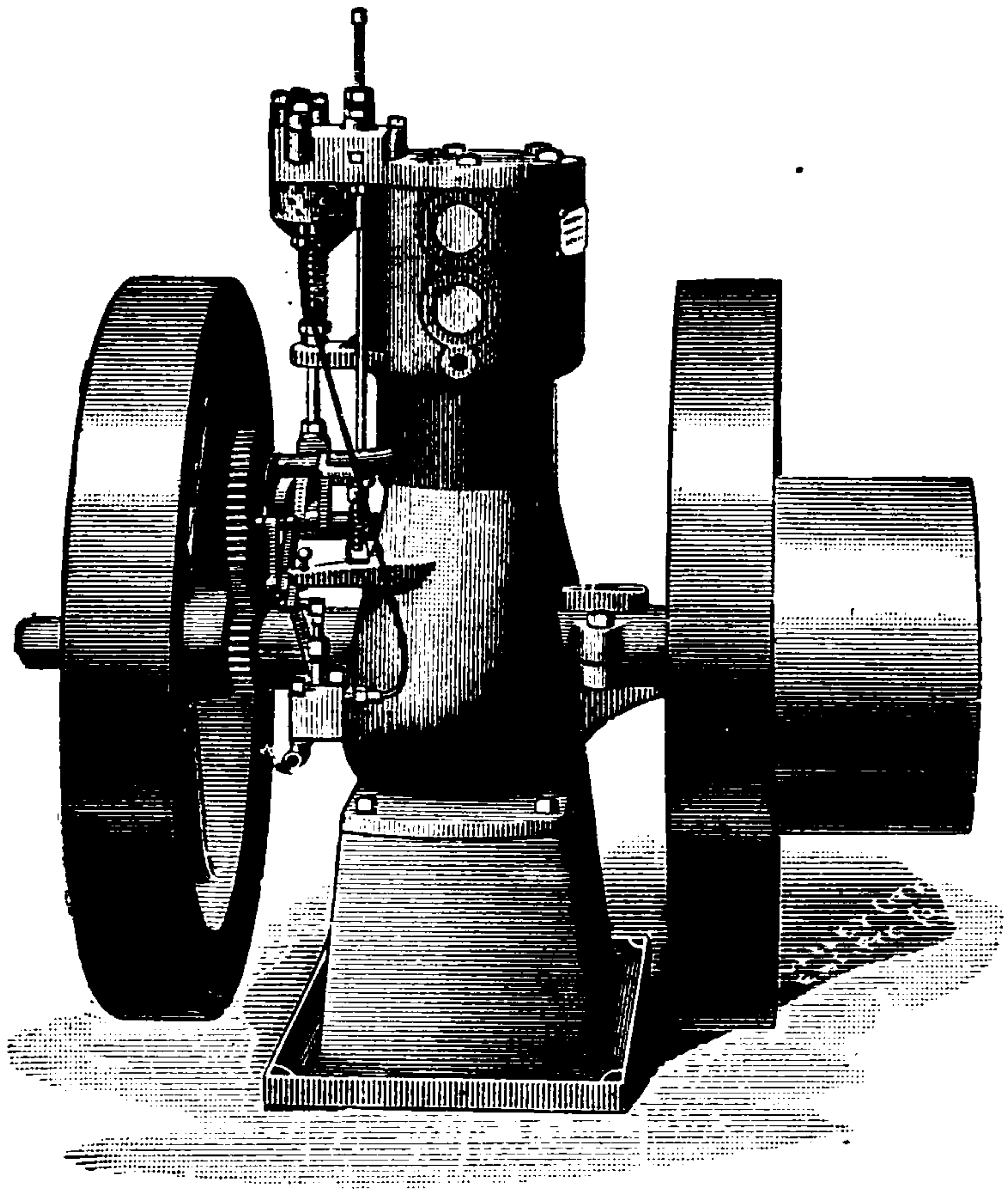


FIG. 102.—THE JUNIOR STATIONARY.

.63 to .76 gravity. The marine engines use an injection of gasoline fluid into an air chamber, from which the vapor-and-air mixture is drawn into the closed crank chamber by the upward stroke of the piston.

The junior stationary engine (Fig. 102) is of the four-cycle class, taking its charge of gas or gasoline by the suction of the piston, compressing by the upward stroke, and exploding by a tube or electric igniter. The gasoline pump as shown in the cut is operated by a bell-crank lever and roller running on an eccentric on the secondary gear. The exhaust valve is operated from a cam also on the secondary gear. The speed is

of the up-stroke the charge of explosive gas is exploded by an electric spark, which drives the piston down. When the piston is near the end of the down-stroke it uncovers an annular port on the side of the cylinder which permits the exhaust to escape, and immediately after the exhaust port opens, the port in the cylinder head is opened, admitting a new charge, at the same time driving the balance of the exploded charge out of the exhaust port. This is repeated at every revolution.

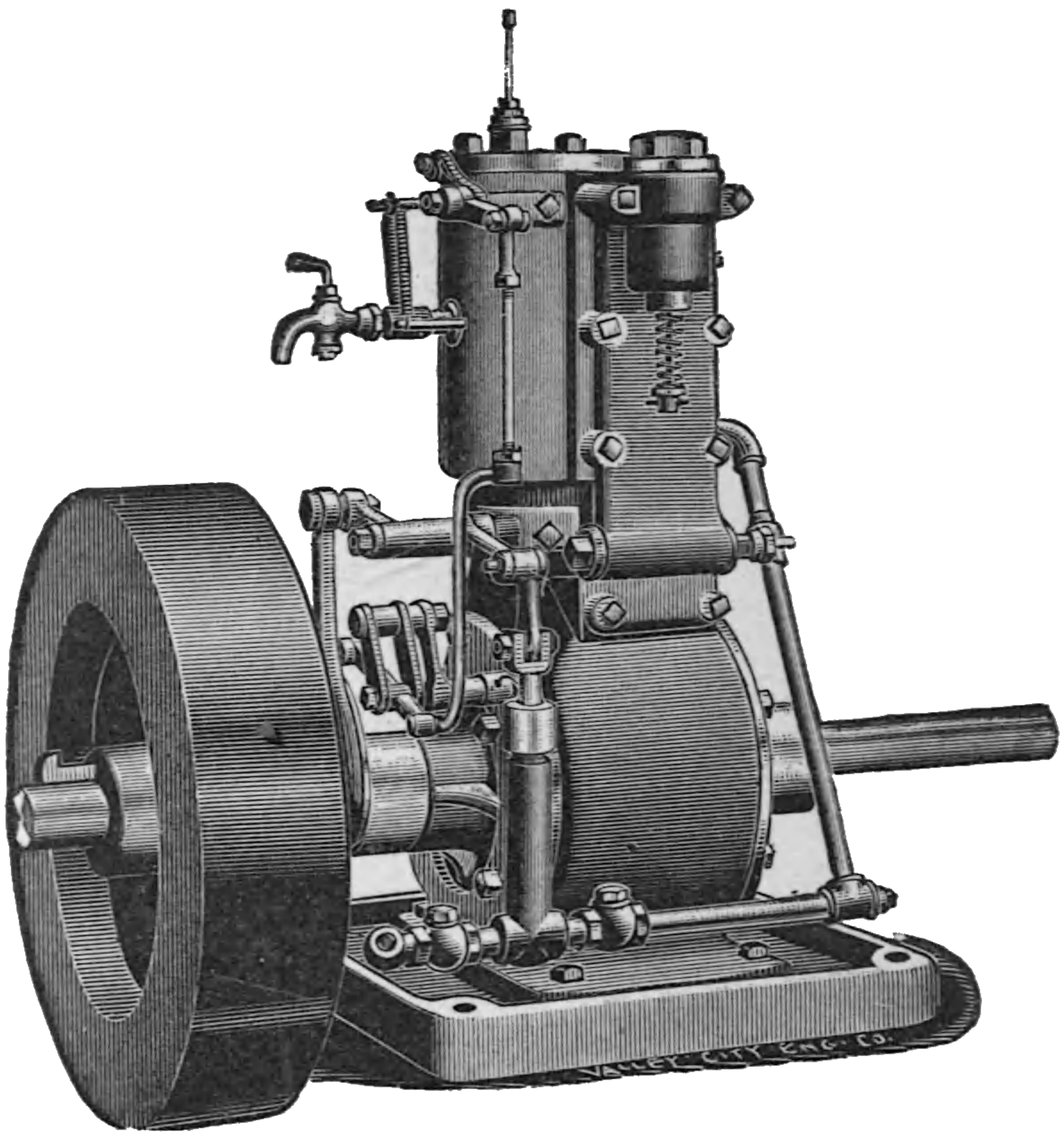


FIG. 104.—THE MARINE ENGINE.

The stationary engines are made in sizes of ¾, 1, 2, and up to 12 H.P.

In Fig. 104 is illustrated the Wolverine single-cylinder marine engine. Its principles of action are the same as in the stationary engine, with the addition of a water-circulating pump driven from an eccentric, through a rock shaft; a reversing gear by which the motion of the engine is reversed, the same as with marine steam engines. It is reversed while running, and requires no handling of the fly-wheel for reversal. It is made in sizes of ¾, 1, 2, 4, and 6 H.P., with boat shaft and propeller complete.

In Figs. 105 and 106 are illustrated the double-cylinder marine engines of this company. The eccentric on this engine operates the water pump and exploders for both cylinders, both for the forward and backward gear.

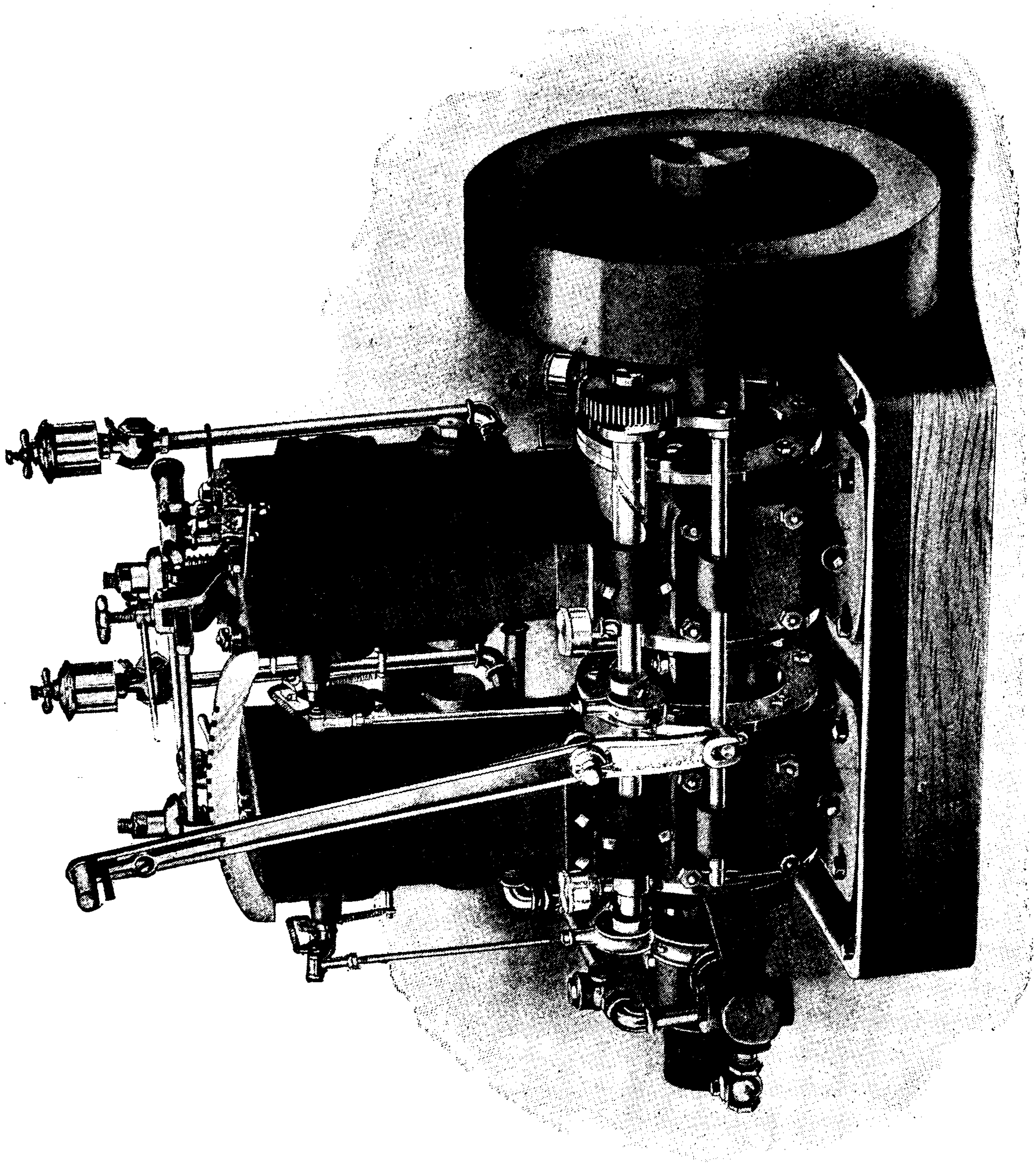
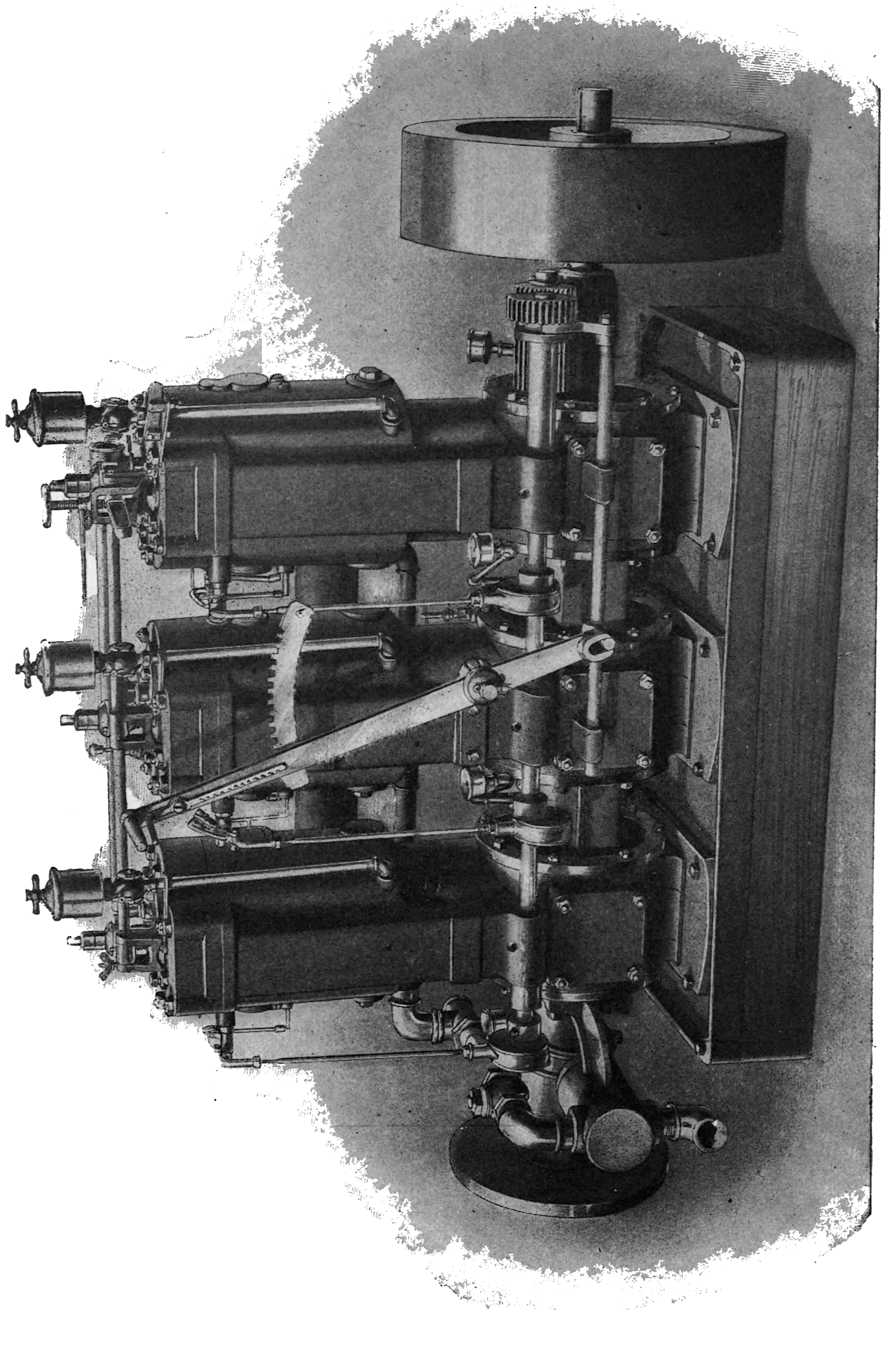


FIG. 105.—THE WOLVERINE DOUBLE MARINE ENGINE—FRONT VIEW.

The generator is a pipe with an open fitting containing an air-check valve and a needle valve for adjusting the gasoline injection. The generator pipe leads to each crank shaft chamber, with a light check to each opening to prevent back draught from one cylinder to the other by the alternate strokes of the



electrodes are located in the head of the cylinder, with its sparking-device operated by the exhaust-valve push-rod through a second push-rod and arms.

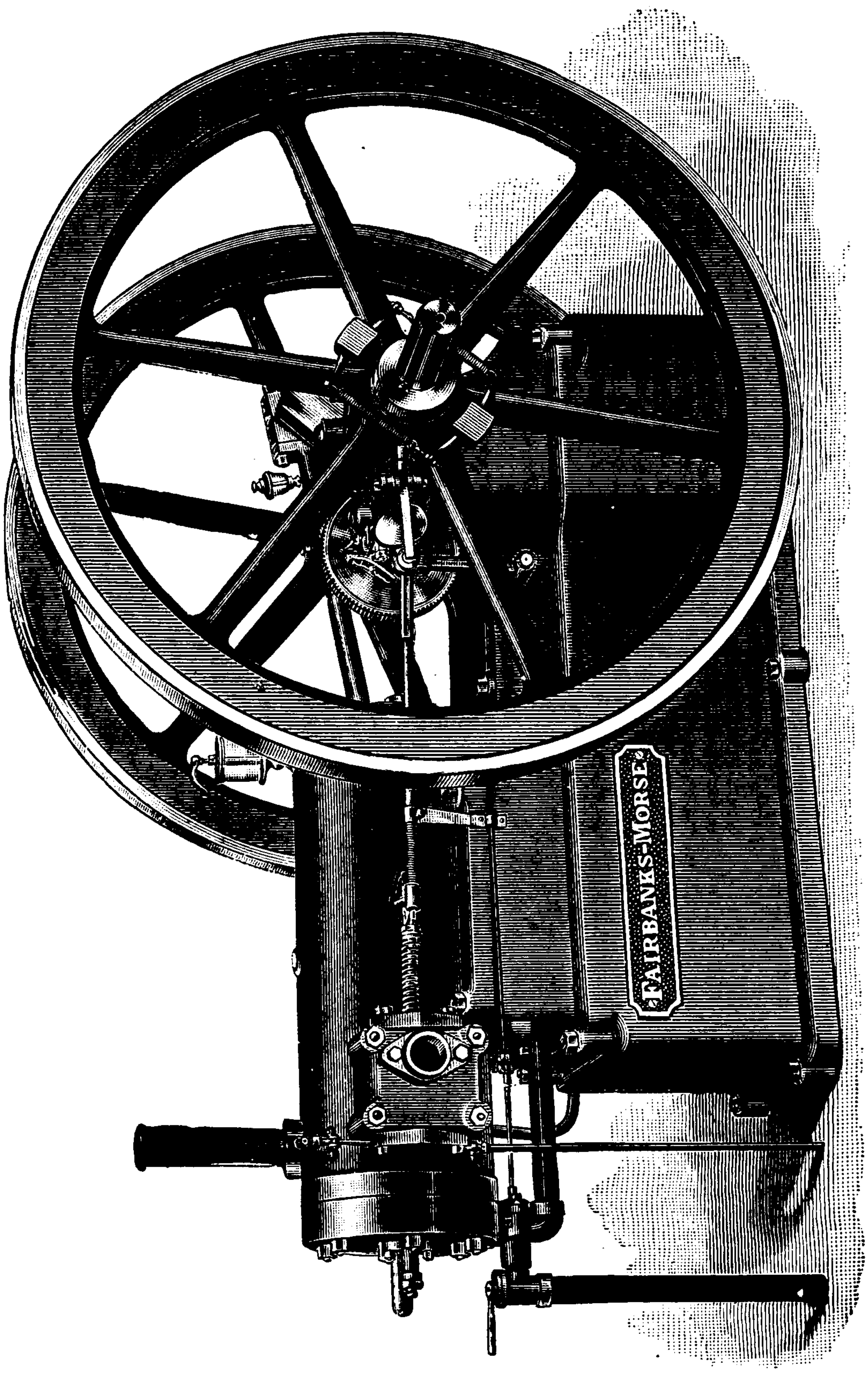


FIG. 107.—THE FAIRBANKS-MORSE GAS ENGINE.

The engine as arranged for gas is shown in Fig. 107.

The gasoline engines (Figs. 108 and 111) of various sizes represent the arrangement for gasoline. They have a gasoline pump attached to the base of the engine directly under, and driven by a crank pin on the face of the exhaust eccentric. The pump drawing a supply from a tank placed in a safe place below the level of the pump, discharges into a small reservoir (P in Fig. 109, and also shown in the cylinder heads of Figs. 108 and 110), and overflows the surplus back to the tank. A small valve K in the reservoir P regulates the flow of gasoline to the mixing-chamber. In the air pipe is a nozzle leading to the reservoir P, and the ingoing air draws from the nozzle the proper amount of gasoline to form a perfectly combustible mixture of gasoline and air.

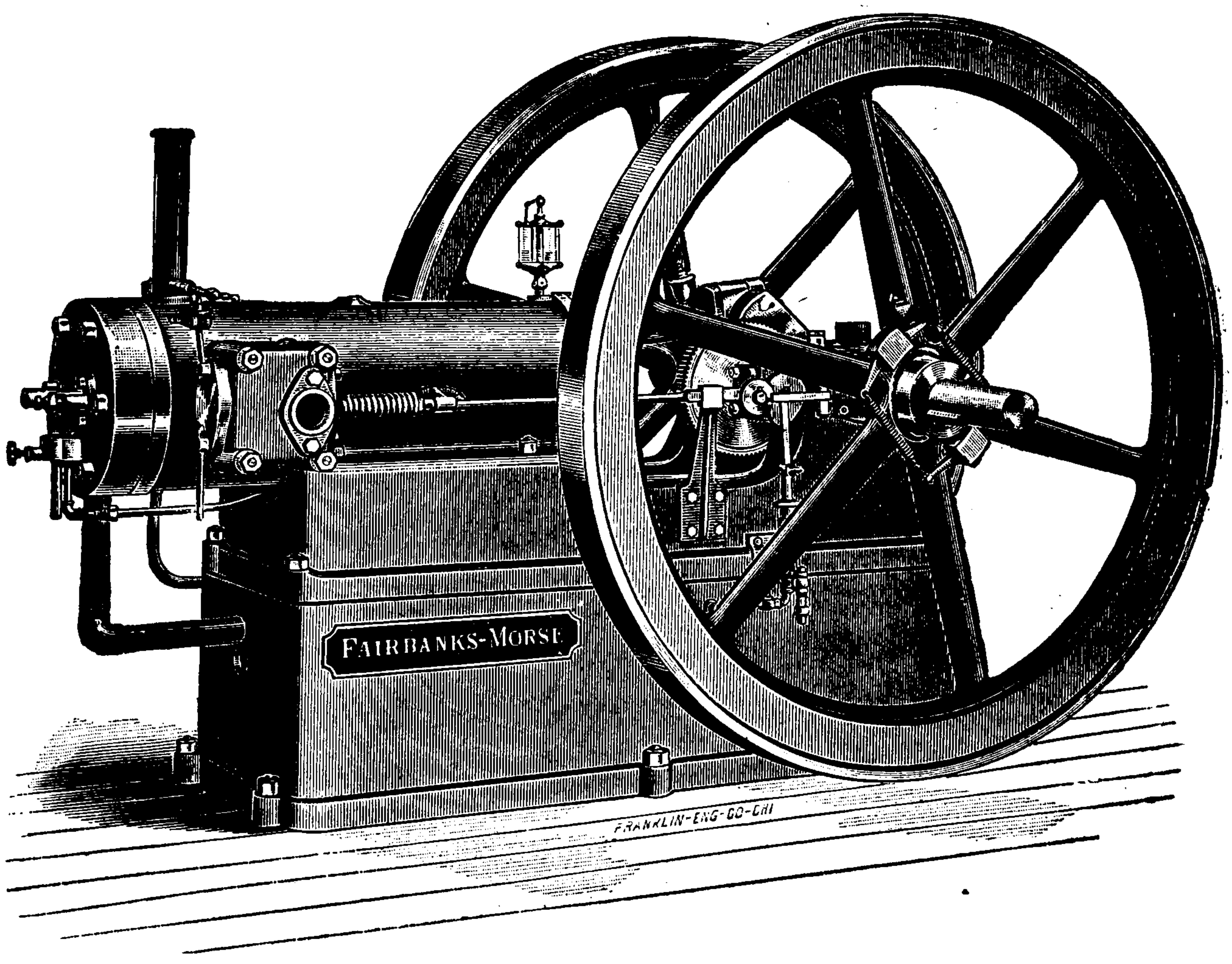


FIG. 108.—THE FAIRBANKS-MORSE GASOLINE ENGINE, 3 TO 5 H.P.

Each suction of the engine draws up fresh gasoline from the reservoir P, and always the same quantity, as controlled by the supply or throttle valve K.

The self-starting devices are shown in Figs. 111 and 112, and consist of a small hand air-pump for medium-sized engines,

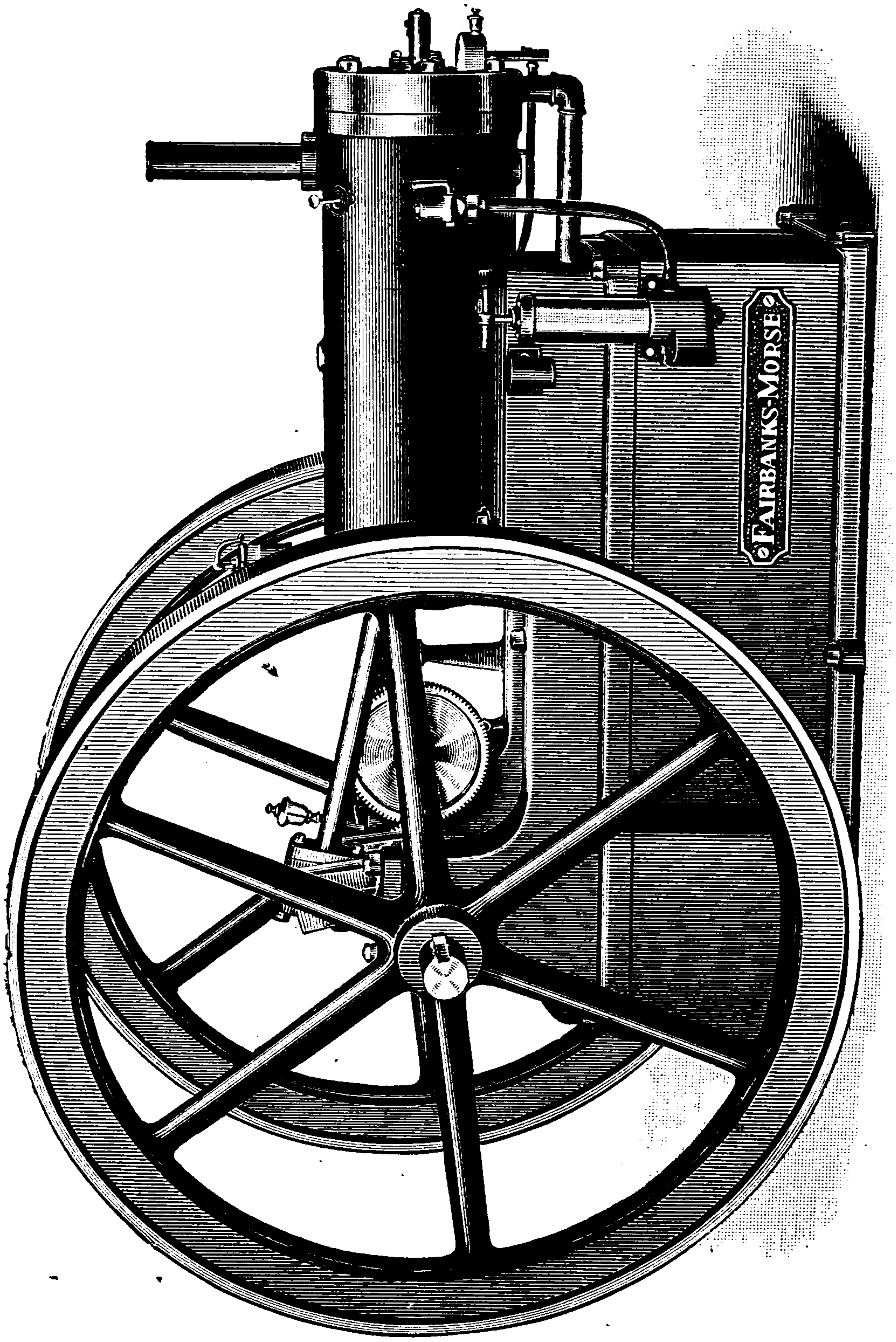


FIG. 111.—THE GASOLINE ENGINE, SHOWING THE SELF-STARTER CHARGING-PUMP.

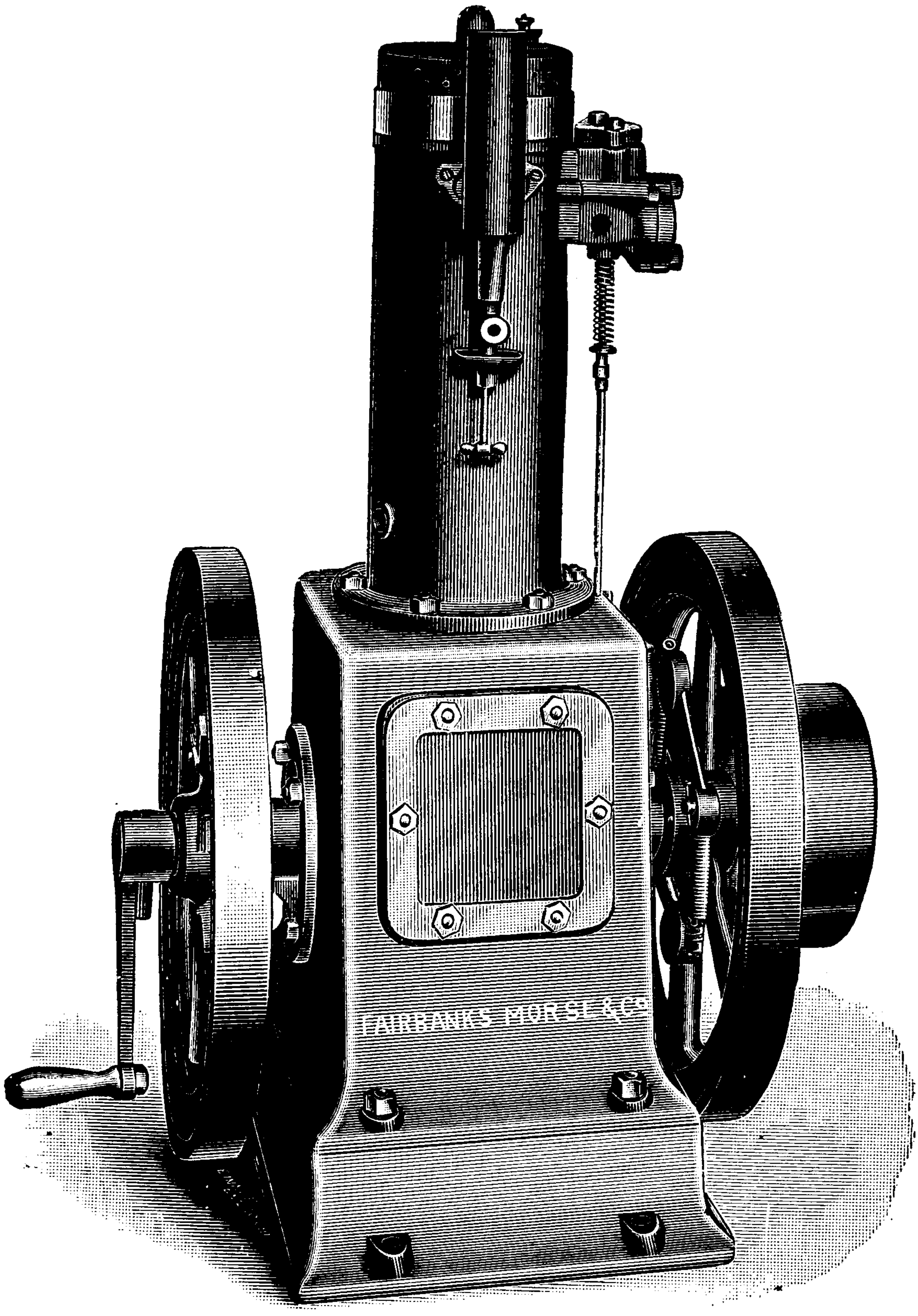


FIG. 113.—THE VERTICAL ENGINE, SHOWING RATCHET CRANK FOR STARTING ENGINE.

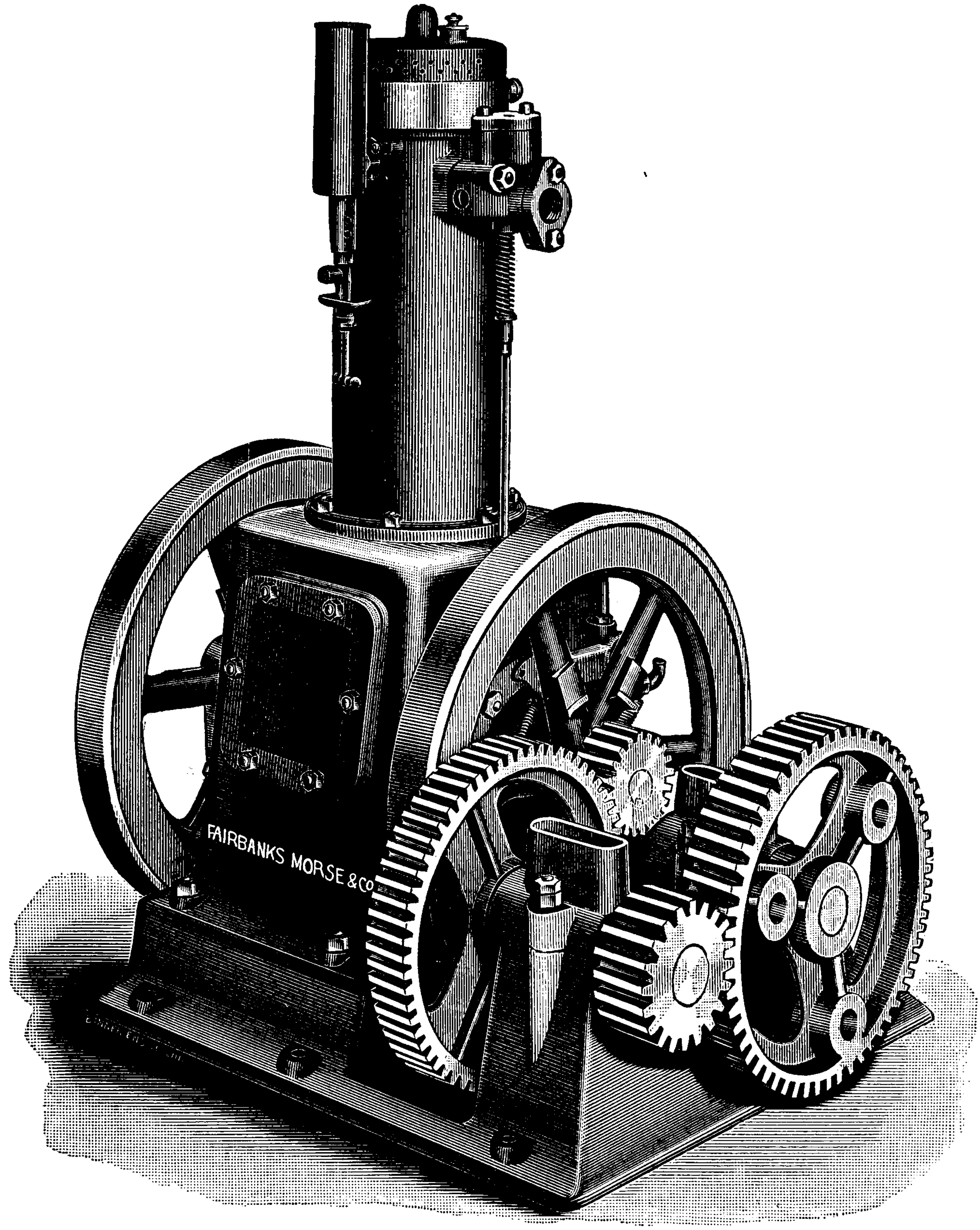


FIG. 114.—THE VERTICAL GEARED ENGINE ON ONE BASE FOR PUMPING AND HOISTING.

and a hand crank pump on the larger size attached to the base of the engine. A small receptacle in the base of the pump is charged with gasoline of sufficient quantity for a single engine charge. The operation of the pump then charges the cylinder, and a match exploder fires the charge.

The small vertical engines of this company are illustrated in Figs. 113 and 114, for power and pumping purposes.

The bearings, crank, and valve gear are enclosed in the base and run in an oil bath, so that the piston and other moving parts are perfectly lubricated by the dash of the crank.

Fig. 113 shows the ratchet crank for starting the engine, and Fig. 114 shows the geared engine on one base as used for pumping or hoisting.

The Ruger Gas and Gasoline Engine.

The Ruger gas and gasoline engines are built in the vertical style, as in Fig. 115, of 1, 2½, 5, and 8 B.H.P.; and in the horizontal style, of 10, 15, 20, 25, 30, 35, and 50 B.H.P. They are of the four-cycle compression type; are arranged for gas, gasoline vapor or liquid, natural and producer gas. The gas engines have three poppet valves in two valve chambers, and the gasoline engines have only two poppet valves in one valve chamber.

Any of the valves can be quickly removed, cleaned, and replaced by the unscrewing of a plug. The adjustments are simple, and the ignition by hot tube or electric spark, as desired.

The governing is accomplished by controlling the exhaust valve; that is, holding it open when the speed is above the normal. The governor is located in the secondary gear, and by its centrifugal action retards the closing of the exhaust valve—thus relieving the piston from doing work by com-

pressing idle charges of air when the engine is running light.

The large sizes for electric lighting are built double, with impulse at every revolution of the shaft. For 30 H.P. and over, a self-starting device is provided. The gasoline pump is driven by an adjustable lever and rod operated from a cam on the reducing-gear.

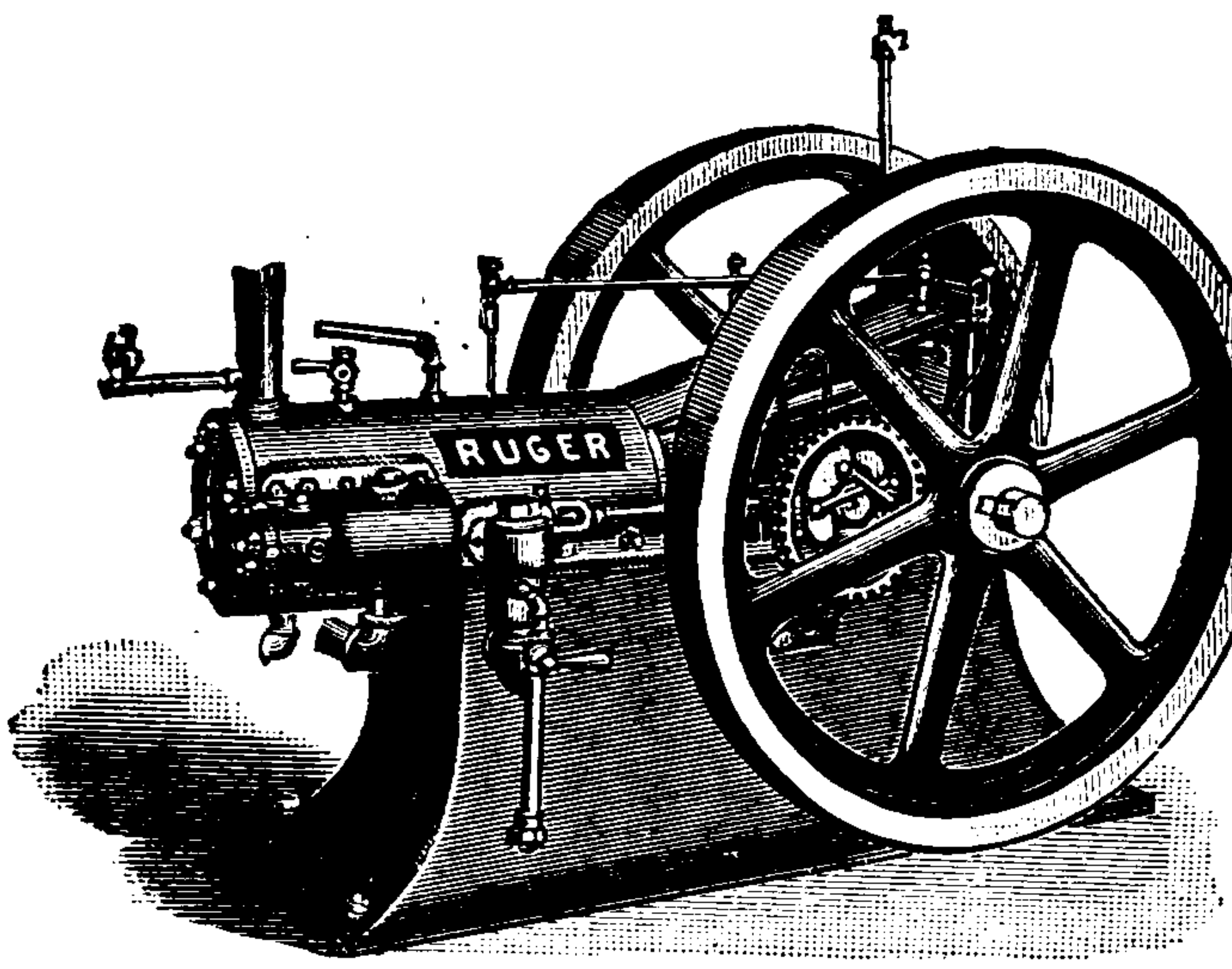


FIG. 117.—THE RUGER, 10 H.P.

The pumping engines are vertical, and carry the pump and gear on the same base.

The igniting device is hot tube or electric, as preferred.

A special starting-device is furnished with the large engines.

The American Gas Engine.

The American Gas Engine Company have the control of the American patents of the Griffin gas engines, and of Dick Kerr & Co. of London, and Kilmarnock in Scotland. The Western Gas Construction Company are the manufacturers of these engines in all the patterns as made in Europe.

In Fig. 118 is illustrated their four-cycle compression engine, with poppet valves operated from a longitudinal cam shaft driven by spiral gear—the gas and air inlet entering

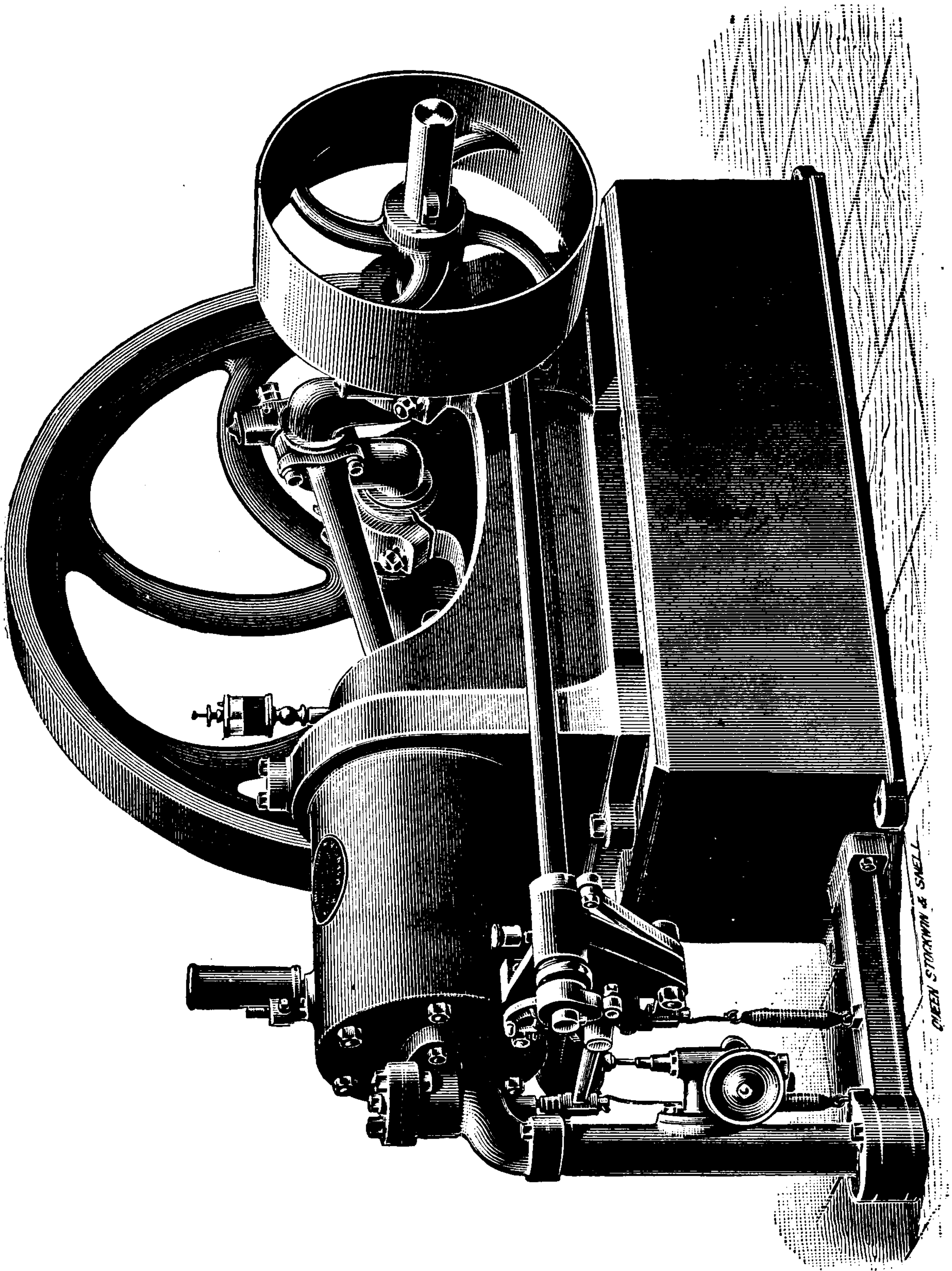


FIG. 118.—THE AMERICAN GAS ENGINE.

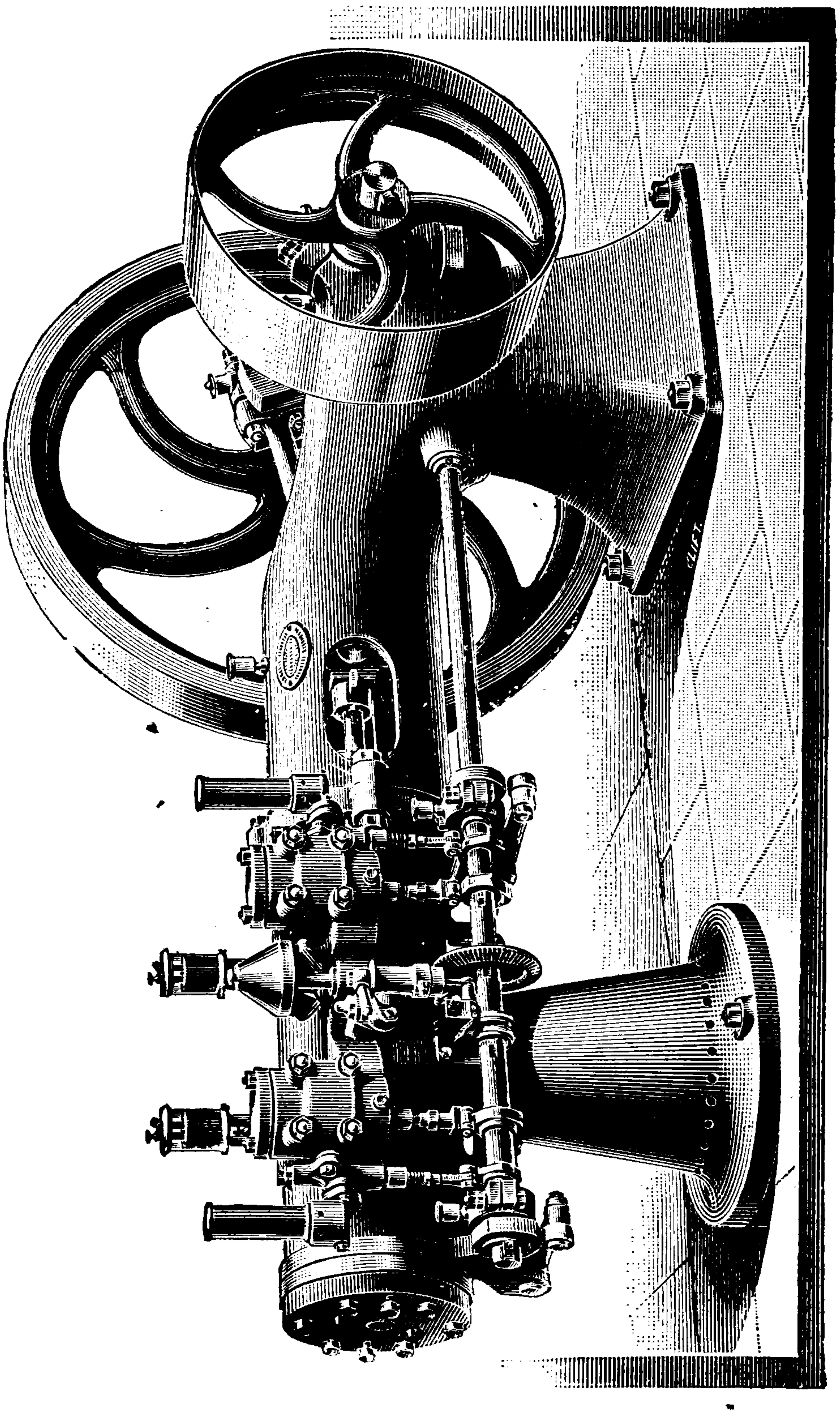


FIG. 119.—THE AMERICAN DOUBLE-ACTION GAS ENGINE.

of the engine as made in England, showing the water-cooling jacket around the piston rod.

As a double-acting engine using the fourth stroke of the piston each way as an impulse stroke, it makes the action of the engine equivalent to a two-cycle type for steadiness of running. The single-acting engines are made in six sizes, from $1\frac{1}{2}$ to $11\frac{1}{4}$ B.H.P. The double-acting engines are made also in six sizes, from 4 to $18\frac{1}{2}$ B.H.P.

The Vreeland Gas Engine.

This engine is designed in the four-cycle compression type, with the principal exhaust through ports in the cylinder, un-

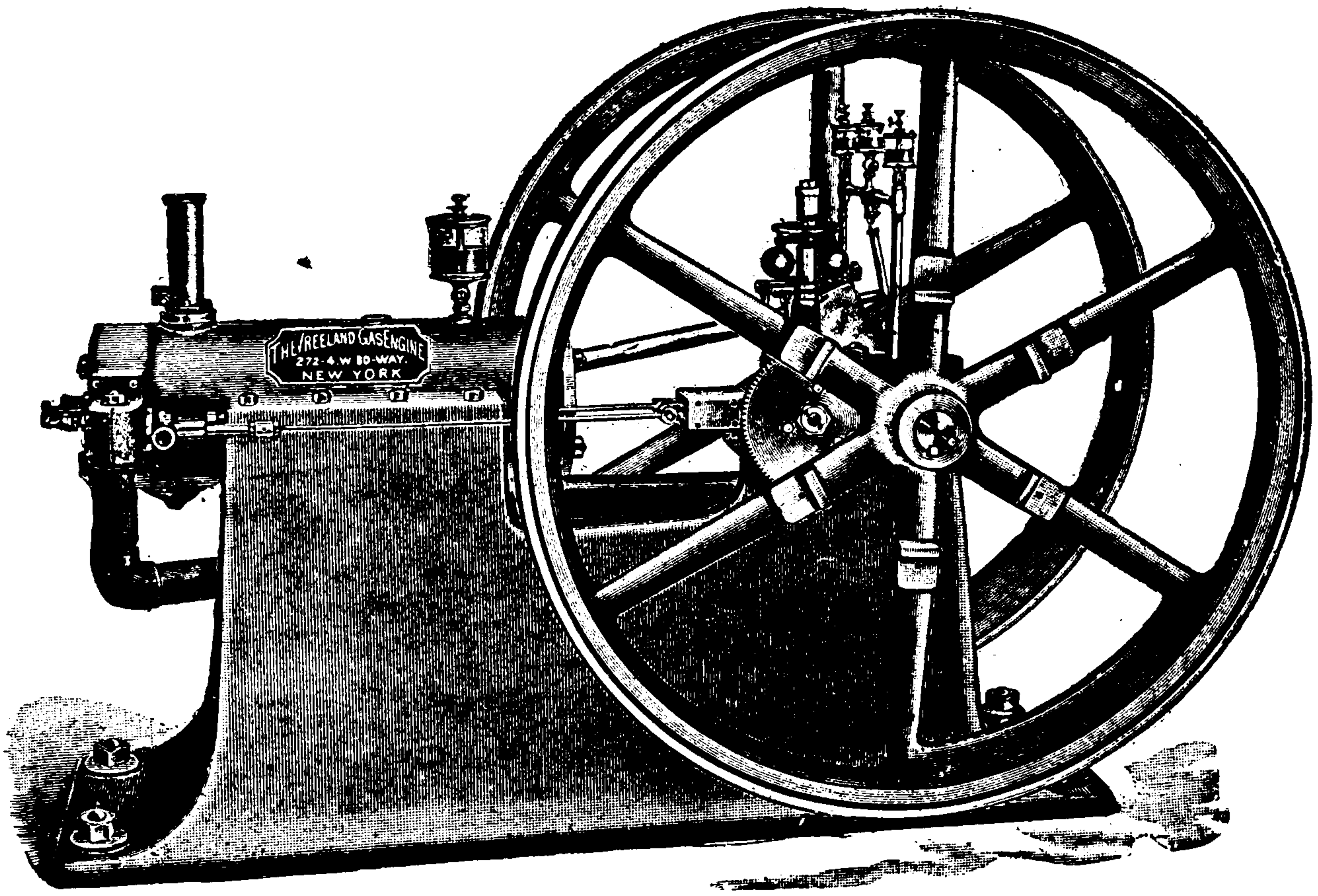


FIG. 121.—THE VREELAND GAS ENGINE.

covered by the piston at the end of the explosive stroke. It has also a supplementary exhaust valve in the head of the cylinder for completing the exhaust by the return stroke. The supplementary exhaust valve is operated by a lever across the cylinder head and a push-rod moved by a cam on the reducing gear.

The supplementary exhaust valve has a free communication by a pipe with the main exhaust. Both the cylinder and cylinder head have a water-cooling circulation. An independent push-rod from the gas-valve stem to a cam on the reducing-gear is controlled in its motion by the lateral movement of a roller, which is actuated through a bell-crank lever from the centrifugal ball governor. The governor is on a vertical spindle driven by a bevel gear attached to the reducing-gear—thus making a mischarge at the moment that the speed exceeds the normal adjustment of the governor.

Ignition is by hot tube on top of the combustion chamber.

A relief cock at mid-stroke facilitates easy starting. These engines are built in seven sizes, from 2 to 20 B.H.P.

The Backus Gas Engine.

The engines of the Backus Water Motor Company are built in the horizontal and vertical styles, as illustrated in Figs. 123 and 124. The horizontal engines are built in fifteen sizes,

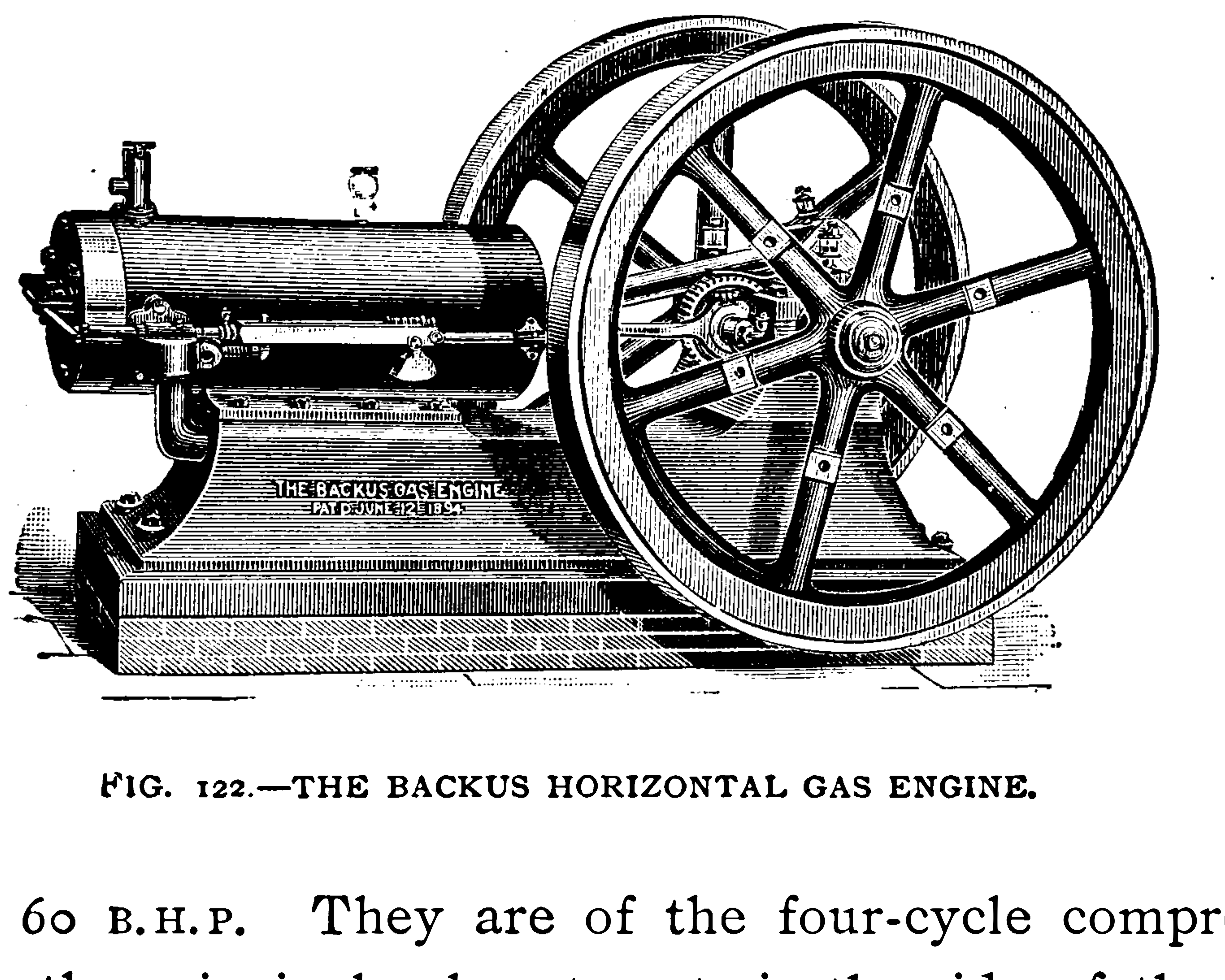


FIG. 122.—THE BACKUS HORIZONTAL GAS ENGINE.

from 5 to 60 B.H.P. They are of the four-cycle compression type, with the principal exhaust ports in the side of the cylinder opened by the piston at the end of the impulse stroke. They have also a supplementary exhaust valve in the cylinder head, with its exhaust passage connecting with the main exhaust. The exhaust push-rod is operated by an eccentric on the reducing-gear shaft, and carries a pendulum governor pivoted in the square box seen in the illustrations of the horizon-

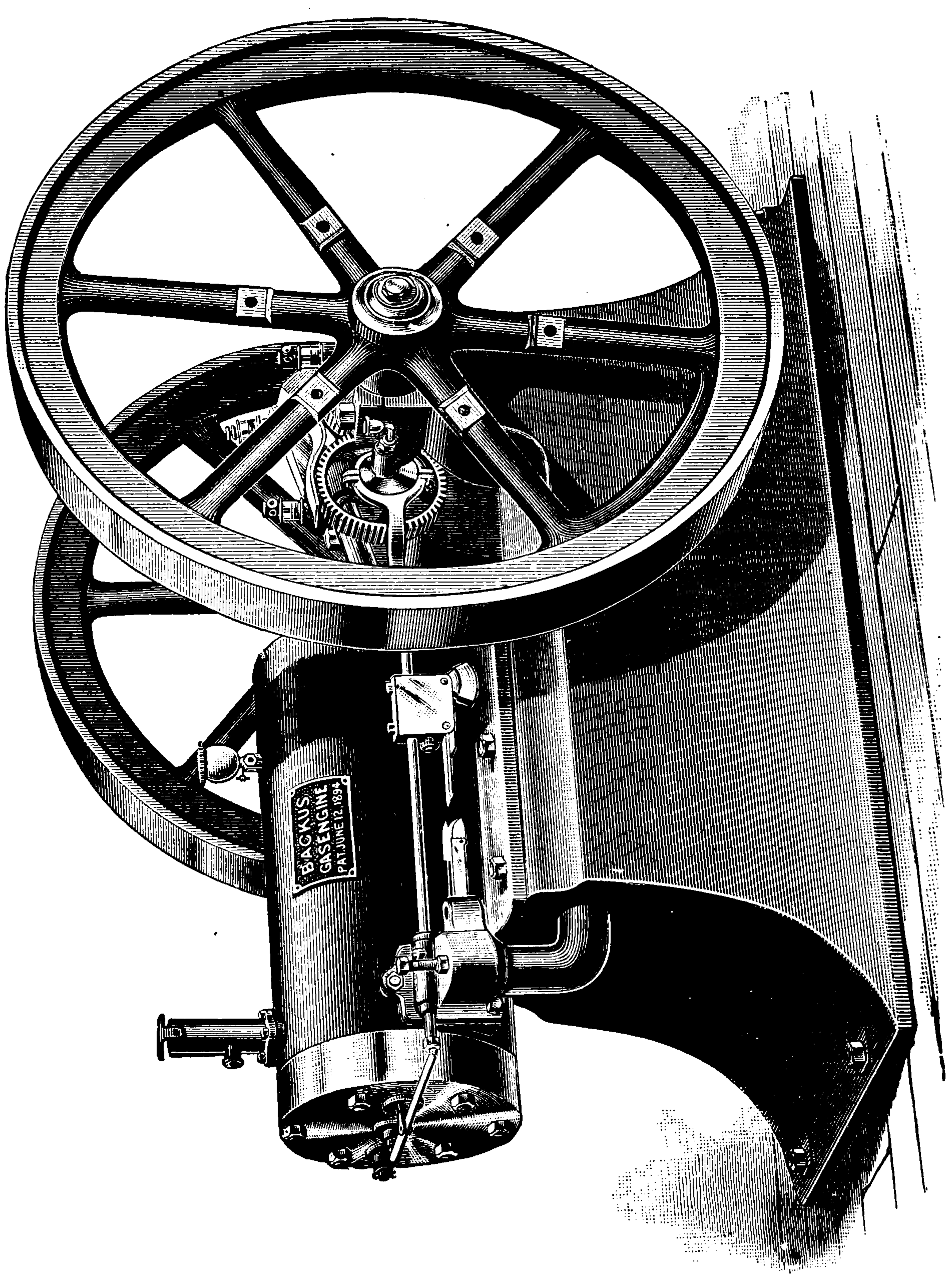


FIG. 123.—THE BACKUS GAS ENGINE.

tal engines (Figs. 122 and 123). The push-blade of the governor is pivoted in the same box as the pendulum, with one end loosely locked in a Y-extension of the pendulum. The adjustment can be made while the engine is running, by a small

ing-gear, while the gas valve is governed by a centrifugal governor in the pulley. The governing is by limiting or shutting off the gas, but the general regulation is made by an index valve. The gas inlet is through the air-inlet valve seat, so that when the engine stops the air valve closes the gas inlet by the

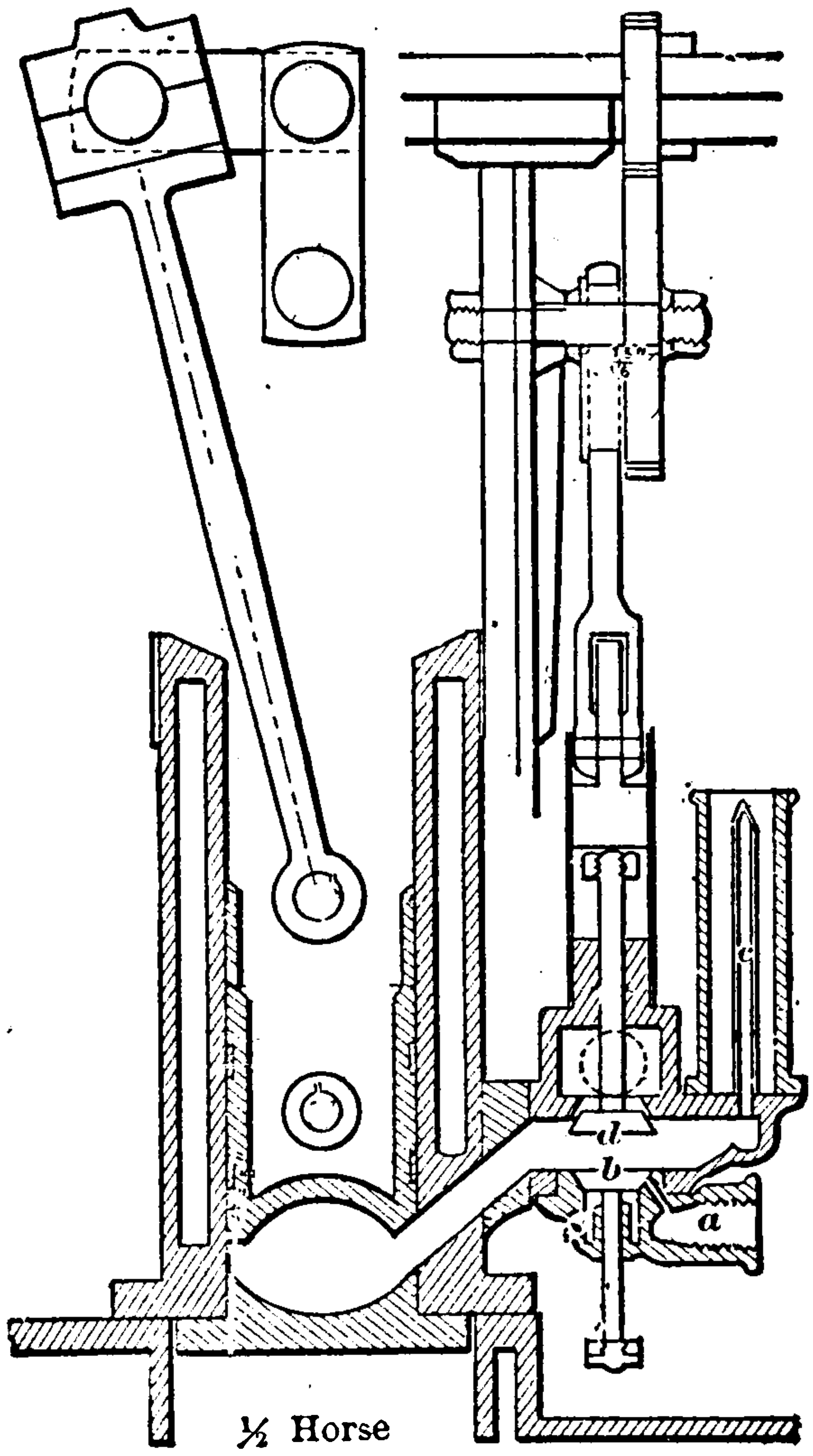


FIG. 125.—VERTICAL SECTION OF THE BACKUS GAS ENGINE.

action of its spiral spring, which is not shown. This is independent and automatic, and prevents the escape of gas by leaving the gas valve open.

The concave piston and cylinder head are shown in the cut; the gas inlet at *a*, combined gas-and-air valve at *b*, and the exhaust valve at *d*.

The Hartig Gas Engine.

The engines of the Hartig Standard Gas Engine Company are all made in the vertical style for gas or gasoline vapor, from a carburetter that gives a saturated air-vapor mixture, which is not explosive until a further admixture of air in the mixing-chamber of the engine completes its explosive quality.

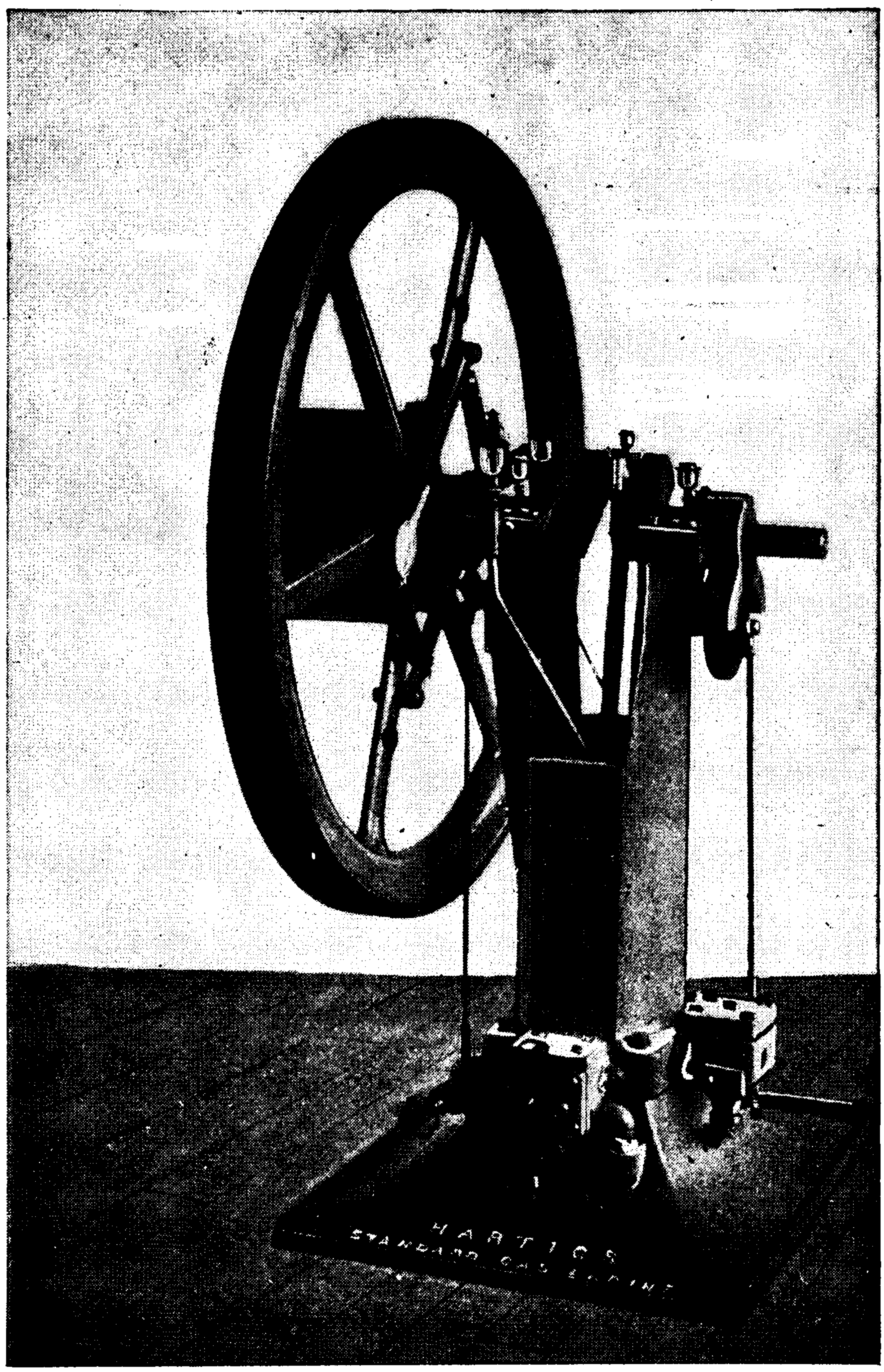


FIG. 126.—THE HARTIG GAS ENGINE.

The engines are of the four-cycle compression type; ignition by hot porcelain tube or electric spark, and time igniter for the hot tube. The valves are of the poppet type. The exhaust valve is operated from a reducing-spur gear by crank pin, rod, and lever. The governor is of the centrifugal lever type, connected to a cam sleeve that has a circular motion by the movement of the balls, and a longitudinal motion by a spiral slot in

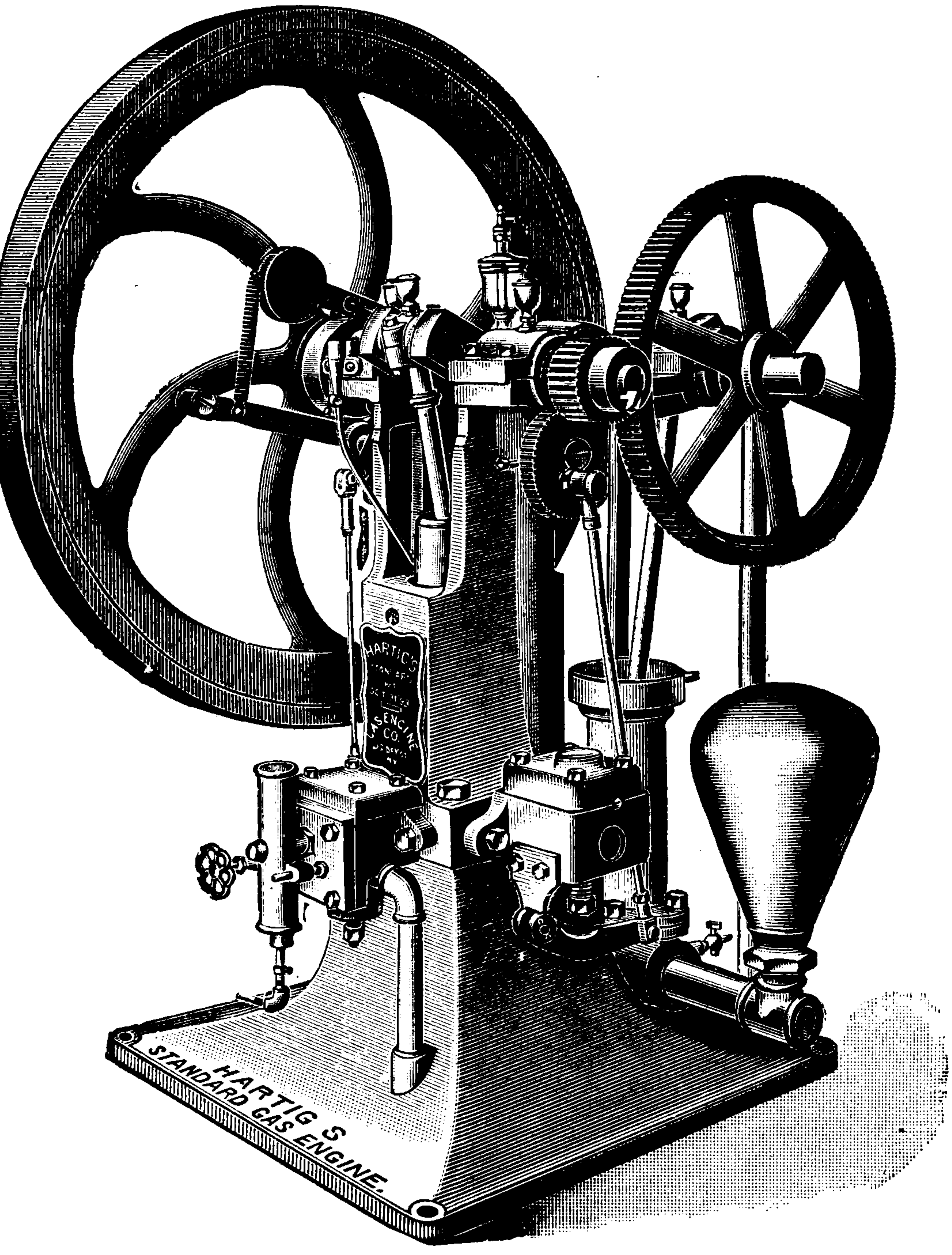


FIG. 127.—THE HARTIG PUMPING ENGINE.

the sleeve moving over a fixed pin in the main shaft. By this means the longitudinal movement of the sleeve rides the push-rod roller of the gas valve on to or off the cam, in such a way as to graduate the gas charges to meet the speed emergency.

The adjustment of the governor is made by spiral springs holding the balls in the position for normal speed

sizes from 2 to 15 B.H.P., is of the four-cycle compression type, mounted on a substantial iron base. The valves are of the poppet type, the exhaust valve being operated by a cam on the reducing-gear, and a roller disc on a lever actuating a second

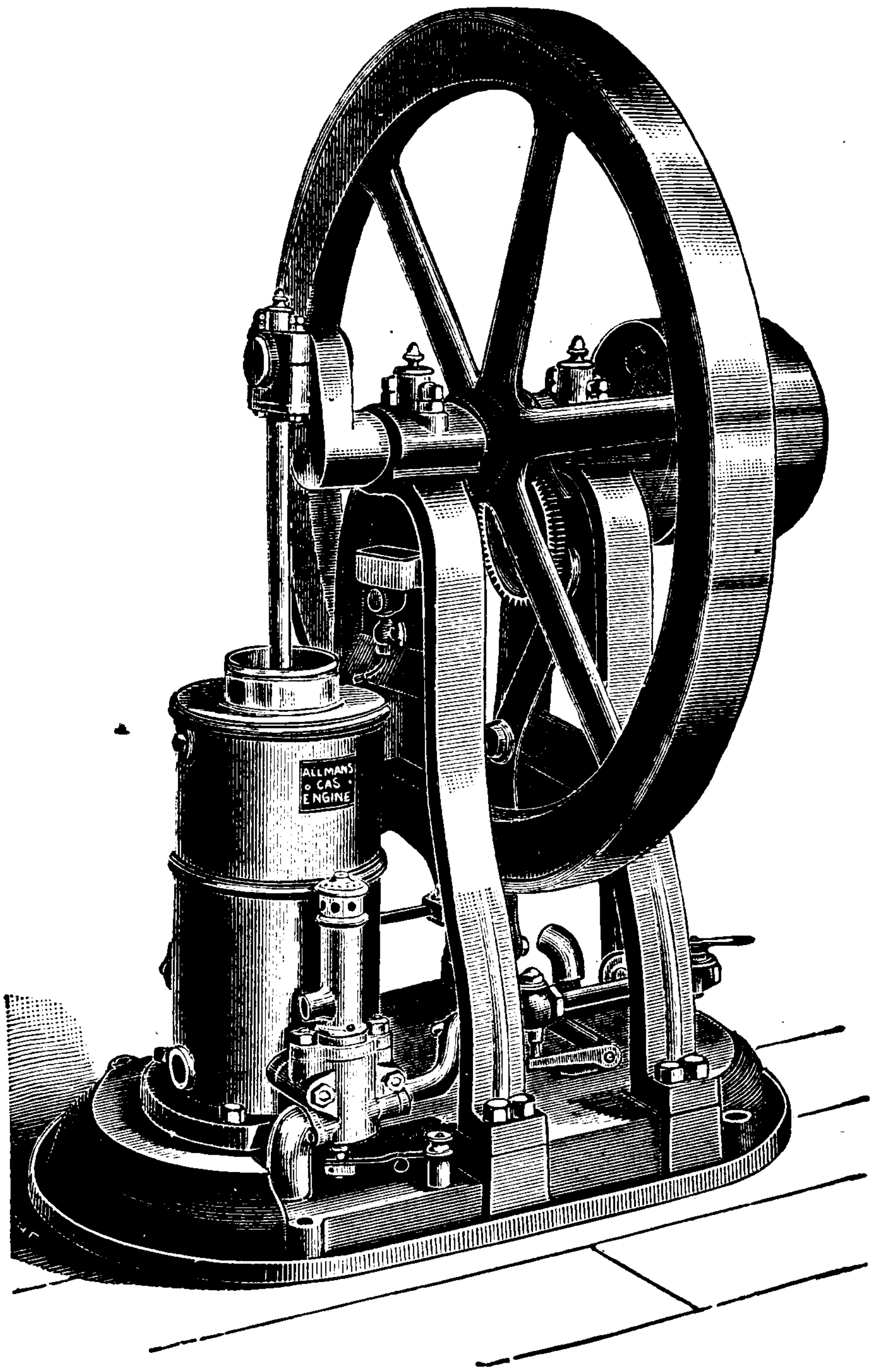


FIG. 129.—THE ALLMAN VERTICAL.

lever at the valve stem through a connecting rod. The governor is a novel application in its adaptation to both governing and in balancing the crank motion.

The block shown on the hub of the fly-wheel (Fig. 128) is the frame plate of the governor, which supports a radial pin on which slides a rectangular block of steel, with angular grooves on each side, in which the pins of a yoke lever slide by the centrifugal action of the steel block.

The other end of the yoke lever has also a yoke that straddles the sliding-sleeve on the main shaft, in which are pins en-

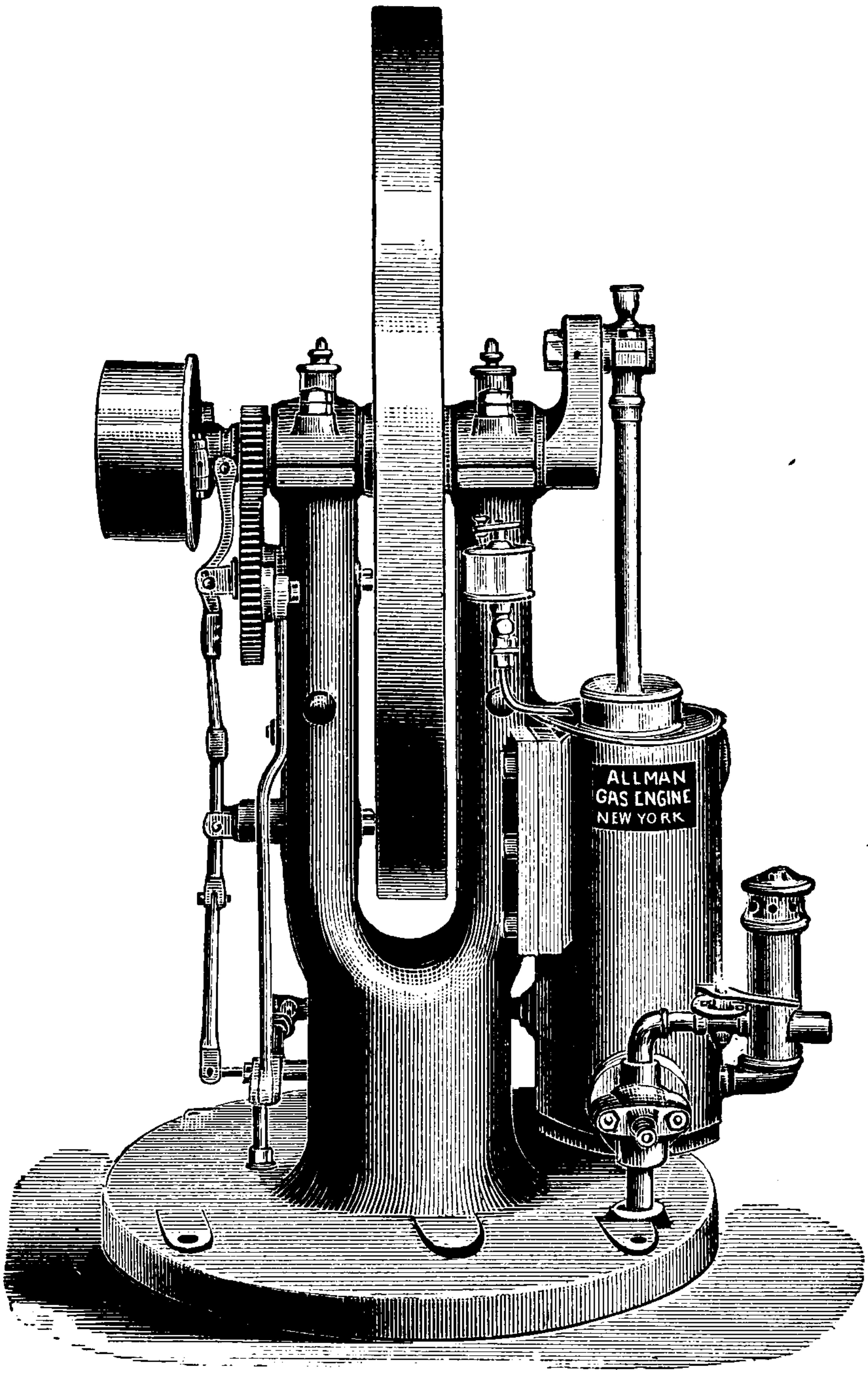


FIG. 130.—THE ALLMAN VERTICAL, ¾ H.P. ACTUAL.

tering a groove in the sleeve, and thus by the centrifugal action of the sliding steel block controls the movement of the sleeve in the direction of the axis of the shaft.

At the outer end of the radial pin, a spiral spring adjusted by a nut and check nut holds the steel sliding-block to the proper position at the normal speed of the engine. By the adjustment of the tension of the spring, the governor controls the engine at any desired speed.

A second groove in the sliding-sleeve operates a yoke lever and bell crank, touching the gas-valve stem with an adjusting screw—thus regulating the gas charge volume or cutting off as required.

The vertical engine, of this company (Fig. 129) are made on the same general principles as the horizontal type, and of 2, 3, and 4 B.H.P.

The governor on the vertical engine is of the horizontal, centrifugal ball type, with bell-crank movement of a sleeve on the main shaft—the governor being located in the pulley.

The lever, which is operated by a groove in the governor sleeve, extends down to and ending with a roller disc that rides on an adjustable wedge, resting on the arm of a rock shaft, the opposite arm of which lifts the gas-valve stem.

The range of travel of the push-roller on the wedge is limited by the governor, and thus makes a variable charge of gas.

The smallest size vertical of $\frac{3}{4}$ B.H.P. (Fig. 130) are constructed on the same general principles as the larger engines, but with a pedestal and base in one solid piece. The governing is in the same line as described for the larger vertical engines, but is applied to the exhaust valve, which is made to open partially or fully, or remain closed for regulating the speed—the wedge action for the exhaust valve being the same as for the gas charge in the other engines.

The Nash Gas Engine.

The Nash engines are built by the National Meter Company. They are of the vertical style, in nine sizes from $\frac{1}{3}$ to 10 H.P. with single cylinders; and in ten sizes from 10 to 200 H.P. with double and quadruple cylinders. The smaller engines are of the two-cycle compression type, taking an impulse at every revolution in each cylinder, thus making the action of

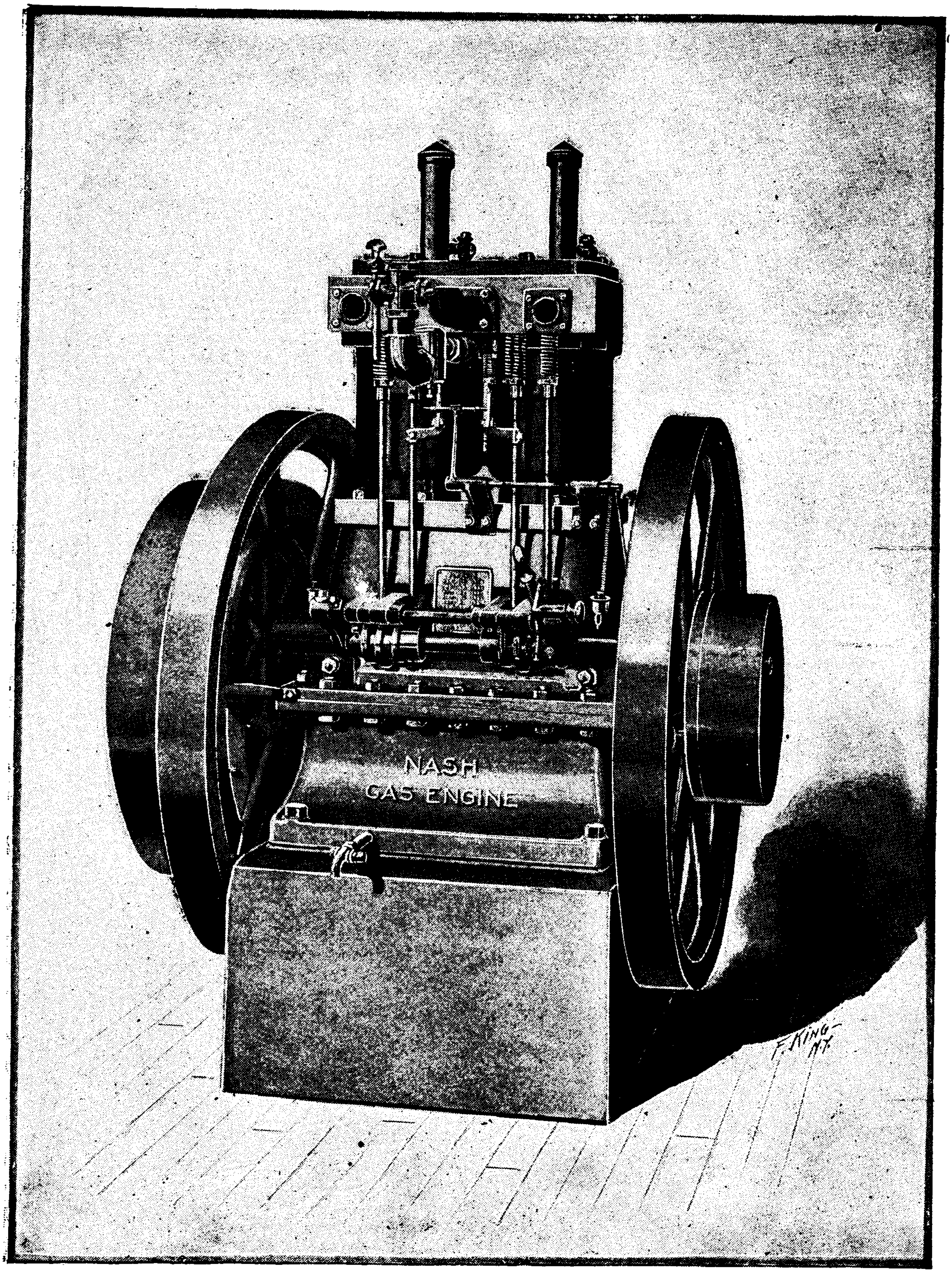


FIG. 133.—THE NASH DOUBLE CYLINDER ENGINE, 10 TO 75 H.P., SPECIALTY FOR ELECTRIC LIGHTING.

the double-cylinder engines equivalent to the action of a single-cylinder steam engine or an impulse at each half-revolution of a single crank.

The double-cylinder engine (Fig. 133), the single cylinder with double fly-wheel (Fig. 132), and the sn all single cylinder with one fly-wheel (Fig. 134) represent the general appearance of the engines of this company. They are all adapted for the

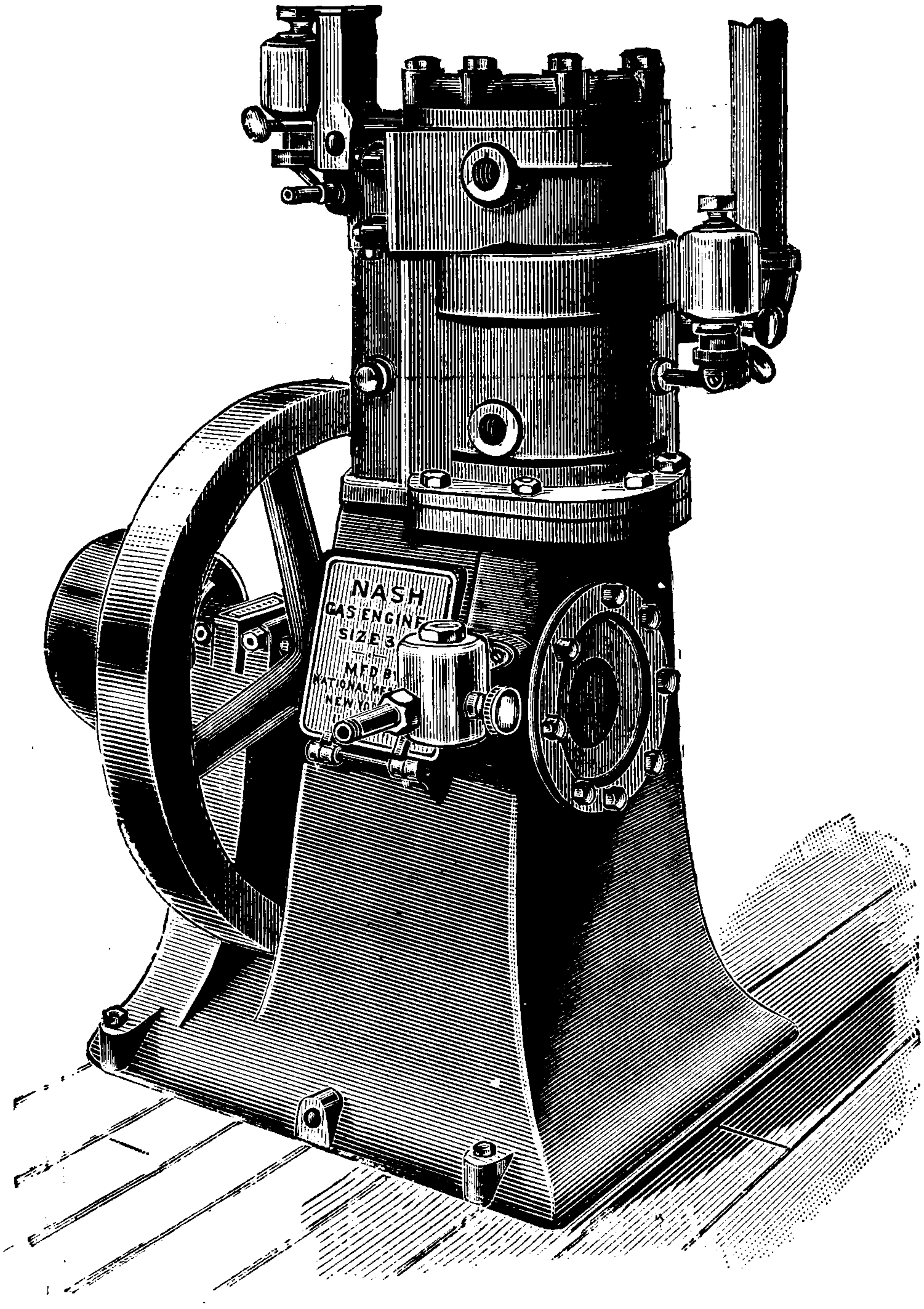


FIG. 134.—THE NASH, SMALL SIZES.

use of illuminating gas, gasoline, natural or producer gas. Ignition is by hot tube or the electric spark, as desired.

The larger engines have poppet valves, and are of the four-cycle compression type, and are now made in one-, two-, and four-cylinder vertical style, with reducing-gear and cam shaft, which operates the inlet and exhaust valve by direct-acting push-rods with back springs. The inlet-valve push-rods have bracket arms with pivoted push-blades that regulate the gas charge by the governor through a rock shaft and levers, which trip the push-blade contact for each gas-inlet valve.

This class of two- and four-cylinder engines is built in

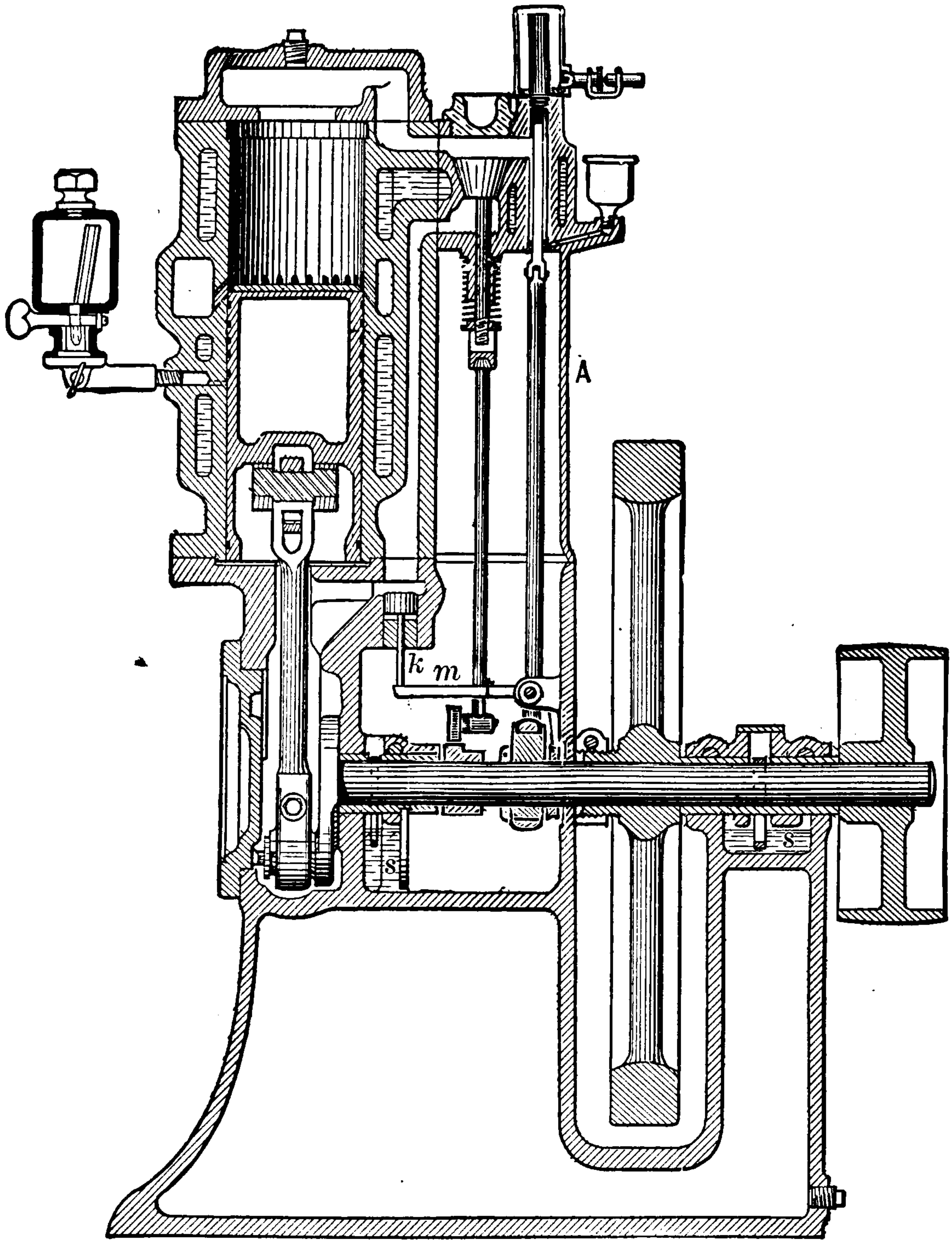


FIG. 135.—SIDE SECTION ELEVATION.

many sizes, ranging up to 200 B.H.P., with multipolar generators on the same base for electric lighting. Also combination pumping engines on a single base for deep wells; also combination engines and air compressors adapted to any required air pressure.

It is a special feature of the Nash system that the engine and dynamo are not rigidly connected, but the coupling operates as a regulating device to correct any tendency of the dynamo to

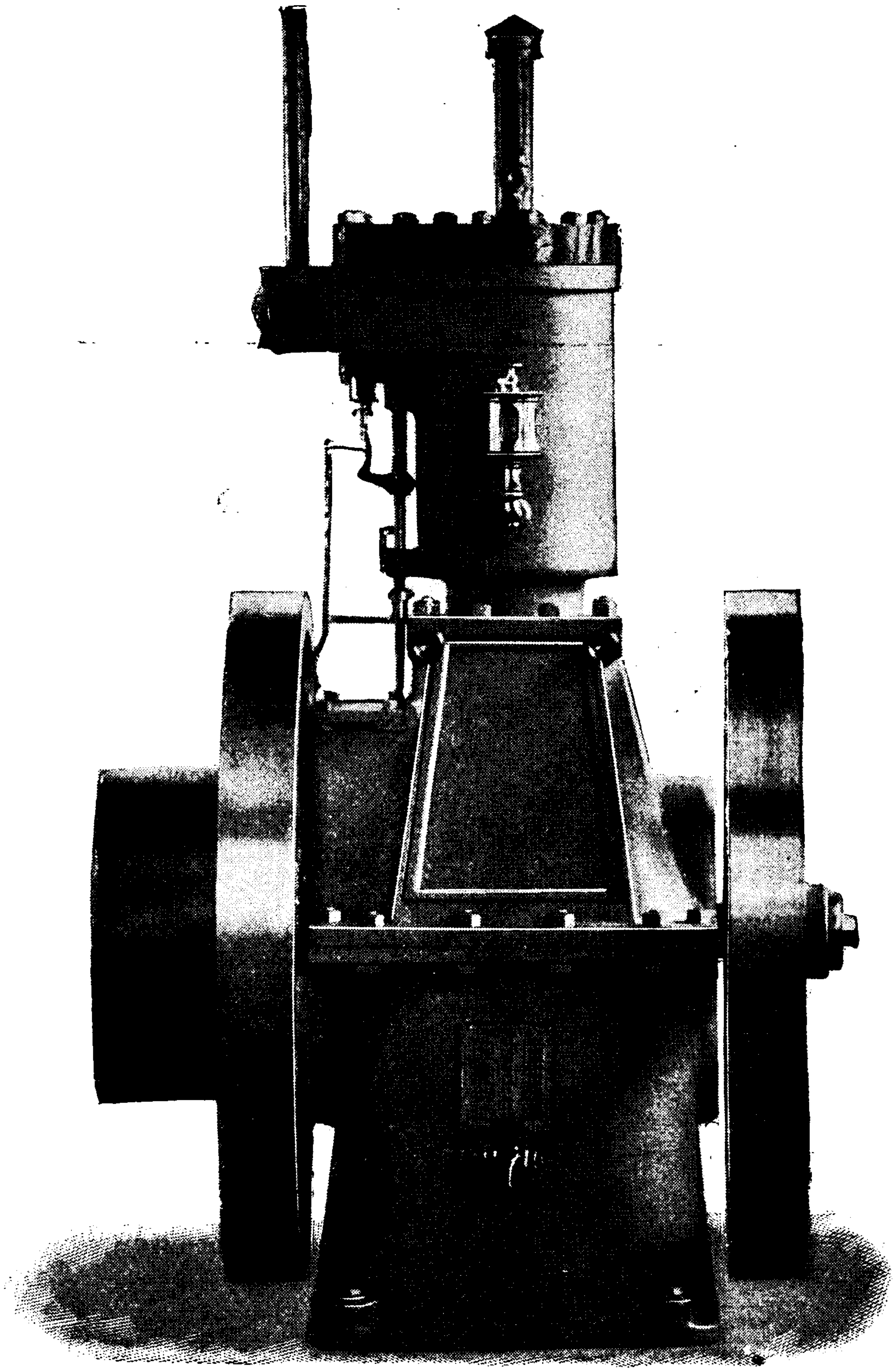


FIG. 137.—NASH FOUR-CYCLE VERTICAL, SINGLE-CYLINDER GAS ENGINE.

follow the engine in such variations in speed as occur during a cycle, or through changes in the load. So thoroughly is this compensation effected, that the generator maintains a practically unvarying speed, and therefore produces a light so steady that the eye is unable to detect any flickering in the lamps, while the fluctuations of the voltmeter are almost imperceptible in ordinary working, and are insignificant under changing loads, even when

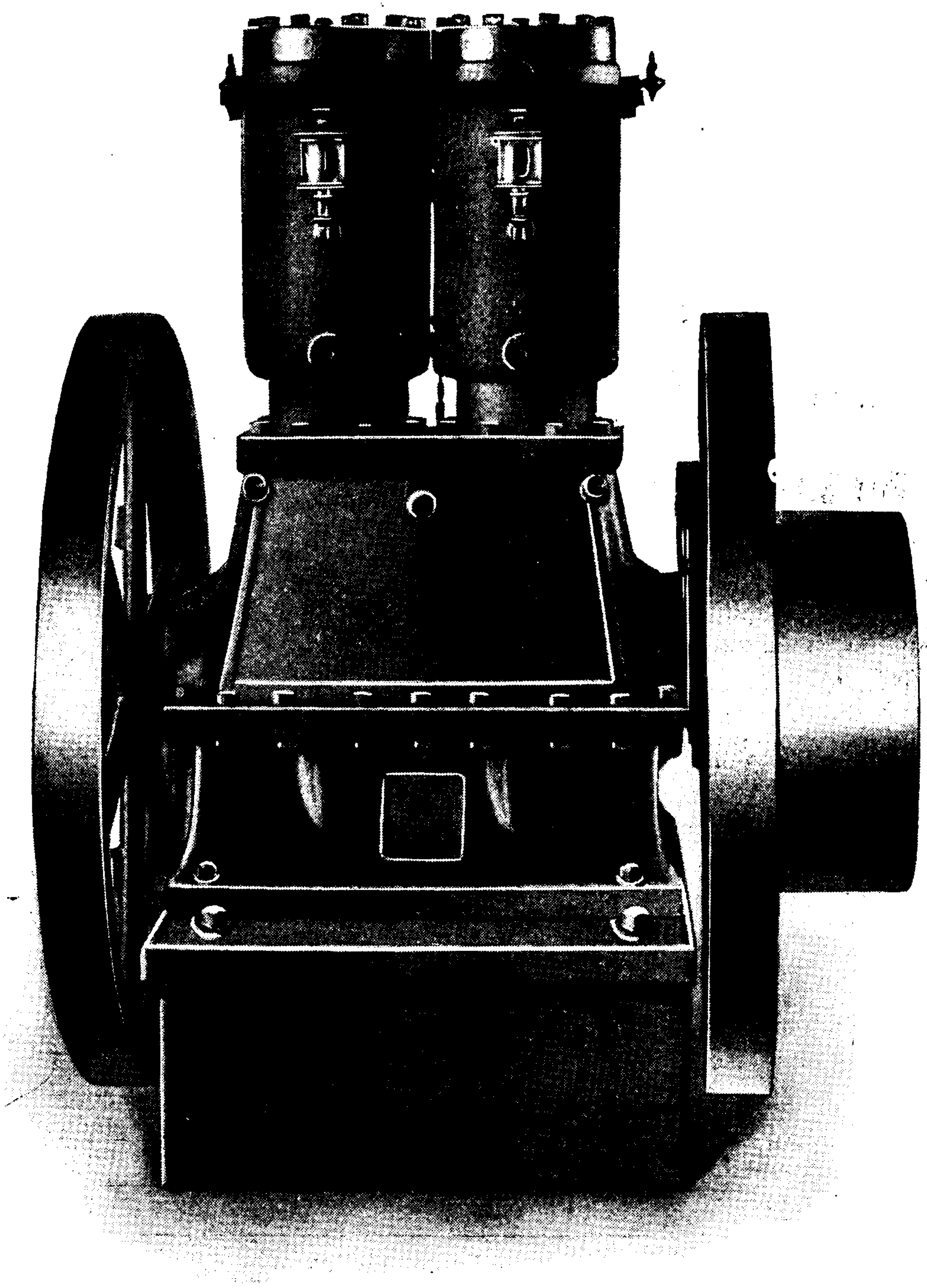


FIG. 138.—FOUR-CYCLE VERTICAL.

operating an elevator in connection with the lighting. Regulation so fine as this, and so essential to a commercially successful electric lighting system, is, we believe, unapproached by any other system of gas engine combination.

The advantages of direct-connected plants, such as simplicity, absence of belts, and compactness, permitting installation in

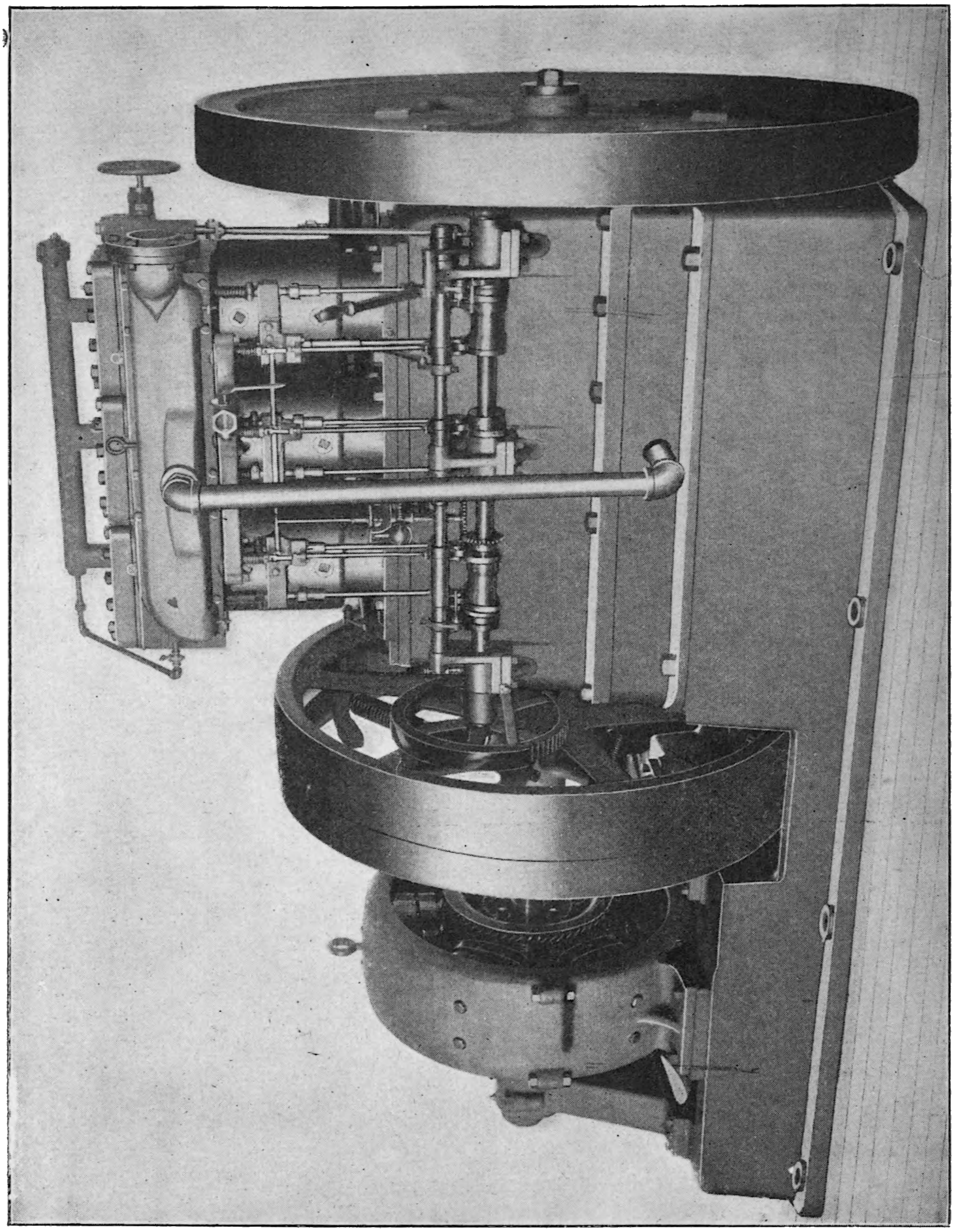


FIG. 139.—5CO-LIGHT NASH DIRECT-CONNECTED GAS ENGINE AND DYNAMO, WITH CENTRIFUGAL CLUTCH-COUPLING AND REGULATOR.

limited space, are all now so generally appreciated that this type has become the favorite form.

The principal difficulty met in producing a satisfactory direct-connected electric lighting plant, operated by a gas or gasoline

itself is not influenced by the jostling of a vehicle. The design of this engine was in view of its adaptation for driving road and traction wagons. It is also built for stationary power.

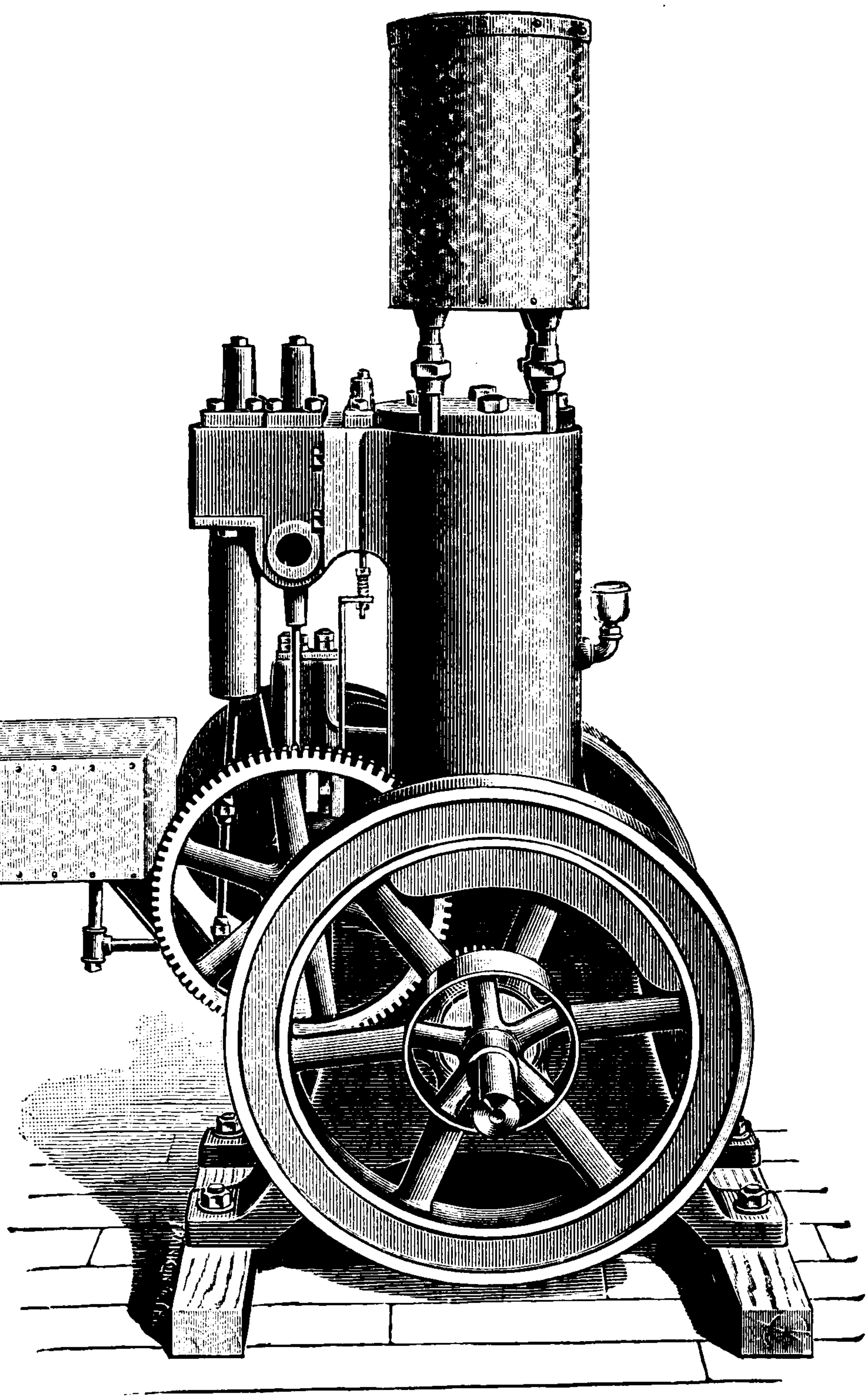


FIG. 141.—THE PROUTY ELECTRO-GASOLINE ENGINE.

A peculiar muffler made by this company gives a silent discharge of the exhaust so desirable in road and street motors.

Ignition by spark takes place in the inlet throat, between the valve chamber and cylinder, and at such time as to avoid the jar from sudden explosion at the exact end of the stroke of the piston.

The Lambert Gas and Gasoline Engine.

The engines built by the Lambert Gas and Gasoline Engine Company are all of the horizontal four-cycle type. They are

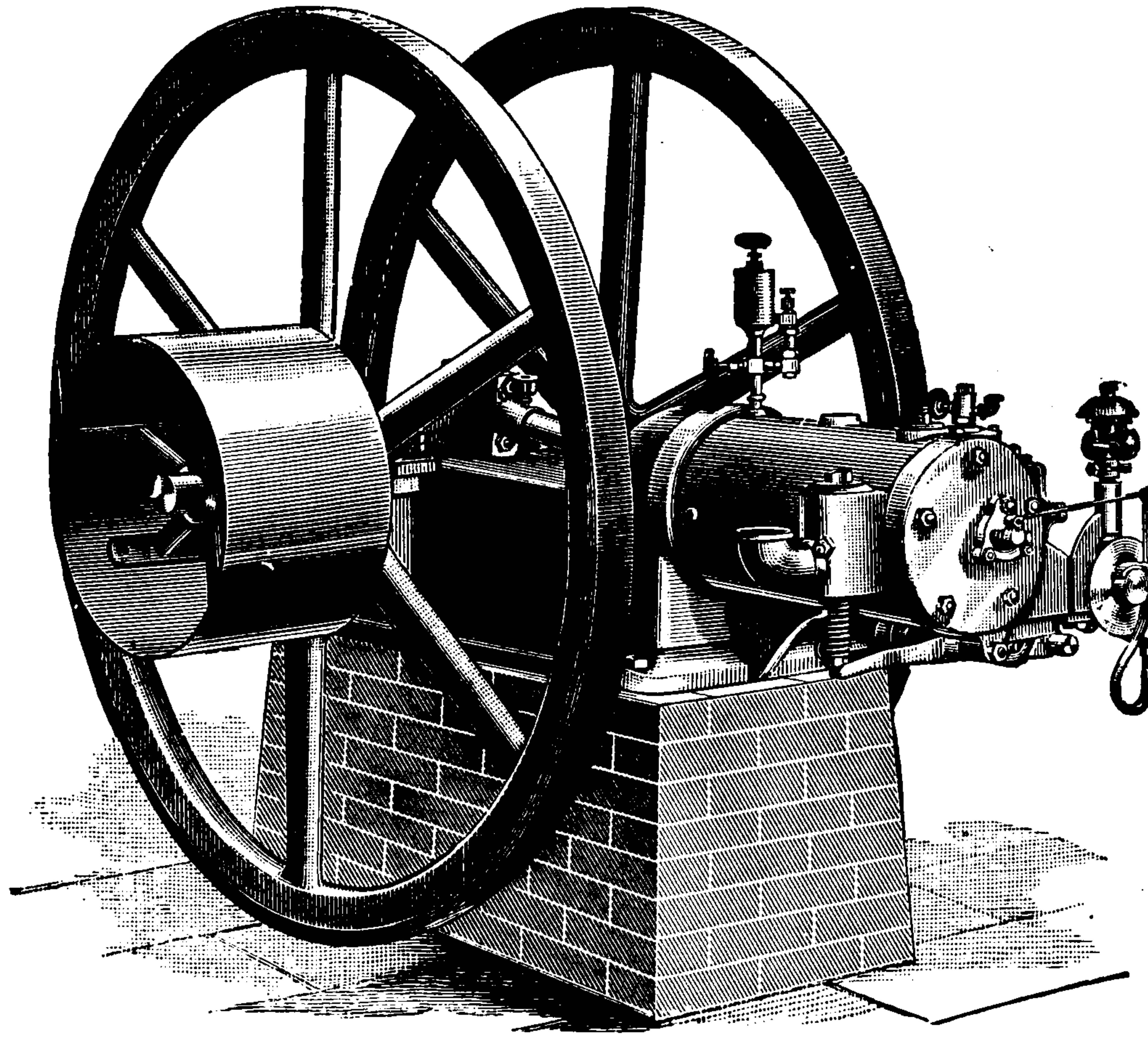


FIG. 142.—THE LAMBERT ENGINE, FRONT END VIEW.

scheduled in fifteen sizes, from 1 to 40 B.H.P. The valves are all of the poppet type and are operated by a secondary shaft and

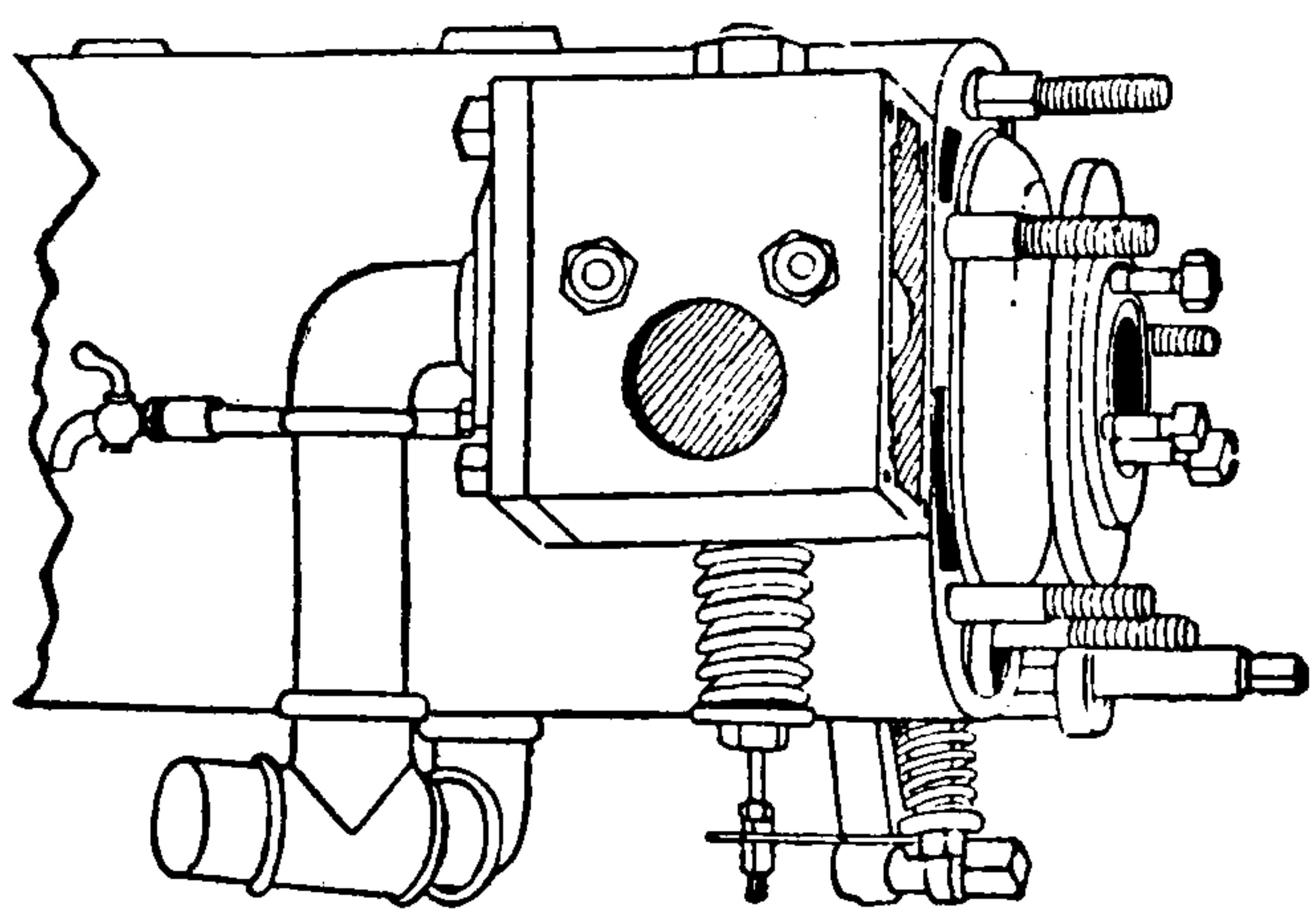


FIG. 143.—EXHAUST VALVE BOX, WATER HEAD OFF.

worm reducing-gear. The exhaust valve is opened by a lever across and under the end of the cylinder, the lever having a roller riding against a cam on the secondary shaft. The exhaust chamber (Fig. 143) has a water circulation through a jacket, and the cylinder head is also jacketed and connected, so that there can be no leak into the cylinder from the water circulation.

In Fig. 144 is shown the left side with the valve gear and

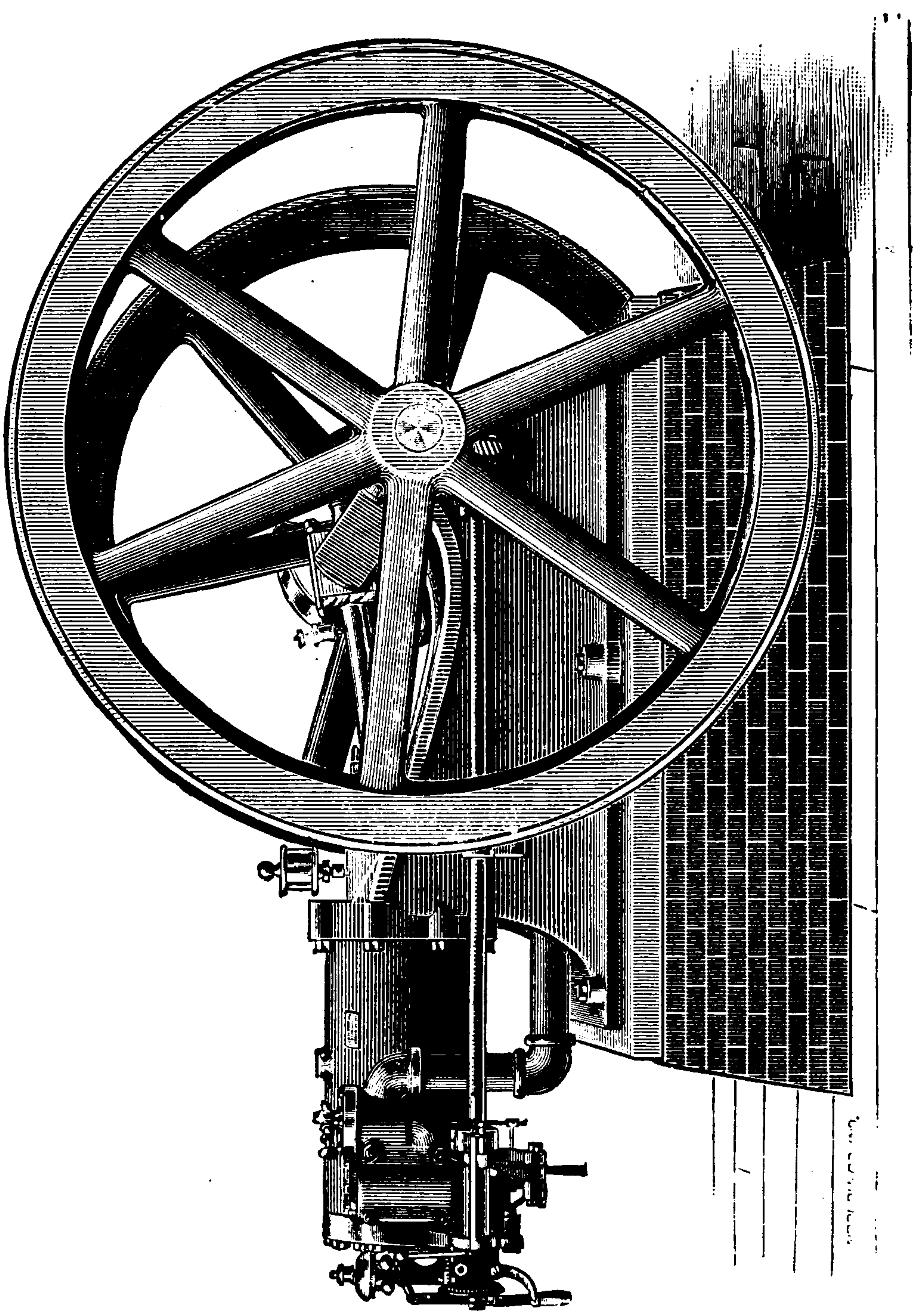


FIG. 144.—THE LAMBERT GAS AND GASOLINE ENGINE.

location of the governor, which is driven by a bevel gear on the secondary shaft.

In Fig. 145 is shown the detailed end view of the engine; the bell-crank lever that operated the gas-inlet valve from a cam on the secondary shaft, as also the sparking-cam *o* at the end of the shaft.

The "Leaflet" of directions issued by the Lambert Company is an excellent guide to the operator of a gas or gasoline

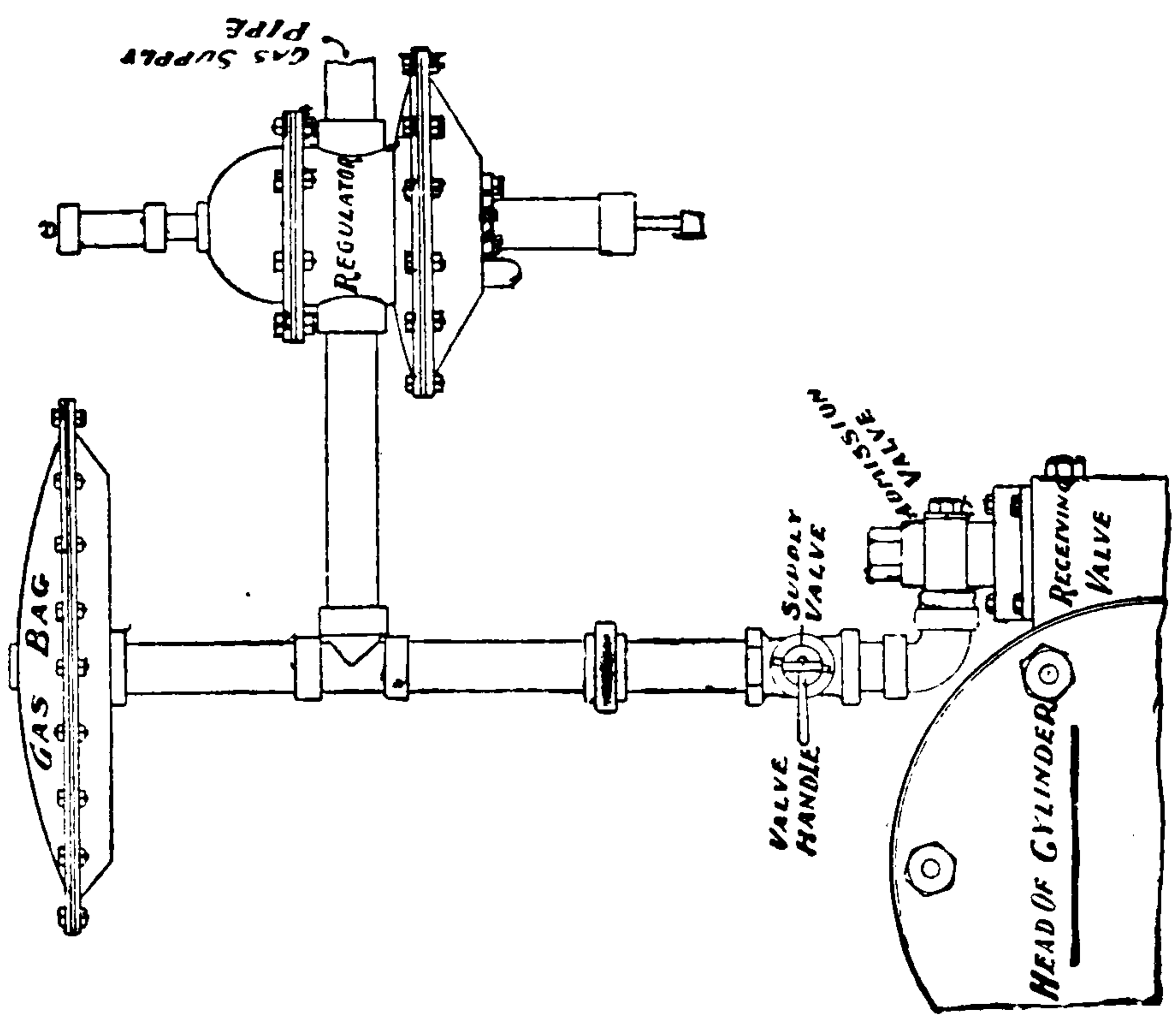


FIG. 147.—GAS REGULATOR AND GAS BAG.

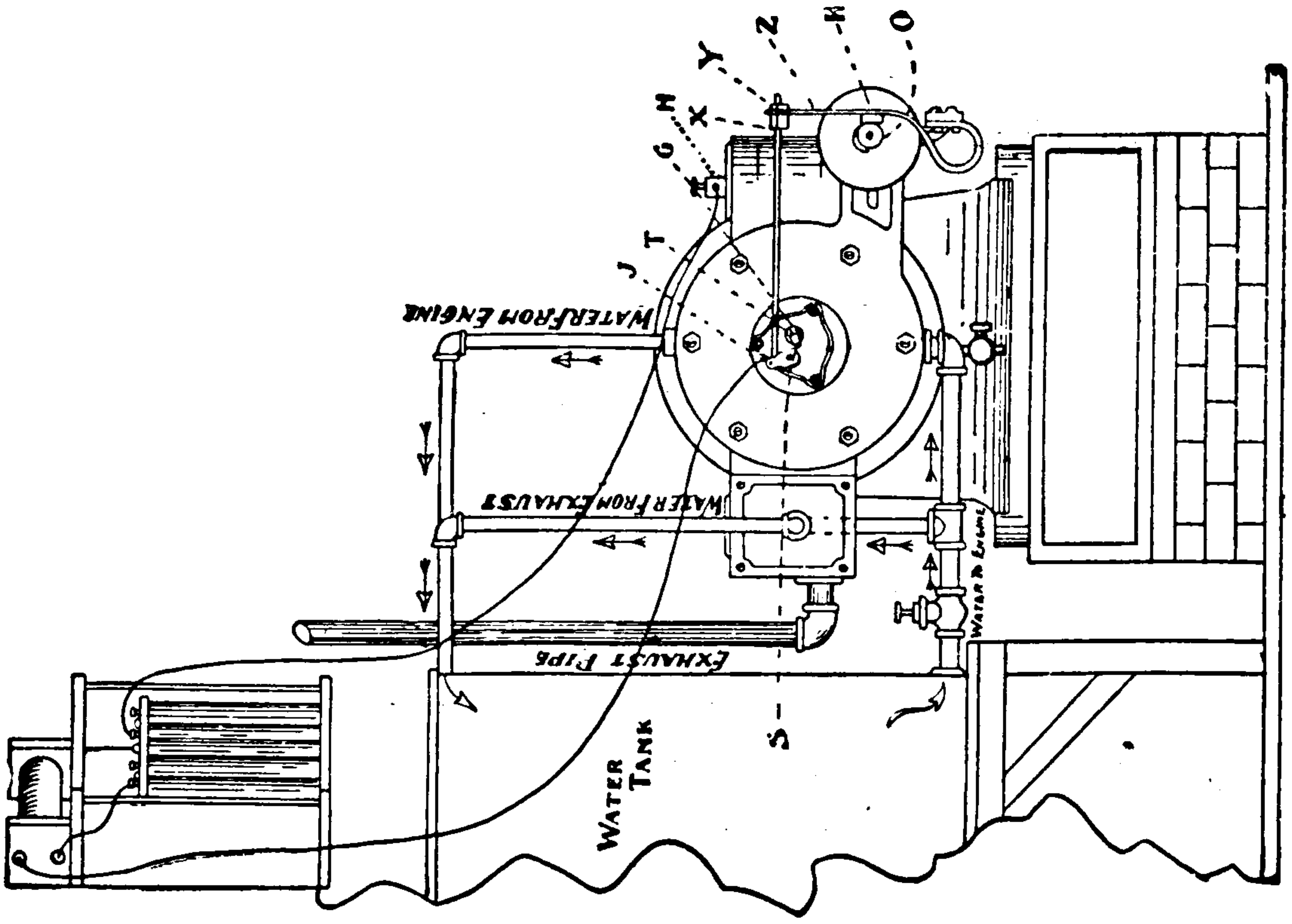


FIG. 146.—THE ELECTRIC CONNECTION.

engine, and gives special directions for observing the internal action of the engine by the sounds to the ear.

The Columbus Gas and Gasoline Engine.

We illustrate a general view of the gear side of this engine in Fig. 148 and the details of its leading parts in Figs. 149 to 152.

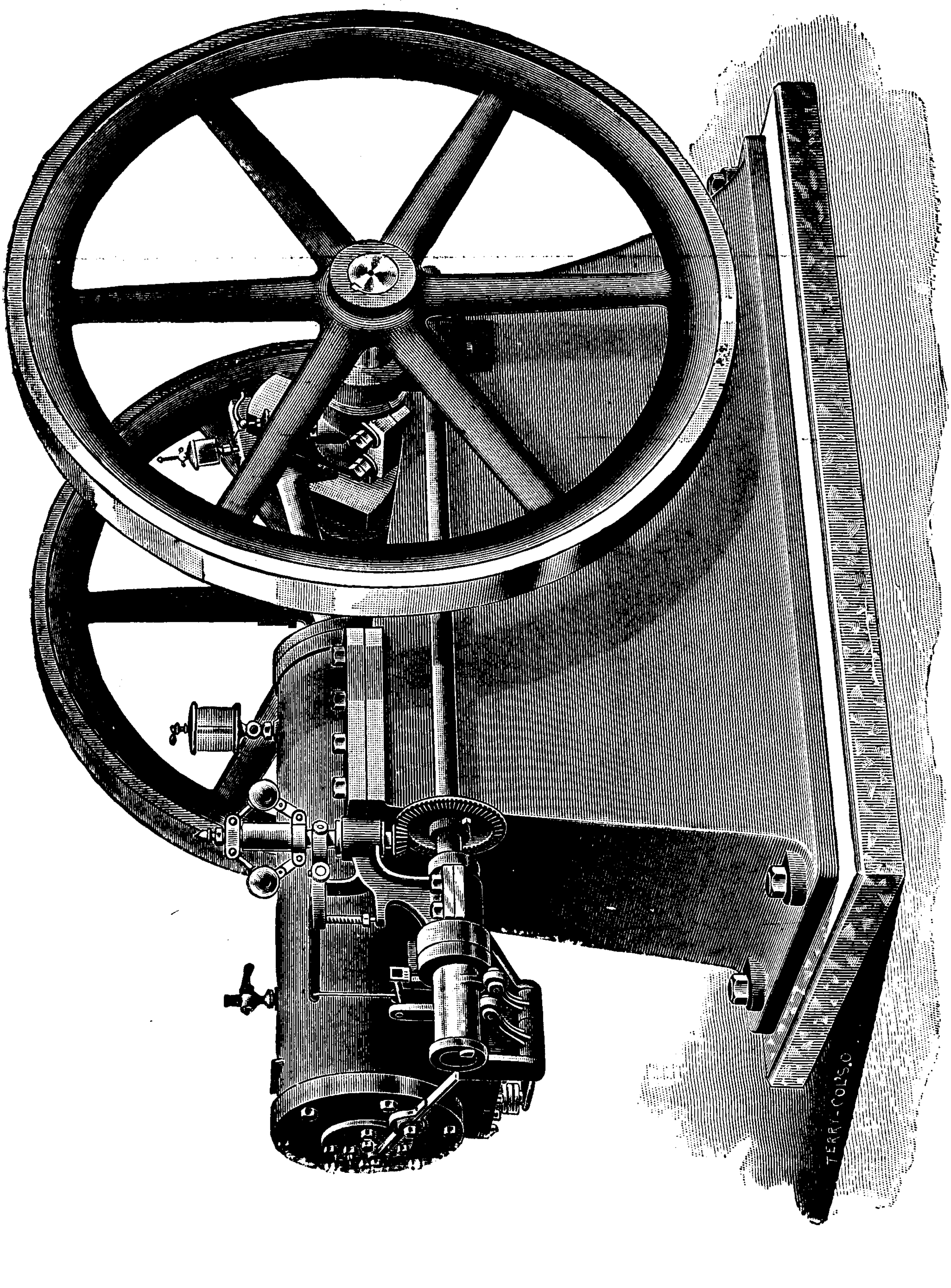


FIG. 148.—THE "COLUMBUS" GAS AND GASOLINE ENGINE.

It is built by the Columbus Machine Co., Columbus, Ohio. In the details, as shown in the sectional cuts, the design has been toward the fewest parts that will give efficiency, ready adjustment and renewal of vital wearing parts, together with a gas and gasoline attachment that allows of interchange of fuel elements without stopping the engine, if necessary.

It has a supplementary exhaust through a port in the cylinder, opened by the piston at the end of its stroke, which has been shown to be a great relief to the work and wear of the exhaust valve, as by this exhaust arrangement the exhaust valve opening follows the piston port opening. The governor controls the gas

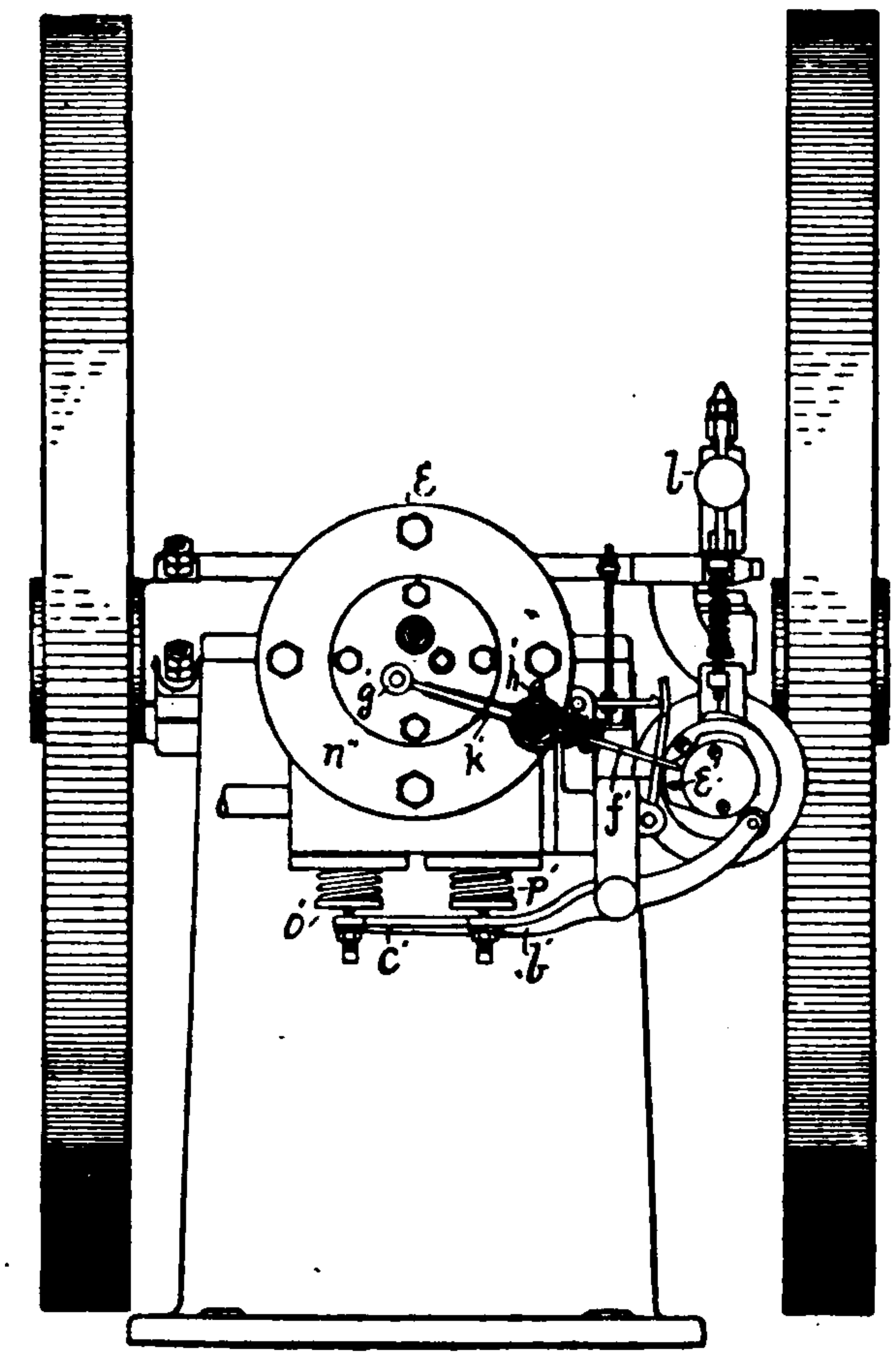


FIG. 149.—VALVE GEAR.

and air charge by holding or throttling the inlet duplex valve, the lower section around the spindle being a gas chamber fed by the pipe *y*, Fig. 151, while the annular chamber receives the air through a side inlet, the mixture taking place between the two valves. The spindle of the gas valve is hollow, through which the spindle of the inlet valve passes beyond the spring block *x*, at *b*, so that the cam operated lever opens the inlet valve first and wider than the gas valve. Both valves are fitted and seated in

small needle valve *z*, and tube *b*, discharging into the air-mixing chamber *u*.

The engines are fitted with tube igniters when preferred; otherwise the break contact is recommended, it being so placed as shown in the cylinder section that the fresh charge is drawn against it and thus keeps it comparatively cool. These motors are very quiet and smooth running and are simple in all their details. They are now built in eleven sizes from 5 to 60 horse power.

The Daimler Motors.

The Daimler Motor Company, manufacturers of stationary gas, gasoline, and kerosene motors, and gasoline motors for boats, carriages, street-railway cars, fire engines, and portable electric lighting, are the sole owners of the United States and Canadian patents of Gottlieb Daimler, of Canstadt, Germany.

Their motors are all of the four-cycle compression type, following the principles formulated by M. Beau de Rochas, and carried out practically by Otto and Daimler in Germany, and now made by this company with many improvements derived from experience. All the valves are of the poppet style, closing automatically with springs. In the earlier engines and those of the duplex style with a single crank, the governing was made by a miss in the push-rod blade on the exhaust-valve stem by which the exhaust valve remained closed through a single cycle or more, as required by the action of the governor—the governor being of the horizontal centrifugal style, located in the pulley on the main shaft or in the fly-wheel when an outside fly-wheel is used.

The operation of the governor is transferred through a grooved sleeve to the lateral arm of a bell-crank push-blade on the push-rod of each cylinder, by a vertical pivoted lever carrying a stop-block, which is thrown out and into contact with the arm of the bell-crank push-blades, and makes a miss-opening of the exhaust valve, as shown in the duplex motor (Fig.

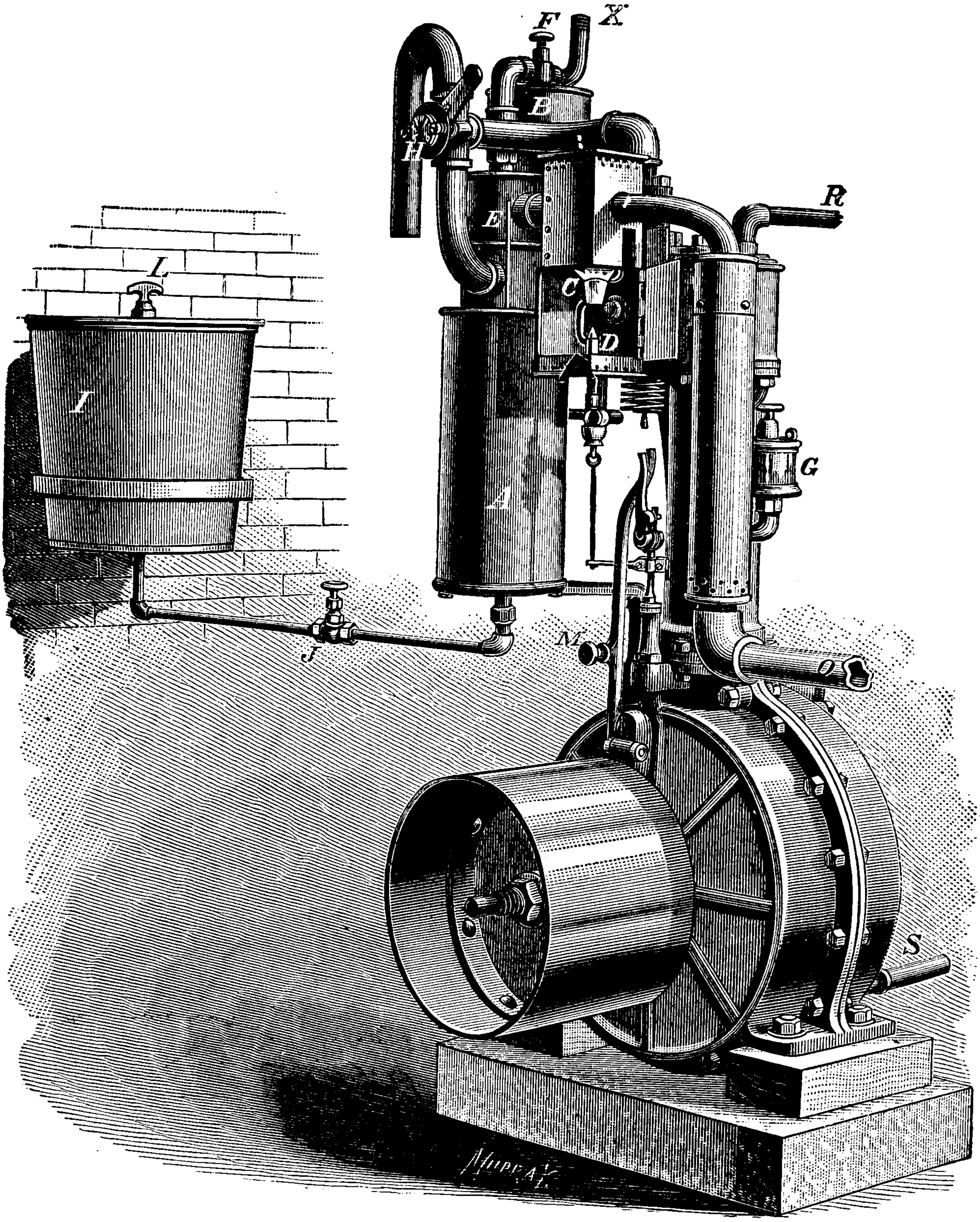


FIG. 155.—THE DAIMLER GASOLINE ENGINE, WITH CARBURETTER AND TANK READY FOR RUNNING.

A, carburetter; *B*, supply reservoir for burner, regulated by the valve *F*; *D*, the burner; *C*, the platinum ignition tube; *H*, the regulating valve for the mixture from the carburetter and free air; *I*, gasoline supply tank for carburetter; *O*, exhaust pipe, with air jacket for supplying warm air to the carburetter.

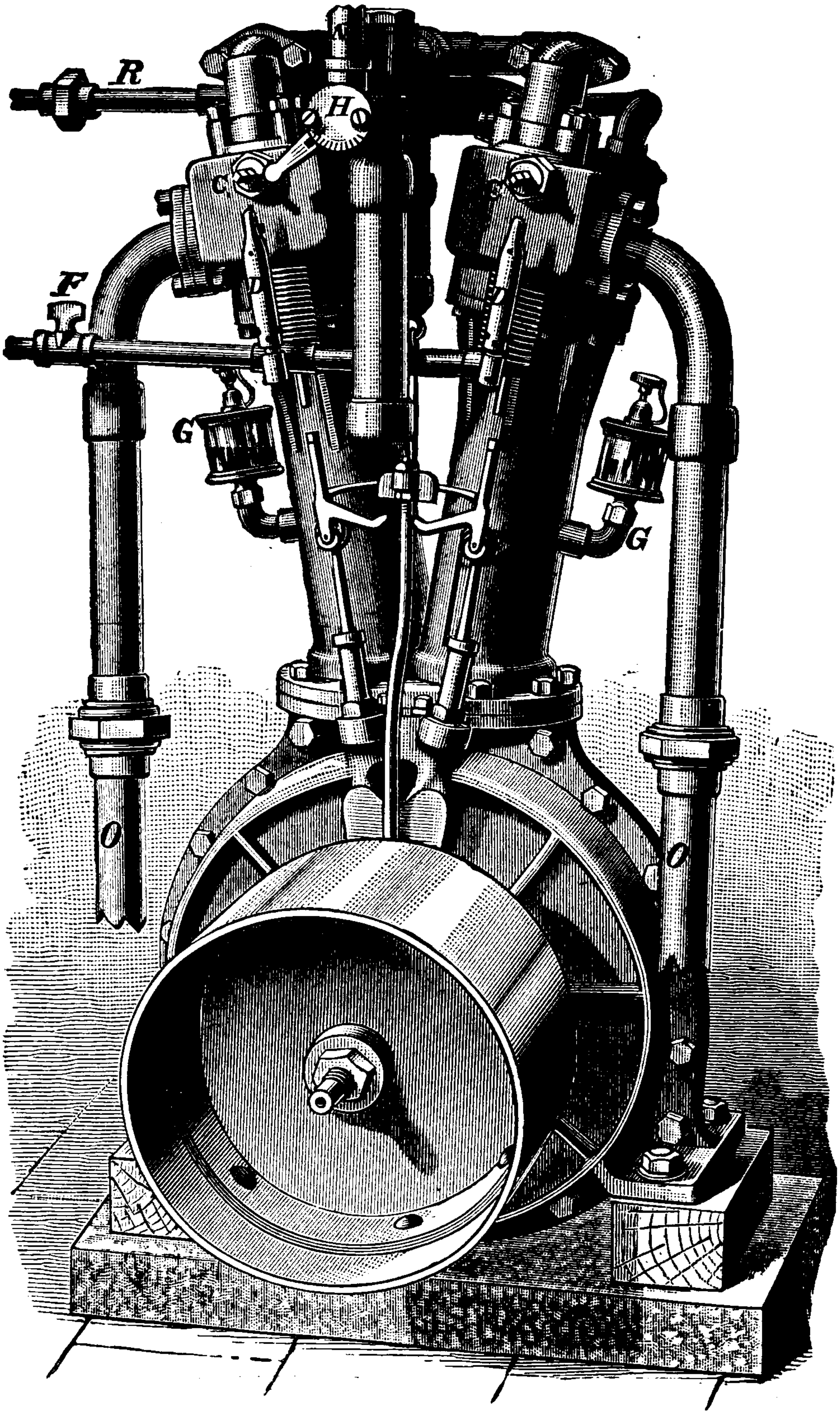
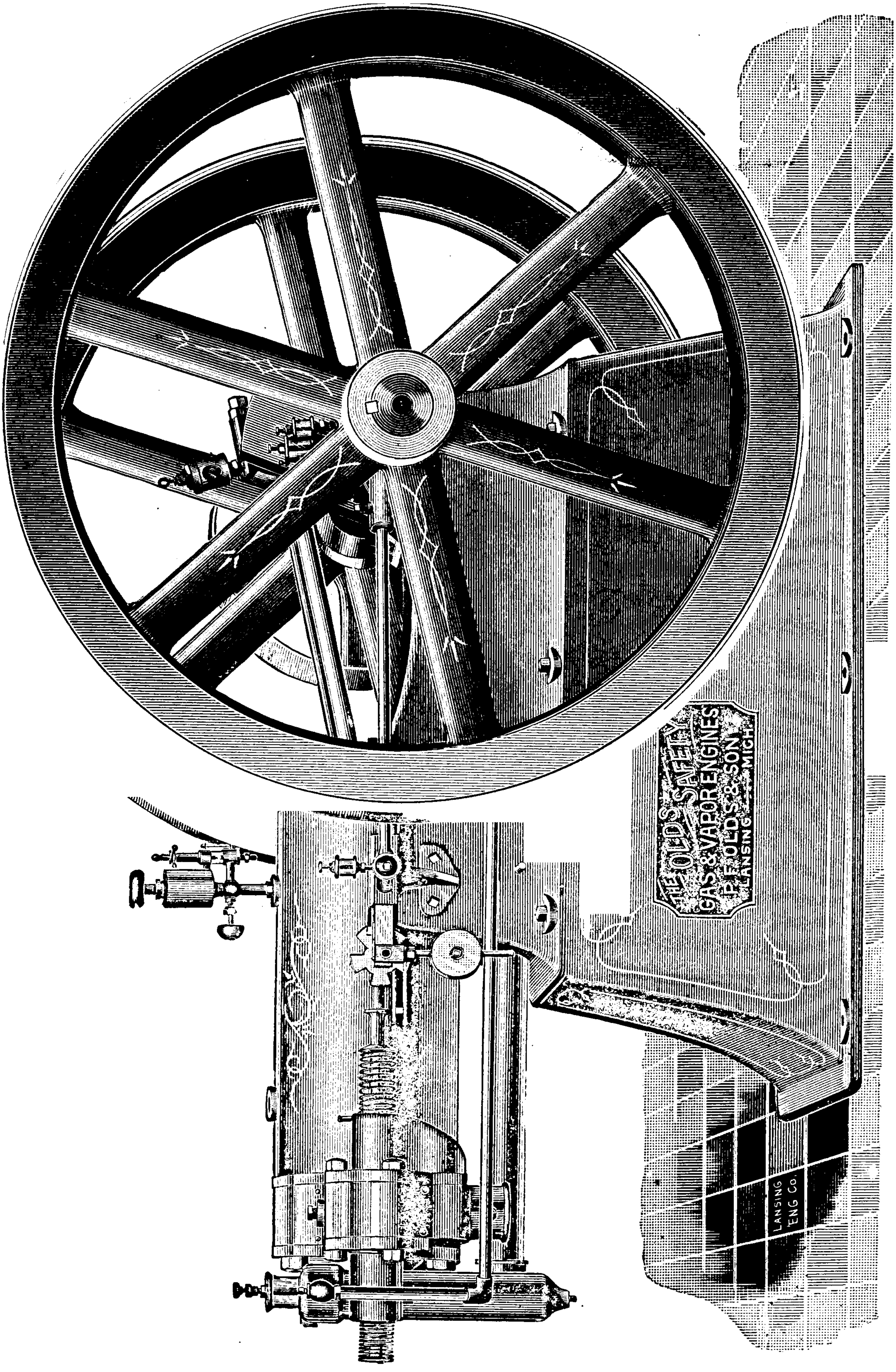


FIG. 156.—THE DAIMLER TWO-CYLINDER GAS ENGINE.

Showing the burners *D*, *D*; platinum igniters *C*, *C*; the gas flow pipe *R*; and regulating valve *H*; and the exhaust valve-gear with regulating stop-block and governor rod operated by the governor located in the pulley; *N*, the free-air inlet; *F*, the regulating cock for the Bunsen burners.


THE OLDS SAFETY
GAS & VAPOR ENGINES
P. F. OLDS & SON
LANSING MICH.
LANSING ENG Co.

GINE.

the spindle when the speed is above the normal. By throwing out the pawl which operates the alternating wheel, compression will be omitted by the open exhaust, and the engine can be

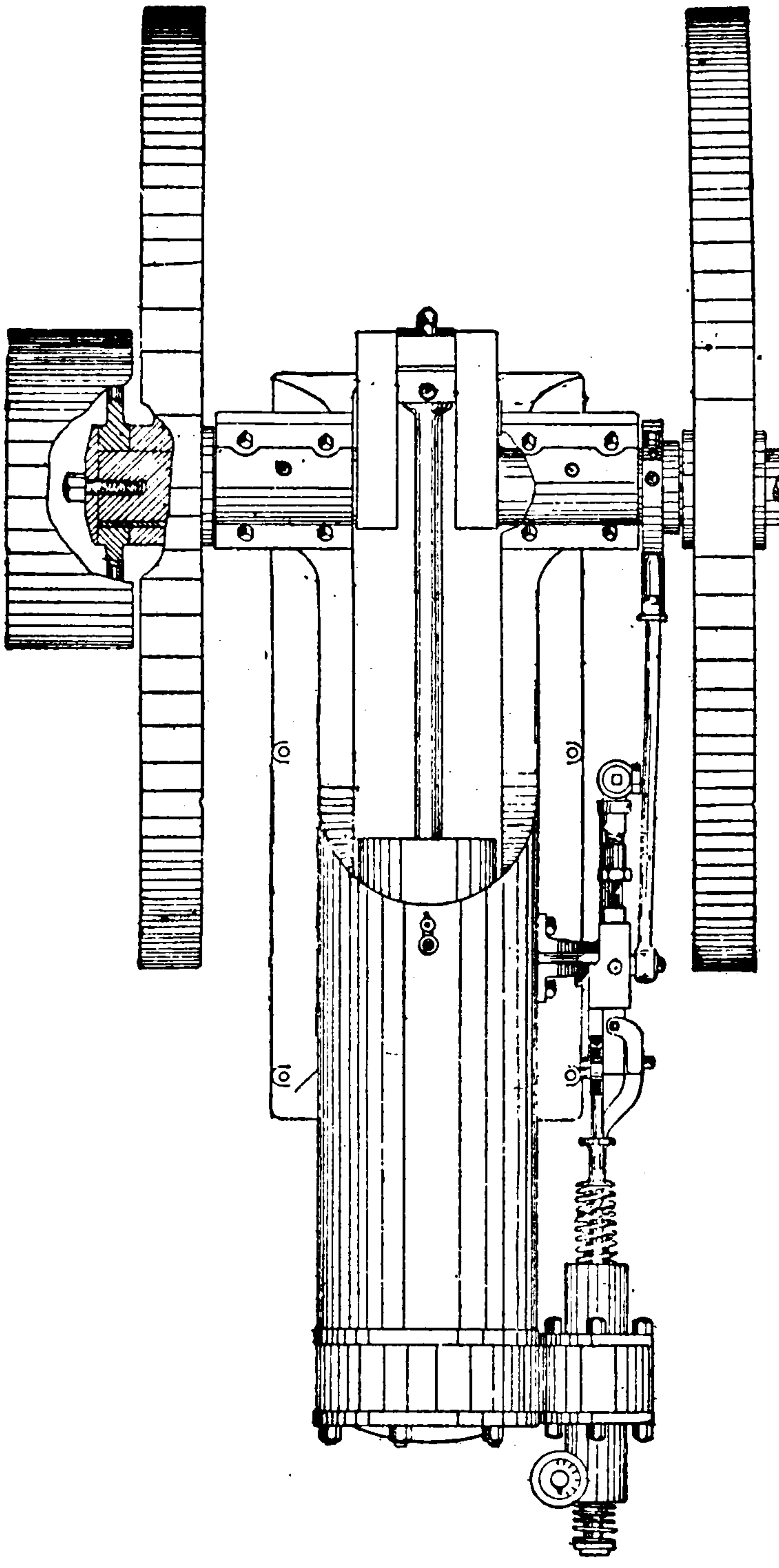


FIG. 165.--PLAN OF THE OLDS GASOLINE ENGINE.

easily turned to any point for starting without the resistance of compression.

The inlet valve is opposite and in line with the exhaust valve, and is opened by the suction of the piston. The vaporizing chamber for gasoline is in front of the cylinder head, and receives near its bottom the air pipe from the engine-bed frame.

When running with gasoline, a small pump is operated by the eccentric rod, which supplies a small reservoir over the inlet valve, arranged so that the surplus runs back to the reservoir below the level of the pump, thus avoiding the possibility of accidental overflow of gasoline. On the top of the reservoir is a sight glass that shows the flow of the gasoline, with a set valve to regulate the feed to the mixing-chamber, where it is atomized by the inrush of air to the cylinder during the charging stroke.

The igniter is by hot tube or electric, preferably a hot tube, with some special improvements that make this style of ignition very desirable. The igniters are not shown in the cut, but occupy the place of a plug seen on top of the valve chamber.

This company also makes a vertical engine on the same principles as the horizontal one, in sizes of from 1 to 5 H.P. Their horizontal engines are made in five sizes, from 7 to 50 B.H.P. Also double-cylinder launch engines and launches—2 H.P. for 18- and 20-foot launches, 4 H.P. for 25-foot, and 8 H.P. for 35-foot launches. In these launch motors the gasoline for a day's run is stored in an iron receptacle at the motor, thus avoiding all danger from pipes and separate tank leakage.

In these boats the engine is not required to be set exactly in line with the propeller shaft. A reversing friction-clutch is used with a flexible shaft connection, so that the setting of the engine and shaft in any boat is an easy matter. The cooling water from the cylinders is discharged through the exhaust pipe, which is a rubber hose passing out at the stern. By this arrangement the rubber exhaust pipe is kept cool, and its flexibility makes a silent exhaust.

The Weber Gas and Gasoline Engine.

The engines of the Weber Gas and Gasoline Engine Company are of the four-cycle compression type, with poppet valves operated by direct push-rods and cams on the reducing-gear, which is enclosed with the governor in an iron box, partly

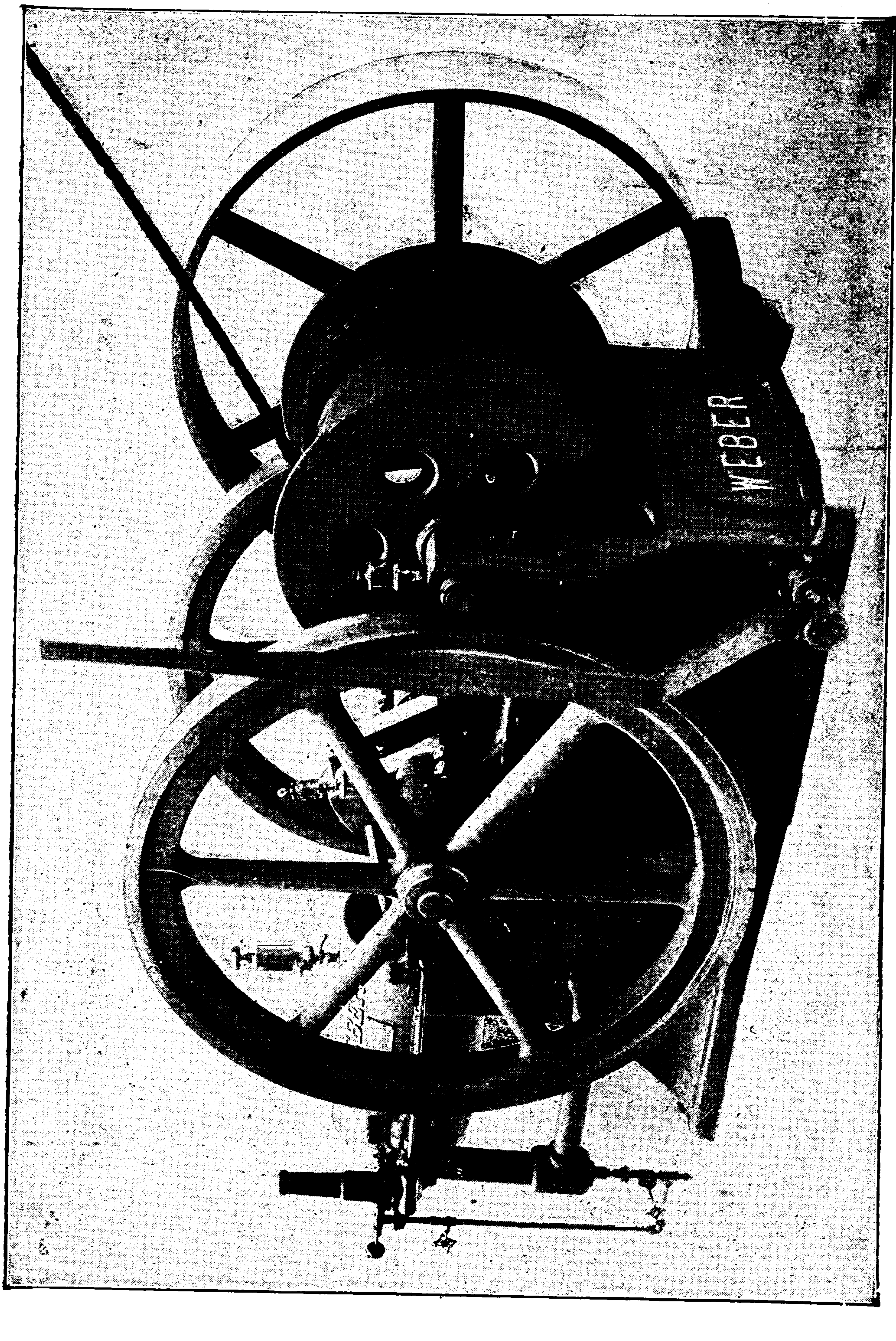


FIG. 169.—THE WEBER GASOLINE HOISTING ENGINE.

miners, quarrymen, and contractors. The engines of this company are also designed for the use of kerosene, crude oil, and distillate.

The style of horizontal engine (Fig. 166) of from 3 to 15

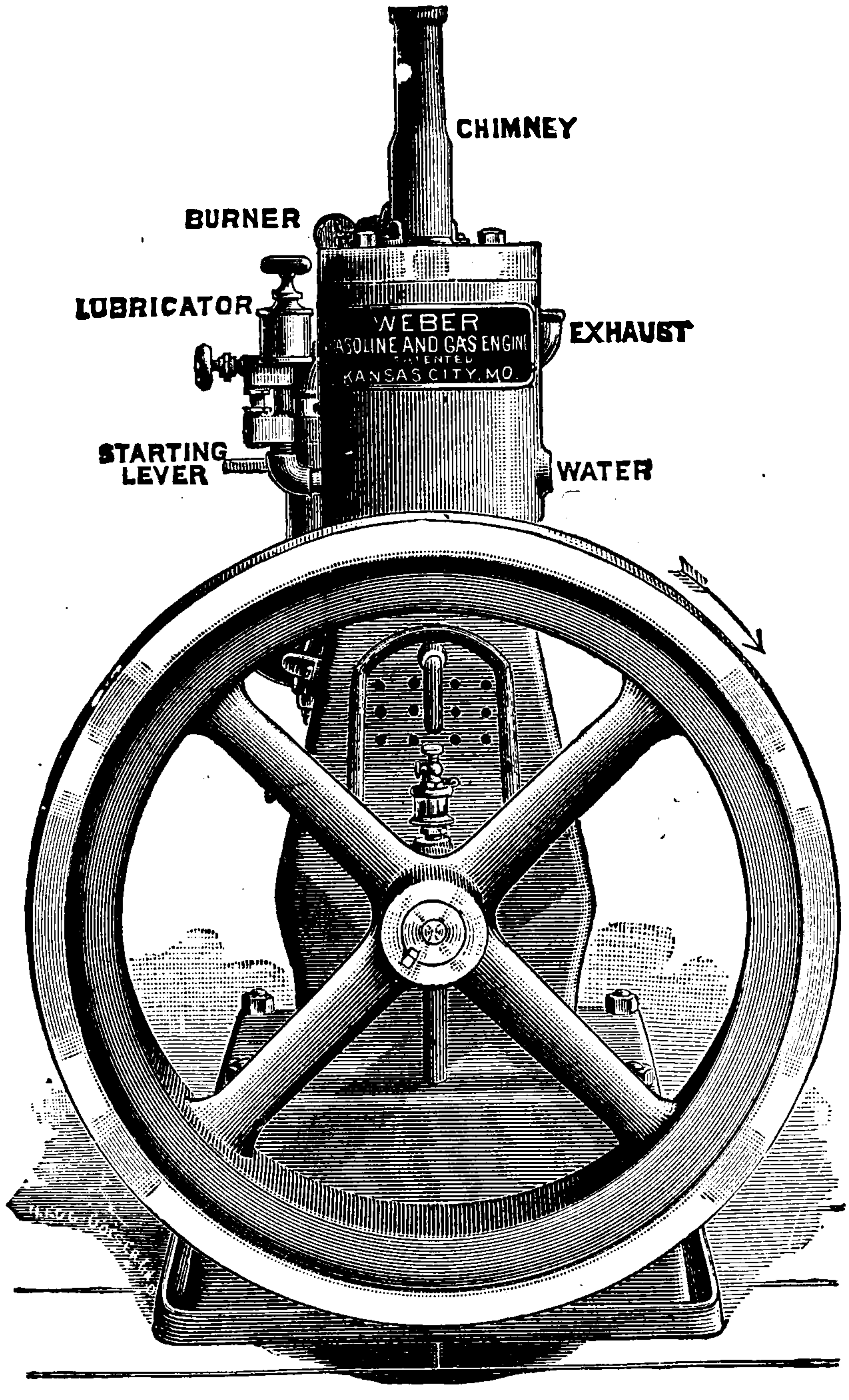


FIG. 168.—THE VERTICAL WEBER.

B.H.P. has three valve push-rods—the inner one opens the exhaust valve, the middle one opens the inlet valve, and the outside rod operates the timing-valve in the igniter passage.

Referring to the lettered diagram (Fig. 167), which is arranged for gasoline, A is the needle valve to the igniter burner, B the gasoline valve, C the handle of the gasoline mixing-valve. which is also the starting-lever for letting in the first charge of gasoline. When the engine is running this valve is opened by the suction of the piston. In the larger engines it is counterweighted, as seen in Fig. 170. D is a collar for connecting the vaporizing pipe L; E, valve for regulating the gasoline supply; *e*, a lever to throw out the timing-valve when starting.

The governor on the smaller engines is of the pendulum type. It operates the inlet or charging valve, opening the valve at every other revolution at normal speed, and missing the contact at increased speed when the spring holds the valve closed until decreasing speed allows the governor to act on the push-rod and again open the inlet valve.

The governor on the larger engines is a fly-weight on the reducing-gear, adjusted by a spring and set nuts. O is a glass gauge to show the height of oil in the gear box; J is its cover.

In their latest style of engine (Fig. 170) the main exhaust is through ports in the cylinder opened by the piston at the termination of the stroke, with a supplementary exhaust valve in the cylinder head operated by a lever and push-rod. The timing-valve is operated by a lever pivoted on the cylinder, in contact with an adjustable push-block on the inlet-valve push-rod.

In the later designs of the Weber many improvements have been introduced to facilitate easy starting and for adapting it for pumping water for irrigation, for which purpose it is well suited and largely used. Its adaptation for the use of kerosene and heavy petroleum oils, and also for crude petroleum, has made it a very useful motive power for agricultural work.

The Priestman Oil Engine.

This has been long in use in Europe, and for several years past has been largely improved by the American builders, Priestman & Co., who have introduced a new system for perfecting the atomization of crude and kerosene oils, or any of the cheap distillates of petroleum. By the system adopted in

high test (usually 150° test) oil, from which oil under air pressure is forced through a pipe to the B three-way cock, and thence conveyed to the C atomizer, where the oil is met by a current of air

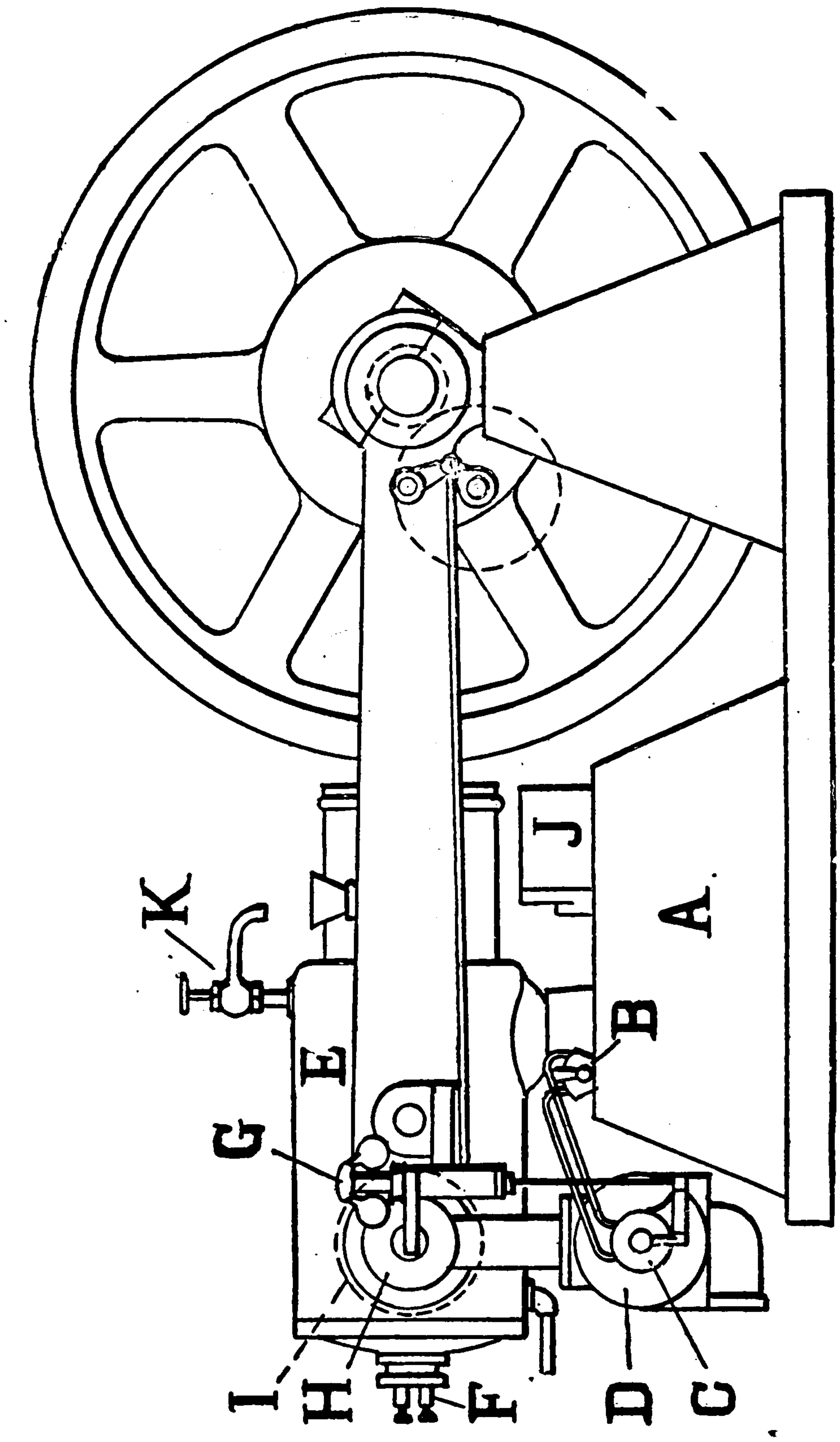


FIG. 172.—THE PRIESTMAN, LETTERED PARTS.

and broken up into atoms and sprayed into the D mixer, where it is mixed with the proper proportion of supplementary air and sufficiently heated by the exhaust from the cylinder passing around this chamber. The mixture is then drawn by suction through the I inlet valve into the E cylinder, where it is compressed by the piston and ignited by an electric spark passing between the points of the F ignition plug, the current for the spark being supplied from an ordinary battery furnished with the engine, the G governor controlling the supply of oil and air proportionately to the work performed. The burnt prodncts are then discharged through the H exhaust valve, which is actuated by a cam. The I inlet valve is directly opposite the exhaust valve. The J air pump is used to maintain a small

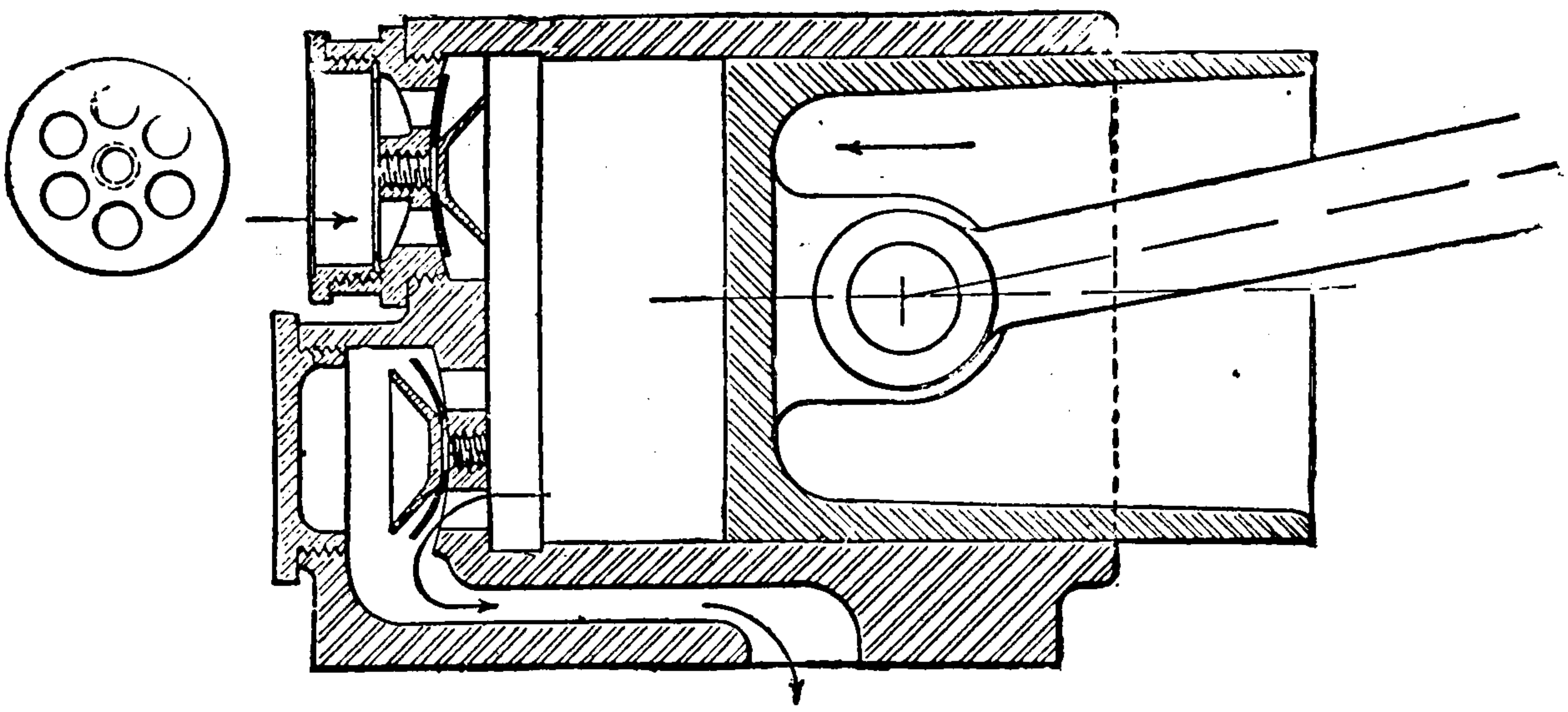


FIG. 173.—THE AIR PUMP.

pressure in the oil tank to form the spray. K is the water-jacket outlet.

Fig. 171 illustrates the general features of this engine It is built on the straight-line principle, by which the moment of greatest strain from the power impulse is met by the frame in direct lines between the points of pressure.

The design is of the four-cycle compression type, with poppet valves, and its regulation is by varying or cutting off the supply of atomized oil. The oil fuel is placed in the base of the engine in an air-tight chamber, A in Fig. 172. A small air-pump, J, operated from the reducing-gear shaft forces air into the oil chamber with a pressure sufficient to cause the oil to be lifted to the three-way adjusting cock B, which also admits air from the compressed air in the oil tank; and oil and air pass to the atomizer through two small pipes, where their proportion and quantity are regulated by the governor.

The atomized oil and air are then injected into a jacketed cylinder, seen beneath the cylinder head and shown in section in Fig. 174, where it is completely vaporized by the heat from the exhaust in the outer chamber and further mixed with air to make a perfect explosive mixture by the indraught of air by the suction of the piston. The indraught of air by the suction of the piston is also regulated by the governor, and enters the

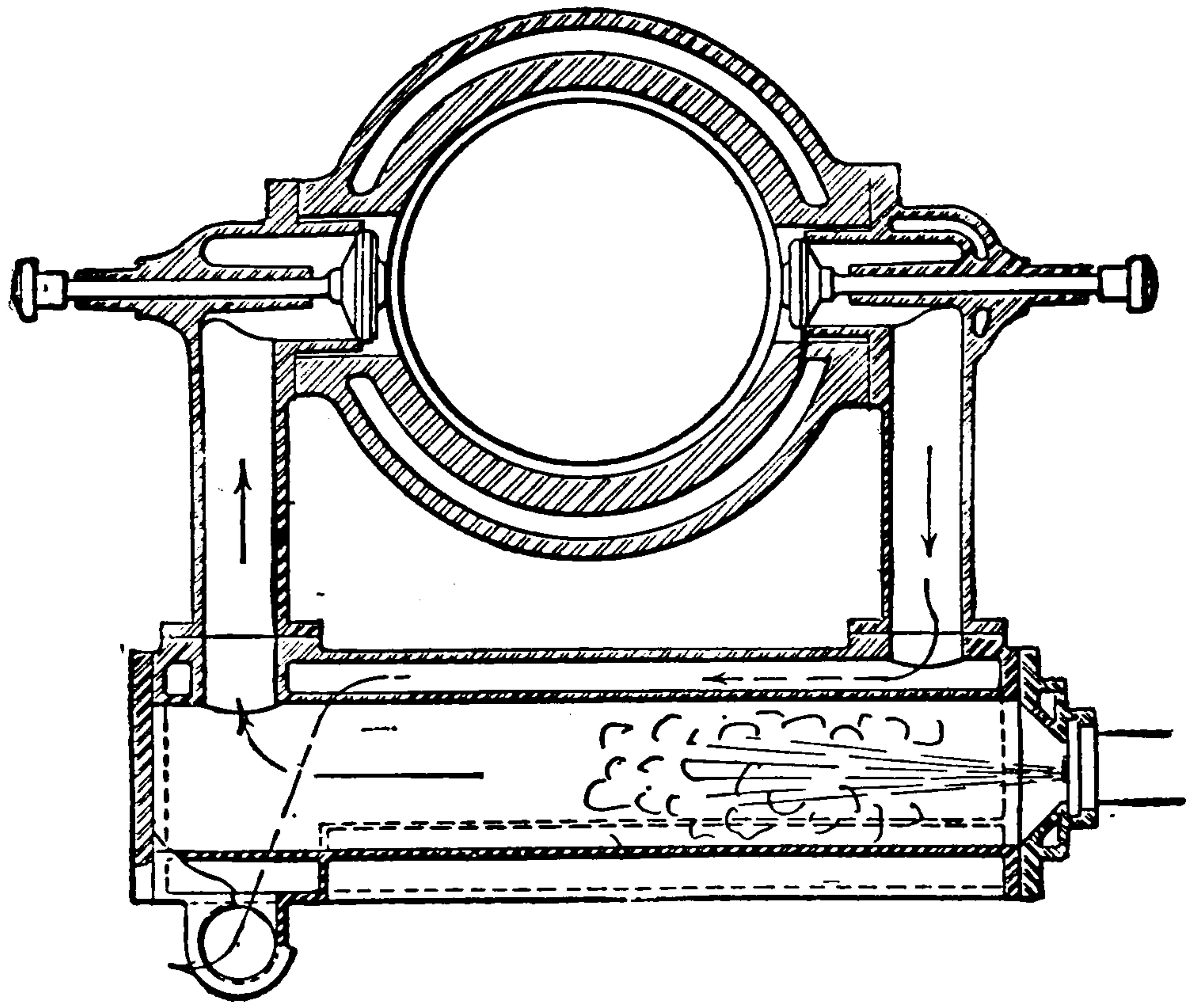


FIG. 174.—THE JACKET VAPORIZING CYLINDER, INLET AND EXHAUST VALVES.

vaporizing jacket cylinder in an annular stream around the atomized jet, as shown in Fig. 175, which represents a section of the governor and inlet passages. For starting the engine a small hand-pump is used for the first charge. The bottom of the inside chamber of the jacketed cylinder is heated to perfect the vaporization of the first charge by a lamp placed under the D-shaped cover seen in Fig. 171. In this engine the lubrication of the cylinder and piston is accomplished by the oil of the working charge. A new heat device has been lately introduced for ignition for the Priestman engines, which for some reasons is preferred to the electric igniter.

In Fig. 176 is represented an indicator card of the Priestman

square inch and is fired just before the termination of the compression stroke. The quick combustion is shown by the nearly vertical line, and its velocity is shown by the bound of the indicator arm above the mean, and its vibration continued, possibly helped by irregular combustion for one-half the stroke, as shown by the upper dotted lines, the continuous line showing the mean curve.

The second dotted line, showing a half-load card, indicates very clearly the retardation of combustion by weakening the charge of both oil and air, and the consequent lowering of all the lines of the card, carrying the charging line far below the atmospheric line. In the lowest and light-running card, the whole value of the card drops so as to make the card-mean value about equal to the engine friction. It is certainly an interesting card for study, and we only wish that we could show this class of cards on a larger scale and for all the conditions of governing by limitation of fuel to compare with governing by closure of the exhaust valve.

The Lawson Gas and Gasoline Engine.

The Lawson engines are built by Welch & Lawson. They are of the four-cycle compression type and of the vertical style. They are built in eight sizes, from ½ to 15 B.H.P. with single cylinders, and of 20 and 30 B.H.P. with double cylinders. The concern also builds gasoline engines for horseless wagons and carriages. Figs. 177 and 178 represent two styles of the vertical engine. The valves have a positive motion from two sets of reducing-gear, Fig. 177, one of which operates the poppet-exhaust valve by a push-rod and cam on the reducing-gear shaft. The gas and air inlets are on the opposite side of the cylinder from the exhaust. The gas valve is a poppet, operated directly by a push-rod from a cam on the reducing-gear shaft, while a piston valve operated by a push-rod from a crank-pin on the reducing-gear governs the air inlet independently of the gas-inlet valve.

By this arrangement the air inlet is opened before the gas inlet is opened, and allows a sweep of pure air to enter at the head of the cylinder, followed by the mixture of gas and air; thus in a measure keeping the explosive mixture of gas and air

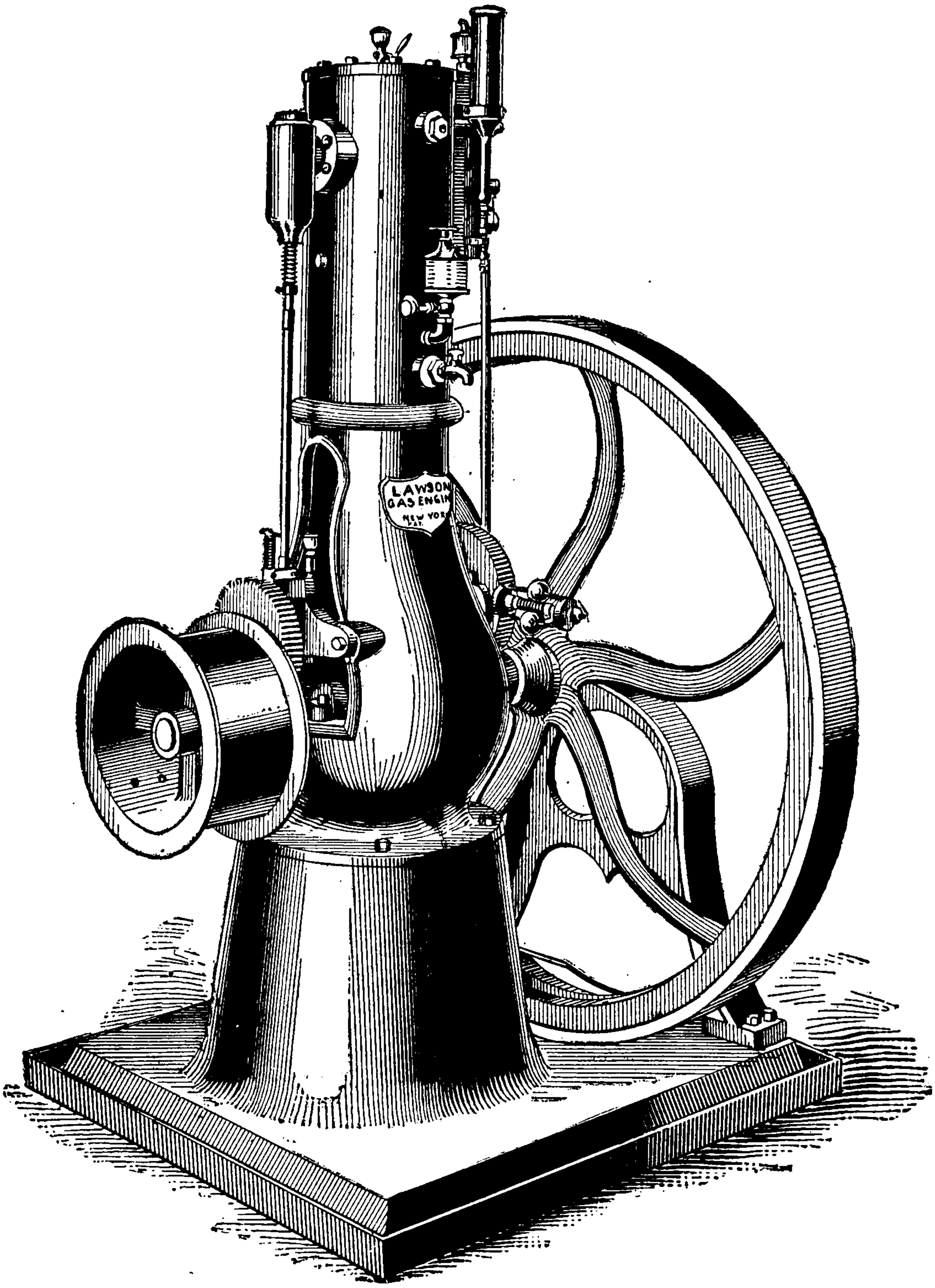


FIG. 177.—THE LAWSON VERTICAL.

separate from the products of the previous explosion by injecting it across and next to the cylinder head where the igniter inlet enters the cylinder. The same cycle of operation is made in the engine Fig. 178, by a single set of gearing.

The igniter is of the hot-tube style, entering the side of the cylinder directly under the head. The governor is of the horizontal, centrifugal style, taking its motion through a bevel gear

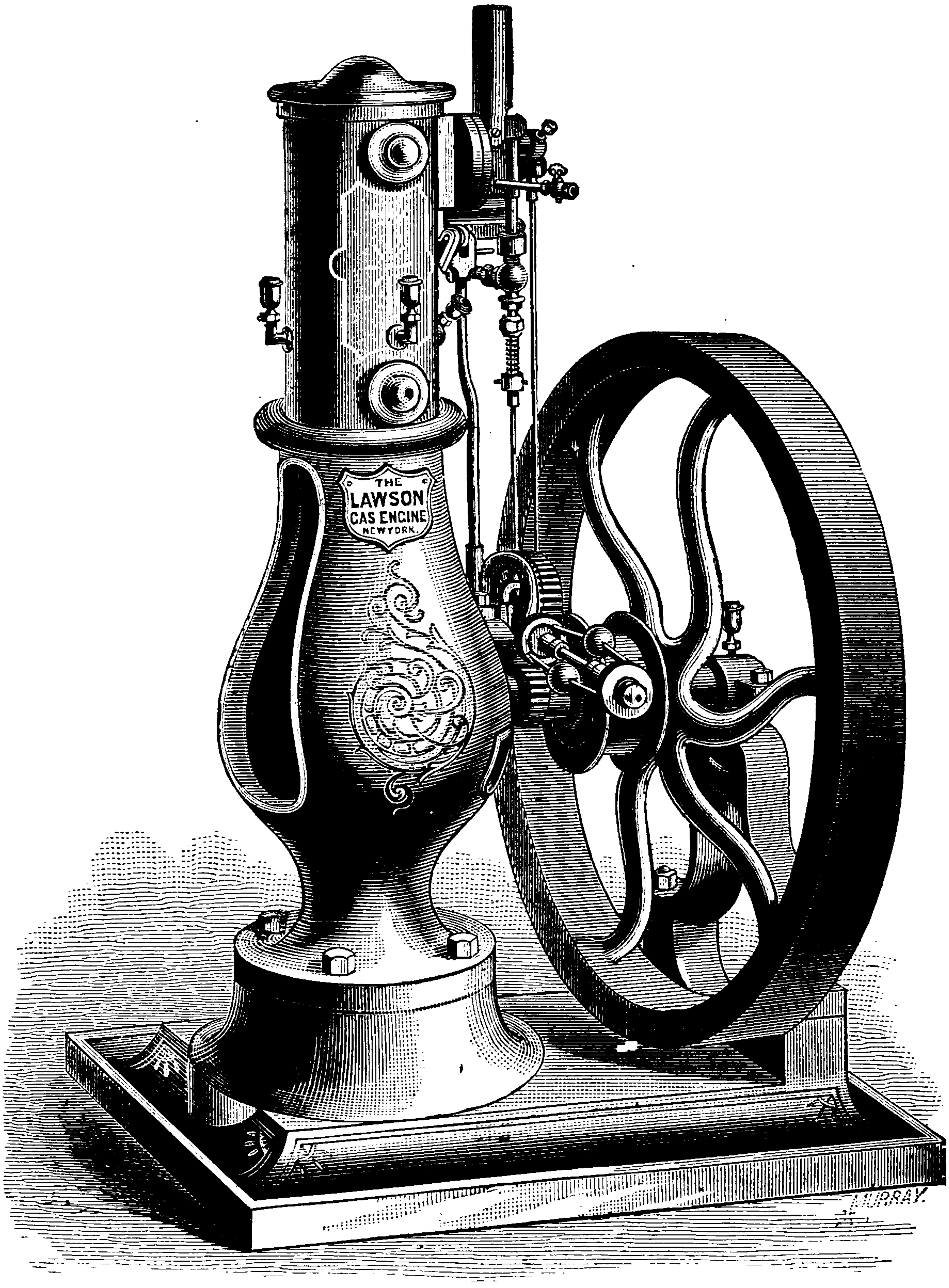


FIG. 178.—THE LAWSON AIR AND GAS VALVE GEARING.

from the reducing-gear shaft, and operates the gas-valve push-rod for a variable gas charge.

The Lawson pumping engines (Fig. 179) are made in two

The Racine Gas and Gasoline Engine.

The engines of the Racine Hardware Company combine some of the most recent improvements in construction. They

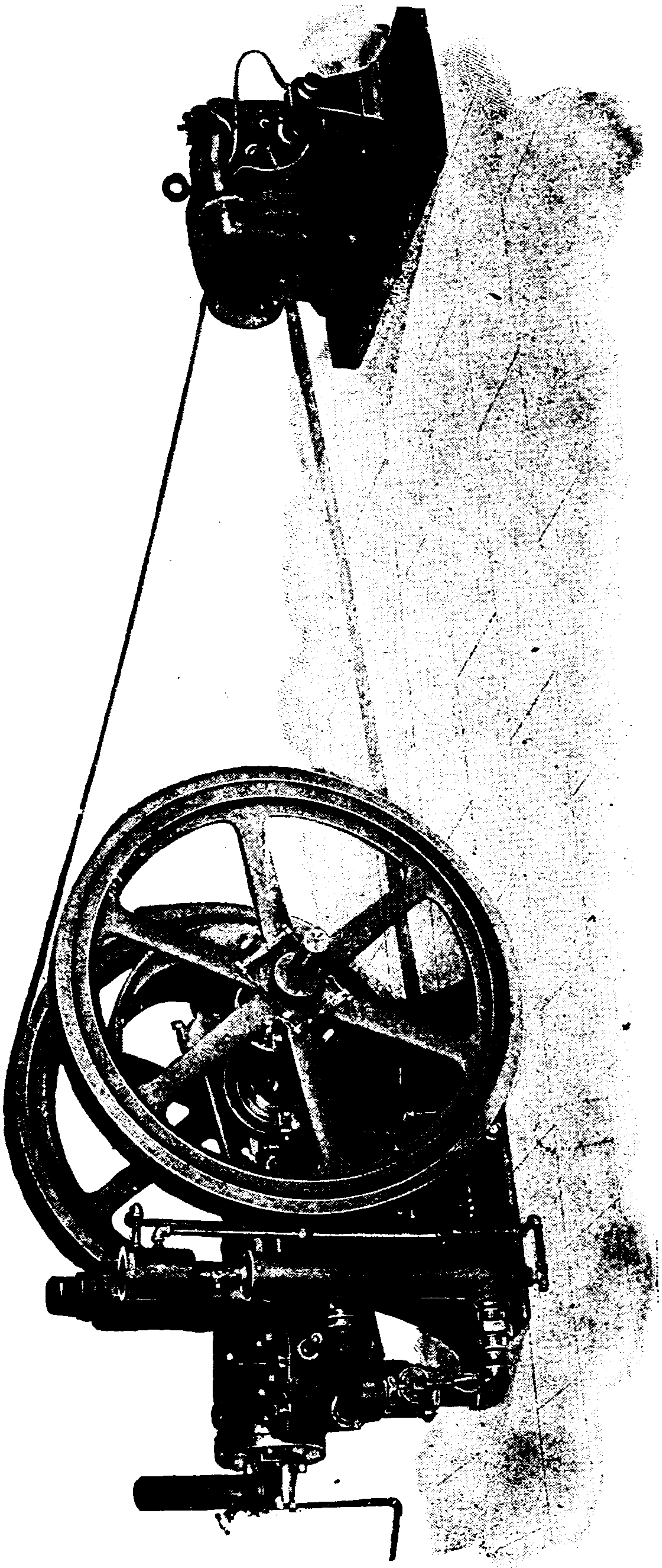


FIG. 180.—THE RACINE GAS AND GASOLINE ENGINE.

are of the four-cycle compression type. All valves are of the poppet style. The regulation of speed is made by a miss-opening of the exhaust valve, by which a fresh charge is excluded when the piston cushions on the previous charge until the normal speed is reached, when the governor again opens the exhaust valve and allows a fresh charge to be drawn in. This company furnishes both hot-tube and electric igniter for all their engines, so that failures shall not occur by the disabling of one or the other of the igniting apparatus.

The governor is of the horizontal centrifugal type, revolv-

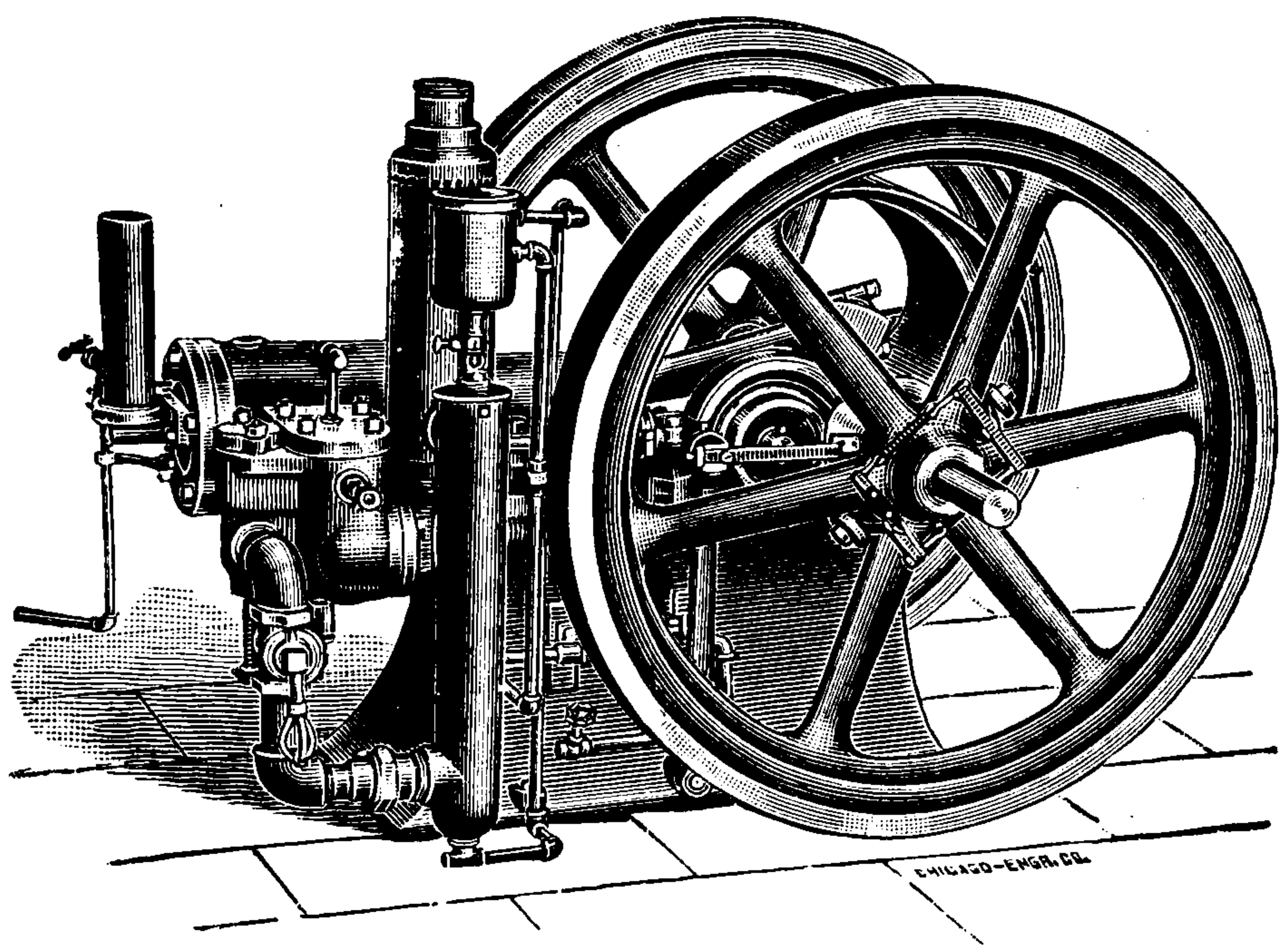


FIG. 181.—THE RACINE GASOLINE ENGINE.

ing on the main shaft, and by a lever connection produces a lateral movement of a rolling disc attached to the lever of the exhaust push-rod. The lateral motion of the governor-controlled disc rides the disc on to or off the exhaust cam on the reducing-gear for a miss-exhaust. The gasoline pump is operated by a cam on a small shaft driven by the reducing-gear, and furnishes a surplus supply to a receiving cup over the mixing-chamber, with an overflow pipe returning the surplus gasoline to the tank by gravity. Between the supply cup and the mixing-chamber there is a sight-feed valve, by which the flow of gasoline to the mixing-chamber may be observed and regulated. Any surplus or overfeeding produces no dangerous conditions, as the gasoline entering the mixing-chamber in excess falls into the recess at the bottom and is conveyed back to the tank through the overflow pipe from the supply cup. It will be observed by inspection of the cuts (Figs. 181 and 182) that the exhaust pipe is jacketed for a short distance above the engine, with inlet holes for the entrance of air at the top and a neck from the jacket to the mixing-chamber below, so that the air is warmed before meeting the incoming gasoline in the mixing-chamber, where by an extended surface the gasoline is perfectly vaporized and mixed with air for best effect. The

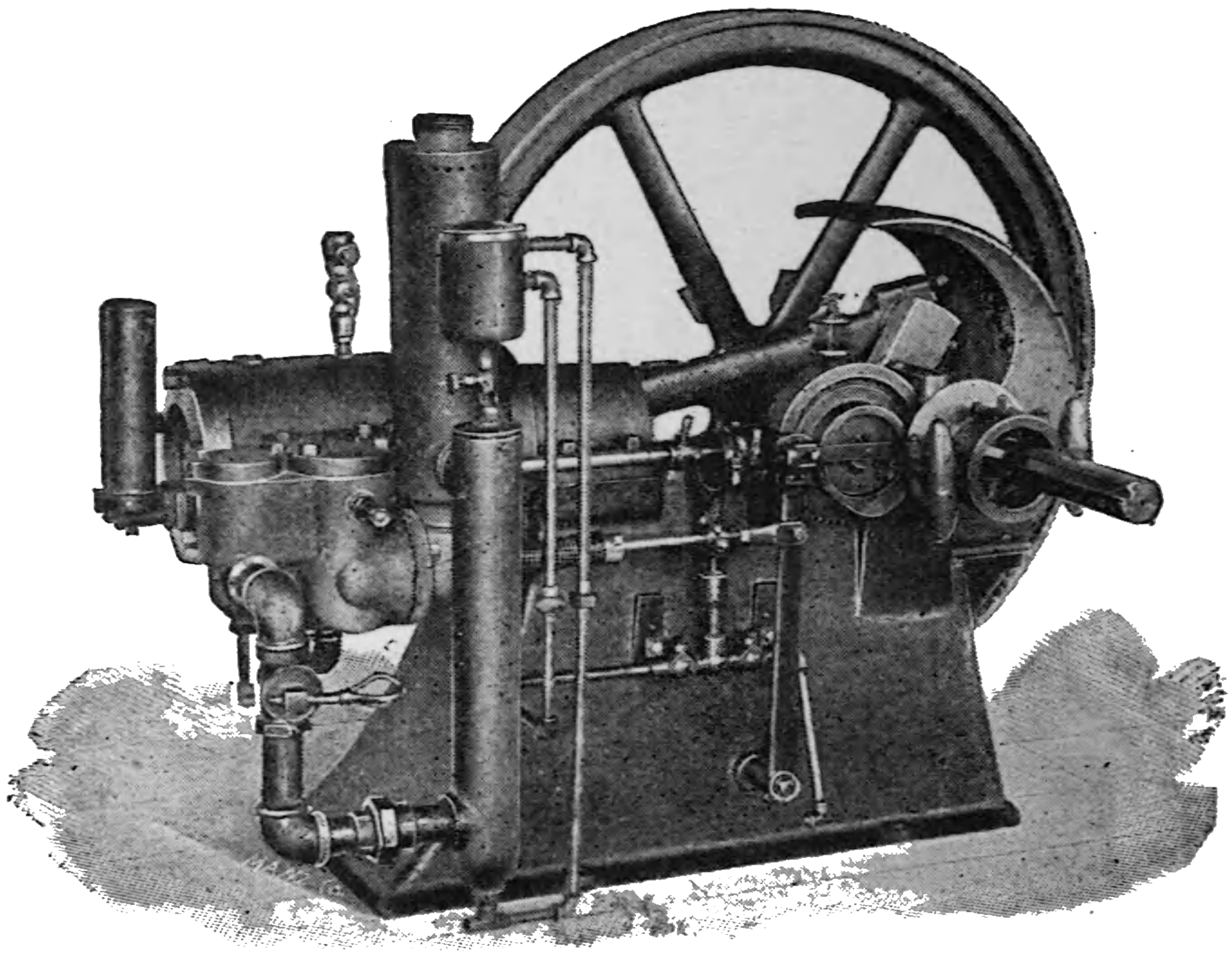


FIG. 182.—THE RACINE GASOLINE ENGINE.

quantity drawn in for ignition is regulated by the index valve near the inlet valve, at which point a further admixture of air completes the proportions necessary for the desired explosive action.

At present these engines are built of 2, 3, and 4 B.H.P. They are well adapted for small electric-lighting plants, as shown in Fig. 180.

The Hornsby-Akroyd Oil Engine.

This engine is of English origin and now built by the sole licensees of the United States patents—the De La Vergne Refrigerating Machine Company—in all sizes from 4 to 55 H.P They are of the four-cycle compression type, using any of the heavy mineral oils or kerosene as fuel.

time of ignition, giving as they do a sharp corner at the compression terminal, a quick and nearly vertical line of combustion, and an expansion curve above the adiabatic, equivalent to an extra high mean engine pressure for explosive engines.

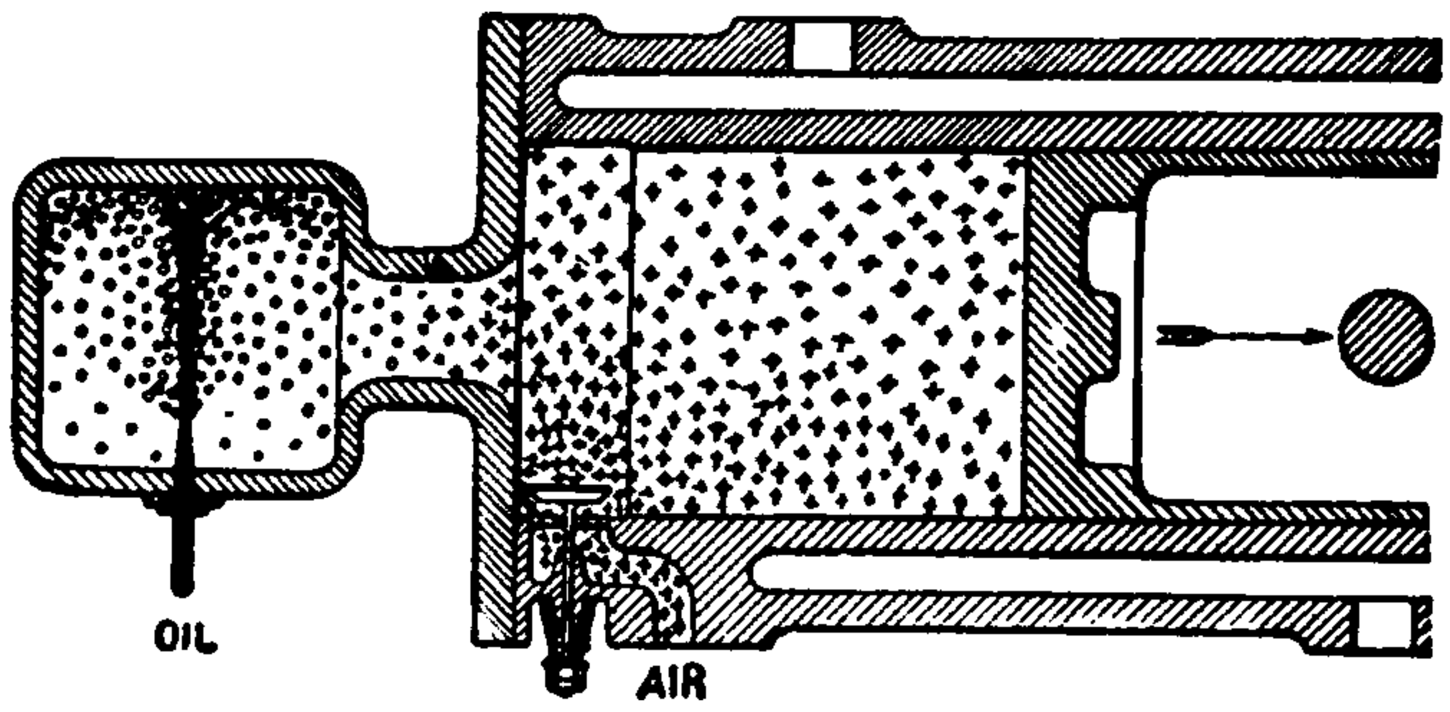


FIG. 184.—INJECTION, AIR AND OIL.

The oil is injected into the retort in liquid form by the action of the pump at the proper time to meet the impulse stroke,

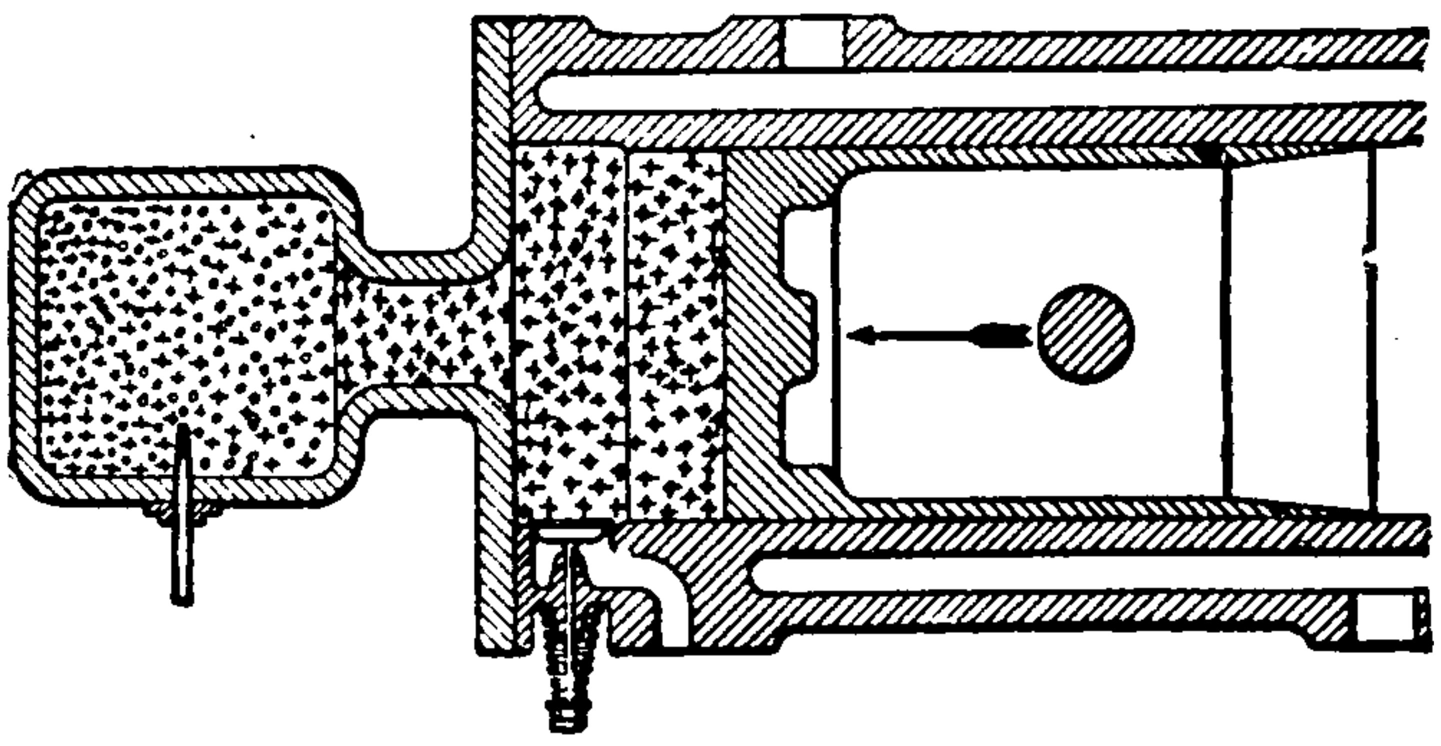


FIG. 185.—COMPRESSION.

and in quantity regulated by the governor. During the outer stroke of the piston air is drawn into the cylinder and the oil is

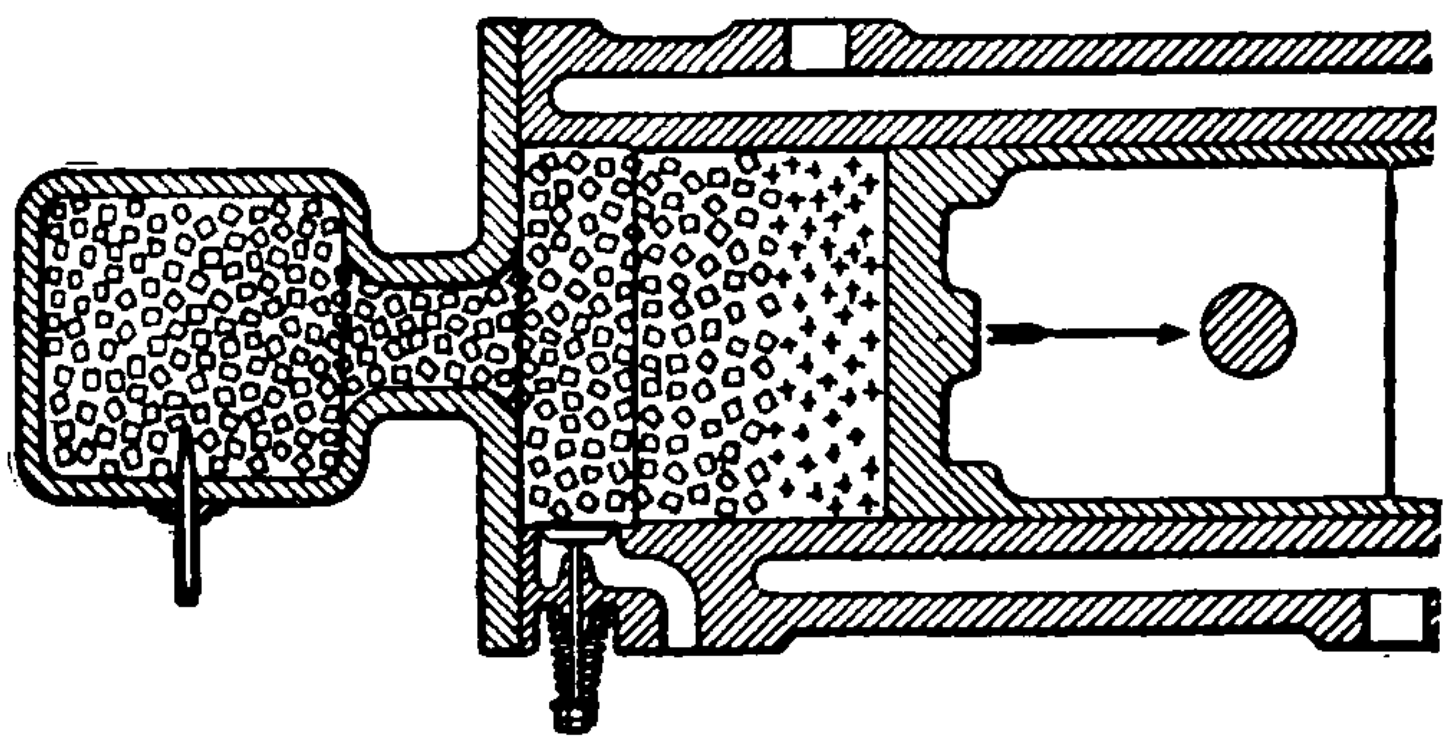


FIG. 186.—COMBUSTION AND EXPANSION.

vaporized in the hot retort. At the end of the charging stroke there is oil vapor in the retort and pure air in the cylinder, but non-explosive. On the compression stroke of the piston the air is forced from the cylinder through the communicating neck into the retort, giving the conditions represented in Fig. 184 and Fig. 185, in which the small stars denote the fresh air entering, and the small circles the vaporized oil. In Fig. 185 mixture commences, and in Fig. 186 combustion has taken place, and during expansion the supposed condition is repre-

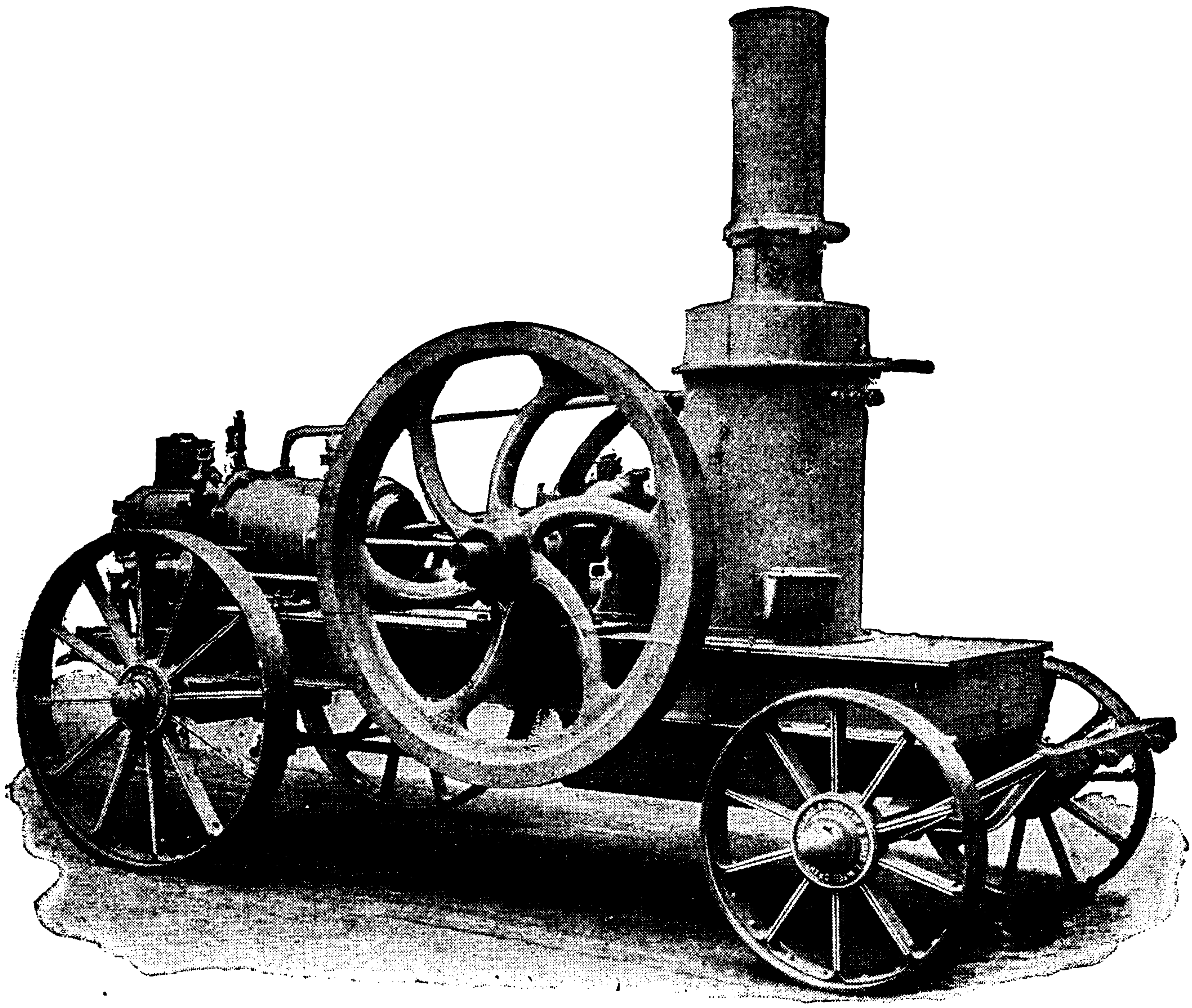


FIG. 187.—THE HORNSBY-AKROYD PORTABLE ENGINE.

sented by the small squares. At the return stroke the whole volume of the cylinder is swept out at the exhaust, and the pressure in the retort neutralized and ready for another charge.

It is noticed by this operation that ignition takes place within the retort, the piston being protected by a layer of pure air.

It is not claimed that these diagrams are exact representations of what actually takes place within the cylinder; nevertheless, their substantial correctness seems to be indicated by the fact that the piston rings do not become clogged with tarry substances, as might be expected.

This has been accounted for by an analysis of the products

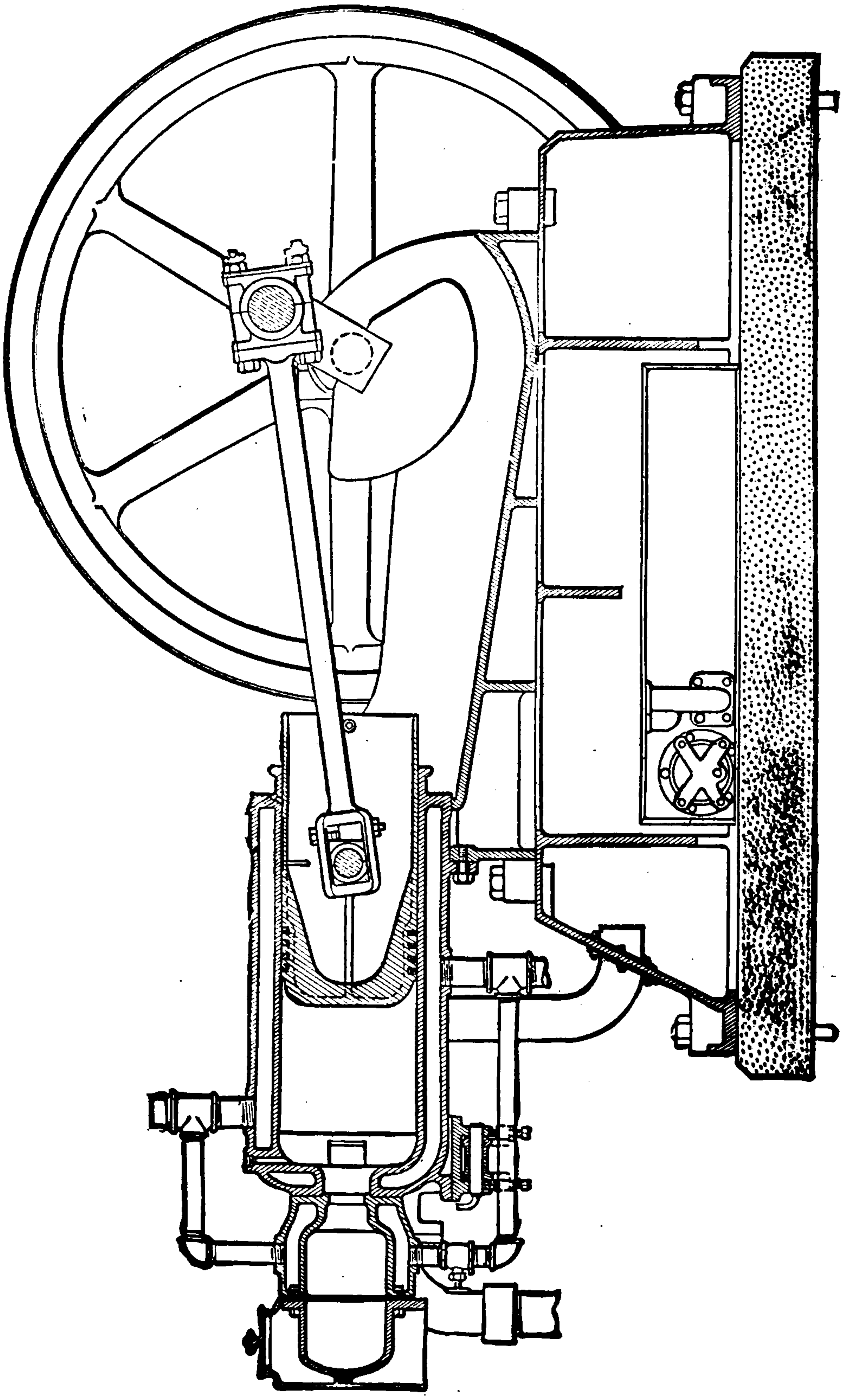


FIG. 188.—SECTIONAL ELEVATION, HORNSBY-AKROYD OIL ENGINE.

of combustion, which shows an excess of oxygen as unburned air; which indicates that the oil vapor is completely burned in the cylinder, with excess of oxygen.

In Fig. 187 is illustrated the adaptation of this engine for portable power. It is largely in use for electric work, for air compressing, ice machinery, and pumping. The United States Light-House Department has adopted this engine for compressing air for fog whistles. Traction engines and oil-engine locomotives for narrow-gauge tramways and mining railways will soon be one of the manufacturing departments of the De La Vergne Company.

In Fig. 188 is shown a sectional elevation, details of design of the cylinder, piston, combustion chamber and its case. It may be noticed that the combustion chamber is made in two parts, flanged together, so that by a special water jacket the front half is kept cool and to limit the firing plane in the combustion chamber to a definite position. The oil reservoir, located in the base of the engine, is partitioned to allow of traversing the intake air over and around the oil to take any vapors or odors from the oil and constantly sweep them into the cylinder.

In Fig. 189 is shown the direct connection of an oil motor with a triplex pump by means of a friction clutch. This convenient and most economical arrangement allows the motor to be easily started alone and its power gradually applied to the pump without undue strain or jar.

The R. & V. Gas and Gasoline Engines.

In Fig. 190 we illustrate the four-cycle engine of the Root & Vandervoort Engineering Co., East Moline, Ill., and in Fig. 192 the bed frame with pillow blocks and spiral reducing gear. In the design of these engines the cylinder is overhung and bolted to the face of the bed frame. The journal bearings are of the quarter box type, babbitted and adjustable. Beneath each box is an oil chamber with chain oiler running over the journal.

The side shaft operates the exhaust valve by a cam and also the gasoline pump, sparker trip, and drives the governor by bevel gear. The governing is by limiting the charge through the gas inlet valve or pump stroke.

Ignition is by the hammer type with electrodes of hard platinum, with attachment at the center of the cylinder head, which is also water-cooled. The sparking trip, which is placed conveniently on the head of the cylinder, is simple and positive in its action; is noiseless and quickly adjustable for timing the spark.

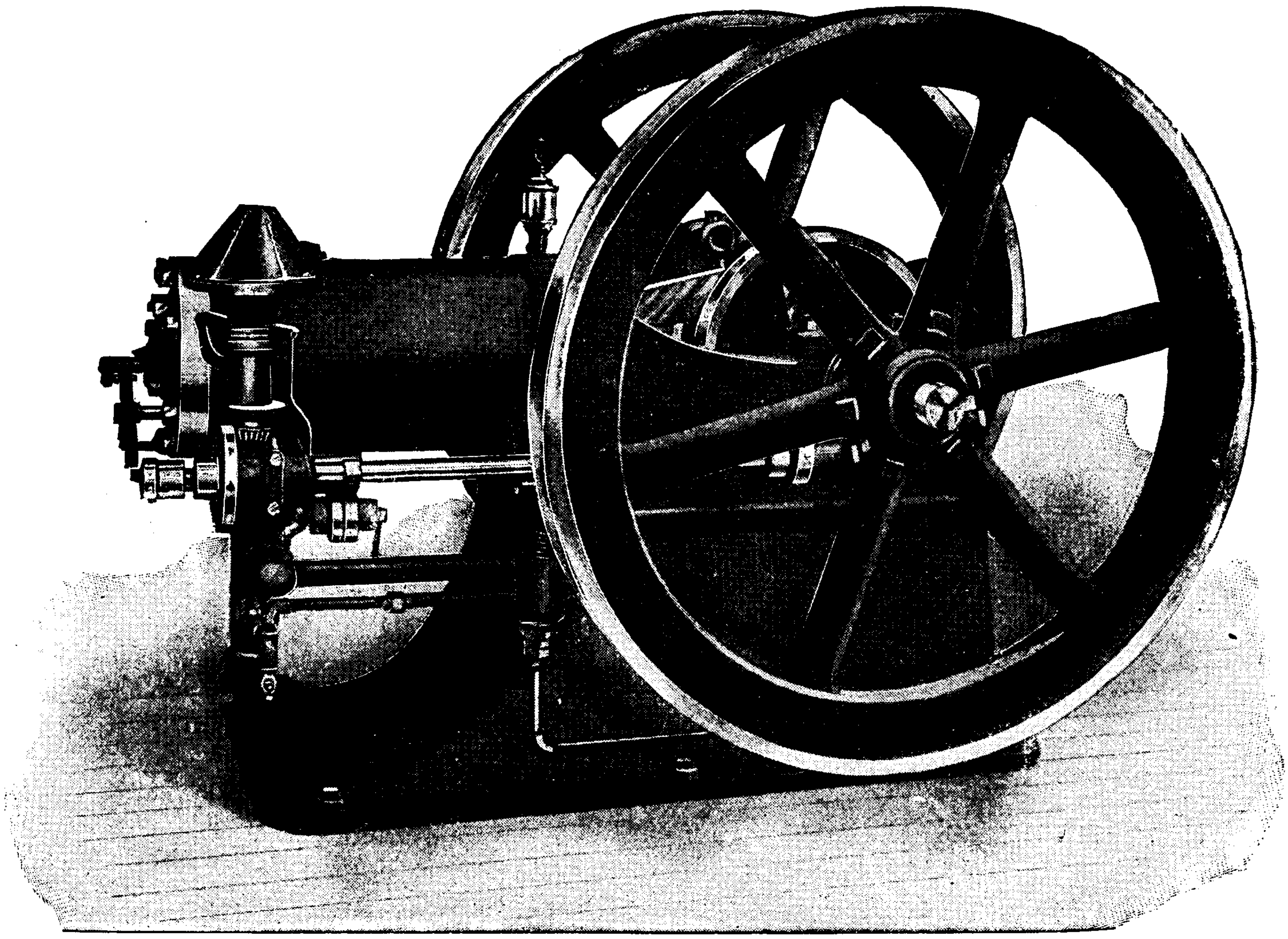


FIG. 190.—R. & V. HORIZONTAL GAS AND GASOLINE MOTOR. THE ROOT & VAN DERVOORT ENGINEERING CO., EAST MOLINE, ILL.

Each engine is furnished with a full equipment for any service with a sparking dynamo, or a set of batteries complete and ready for starting, together with plans and directions for setting, starting and taking care of engine.

The horizontal engines are built in four sizes from 3 to 14 horse power, and of the vertical type in three sizes of 1, 2 and 3 horse power.

In Fig. 191 is well shown the exhaust side of the cylinder and valve lever with the engine connected to a dynamo for lighting

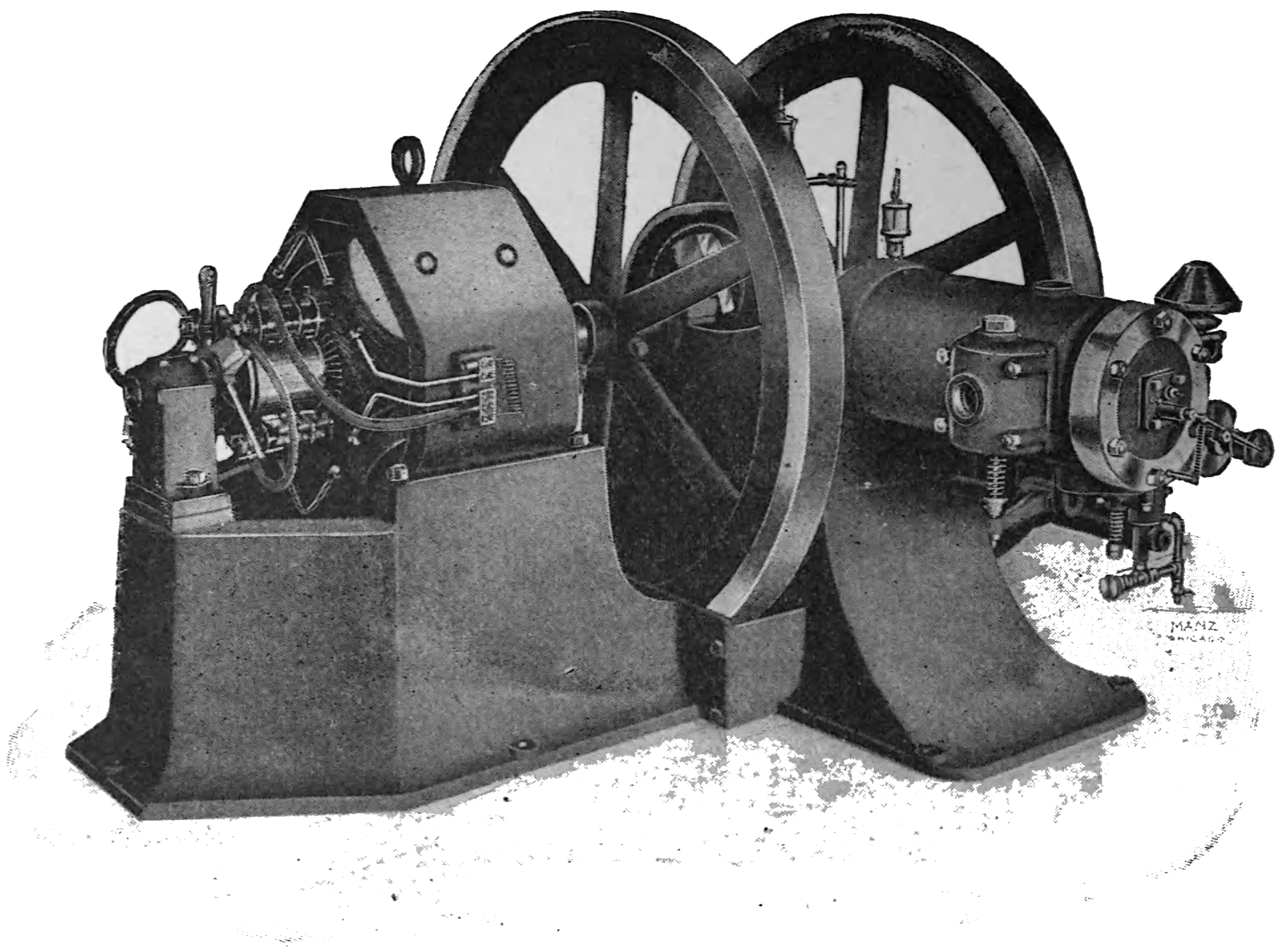


Fig. 191.—R. & V. Direct-Connected to Dynamo.

purposes. The engines are also mounted without the sub-base on wagons for portable use and are becoming very popular among the farming community.

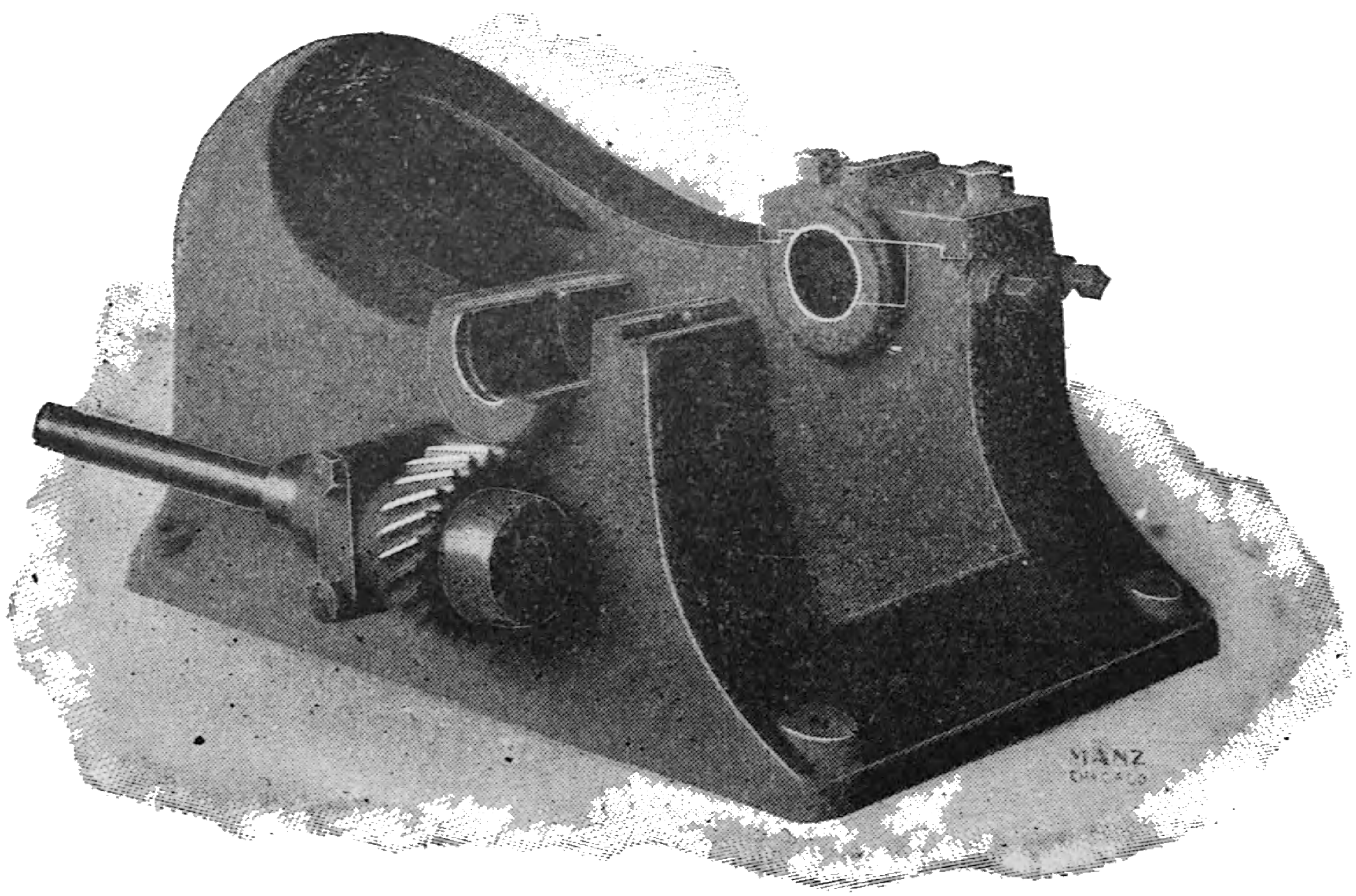


Fig. 192.—The Bed Frame.

and drip at T; U the pump and *c* a strainer. Special packings in the journals at *a, b;* the exhaust lever at D, and the hammer spark device at E, H, G. Lubrication of the internal parts is made by the dasher at the end of the connecting rod.

In Fig. 194 is shown the arrangement for operating the spark-

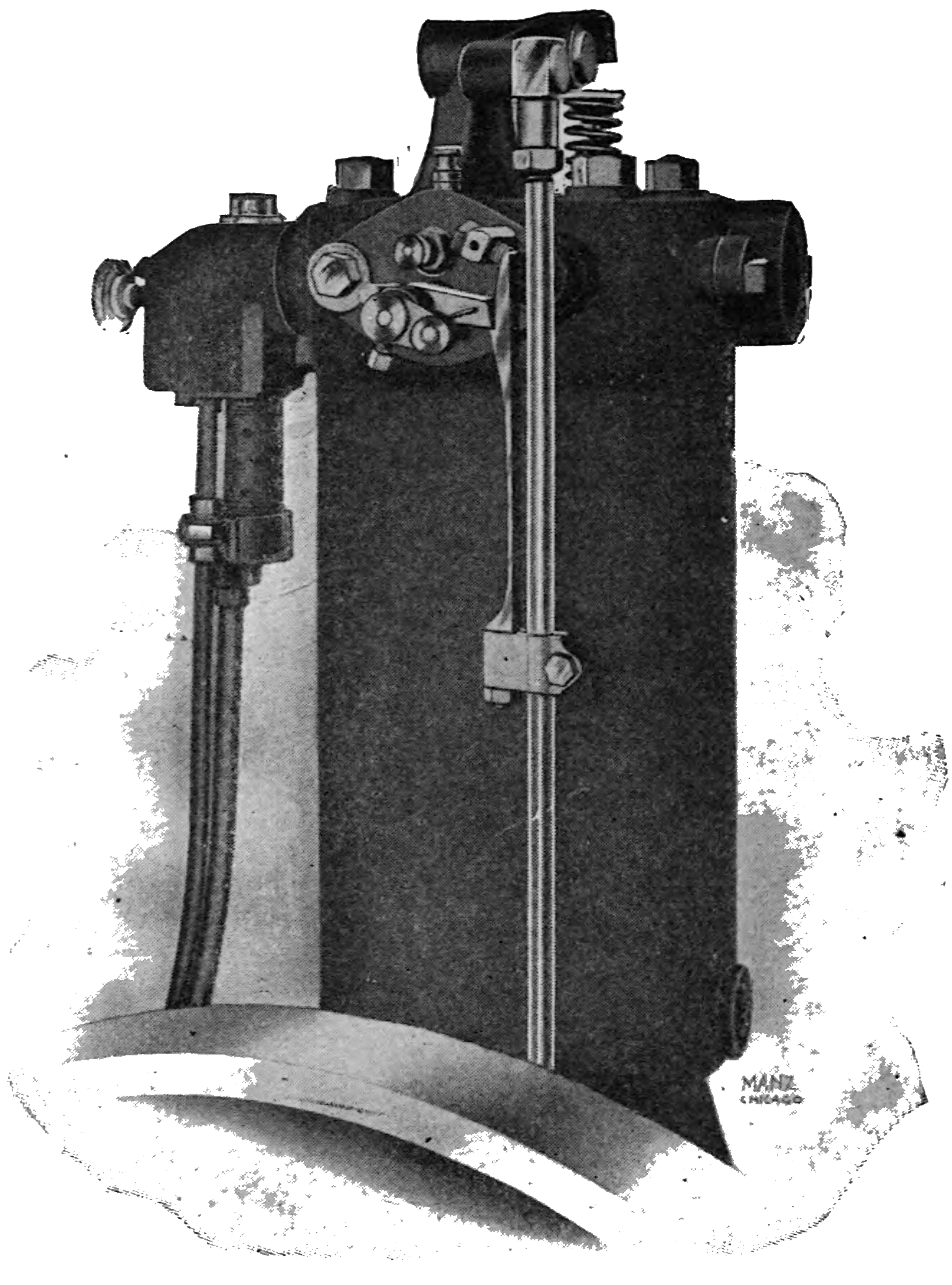


FIG. 194.—EXHAUST VALVE ROD AND SPARKING TRIP DEVICE.

ing device by a spring-clip rod attached to the exhaust valve push rod, the contact and break of the hammer being adjusted as to time by a screw in a block just above the catch which accelerates or retards the ignition time with positive effect.

The charging chamber at the left in the cut is of the constant level type with an excess of overflow back to the tank in the base of the motor.

The White & Middleton Gas Engine.

This engine is equally suited to both gas and gasoline, and is made by the White & Middleton Gas Engine Company. All their engines are of the four-cycle compression type, with the principal exhaust ports opened by the piston at the end of its

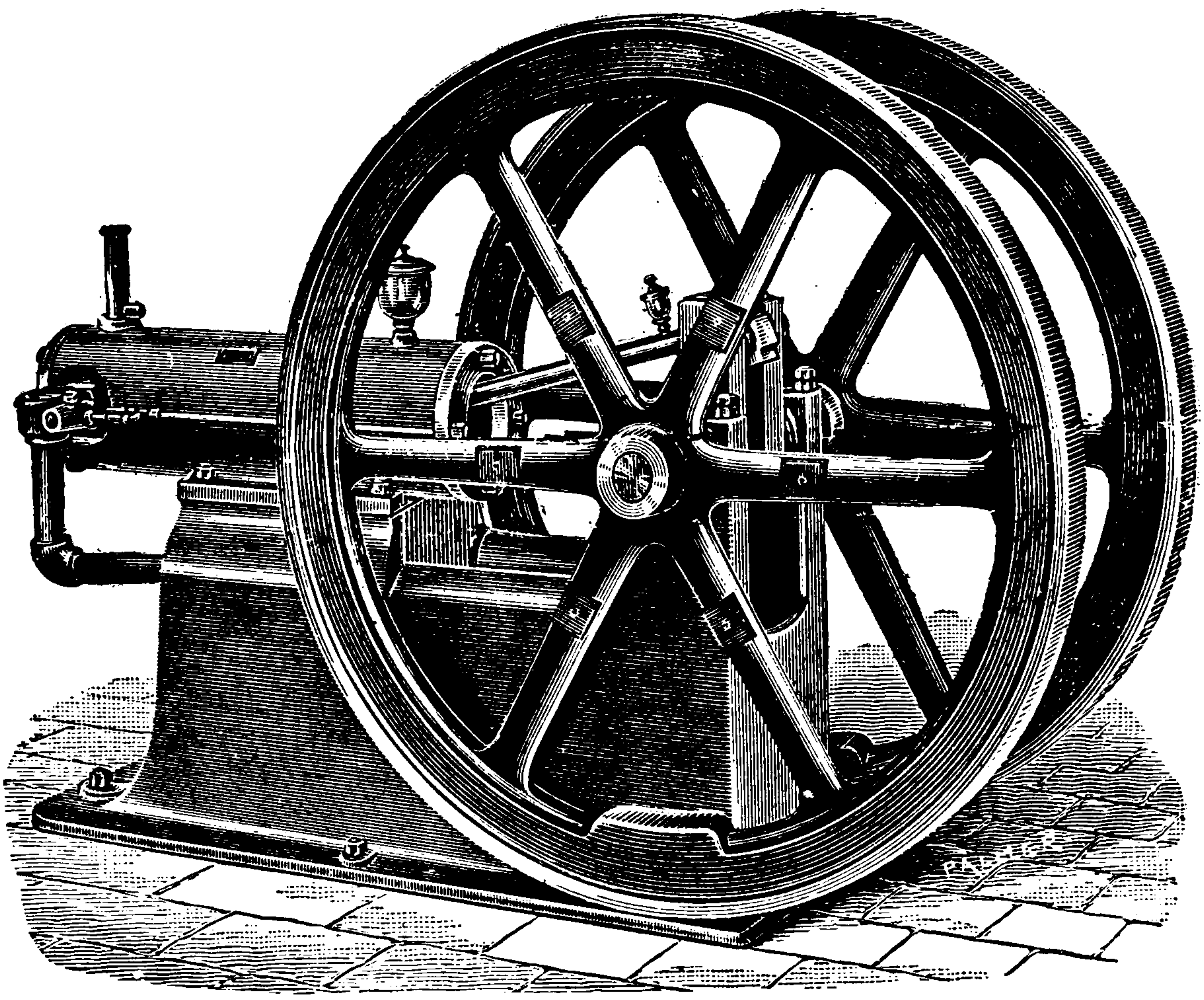


FIG. 195.—THE WHITE & MIDDLETON ENGINE.

explosive stroke, and with an additional or clearance-exhaust valve in the cylinder head.

The valves are all of the poppet type. The supplementary exhaust valve is operated by a lever across the cylinder head and a push-rod direct from a differential slide mechanism, which does away with the reducing-gear used on other engines. An arm on the push-rod operates the gas-valve stem, which is provided with a regulating adjustment.

The small roller disc on the push-rod mechanism is under the control of a centrifugal governor and a spring, being thrown out of gear with the shaft cam whenever the speed of the engine exceeds the normal rate, and thus failing to open the gas supply and the supplementary exhaust valve until the speed of the engine has returned to its normal rate. There is a relief valve opening into the supplementary exhaust passage for relieving the pressure in the cylinder when starting the

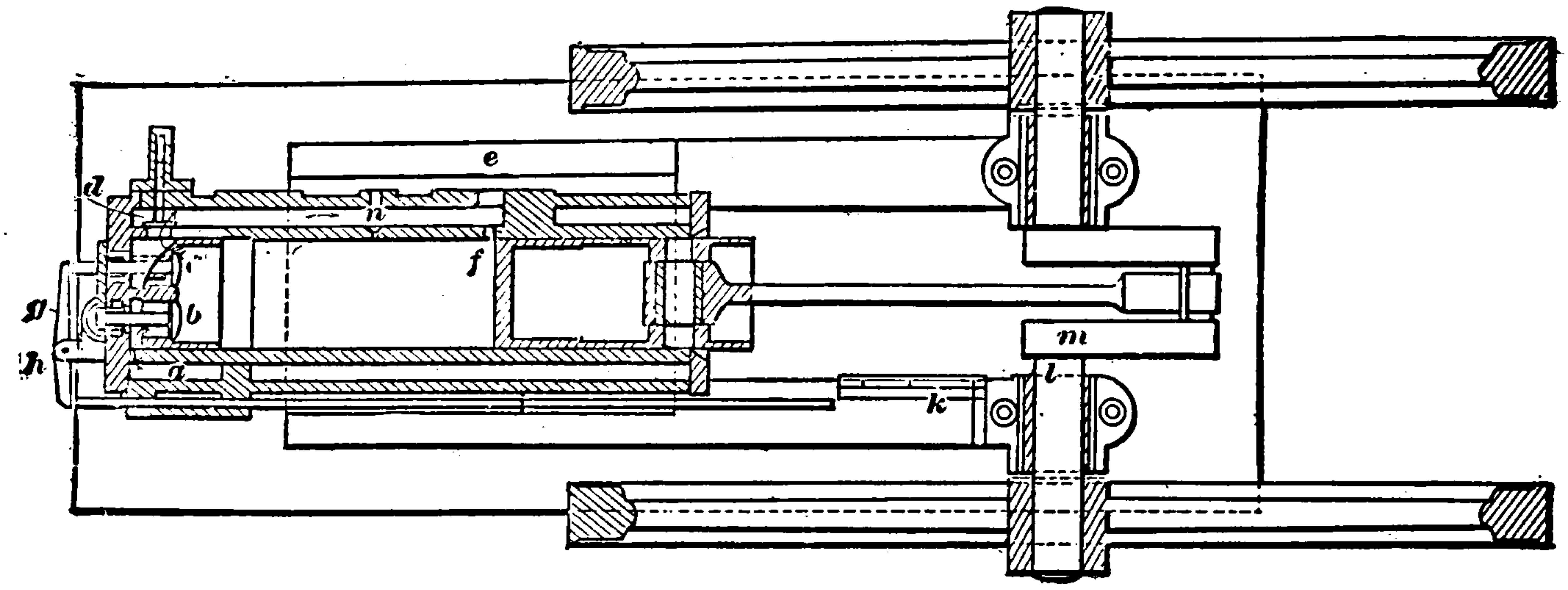


FIG. 196.—SECTIONAL PLAN OF THE WHITE & MIDDLETON ENGINE.

engine. The whole design of the engine is exceedingly simple and its action noiseless.

When gasoline is used the gas-supply valve is replaced by a small pump, which is operated by the push-rod, and its hit-or-miss stroke is governed by the action of the push-rod and its governor.

These engines are built in nine sizes, from 4 to 50 B. H. P.

The Light Weight Motor.

In Fig. 197 we illustrate one of the lightest weight motors on the market, being but 27 pounds per brake horse power at its maximum speed of 1,800 revolutions per minute. The cylinders are 3¾-inch diameter by 3½-inch stroke. The cylinder and head are cast in a single piece, with a water jacket covering both cylinder and head. No gaskets to blow out and no leakage of water to the cylinder.

CHAPTER XIX.

VARIOUS TYPES OF ENGINES AND MOTORS—CONTINUED

Petter's Gasoline Engine and Motor Carriage.

THE Petter engine is an English design and so simple in its parts that we give it a place here for the benefit of our amateur friends.

As designed for a carriage for four persons, the cylinder is made 3½ inches diameter, 6 inches stroke; the inner shell of the cylinder of cast iron, ½ inch thick at the combustion end. The outer shell is made of thin tubing driven over the flanges

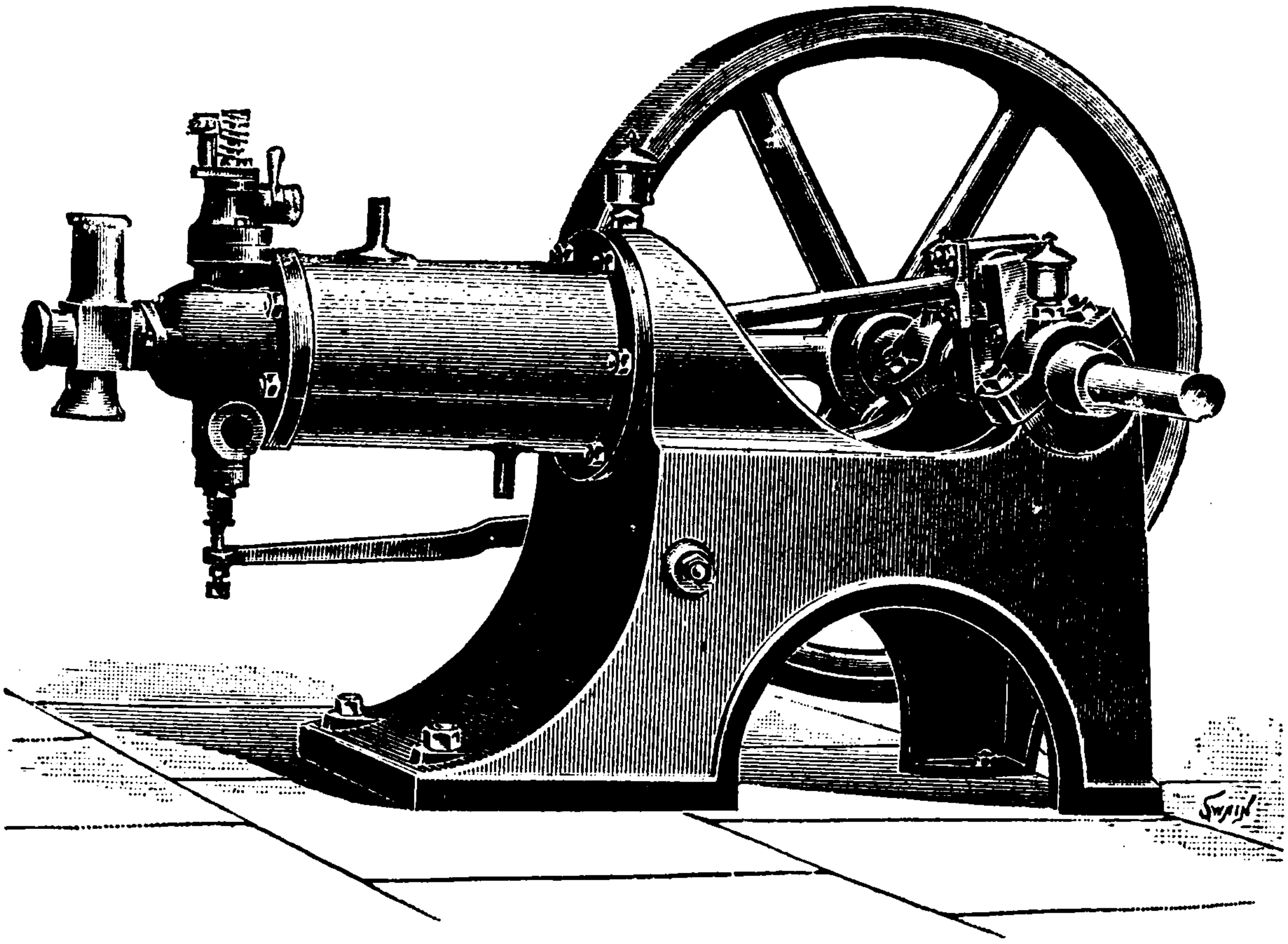


FIG. 217.—THE PETTER STATIONARY ENGINE.

and calked. When made for a stationary engine the outer shell may be made of cast iron and pushed over the inner cylinder, as shown in the sectional cut, Fig. 218.

The engine is of 1 H. P. actual at 200 revolutions. The principles of both stationary and carriage engines are essentially the same. For a carriage, the cylinder is bolted to two parallel steel bars, which carry the main bearings.

The crank shaft is balanced and has a bored recess for oil, holding sufficient for a day's run. The gasoline gravitates to the inlet valve A through a percolator G, Fig. 218, and atomized by the air drawn in through B by the suction of the piston. The exhaust-valve E is operated by a long lever from a cam on the reducing-gear.

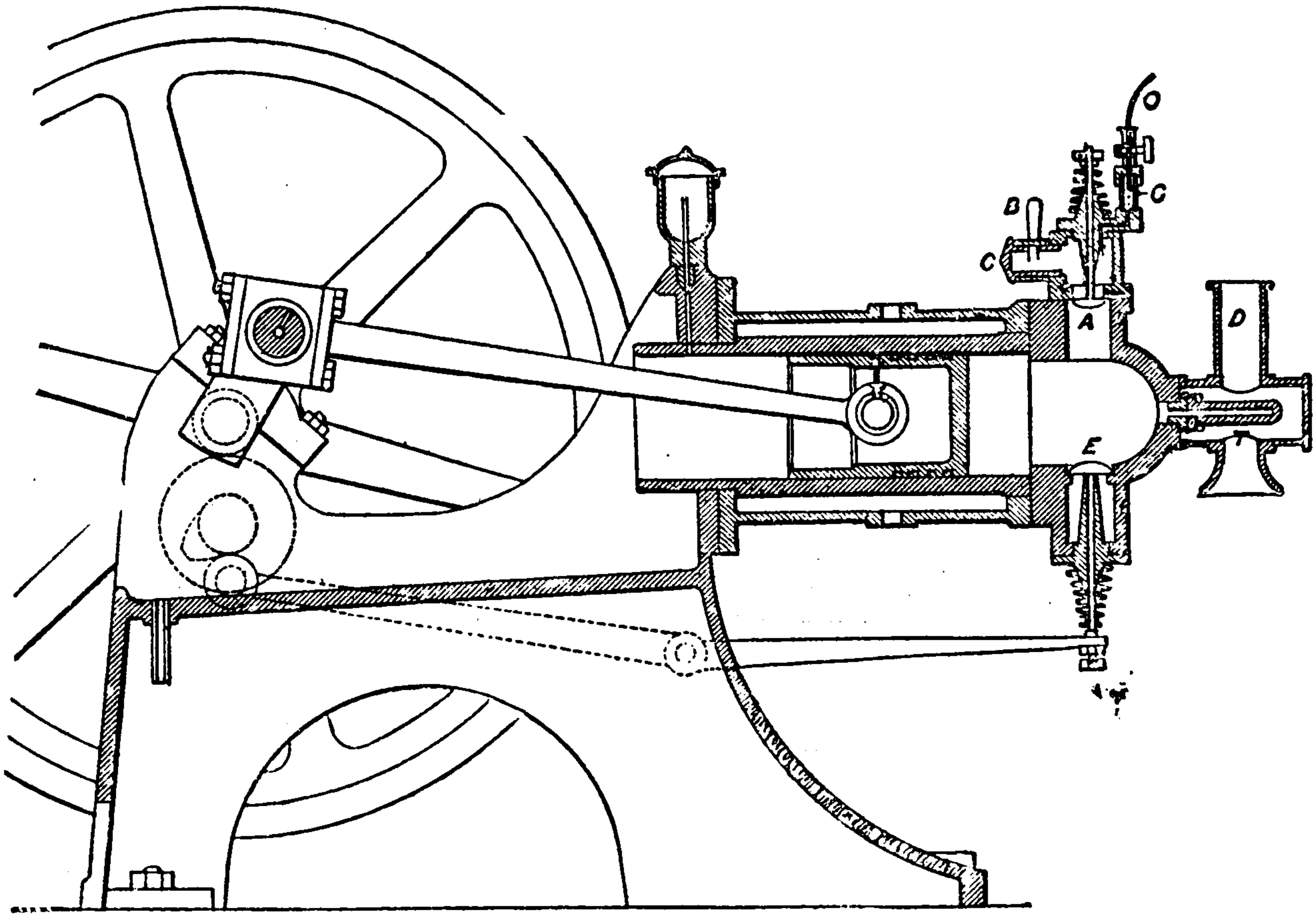


FIG. 218.—SECTION OF THE PETTER GASOLINE ENGINE.

Fig. 219 represents the general plan of the motor carriage and driving-gear. The first motion chain E E′ conveys power to the intermediate shaft H by means of a friction-gear operated by a lever in the carriage at the right hand of the driver at G, which presses the bell crank W, slightly moves the shaft and grips the chain wheel E′ between the wooden blocks on the disks F F F F. The same lever pulled instead of pushed puts on the brake, and thus forms in one the starting, stopping, and brake lever. Another lever M is for changing the speed by releasing or closing the clutch of the high-speed sprocket N.

The low-speed gear L K has an overrunning ratchet on the main axle at R. A removable handle S is used for starting the engine and at the same time by an arrangement not shown in the cut opens the exhaust until the first charge is fired. The water and gasoline are placed under the back seat and neatly enclosed.

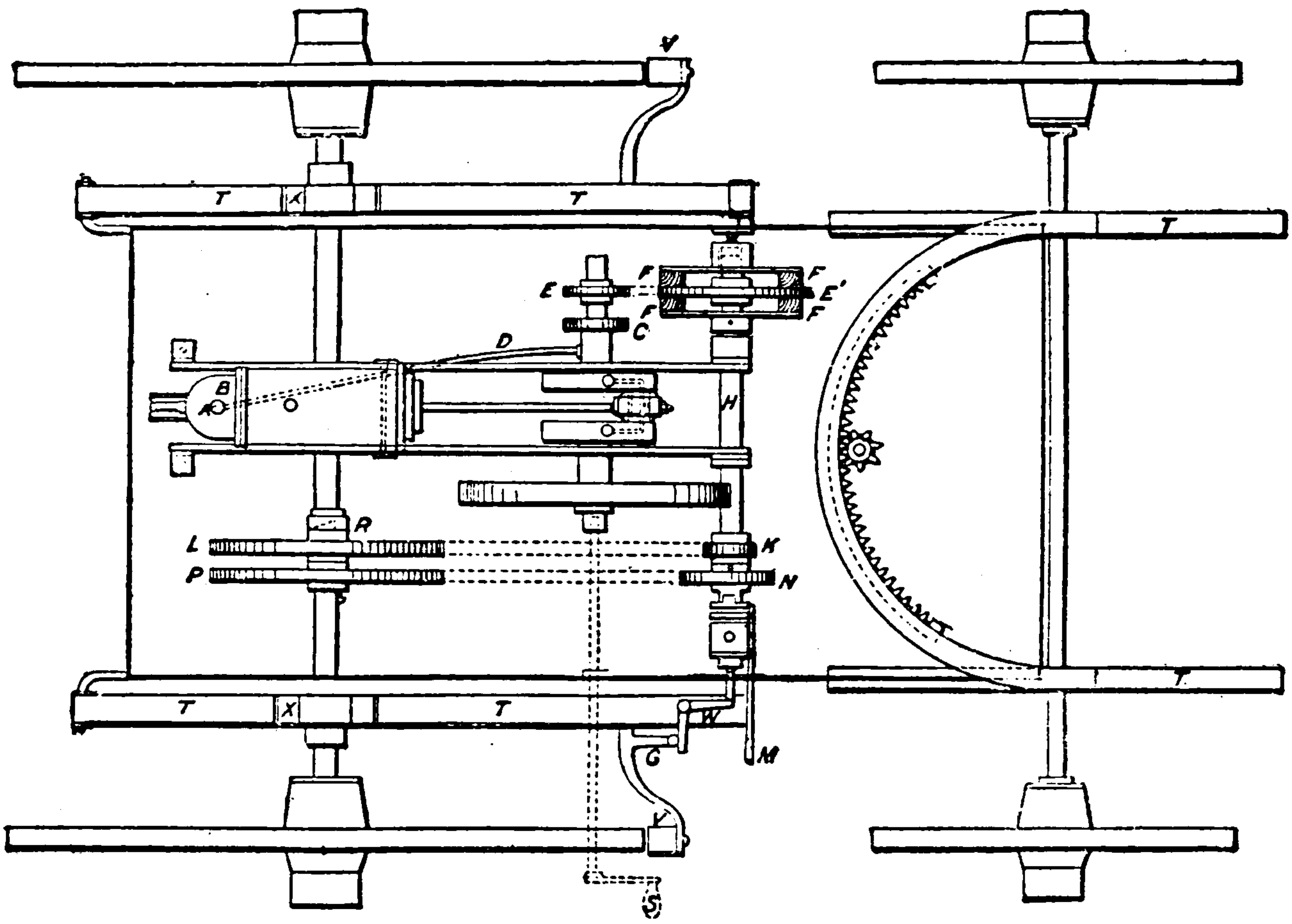


FIG. 219.—PLAN OF THE PETTER MOTOR CARRIAGE.

The Otto Gas and Gasoline Engine.

The "Otto Gas Engine" is essentially a historic name, and as now built by the Otto Gas Engine Works, Philadelphia, Pa., combines the fundamental principles first put in practice by Dr. Otto in Germany in 1867, and which is the basis of our best working engines. The four-cycle compression type seems to have become a standard, and in the workshops of the Otto Co. in the United States has been modified and developed into a most perfect action by improvements in the lines of the most approved details of construction.

FIG. 234.—THE OTTO HORIZONTAL GAS ENGINE OF 45 AND 56 H.-P. WITH SELF-STARTER.

charge. The electric or hot-tube igniter is furnished at the option of purchasers.

The electric spark is made by breaking contact of platinum electrodes, one of which is insulated in the head of the cylinder, the trip being operated on the outside by a swinging push-blade driven by an eccentric pin on the end of the valve-gear shaft.

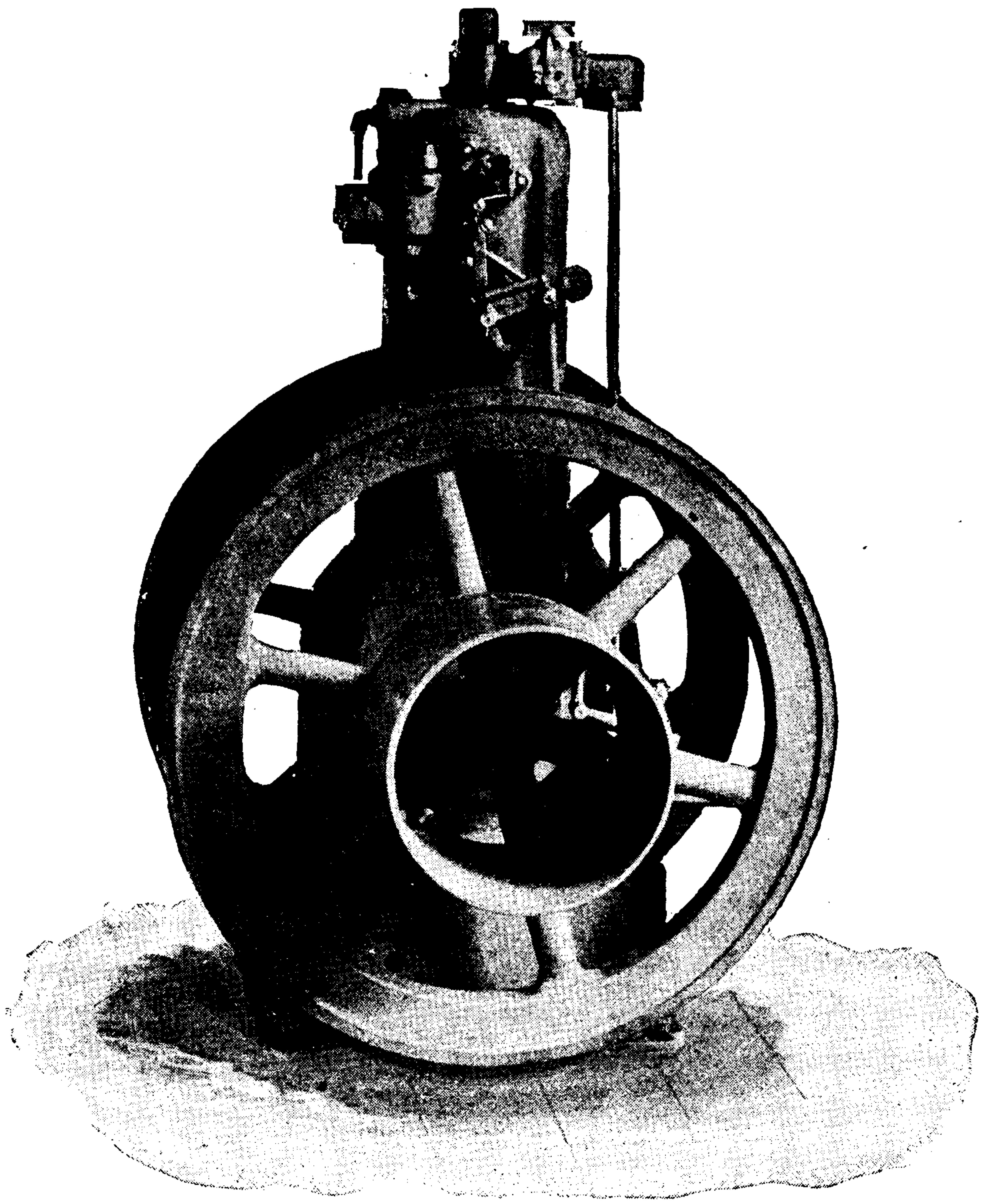


FIG. 235.—THE VERTICAL 3½ H.-P. GAS ENGINE.

The horizontal engines are built in various sizes from 3½ to 100 horse-power. The vertical type of the Otto engines is built in a neat and compact form for both stationary and marine power—the single cylinder from 1 to 12 horse-power, and with double cylinders from 17 to 100 horse-power.

FIG. 240.—THE 5 TTO" WITH 22 H.-P. ENGI N.

Plan, showing arrangement of "Otto" Gasoline Engine, in Yacht "Otto."

FIG. 241.—PLAN OF THE "OTTO."

These engines are of the four-cycle Otto compression type, and equally adapted for the use of gas or gasoline fuel.

For electric lighting power these engines have given a most satisfactory test. Fig. 236 illustrates the vertical two-cylinder or marine type of the Otto gas or gasoline engine with direct connection to a four-pole generator with elastic coupling, which ensures freedom from unequal journal pressures, as between the motor and generator, as well as the elimination of belt friction.

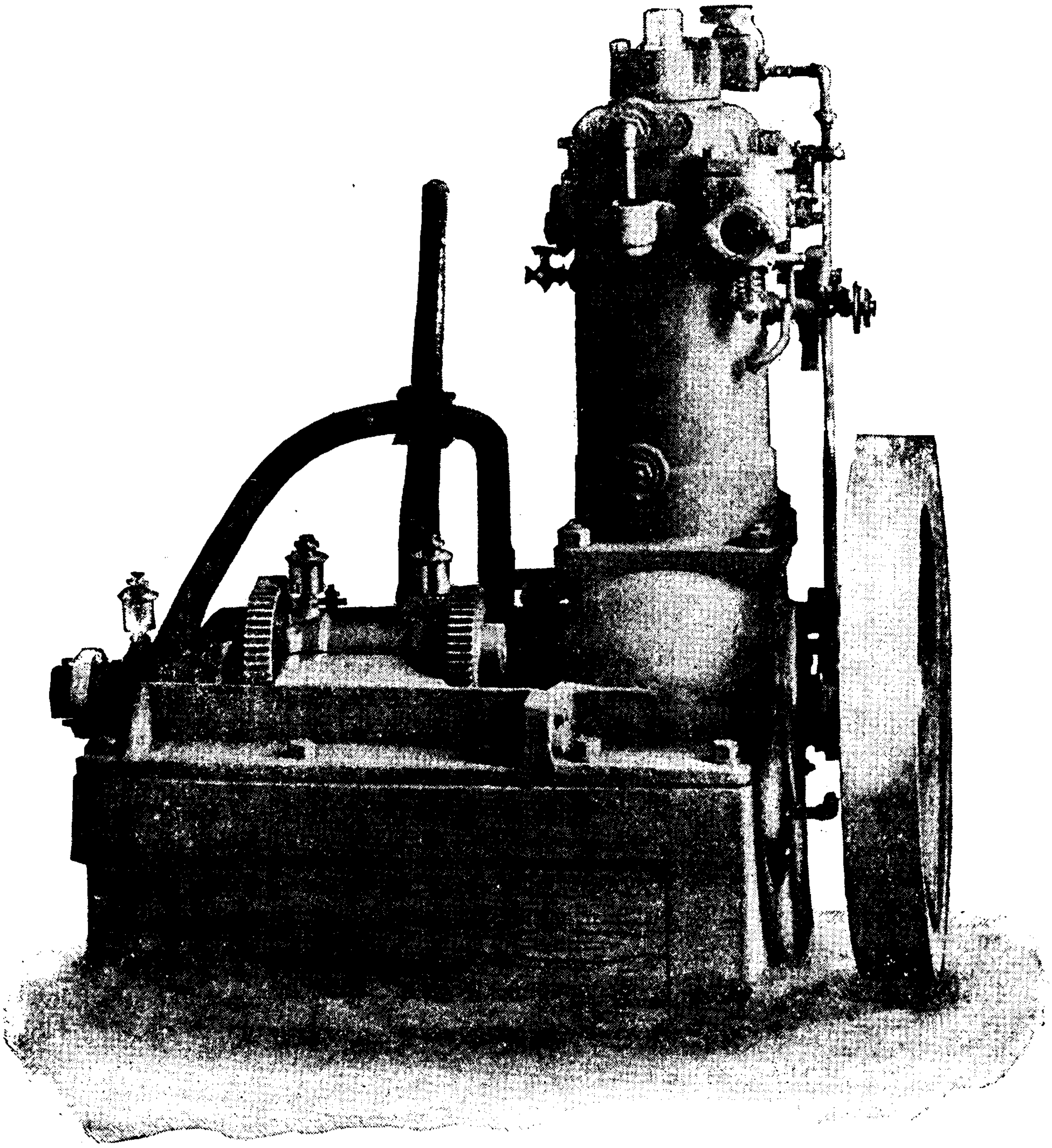


FIG. 237.—SMALLER SIZE MARINE ENGINE WITH REVERSING-GEAR.

The Otto Marine Engine.

The small marine engines have a single cylinder from 1 to 12 horse-power and two cylinders from 17 to 100 horse-power.

All sizes are made with reversing-gear or with reversible propeller blades, as desired. The same general principles of construction characteristic of the Otto type have been carried out in all the marine engines. The crank is enclosed in a case,

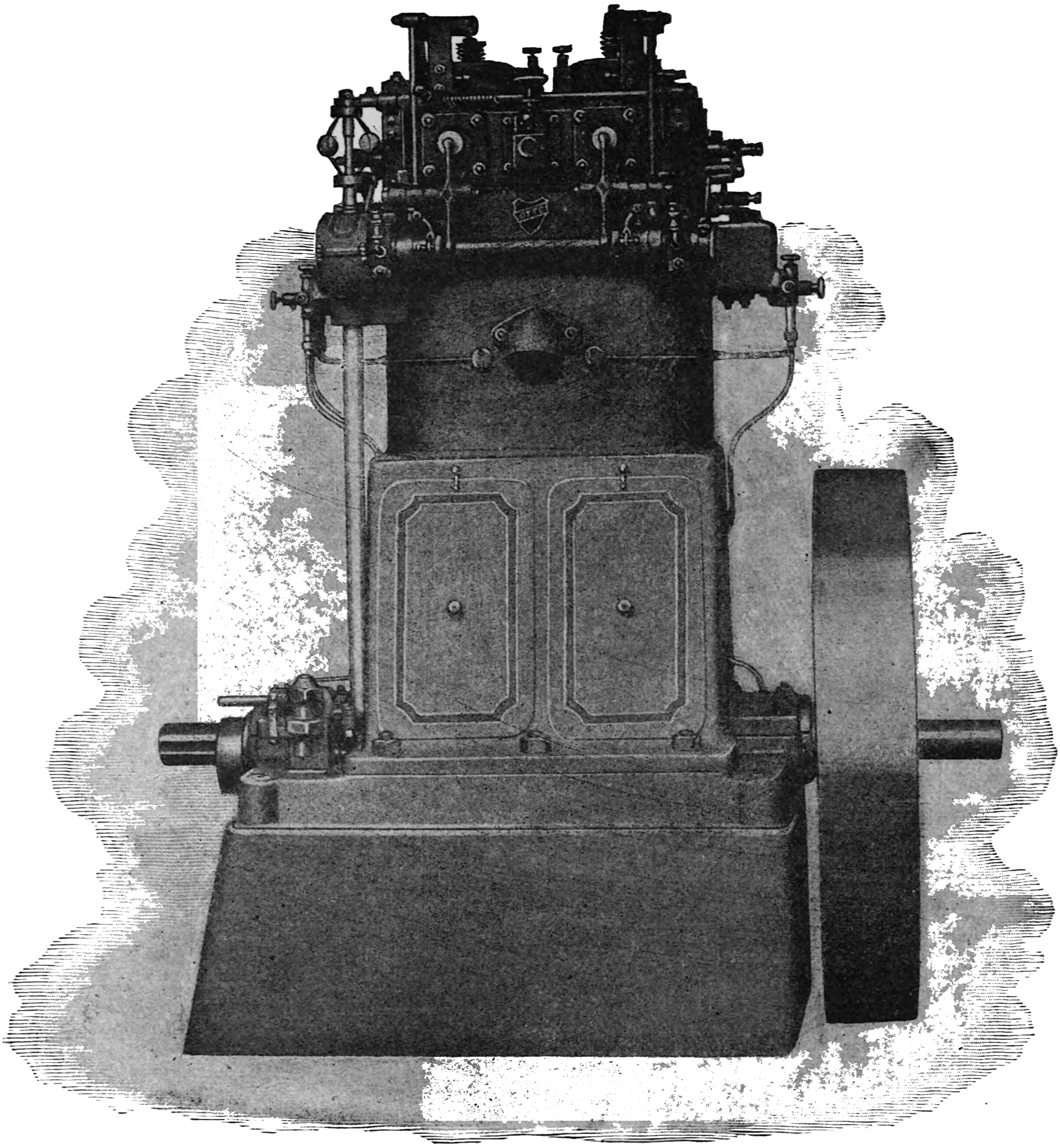


FIG. 238.—THE DUPLEX VERTICAL STATIONARY AND MARINE ENGINE. STARBOARD SIDE. BASE IS NOT USED IN THE MARINE ENGINE.

and all wearing parts are oiled from sight-feed automatic oil-cups, so arranged as to be controllable and in view while the engine is running. The gasoline is forced to the cylinders in

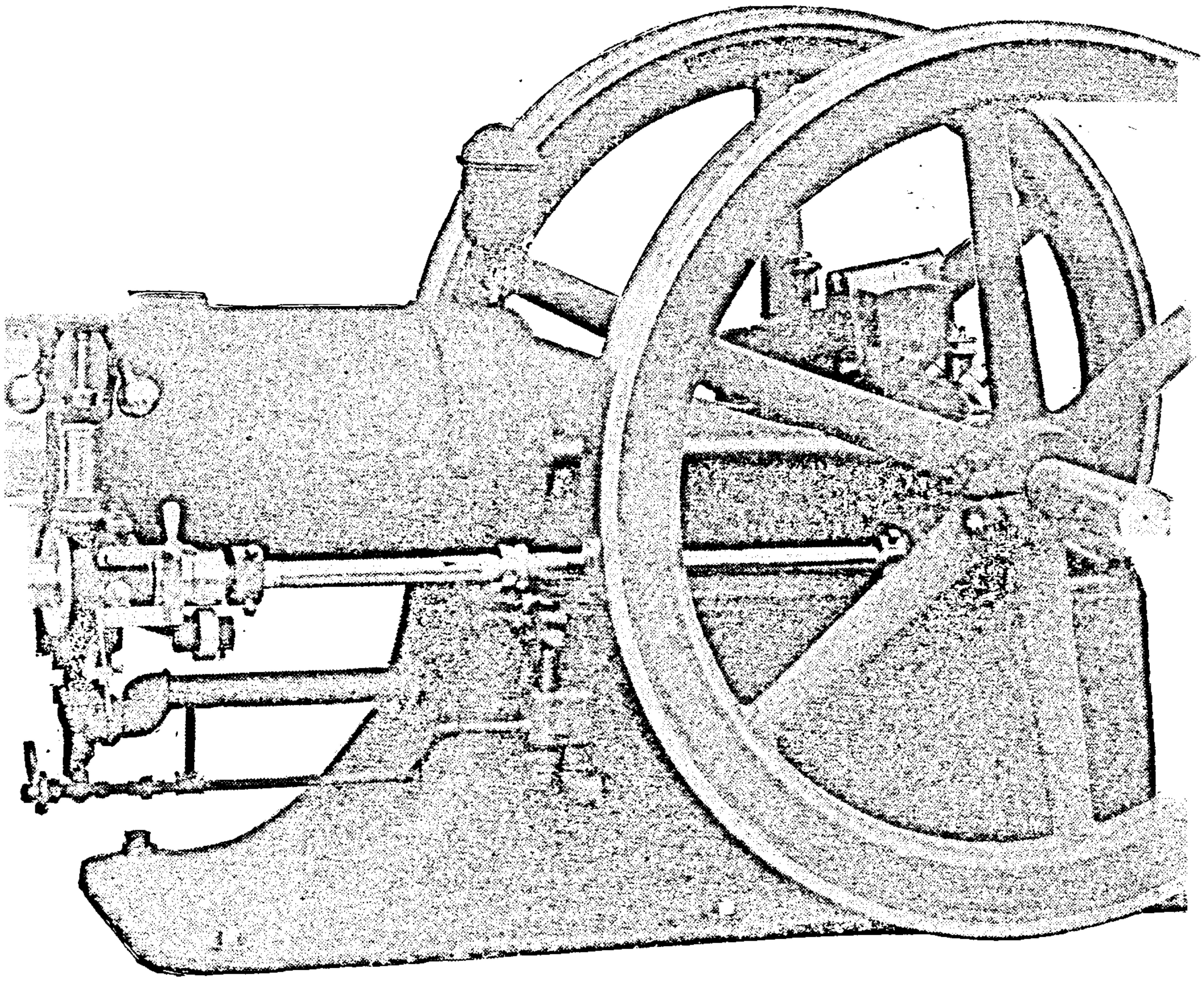


FIG. 242.—THE HAMILTON GASOLINE ENGINE.

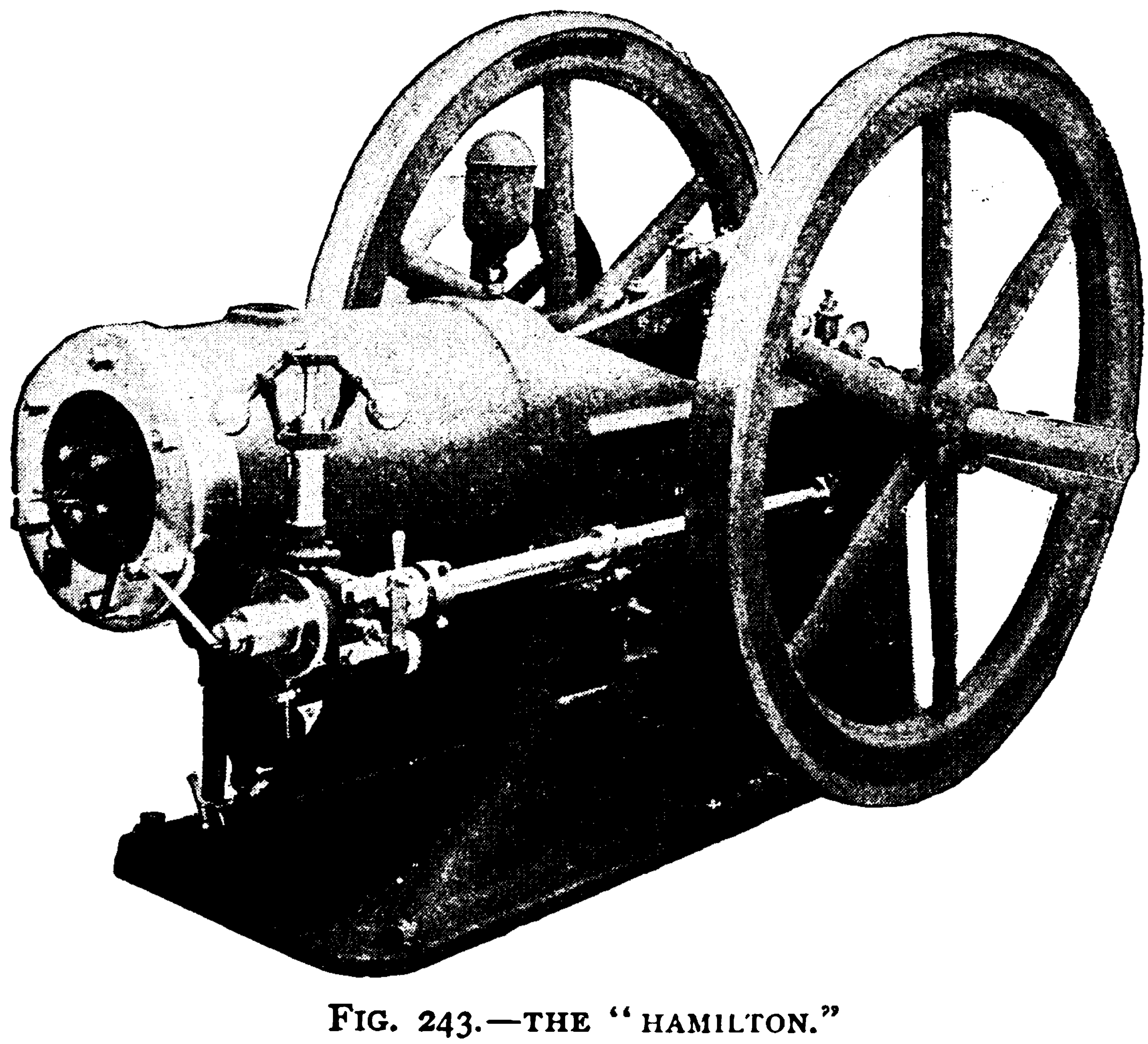


FIG. 243.—THE "HAMILTON."

opened by a cam on the secondary shaft and lever. The mixture of gas or gasoline and air is drawn through a regulated valve by the suction of the piston, always proportional for the best explosive effect, and governed as to quantity by a throttle directly actuated by the governor.

In the gasoline attachment the pump is driven by a cam on the secondary shaft and draws the gasoline from the tank at a level below the engine, forcing it into a small receiver from which the surplus returns by gravity to the tank; the gasoline being atomized and vaporized by the action of the indraft of air from the movement of the piston. The sparking-device is operated by a push-bar and eccentric pin at the end of the secondary shaft.

The unshipping of a small lever noticed on the valve gear stops the fuel flow and the engine by closing the inlet throttle valve.

The Mietz & Weiss Gas and Oil Engines

The gas engine of the Weiss patents is built by August Mietz, No. 87 Elizabeth Street, New York City. It is of the two-cycle type, taking an impulse at every revolution. It has an enclosed crank chamber with a supplementary small cylinder containing a free moving piston counterbalanced by a spring. An opening into the crank chamber under the piston produces compression of the gas in the upper part of the small cylinder by the air pressure in the crank chamber during the impulse stroke and so feeds the gas charge with equal pressure with the air charge made by the outward stroke of the piston. The air charge enters through a port in the cylinder opened at the inward stroke of the piston, which produces a slight vacuum in the crank chamber and thereby causes the air to rush in while the port is open. The return or impulse stroke compresses the air in the crank chamber, which in turn compresses the gas by the movement of the small free piston.

By the opening of a charging port in the cylinder by the piston at the end of its impulse stroke the compressed charge of air and gas enters the cylinder. A larger cylinder-port opening just before the end of the stroke exhausts the cylinder of the products of the burned gases. A projection or deflector on the piston directs the incoming charge towards the head of the cylinder. The charge of gas is made through a small poppet-valve operated by a push-blade, rock-shaft lever, and an eccentric on the main shaft.

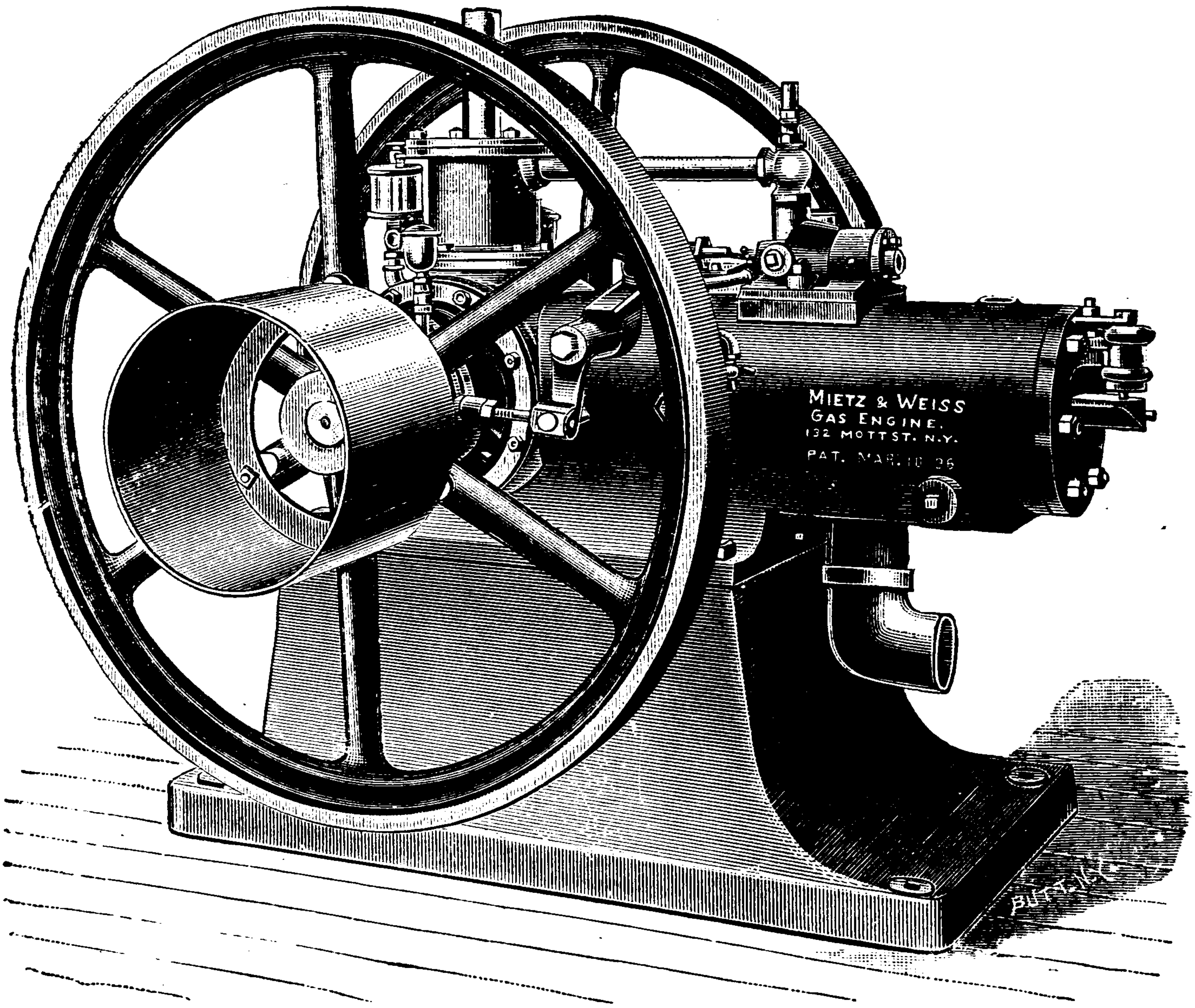


FIG. 244.—THE MIETZ & WEISS GAS ENGINE.

The governing is by the inertia of a weight adjustable as to its position on the push-blade arm by a screw thread, and by the motion of the arm the weight rides up an incline and is released at the top of the incline to fall by gravity and catch the blade of the gas-valve.

An excess in speed sends the weight too high to catch the

The kerosene oil engines are built on the same general plan of the gas engine, only displacing the ignition device in the cylinder for a conical internally flanged vaporizer and igniter, upon the flanges of which the oil is projected in small and definite quantities by the action of a small plunger held back by a spring and pushed forward by the governed push-blade, as in the gas engine. A small valve at the pump cylinder terminus, held back by a spring, limits the amount of oil injected to the exact volume of the plunger stroke. The air charge is exactly the same as described for the gas engine.

To start the oil engine the conical vaporizer is heated by a

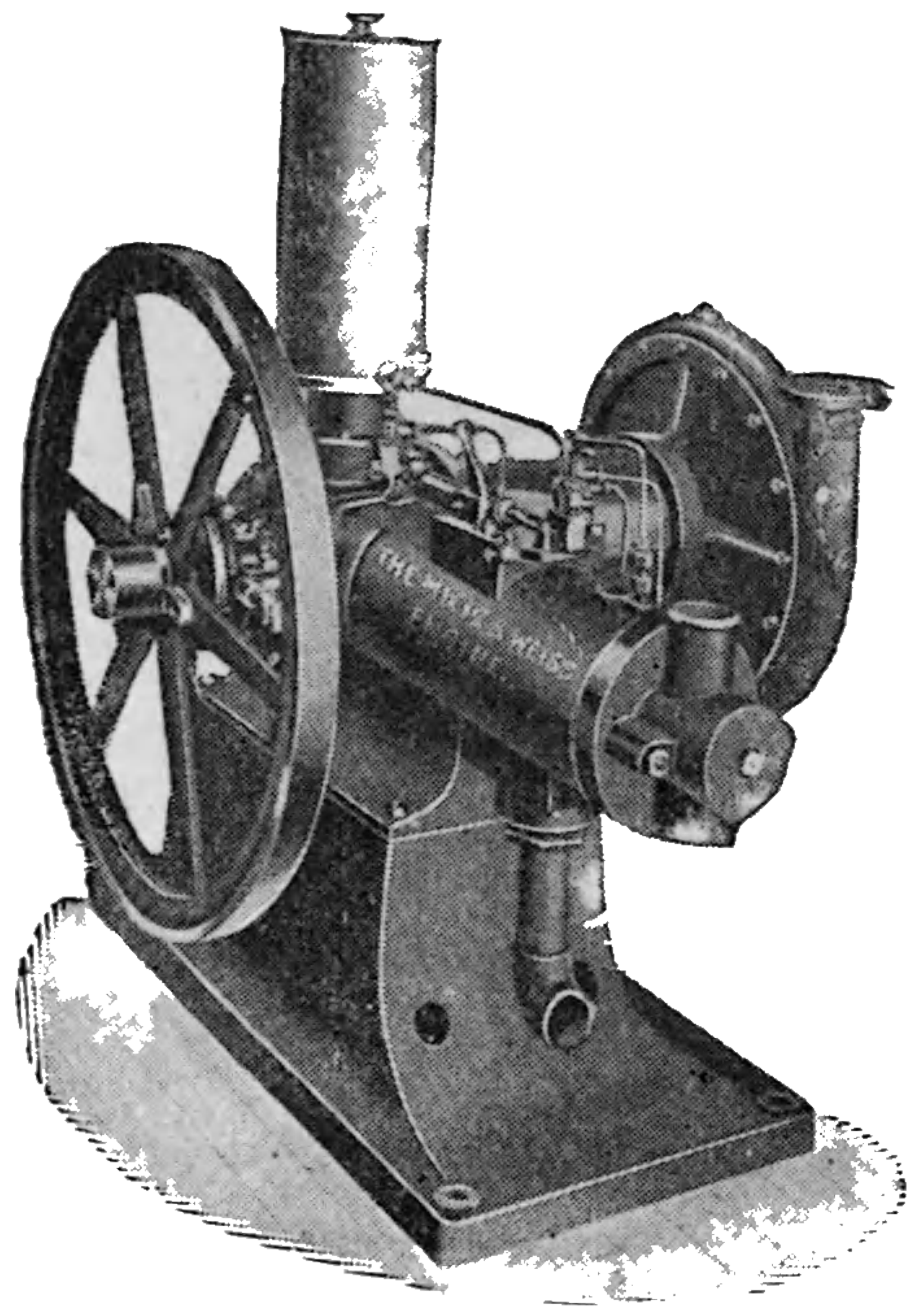


FIG. 245A.—OIL ENGINE.

lamp to the proper temperature to induce ignition of the internal mixed vapor and air by the increased heat of compression, when the engine becomes self-acting by a turn of the fly-wheels.

In the experimental work of Mr. C. W. Weiss, he has carried the compression in the kerosene engine up to 400 lbs. per square inch, at which pressure a very strong engine must be used; but with runs at 100 and up to 250 lbs. compression pressure, a remarkable economy in fuel has been obtained; the combustion being so perfect that no residues are found in the combustion chamber, cylinder, and exhaust.

In Fig. 245A is illustrated a direct-connected centrifugal pump with a high-speed oil engine of the Mietz & Weiss type.

The ring lubrication of the main journal in a Mietz & Weiss oil engine is detailed in Fig. 245B. In this arrangement the oil

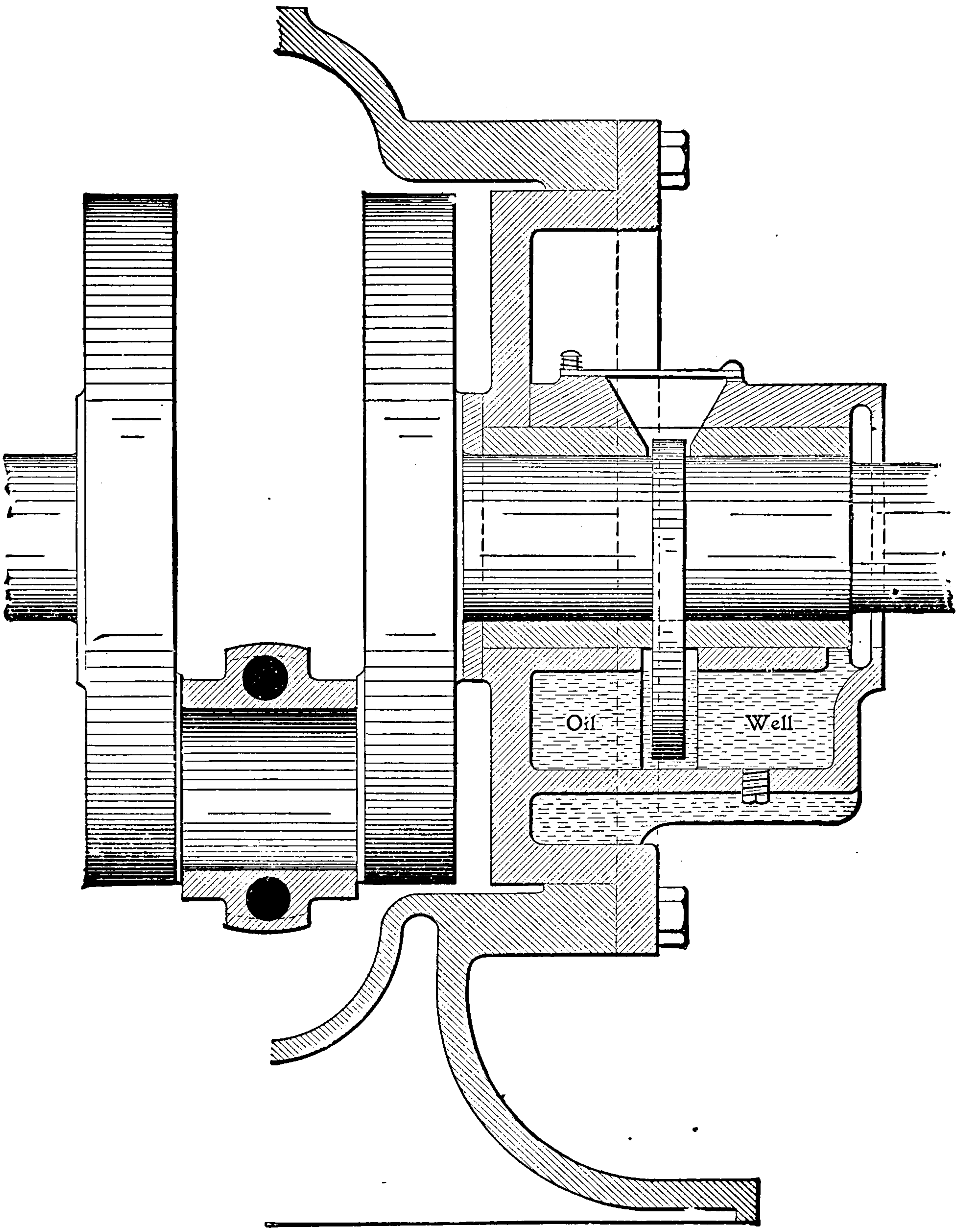


FIG. 245B.—LUBRICATING DEVICE.

seeping to the outer end of the journal drops back into the oil well.

In Fig. 245C we illustrate the working detail of the Mietz & Weiss kerosene oil engine in a sectional elevation showing the conical vaporizer E D, enclosed in a shell for confining the lamp flame when starting and to keep the outer walls hot when the engine is running.

A front view of the vaporizer at the lower left-hand corner

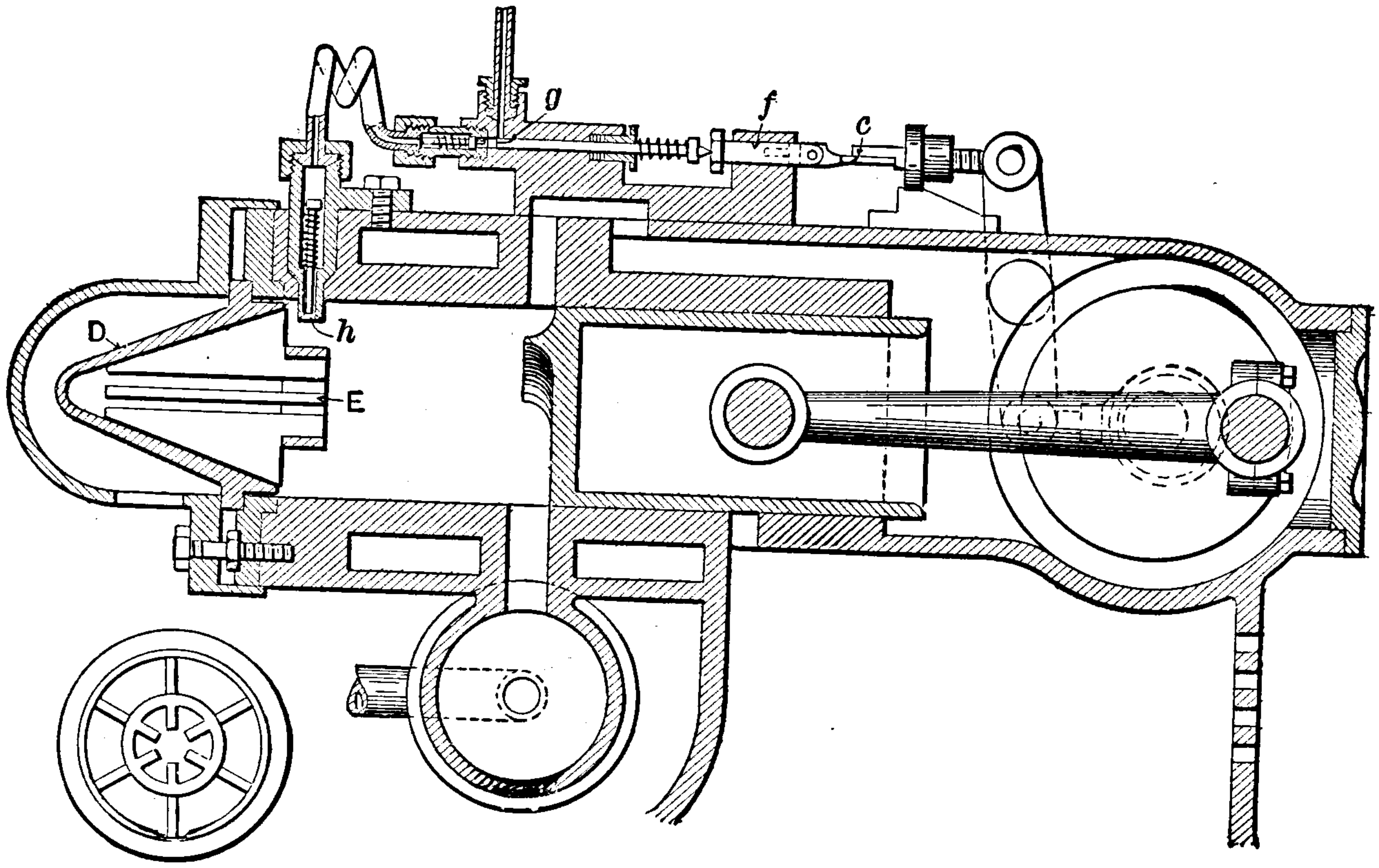


FIG. 245C.—SECTION, MIETZ & WEISS OIL MOTOR.

of the cut shows the extended web surface. The small spring held oil valve at *h*, holds the oil between it and the pump intact during the impulse stroke. The small oil pump at *g* is operated

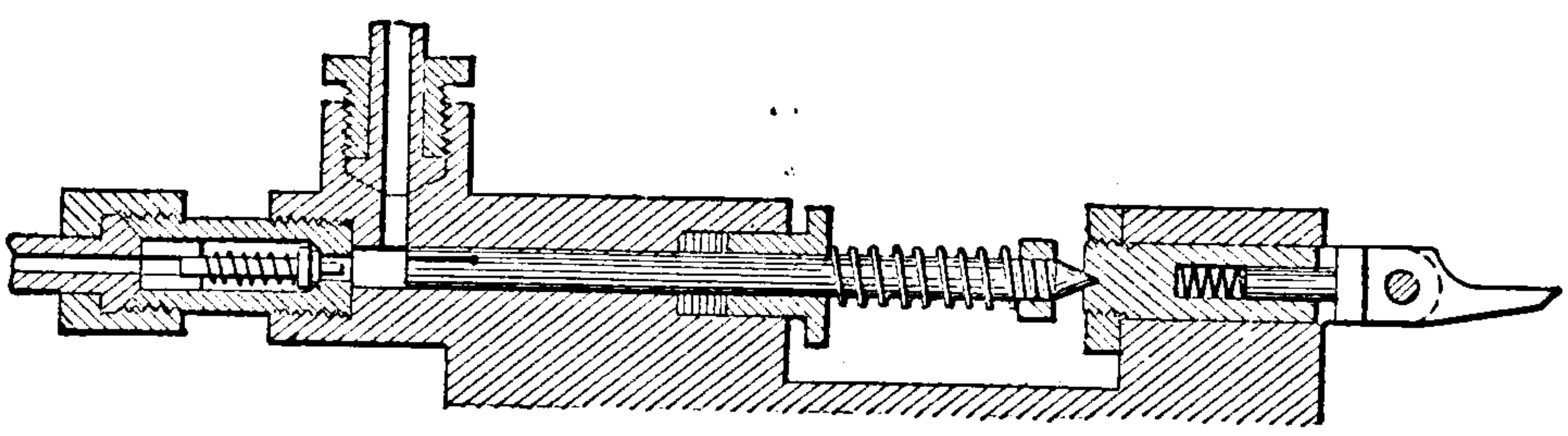


FIG. 245D.—OIL PUMP AND PICK BLADE.

by the pick blade *c*, with a hit or miss charge, governed by the momentum of a small weight sliding on an inclined plane. The amount of charge and the interruption being rapidly adjustable.

In Fig. 245D is shown an enlarged section of the pump and

The spark is made by a hammer break operated by a rod and cam. The contact points are of platinum-iridium, which are very hard and have a lasting quality. A mixing valve regulates the supply of gasoline and air.

This company also make four-cycle vertical and horizontal engines.

The company also, as a concession to amateur mechanics,

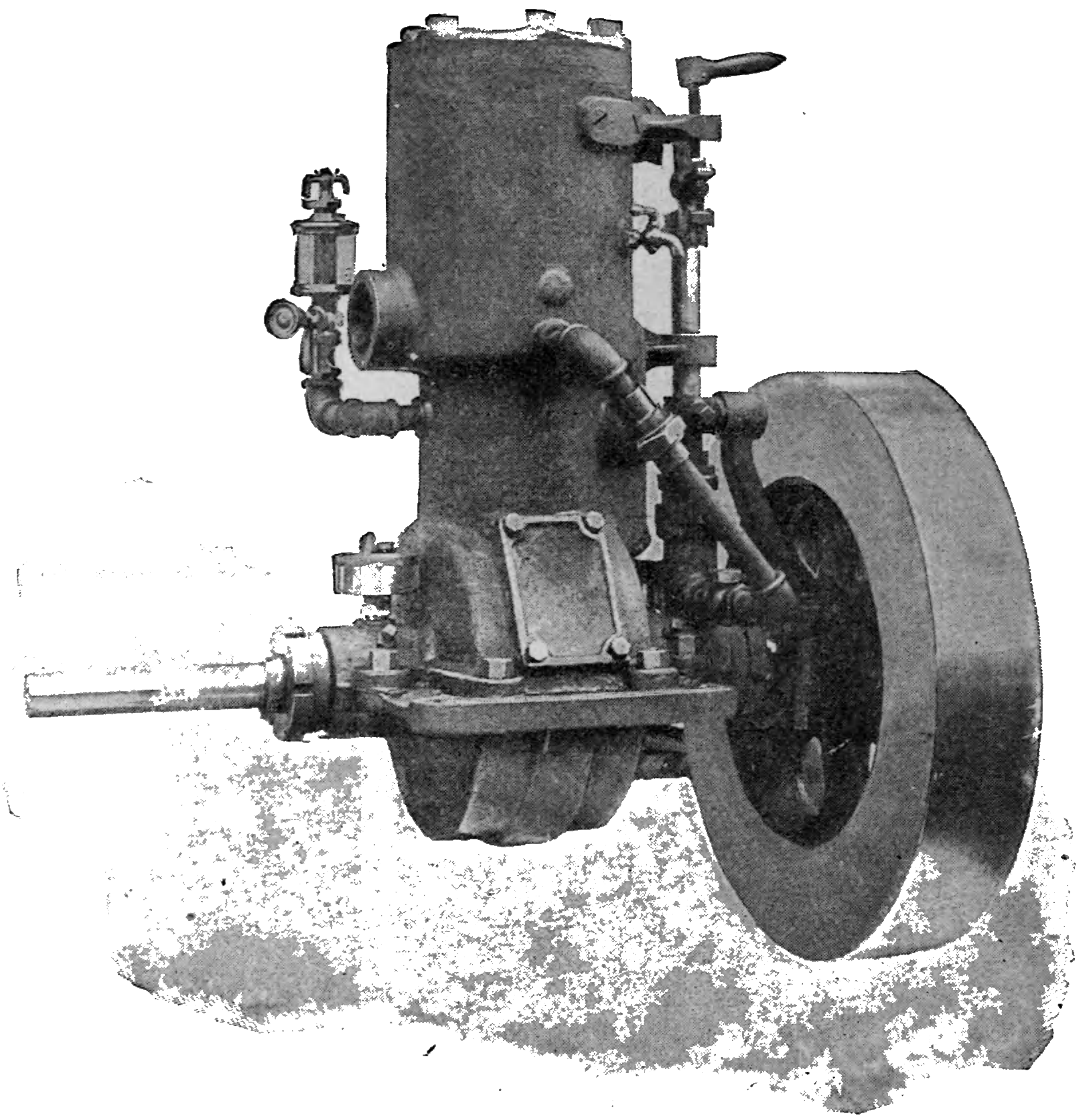


FIG. 245F.—4 HORSE POWER MARINE.

furnish castings of their engines with working drawings, which are far cheaper than to undertake to make patterns. The castings for a 1 horse power vertical with the cylinder bored and faced with the drawings are furnished for $30, and a 1/4 horse power castings and drawings for $15. A fine chance for amateurs to indulge in gas engine work.

Motors of the Lowell Model Company, Lowell, Mass.

A new departure in the explosive motor business has been adopted by this company in undertaking the supply of not only the finished motors, but also of finished parts, partly finished castings, rough castings and every part that will contribute to the amateur's desire to construct a part or the whole of an explosive motor. They furnish, further, all the parts for the frame and

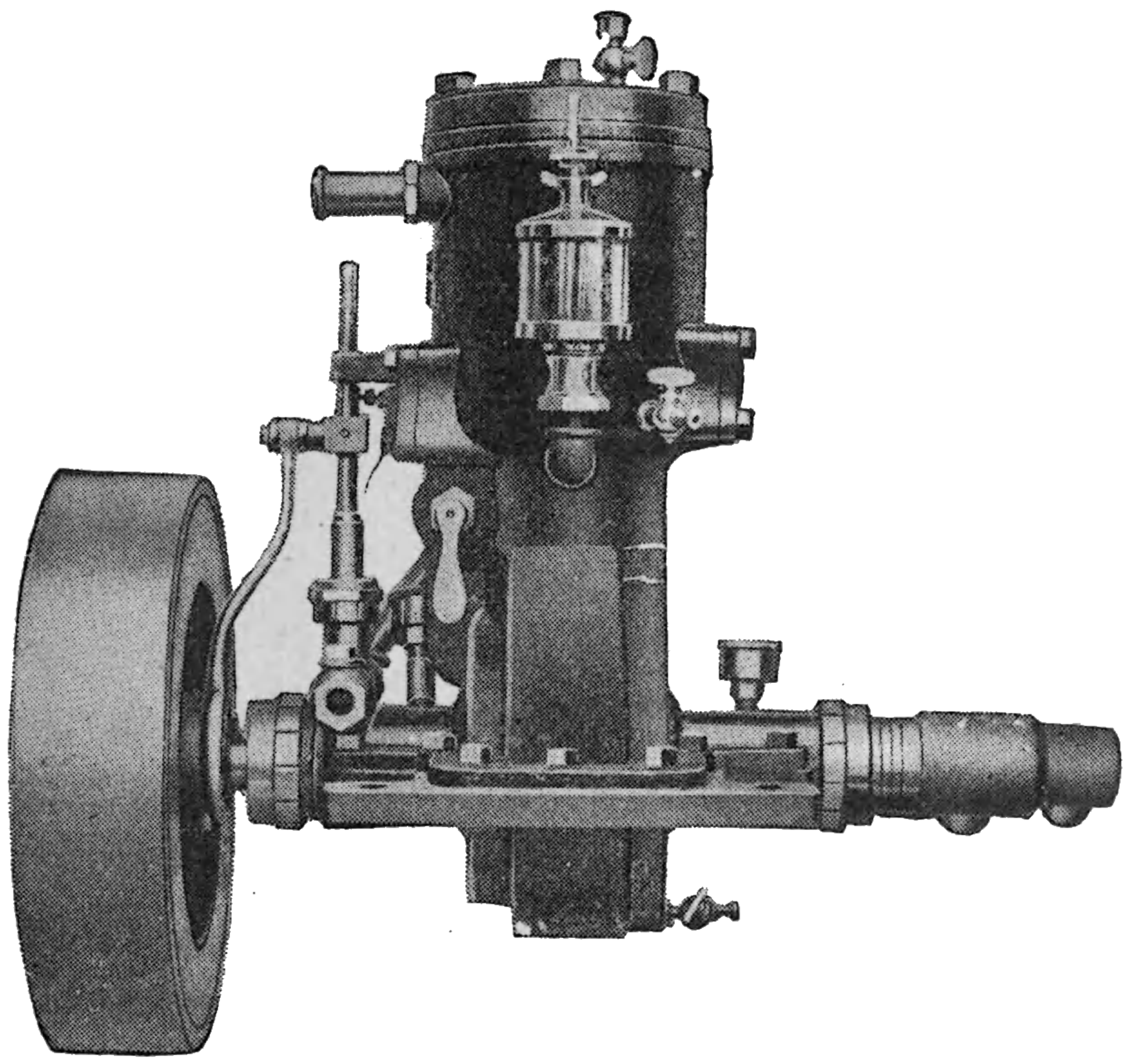


FIG. 245G.—THE GASOLINE MOTOR OF THE LOWELL MODEL CO.

rig for a runabout vehicle. The stationary and marine two-cycle motors are made in four sizes, from ¾ to 4 horse power, with cylinders 3 x 3, 3½ x 4, 4½ x 5, and 5 x 6 inches, for which they supply shafts and reversing propeller wheels for each of the above-sized motors. The illustration shows the marine frame, which is bolted to a base for a stationary motor.

In Fig. 245H is shown a section of a special auto motor of 3½ horse power, four-cycle type, of special design for automobiles. It has a 4 x 4-inch cylinder. Castings for these motors, rough, partly finished, with all the parts, with blue prints figured for construction, are furnished to order—one of the finest opportunities for exploiting amateur work.

In Fig. 245 I is shown the outline model of the light runabout all the parts of which are supplied by the Lowell Model Com-

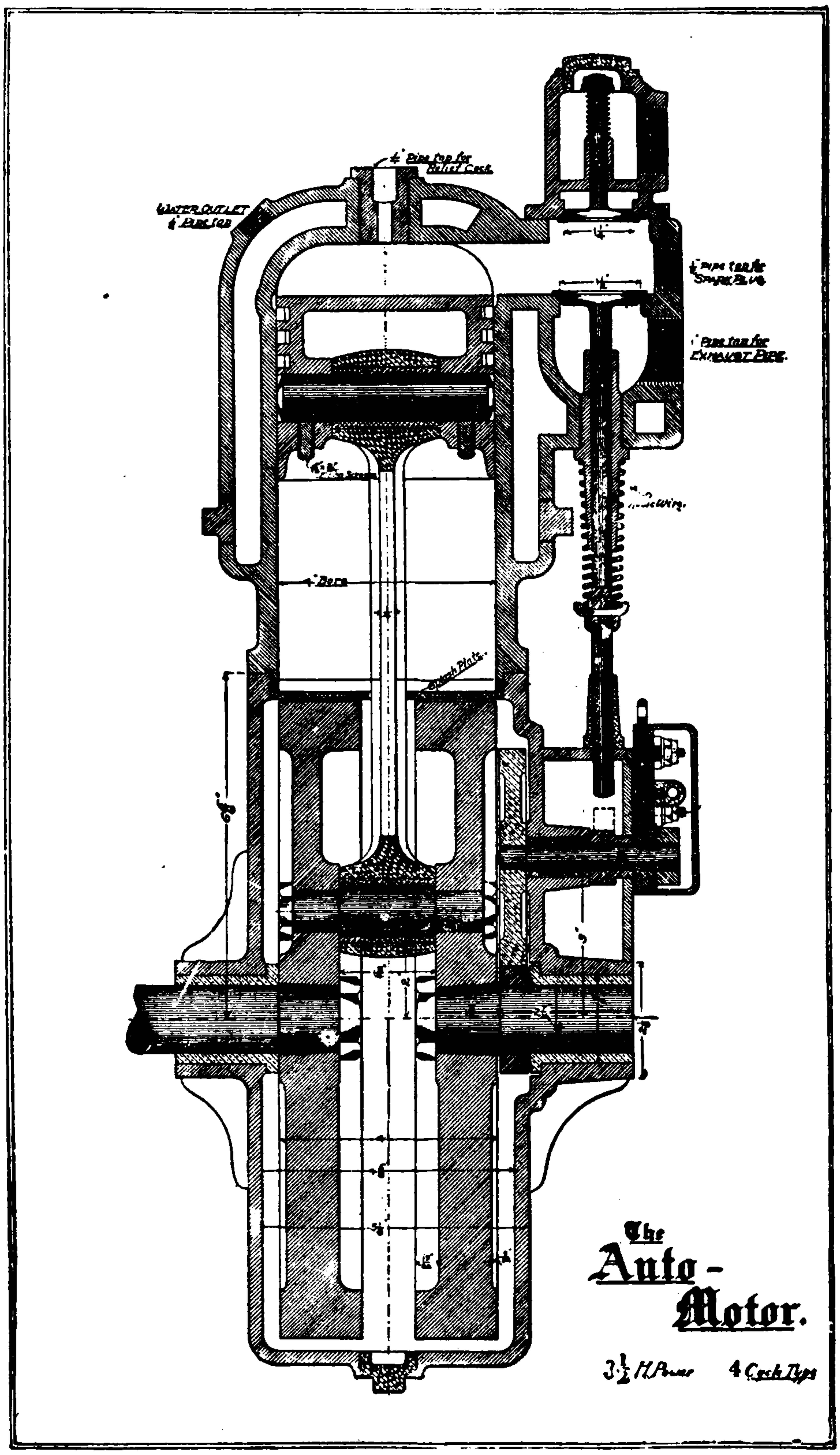


FIG. 245H.—VERTICAL SECTION, LOWELL MOTOR.

pany. The vehicle complete will weigh about 500 pounds, and with the motor described will be capable of a speed of from 18

governor operates a friction-clutch in contact with the screw on the secondary shaft, causing it to stop at the moment of overspeed.

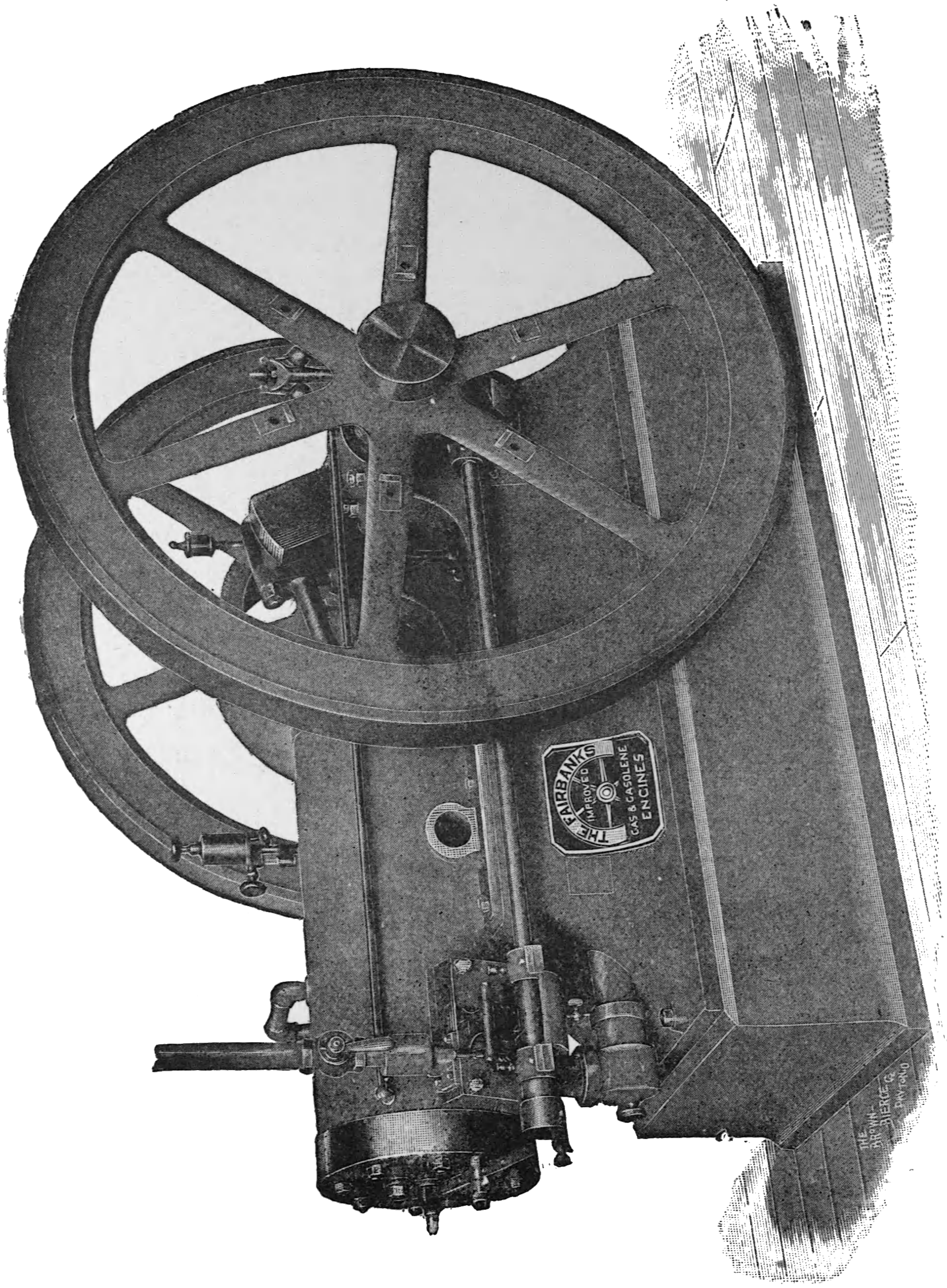


FIG. 249.—THE GAS ENGINE WITH SECONDARY REGULATOR, BY WHICH PERFECT REGULATION FOR ELECTRIC-LIGHTING IS OBTAINED

The main exhaust is through a port in the cylinder at the end of the piston impulse stroke with a supplementary exhaust through a poppet-valve near the cylinder head, which is operated by a cam on the side shaft.

FIG. 248.—SECTIONAL PLAN OF THE "FAIRBANKS."

The supplementary regulator is operated directly from the governor and is delicately adjustable, through the rod connecting a small and independent throttle in the gas-inlet pipe.

The gasoline supply consists of a small lifting pump seen in front, Fig. 251, which draws the gasoline from a lower level and forces it into the small cup reservoir at the right, from which the smaller pump seen at the rear and left forces the liquid in

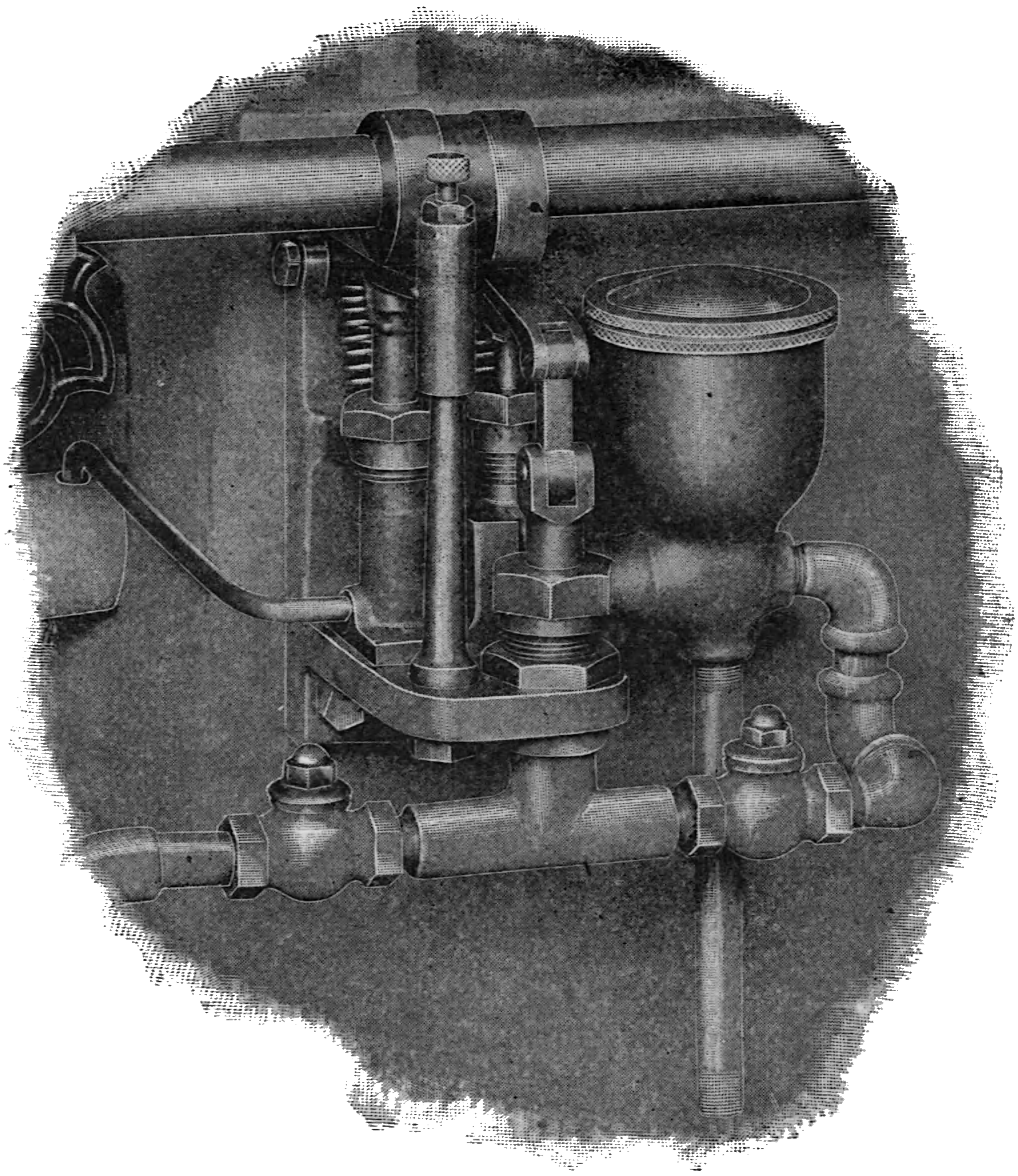


FIG. 251.—THE GASOLINE SUPPLY.

adjustable quantity into the air pipe, where it is vaporized by the indraft of air by the suction of the piston. The surplus gasoline flows back to the main tank by gravity through the overflow in the receiving-cup.

In Fig. 252 is shown the arrangement for a gravity feed from an elevated gasoline tank. The plunger at the right opens two minute ports, governed by the motion of the cam, that feeds a stated quantity of gasoline to the force pump at the

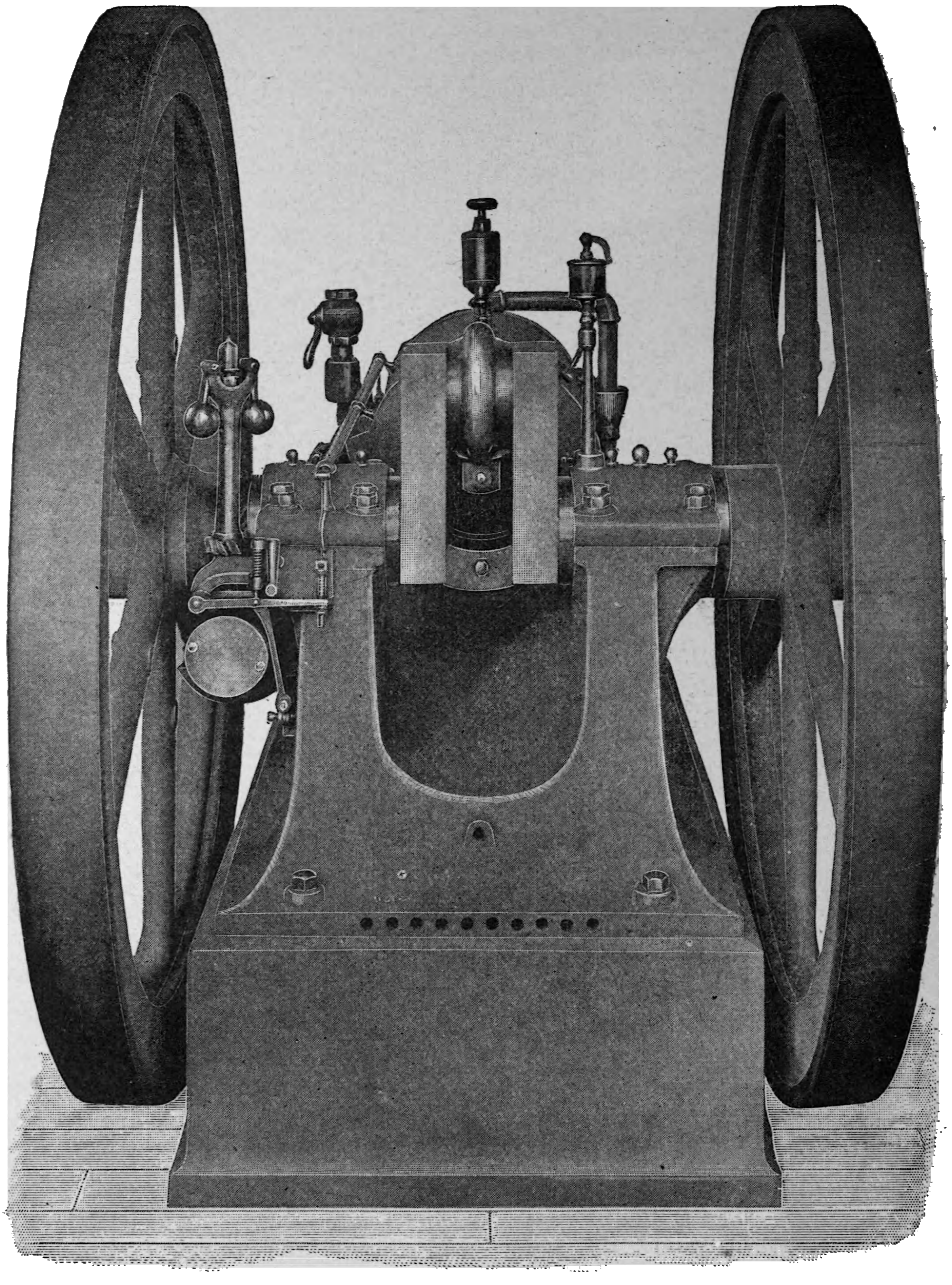


FIG. 254.—CRANK END OF ENGINE, SHOWING DUPLEX GOVERNING-DEVICE FOR ELECTRIC-LIGHTING.

left hand, which further regulates the quantity by the adjustment of the plunger throw and by the suspension of the cam motion by the governor.

Fig. 253 shows the wiping-device for oiling the crank pin. The centrifugal action of the crank draws the oil from the wiper to the bearing without waste.

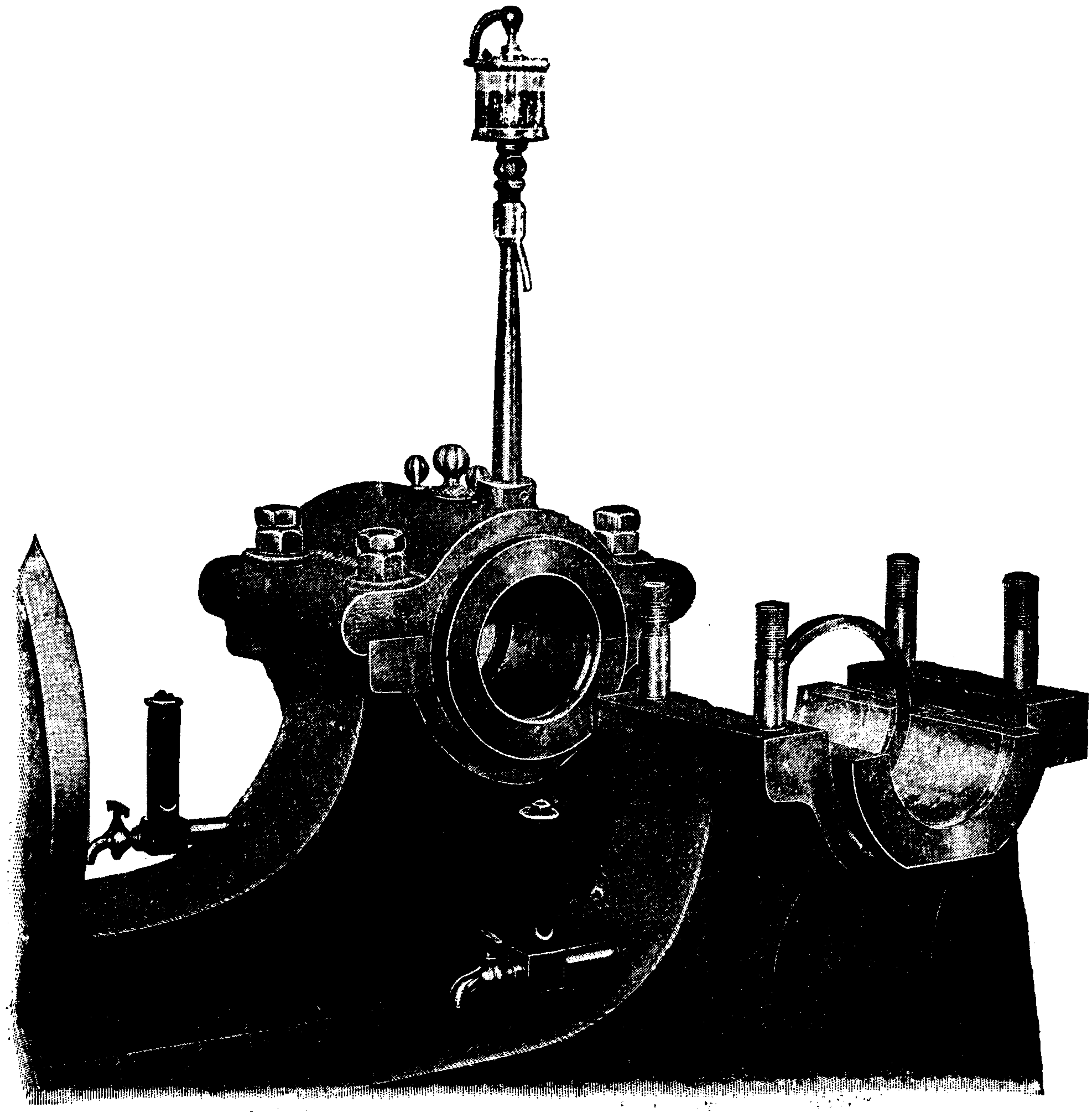


FIG. 255.—THE BRONZE BEARINGS AND RING OILERS.

The oiling-device on the main shaft bearings consists of a bronze ring which rides on the shaft in a channel through the middle of the box, and dips down into a reservoir of oil. Each revolution brings sufficient oil to keep it thoroughly lubricated; any excess of oil flowing back into the reservoir.

A small glass gauge attached to each reservoir shows the quantity in it. The Fairbanks Company are prepared to make their engines in 12 sizes, from 2 to 100 horse-power, actual.

The Watkins Gas and Gasoline Engine.

The engines of the F. M. Watkins Company, Cincinnati, Ohio, are of the four-cycle type, in which the gas and air mix-

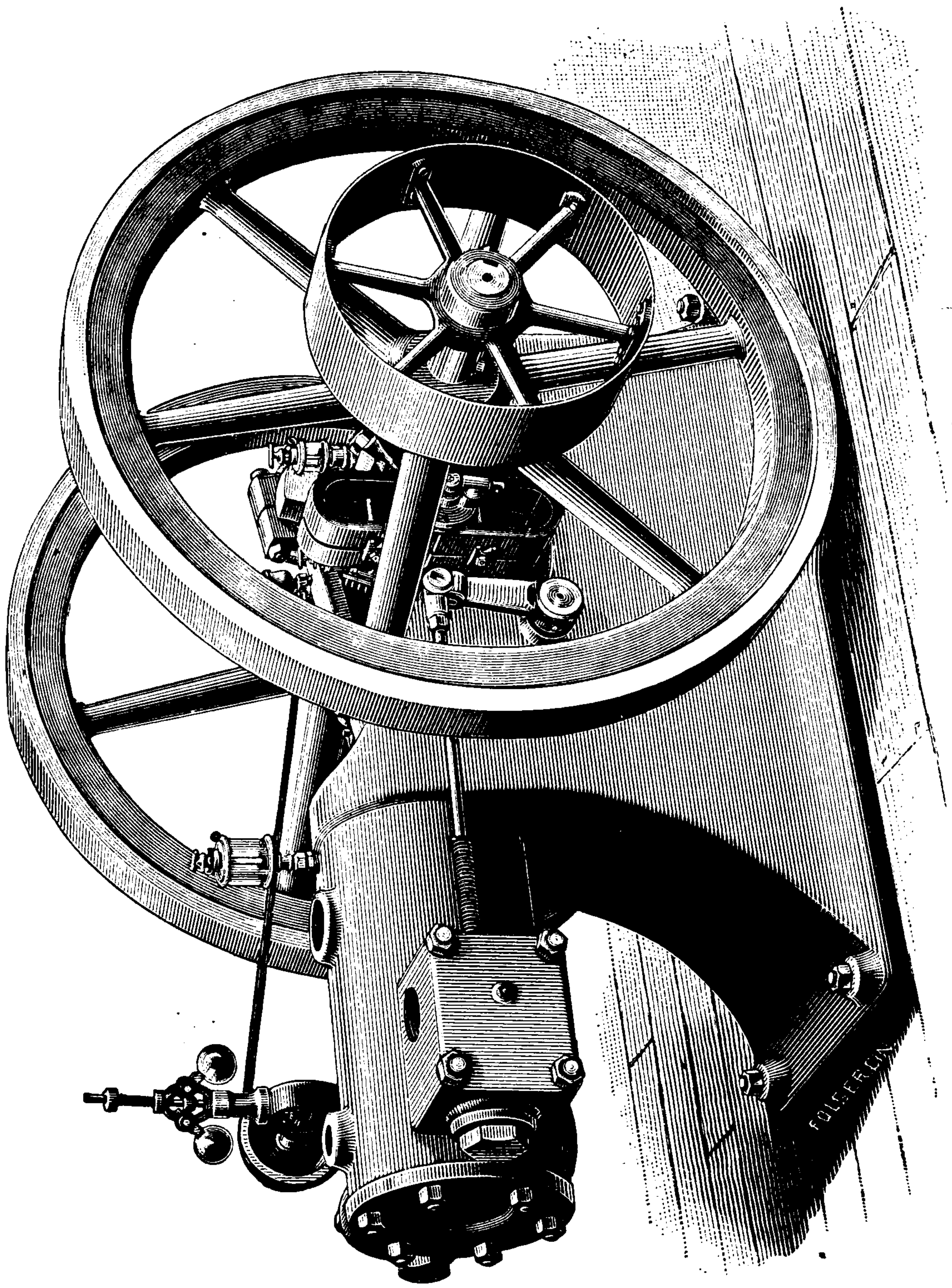


FIG. 256.—THE WATKINS GAS AND GASOLINE ENGINE.

ture is regulated outside of the combustion chamber by a single combination gas and air valve controlled by the governor. The gasoline engines are provided with a pump that lifts the gasoline from a lower level outside of the building, returning the surplus

geared to the main shaft, and in the large size is geared to the reducing screw-gear shaft, which also operates the governor by belt and the pump of the gasoline engines from a cam.

The armature is charged by a permanent magnetic field with a current sufficiently strong to produce an ignition spark by the turning over of the fly-wheels for starting and produces a brilliant spark at full speed. Both contact points are movable from the outside and can be cleaned while the engine is running, by simply pushing the spindles with the thumb, they being held back by a spiral spring.

With a current from the dynamo, as furnished with these engines, the mere turning over of the fly-wheel by hand produces a sharp and full spark, which is well shown by taking out a plug opposite the sparker contact points in the combustion chamber.

Naphtha Yachts and Launches.

The yachts and launches of the Gas Engine and Power Co., Morris Heights, New York City, are propelled by the vapor of a light grade of gasoline, which vaporizes at a comparatively low temperature under the required pressure for operating the three-cylinder, single-acting engine. The regulations of the U. S. Board of Supervising Inspectors now class the naphtha yachts and launches with the explosive motor yachts and launches, so that all vessels of this class of 15 tons and under are not subject to inspection or license, but must comply with the government regulations relating to lights, steering, and the rules of sailing on navigable waters.

Fig. 261 illustrates the general design of the naphtha motor. the leading parts for operating being designated by letters.

The opening into the furnace case at A is for igniting the burner, and another, just above, for inspecting the flame. The small pump with its handle at E is for drawing vapor of naphtha from the chamber of the gasoline tank and forcing it into the

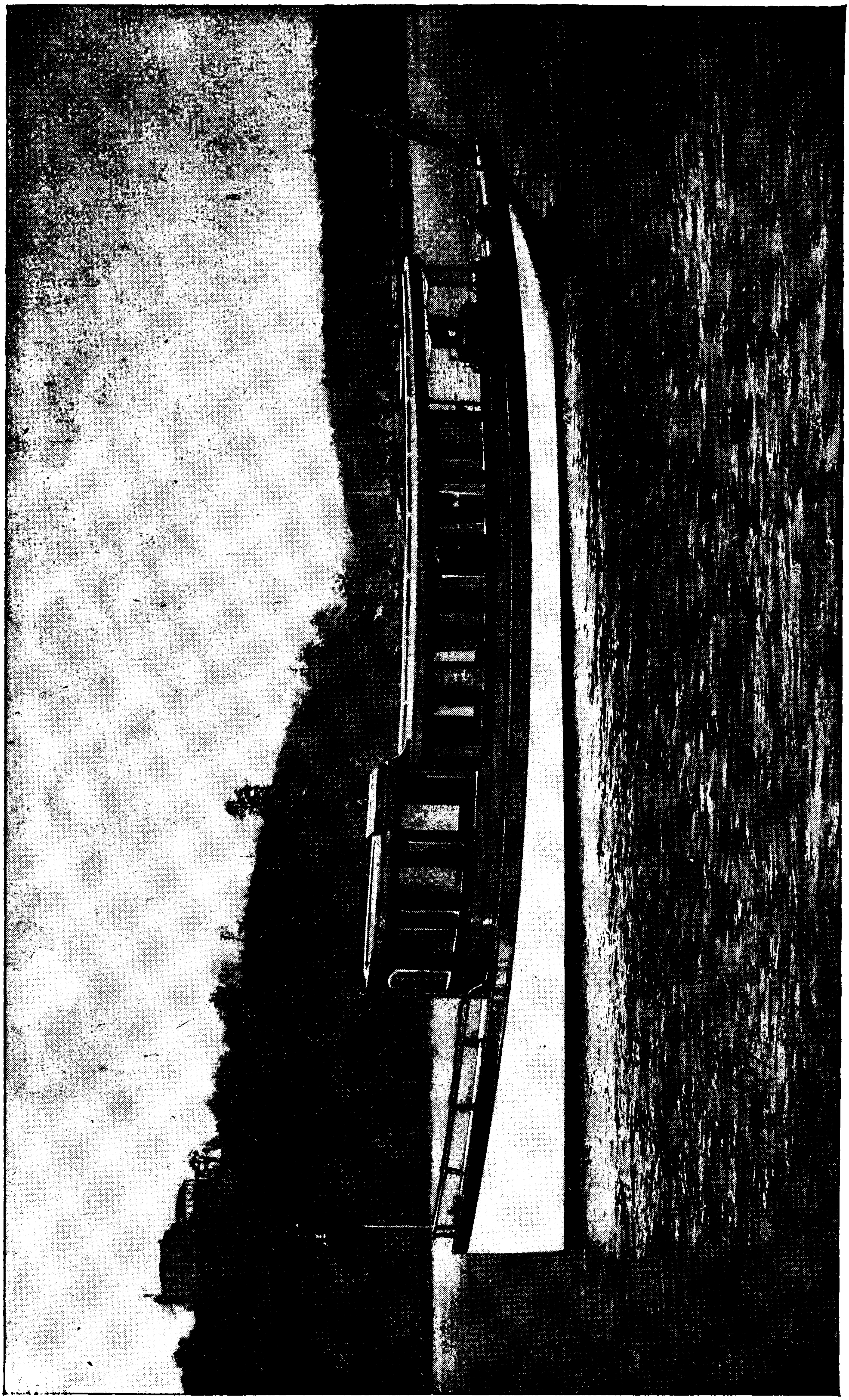


FIG 260.—THE 42-FOOT CABIN NAPHTHA YACHT FOR CRUISING. GAS ENGINE AND POWER CO., MORRIS HEIGHTS, NEW YORK CITY.

burner for heating the vaporizer at starting, and also for blowing the whistle, which is done by shutting off the vapor pipe and opening an air inlet to the pump by the valve B. The valve wheel at D opens the naphtha flow-pipe from the tank to the feed-pump, which is driven from a cam on the main shaft,

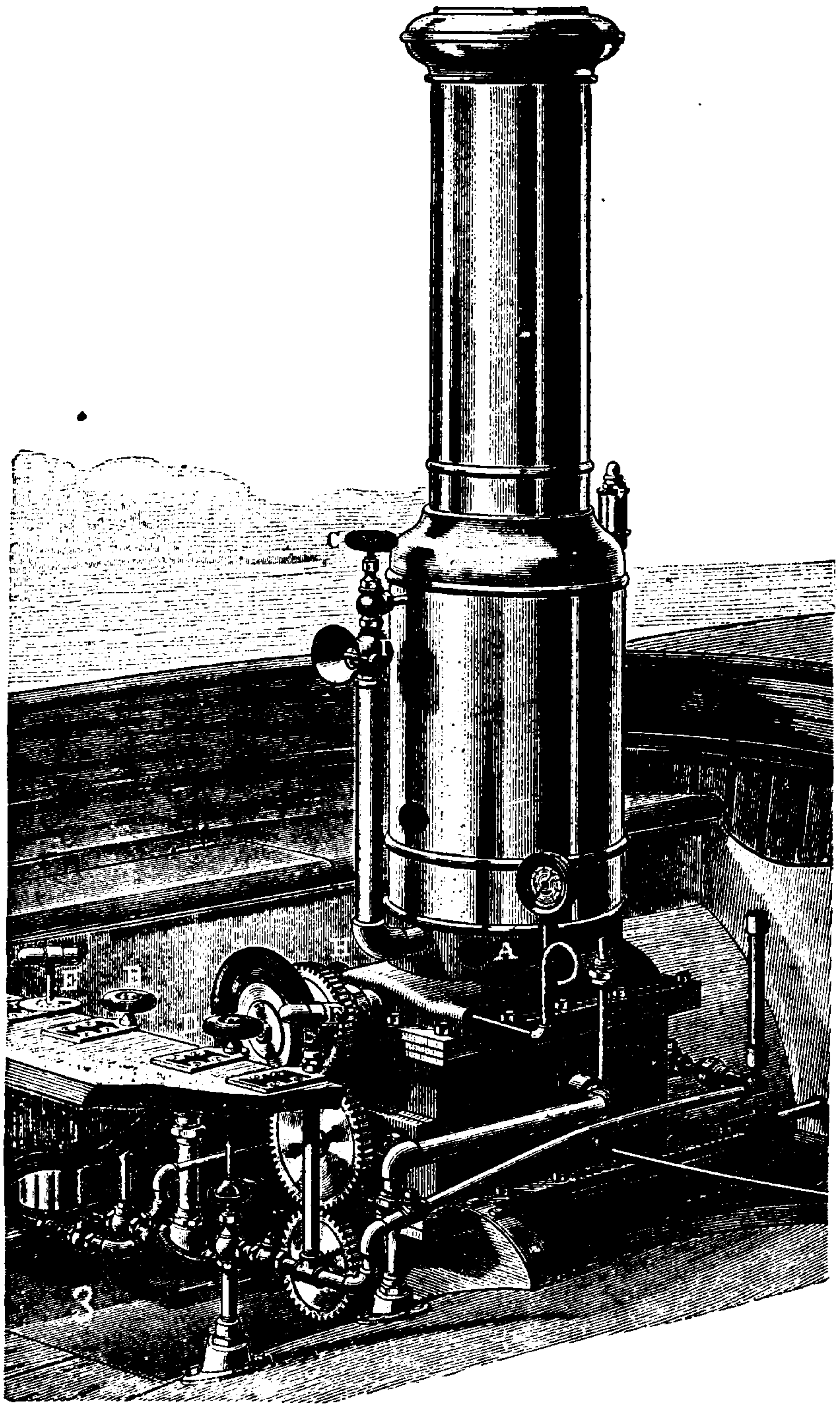


FIG. 261.—THE NAPHTHA ENGINE.

as shown at the right in the sectional elevation, Fig. 262. The lever and small pump at F is for forcing naphtha into the vaporizer before starting the engine.

When the pressure in the vaporizer becomes sufficient to operate the engine, the burner is made automatic by opening

quarter revolution, to reverse the engine. The exhaust enters the crank chamber, which is closed and made tight on the main shaft by stuffing-boxes; thence by a pipe through the hull to the condenser along the keel, from which the condensed naphtha is discharged into the tank at the bow of the boat.

The safety-valve is also a peculiar feature of this motor; it is held closed by a spring, and instead of discharging into the air, causing danger and waste of naphtha, it discharges into the crank chamber and passes the vapor through the condenser and to the tank as fluid naphtha. These motors have gained a high reputation for safety, durability, and economy in the ten years' experience with their use. They are built in all sizes, from 1 horse power to as many as required for a 76-foot cruising yacht.

The Westinghouse Motors.

In Fig. 290 and following we illustrate the general features

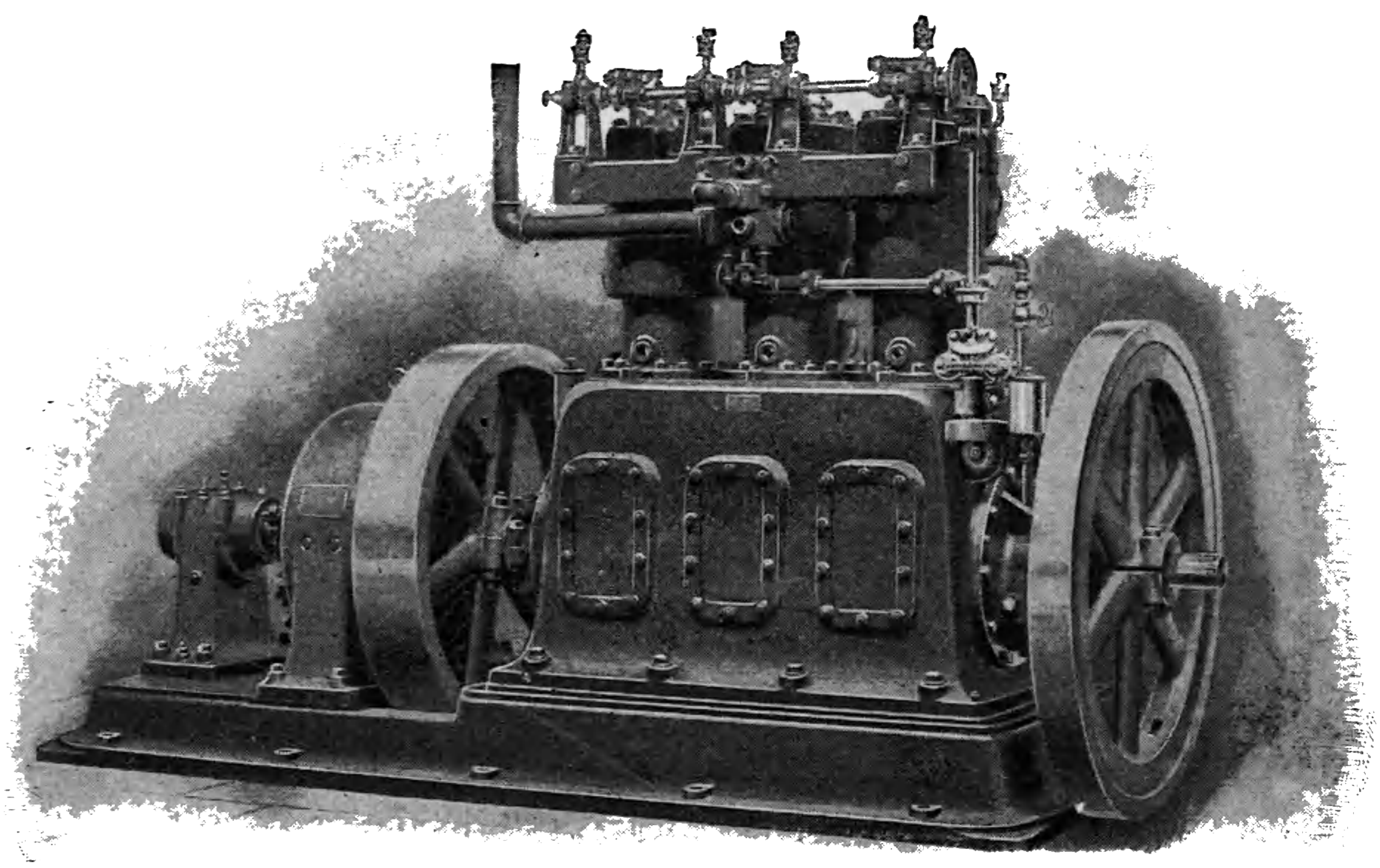


FIG. 290.—THE WESTINGHOUSE THREE-CYLINDER MOTOR.

and details of the Westinghouse Gas Engine of the Westinghouse Machine Co., Pittsburg, Pa. In their general appearance the motors of this company bear a marked resemblance to the

Westinghouse Steam Engines. They are built in two and three-cylinder patterns, and of the latter of sizes up to from 650 to 1,500 horse power.

The large experience of this company in the building and operation of compact high-speed vertical multi-cylinder steam engines has given them facilities of design, which has greatly

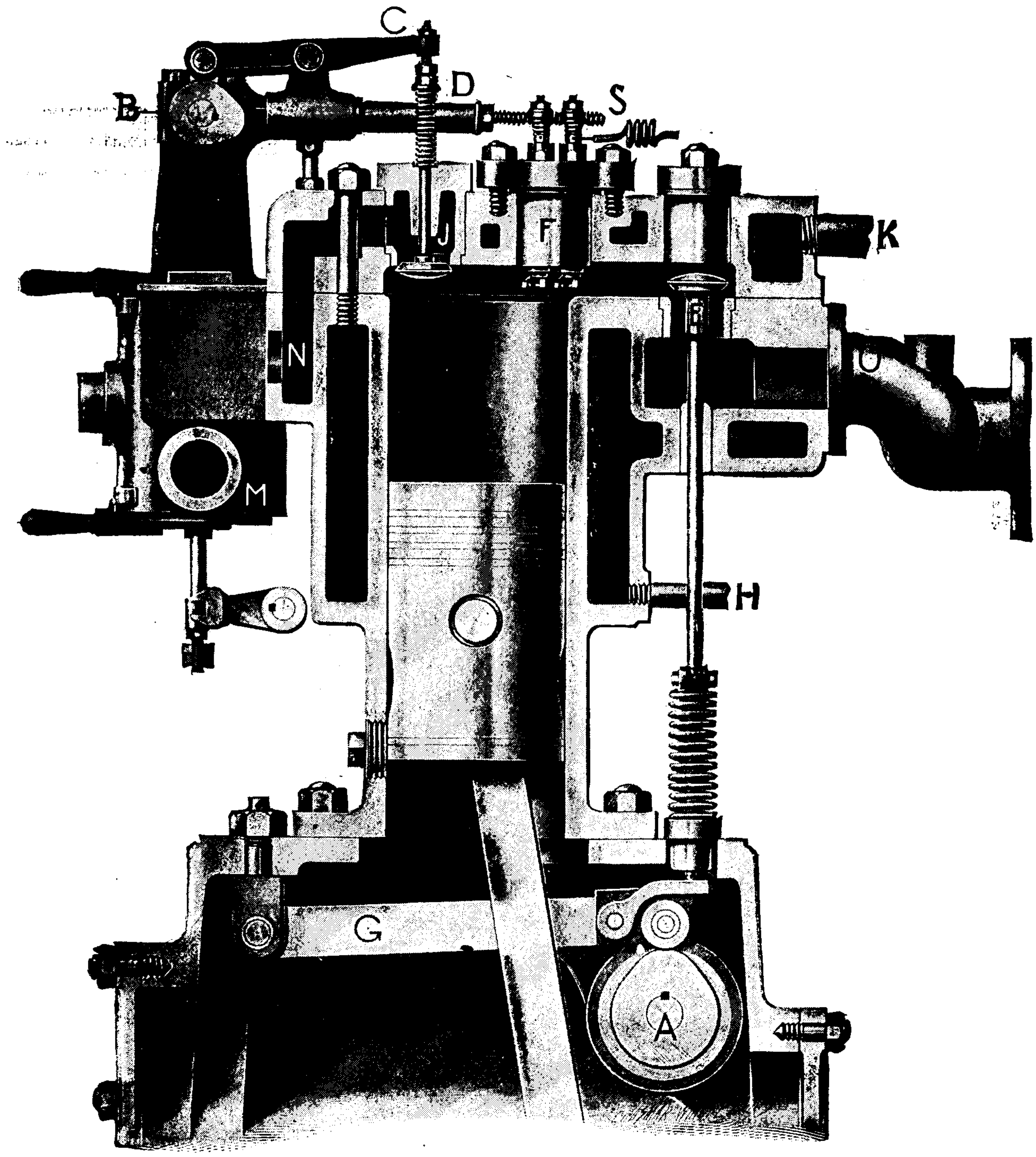


FIG. 291.—SECTIONAL ELEVATION OF THE WESTINGHOUSE.

aided in perfecting and giving a substantial form to their gas and gasoline engines, with a marvelous regulation of speed, and so suiting these motors for electric generating power.

The sectional elevation of one cylinder of a three-cylinder engine is shown in Fig. 291 locating the position of the valve mechanism and igniter. A is the shaft which carries the exhaust valve cams, and is driven by gears from the main shaft. Each exhaust cam works against a roller carried on the free end of the guide lever G. The exhaust valve E has a long stem projecting downward and resting on a hardened steel plate on the upper side of the guide lever G. The spring surrounding the stem serves to

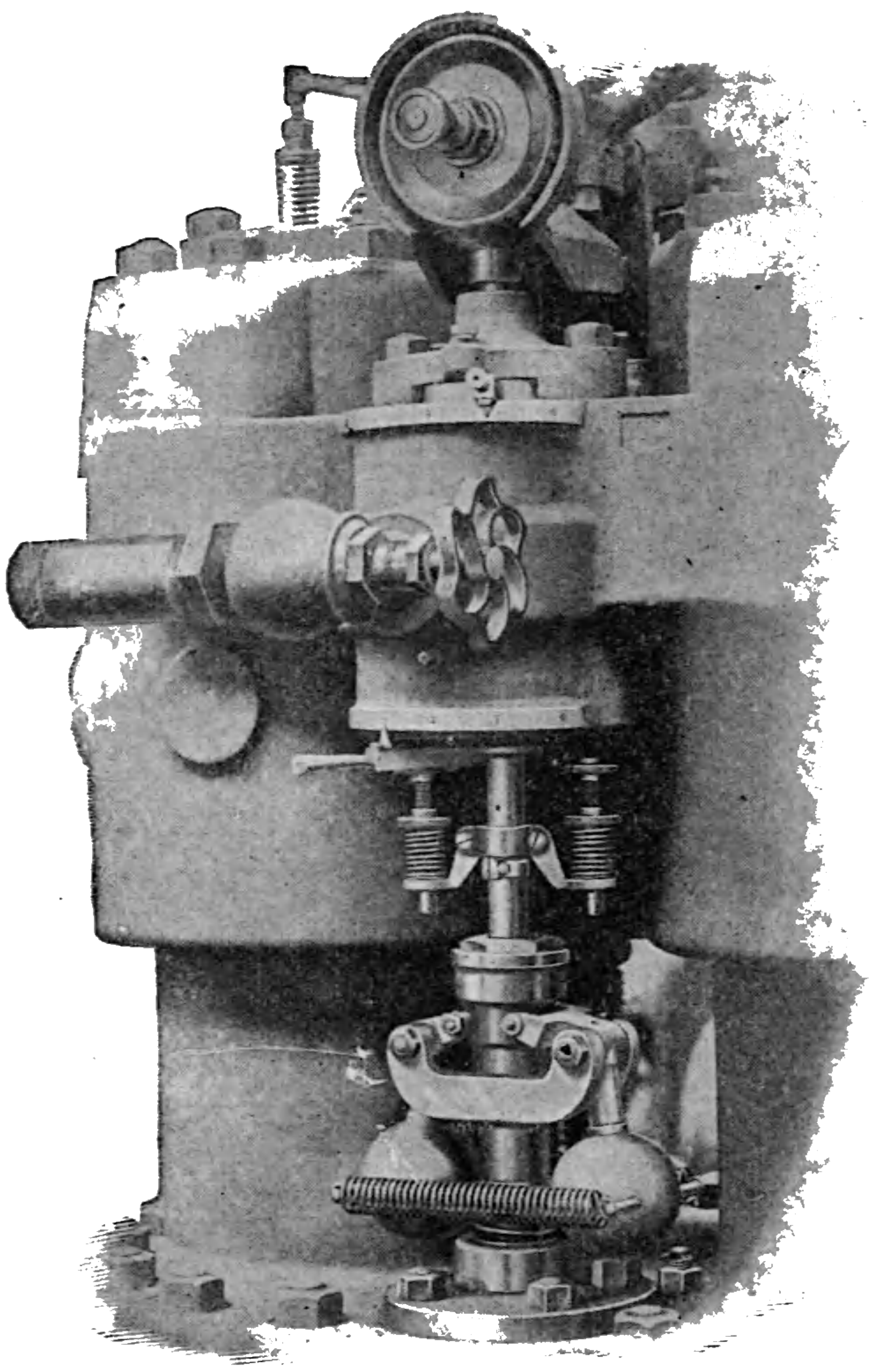


FIG. 292.—GOVERNOR, TWO-CYLINDER ENGINE.

hold the exhaust valve to its seat and the stem in contact with the guide lever. From the exhaust cam shaft A a horizontal shaft with bevel gears leads to the opposite side of the engine, engaging with a vertical shaft, not shown, which in turn drives the upper cam shaft B. Incidentally, the vertical shaft carries the governor. The upper cam shaft carries two cams for each cylinder. One engages against a roller on the end of the horizontal lever C. As the throw side of this cam comes uppermost, the

In Fig. 293 is shown the governor for the two-cylinder engine, which is of the flyball type and located directly under the valve stems that regulate the volume of the charge, so that the regulation of the engine is made by the amount of the charge and not by hit and miss impulses. A lever and index at the top of the mixing chamber controls the gas inlet, and another at the bottom controls the air inlet, so that the proportion of the mixture may be made a set regulation, while the volume of the charge is regulated by the governor without changing the proportion of the mixture.

In the three-cylinder engine the one regulating valve and governor controls the impulse of each cylinder alike, and to accommodate the positions of the driving gear and valve the motion of the governor is transmitted to the valve through a rock shaft and levers, as shown in Fig. 293. The rock shaft and lever are shown directly under the mixing chamber M in Fig. 292.

The Diesel Motor.

This motor is an innovation upon all former ideals in explosive power and indicates the "Ultima Thule" of explosive motor compression, and possibly the limit of fuel economy in this type of prime movers. Mr. Diesel has attempted to realize, within the limitations of practice, an approach to the conditions of the "Carnot Cycle" by the production of a motor of very high thermal efficiency. In order to accomplish this result it was evident that a much higher degree of compression was necessary than that used in existing motors, since it was demanded that the charge be compressed adiabatically to the maximum initial pressure at which the motor was to be operated, this pressure not to be exceeded by the gases generated during the combustion. Such a compression would naturally produce an increase in temperature sufficient to ignite the combustible, and hence it became apparent that the fuel must not be introduced with the air, but that the air must first be compressed adiabatically and that the fuel must then be introduced and burned during the out-stroke of the piston isothermally, if the desired cycle was to be practically realized.

In the Diesel motor the high temperature attained by the compression of the air is sufficient to provide for the ignition of the

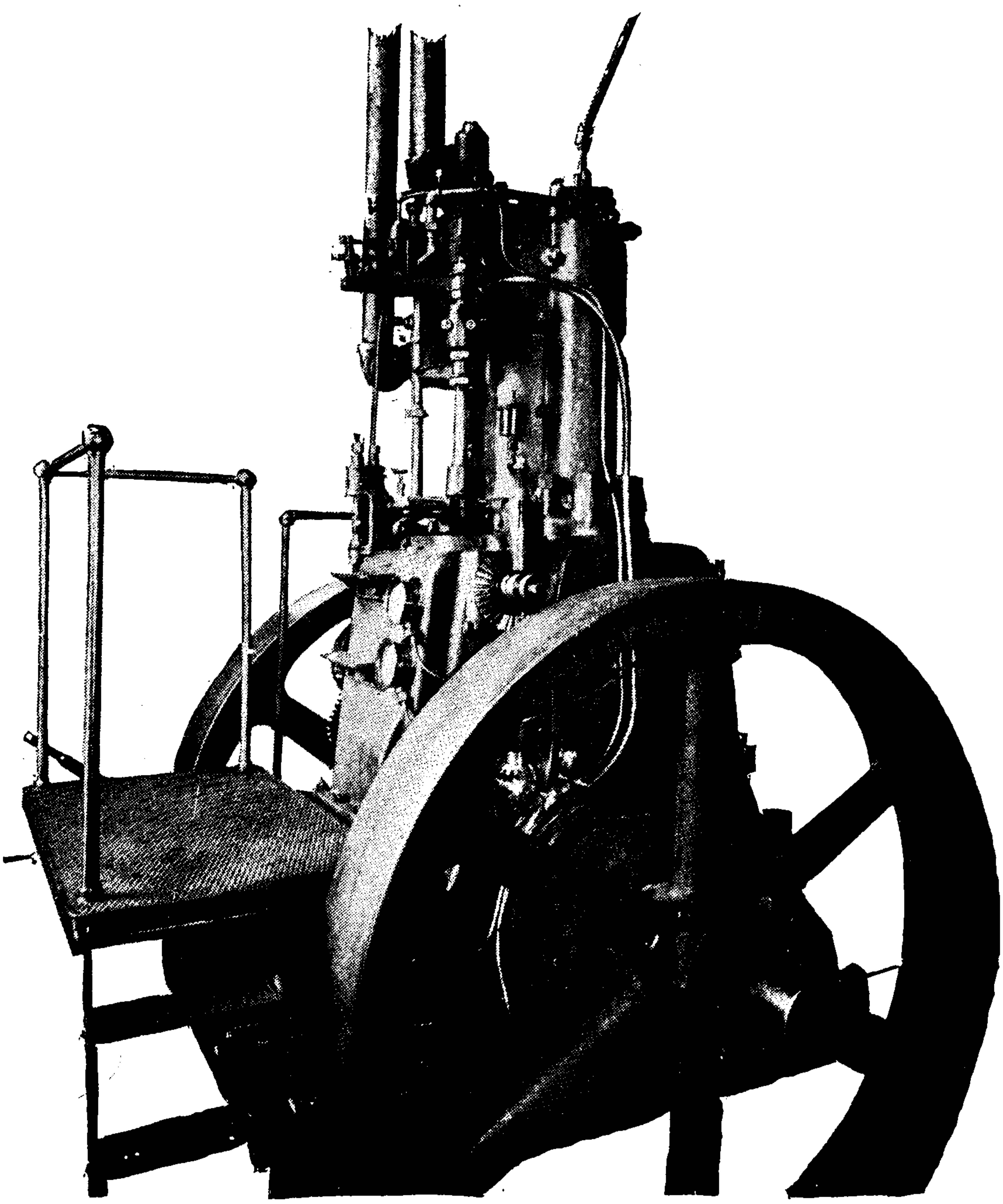


FIG. 294.—30 HORSE POWER DIESEL MOTOR.

combustible, and it is only necessary for the fuel to be injected into the heated air for its ignition and combustion to take place.

In his theoretical discussion of the subject, Mr. Diesel laid down four conditions as essential to the realization of the highest economy:

First, that the combustion temperature must be attained not by the combustion, and during the same, but before, and independent of it, by the compression of pure air.

Second, that this is best accomplished by deviating from the pure Carnot cycle to the extent of combining two of the stages of the cycle, and directly compressing the air adiabatically, instead of first isothermally from 2 to 4 atmospheres, and then adiabatically to 30 or 40 fold.

Third, that the fuel be introduced gradually into the compressed air, and burned with little or no increase in temperature during the period of combustion.

Fourth, that a considerable surplus of air be present.

It will be seen from these conditions that a motor to meet them, although operating upon the so-called "four-cycle" principle, must differ essentially from engines of the Otto type, and it was to realize these conditions that the Diesel motor was designed.

In general construction it resembles the design of a vertical steam engine, except that all parts are built to stand the high pressure employed.

The working cycle is as follows:

On one down-stroke the main cylinder is completely filled with pure air, the next up-stroke compresses this to about 35 atmospheres, creating a temperature more than sufficient to ignite the fuel. At the beginning of the next down-stroke, the fuel valve opens, and the petroleum, atomized by passing through a spool of fine wire netting, is injected during a predetermined part of the stroke into this red-hot air, resulting in combustion controlled as to pressure and temperature. This injection is made possible by the air in the starting tank, which is kept by the small air-pump at a pressure some 5 or 10 atmospheres greater than that in the main cylinder. A small quantity of this air enters with the fuel charge, which it atomizes as described. When the motor is running at full load, a very small quantity of injected air suffices, and the pressure in the air tank steadily rises. At half load, with less fuel injected, more air passes in. For this reason, the start-

ing tank is made large enough to equalize these differences, and a small safety valve is provided on the air-pump.

The petroleum is pumped into the fuel valve casing by a small oil-pump bolted to the base-plate. This pump is arranged to pump a fixed maximum quantity of petroleum. A by-pass is provided so that this whole quantity, or any portion of it, can be returned to the supply tank. The governor controls the action of this by-pass valve, closing it just long enough to compel the exact quantity of the fuel required to pass into the fuel valve casing. The full charge of air being always supplied for complete combustion, it matters not whether the governor permits one or fifty drops of petroleum to enter the working cylinder at each motor stroke, the combustion is always complete. To stop the motor it is only necessary to close the valve which admits the petroleum into the fuel valve casing. The valve gear consists of a series of cams placed on a shaft journaled on brackets cast on the cylinder.

The highest efficiency indicated has been found to be 37 per cent. at full load and 41 per cent. at half load, with a brake efficiency at full load of 25 per cent. and at half load 19 per cent. These high efficiencies are probably due to perfect combustion under high pressure, which is an essential feature of this motor.

In Fig. 295 is illustrated a vertical section of the Diesel motor in which A is the cylinder, B piston, D air pump, E oil-pump lever, F cam shaft driven by screw and bevel gear from the main shaft, H bell crank valve lever, I inlet oil valve, J clearance space, K inlet air valve gear, L exhaust valve gear, M oil valve lever, N high pressure air tank, O valve rod, R water jacket, S water-cooled cylinder head, T oil pump, U oil pump piston, V oil pump connecting rod.

The largest size of these motors in use is a three-cylinder model of 150 horse power. The offices of the Diesel Motor Co. of America are at No. 11 Broadway, New York City.

The Lozier Marine Gasoline Engine.

The great increase in the use of motor power for pleasure boats and as an auxiliary power in yachts has given a new impulse to the designing and building of gasoline motors for this special service, of which we illustrate in Fig. 296 and following the neat and compact motors of the Lozier Motor Company,

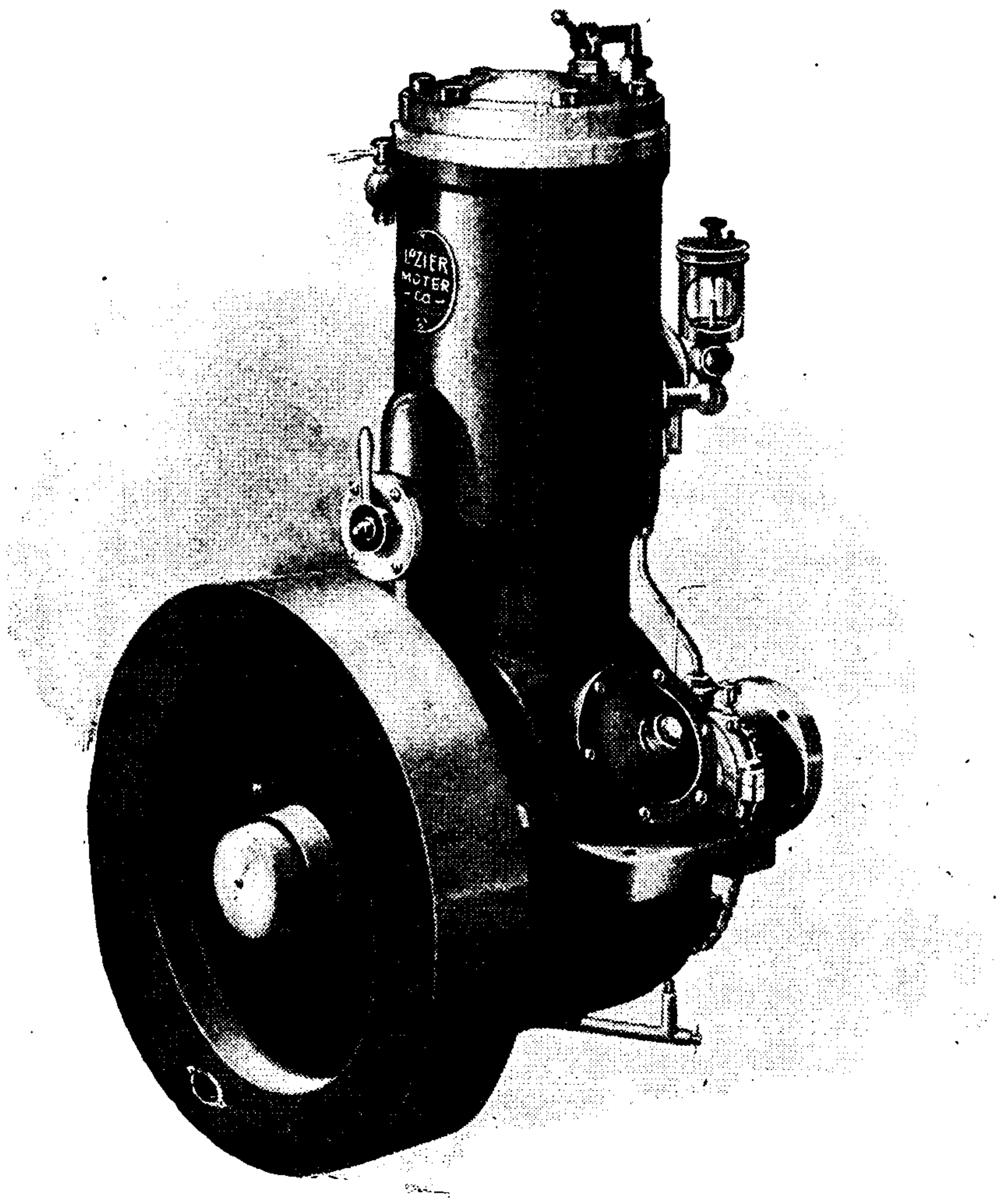


FIG. 296.—LOZIER LAUNCH ENGINE.

Plattsburg, N. Y. They are of the two-cycle water-jacket type, built in sizes with single cylinders from 1½ to 7½ horse power, and with double cylinders from 10 to 15 horse power. The company also build an elegant model of launches and covered motor boats. In operation the gasoline is vaporized in a separate compartment from the crank chamber in which it is atomized in contact with warm air drawn from a jacket over the exhaust pipe, vaporized as an explosive mixture, and then passes into the crank chamber by the draft of the upstroke of the piston. A check valve at the crank chamber inlet allows of compression on the down stroke of the piston.

In the passage between the crank chamber and charging port in the cylinder is located a regulating throttle, shown just over

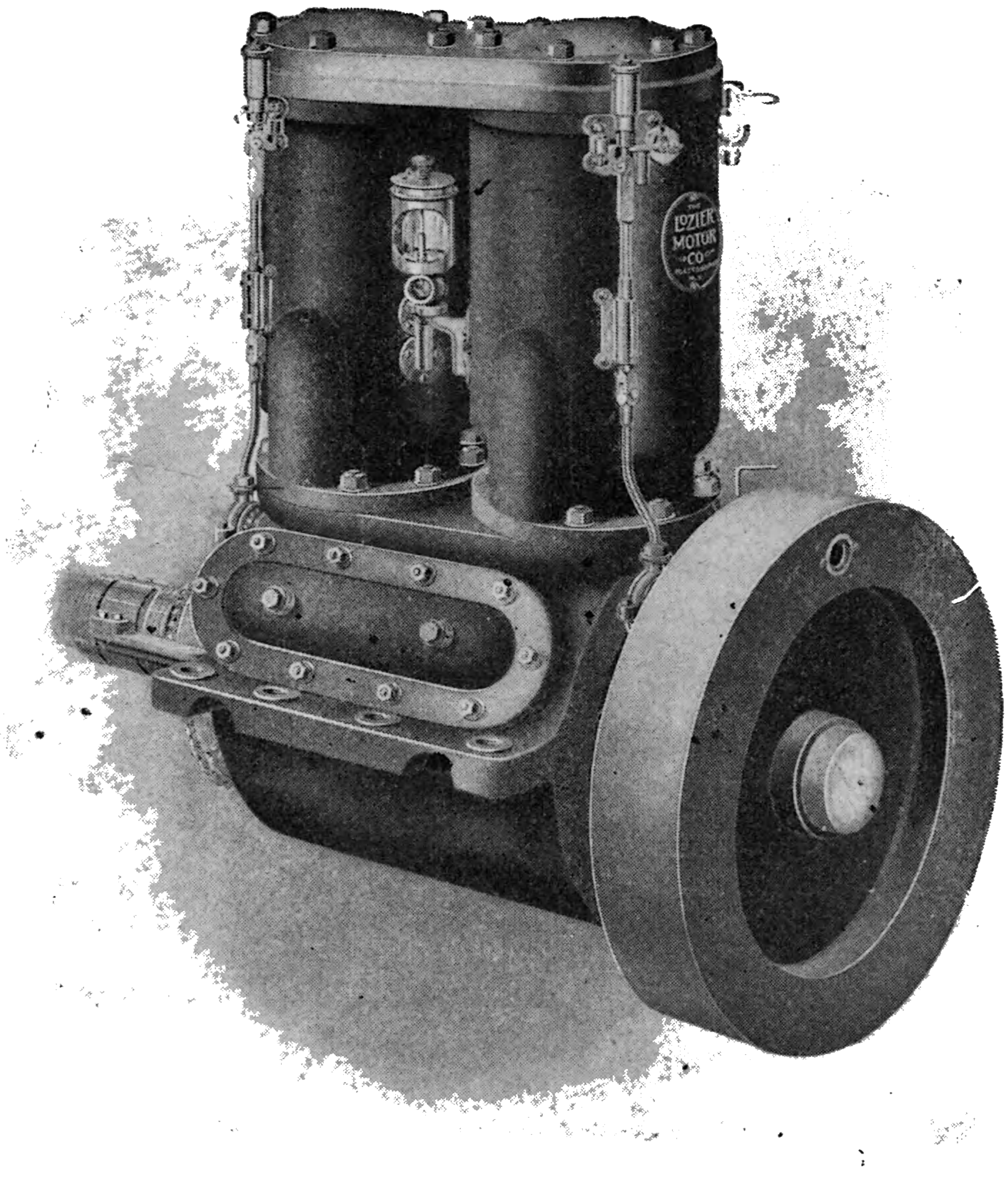


FIG. 297.—LOZIER TWO-CYLINDER ENGINE.

the flywheel in Fig. 296. Ignition is by a break or hammer contact, as shown in the detail figure.

The electric current is generated by a magneto driven by a friction gear at the rim of the flywheel and fixed in position with jointed attachment to the flange on the crank case with spring tension. A battery for use as an auxiliary in starting makes

with the gases of combustion and finally discharges with the exhaust below the water line. In this manner all odors and noise from the exhaust are eliminated.

This motor is well adapted as an auxiliary power for **sailing**

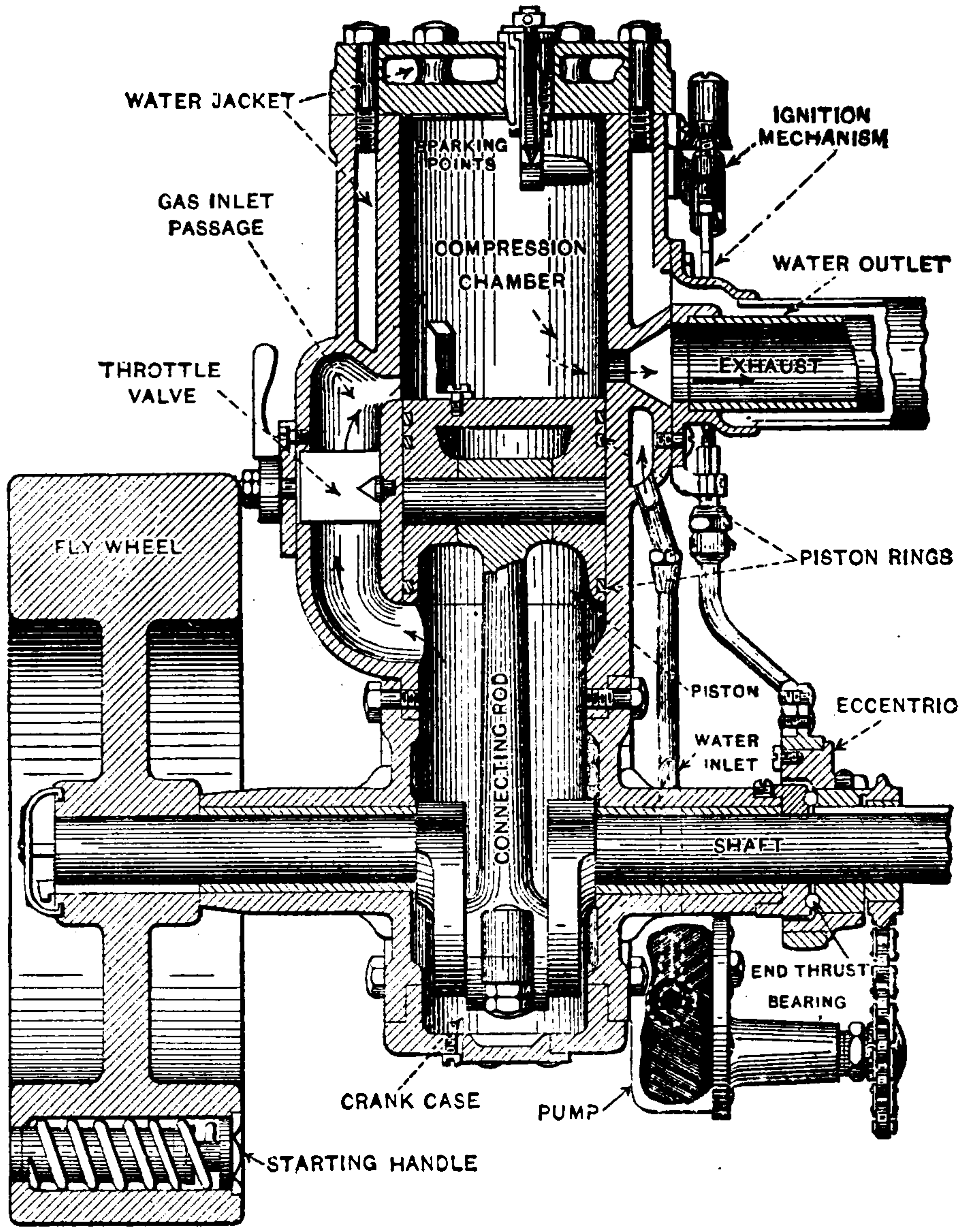


FIG. 299.—SECTIONAL DETAIL OF THE LOZIER MOTOR.

yachts and, together with a large launch service, is much in evidence on the waters of Lake Champlain. The launches are of elegant model and rigged as open, canopied and house boats.

The Marsh Motor and Motor Bicycle.

We illustrate in Fig. 301 one of the latest improvements in motor bicycles which are now taking a prominent lead in our methods of locomotion. The general design and arrangement of the motor parts seem to be faultless. The belt transmission with a tightening pulley appears to be in the line of best practice for

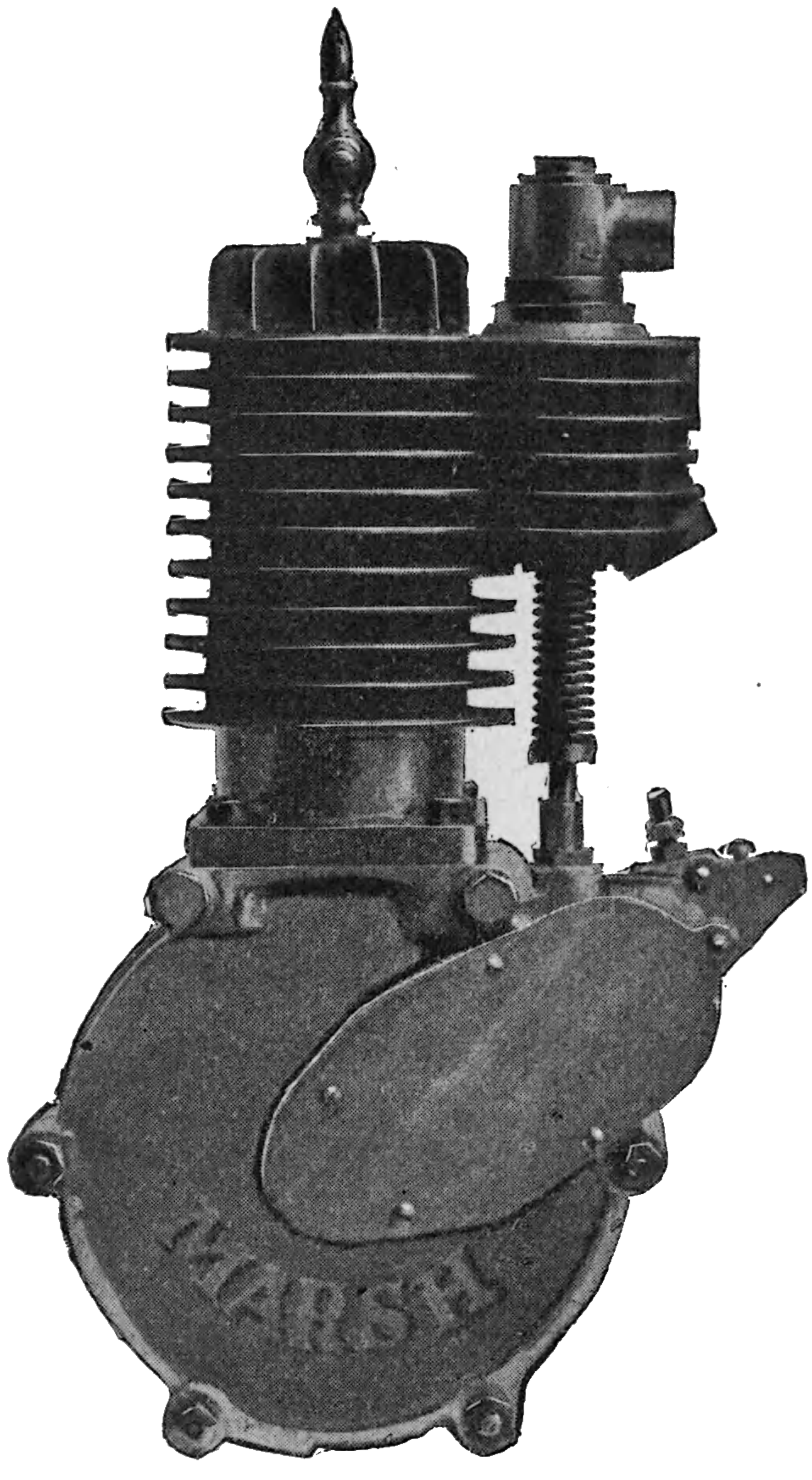


FIG. 300.—AIR-COOLED MOTOR.

easy motion and freedom from the jerky action of sprocket wheels and chain. The diameter of the motor pulley is 3 inches, driving on an 18-inch pulley on rear wheel, 6 to 1; cylinder 2⅝ inches by 2¾ inches stroke. A carburetter of the constant level type, which atomizes and vaporizes the gasoline by the indraft of the piston, is located within the frame. The gasoline tank under the top tube of the frame holds fuel for an 80-mile run. An ample dry battery and sparking apparatus is located on the back tube

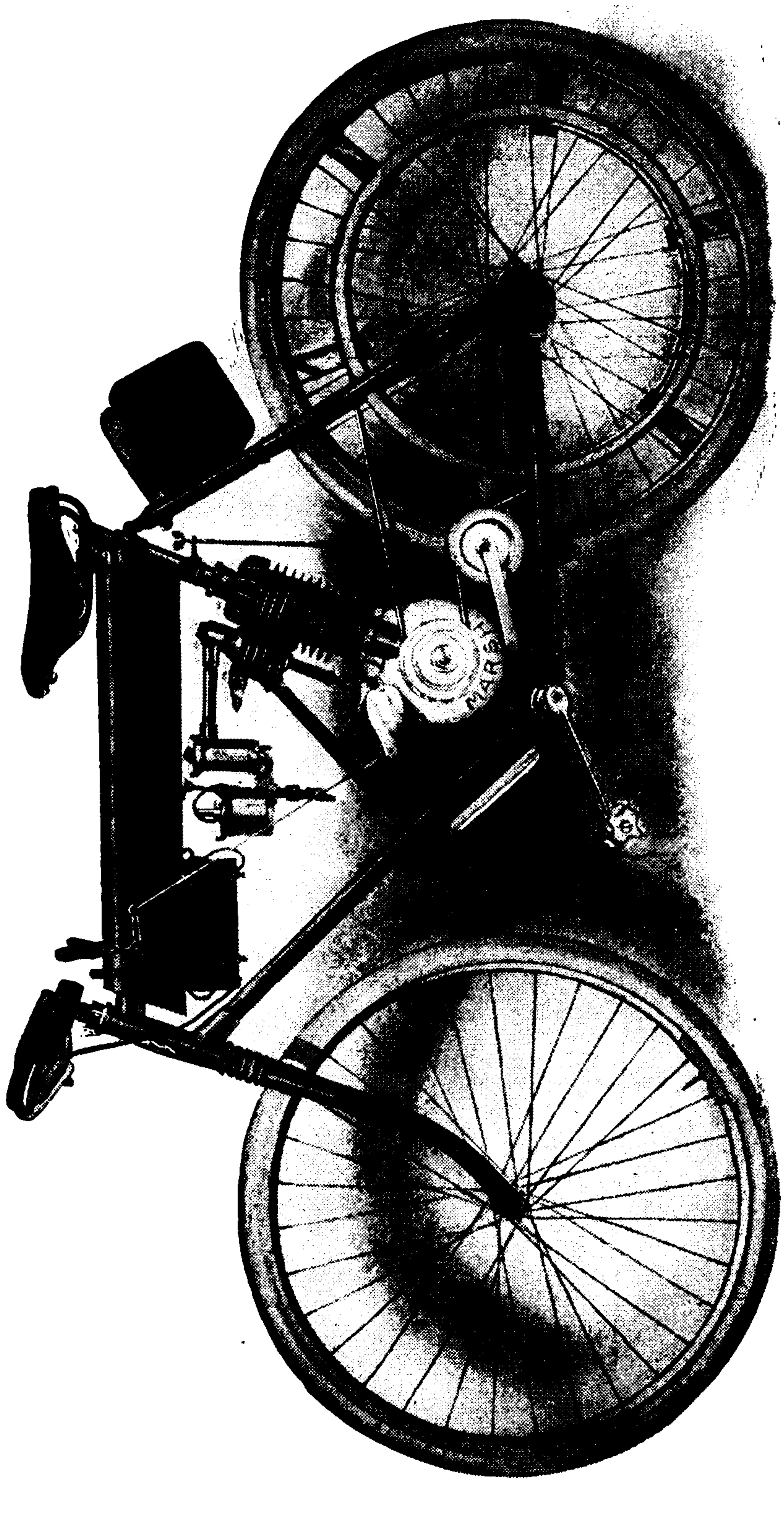


FIG. 301.—THE MARSH MOTOR BICYCLE.

of the frame, presenting altogether one of the neatest motor bicycles that we have seen. Weight complete, 90 pounds. Cost, $175.

These bicycles and motors are made by the Motor Cycle Co., Brockton, Mass.

The Truscott Launches and Motors.

Motors of the Truscott Boat Manufacturing Company, St. Joseph, Mich. The special output of this company are four and

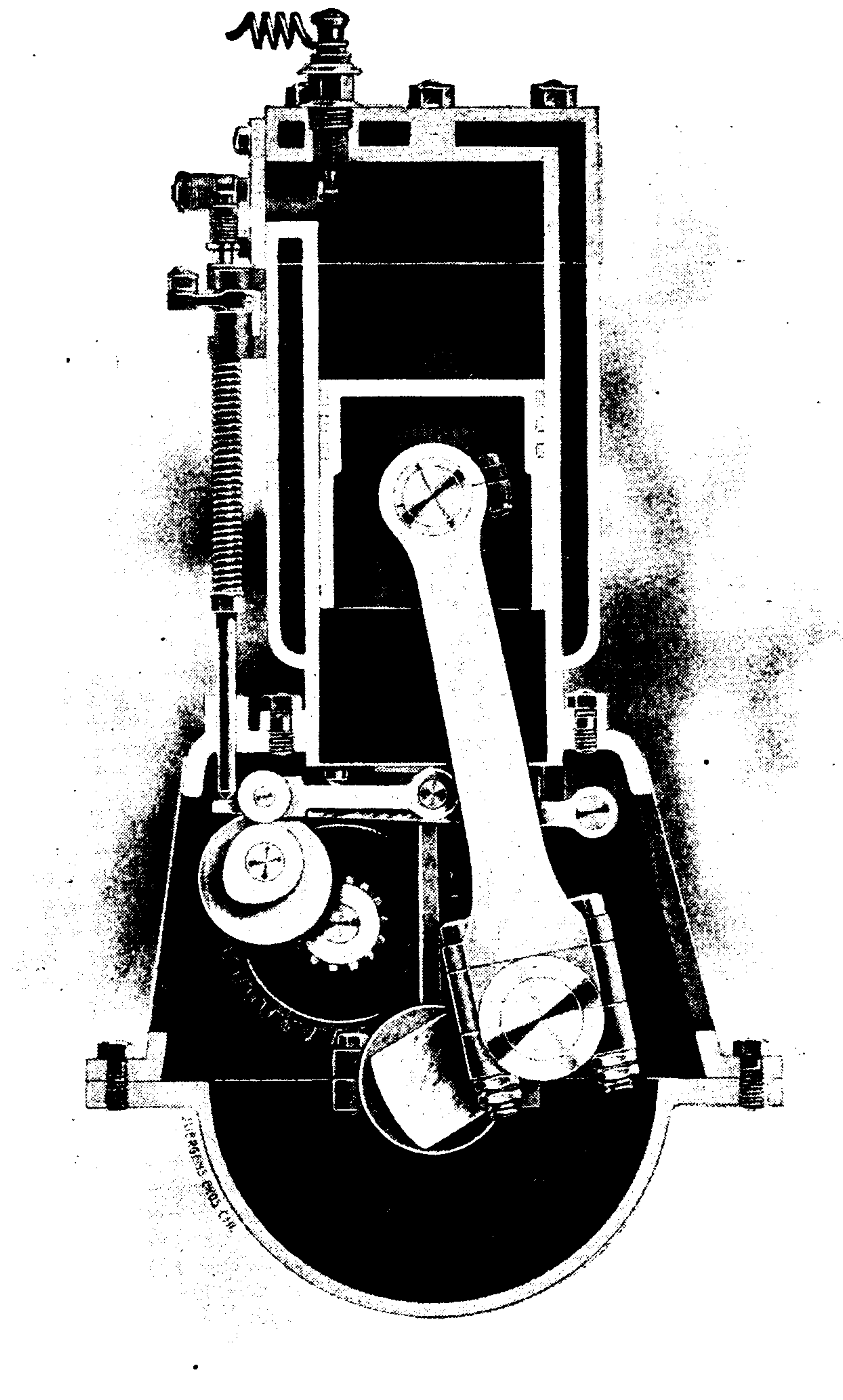


FIG. 303.—FOUR-CYCLE SINGLE MOTOR.

two-cycle gasoline motors for launches, cabin boats and sailing yachts. Their boats are of exceptionally fine model, and are much in evidence on the Great Lakes.

There is a studied elegance in their design and finish and

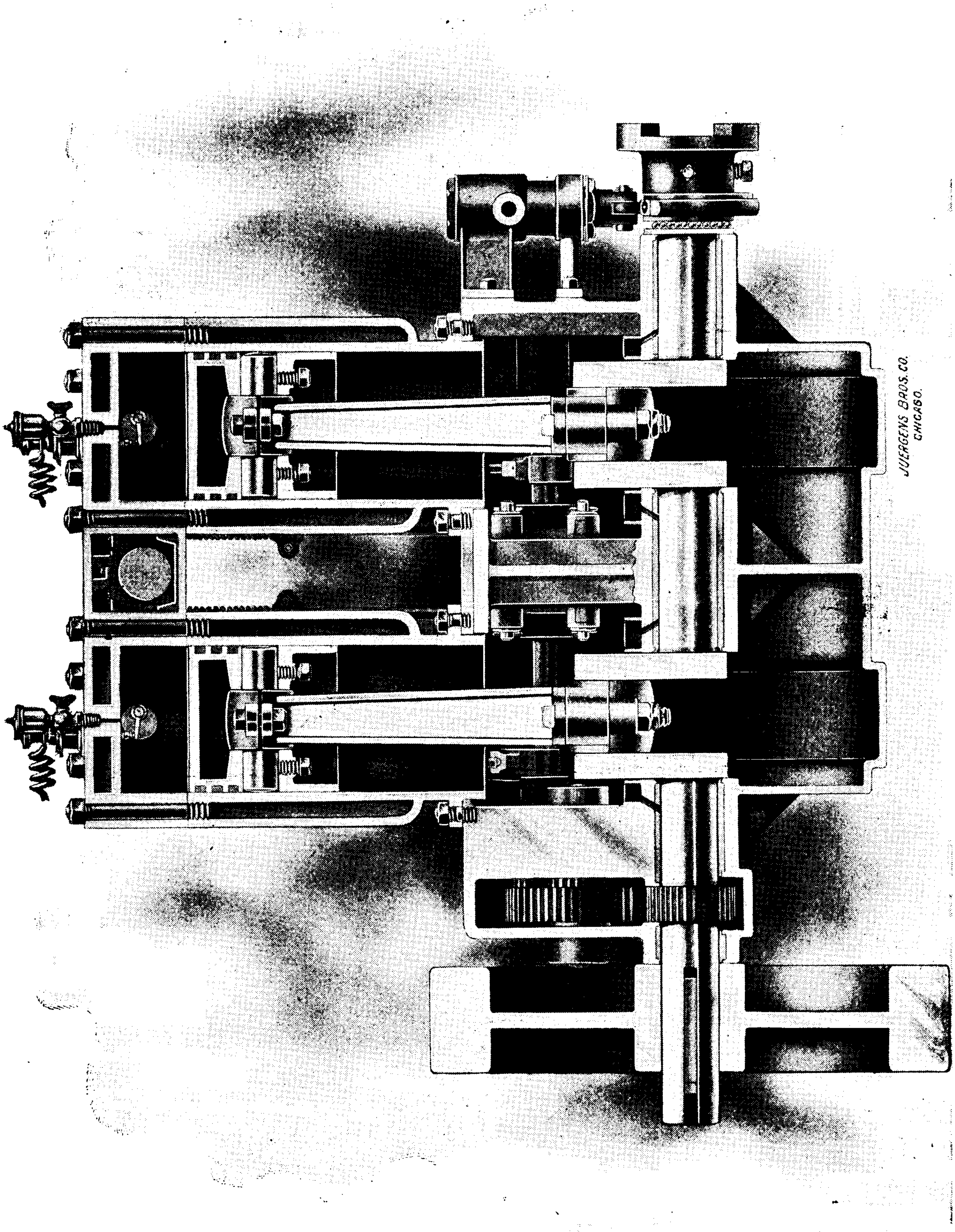


FIG. 304.—FOUR-CYCLE DUPLEX MOTOR.

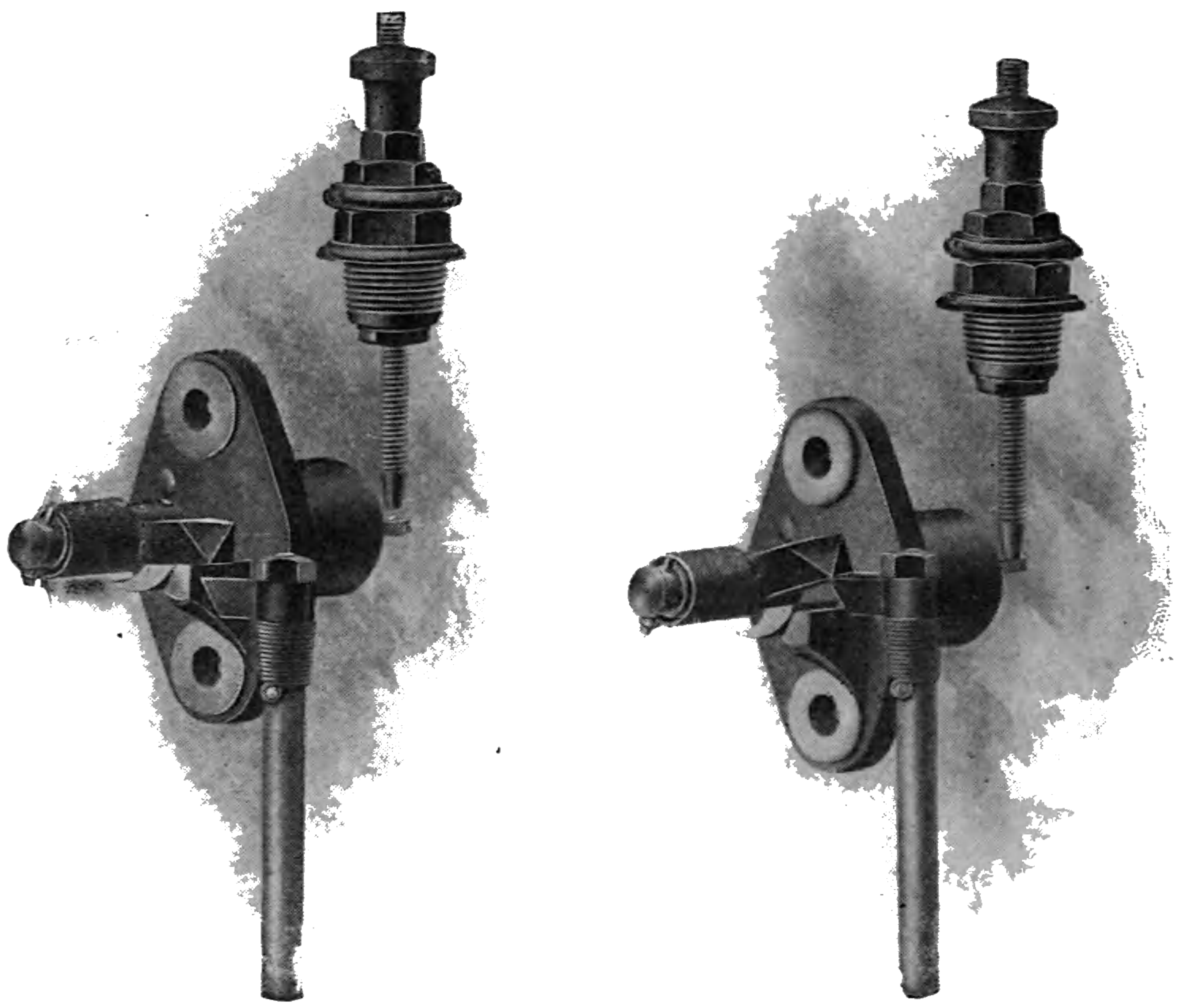


FIG. 305.—THE SPARKING GEAR.

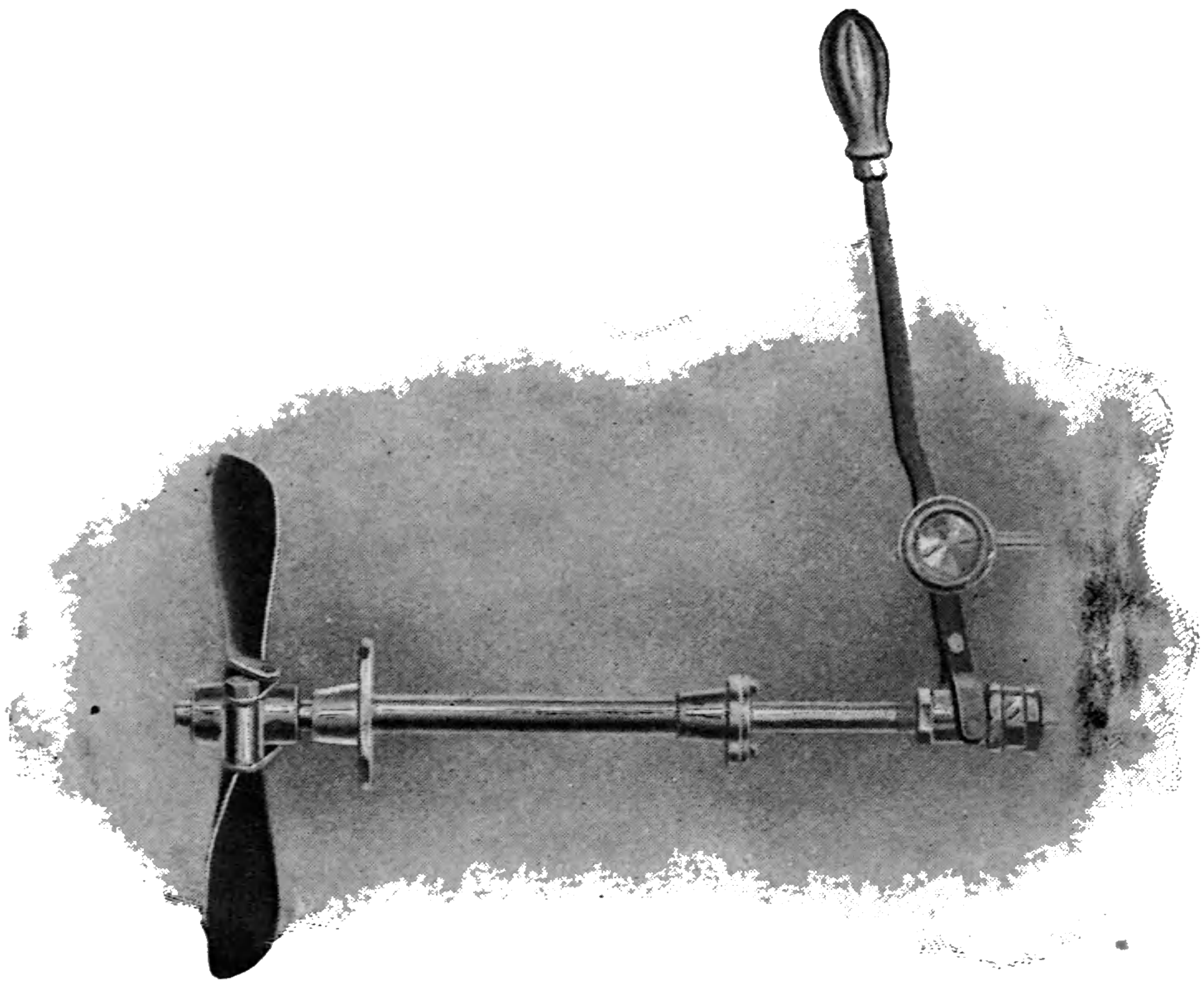


FIG. 306.—REVERSING PROPELLER.

their motors are no less so; for the experience of the builders has brought out the best proportions in the individual parts and the

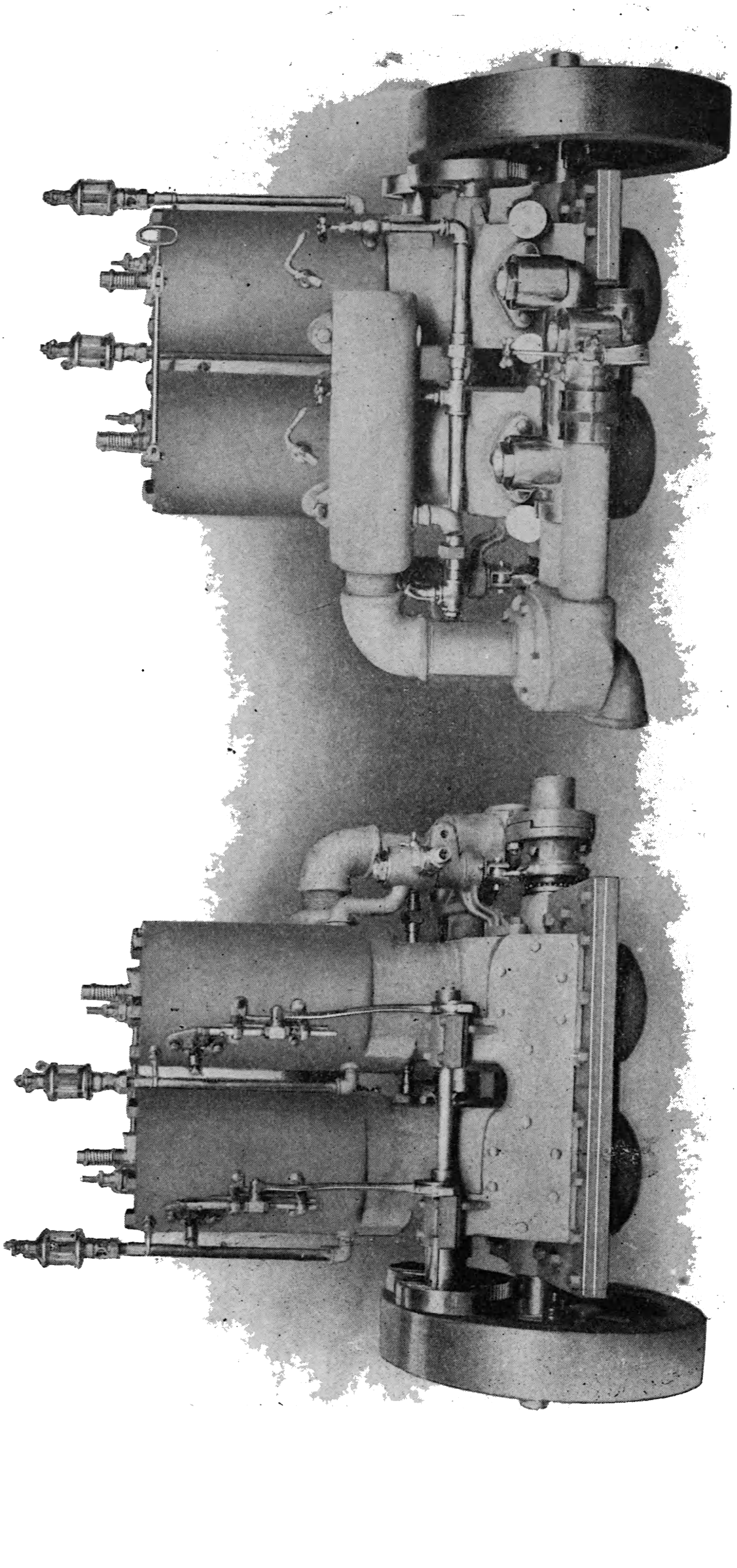


FIG. 303.—RIGHT AND LEFT SIDE, DUPLEX TWO CYCLE MOTOR, TRUSCOTT BOAT MANUFACTURING CO.

and three cylinders. Their design is in the general form of this class of vertical motors and is well shown in Fig. 307. It will

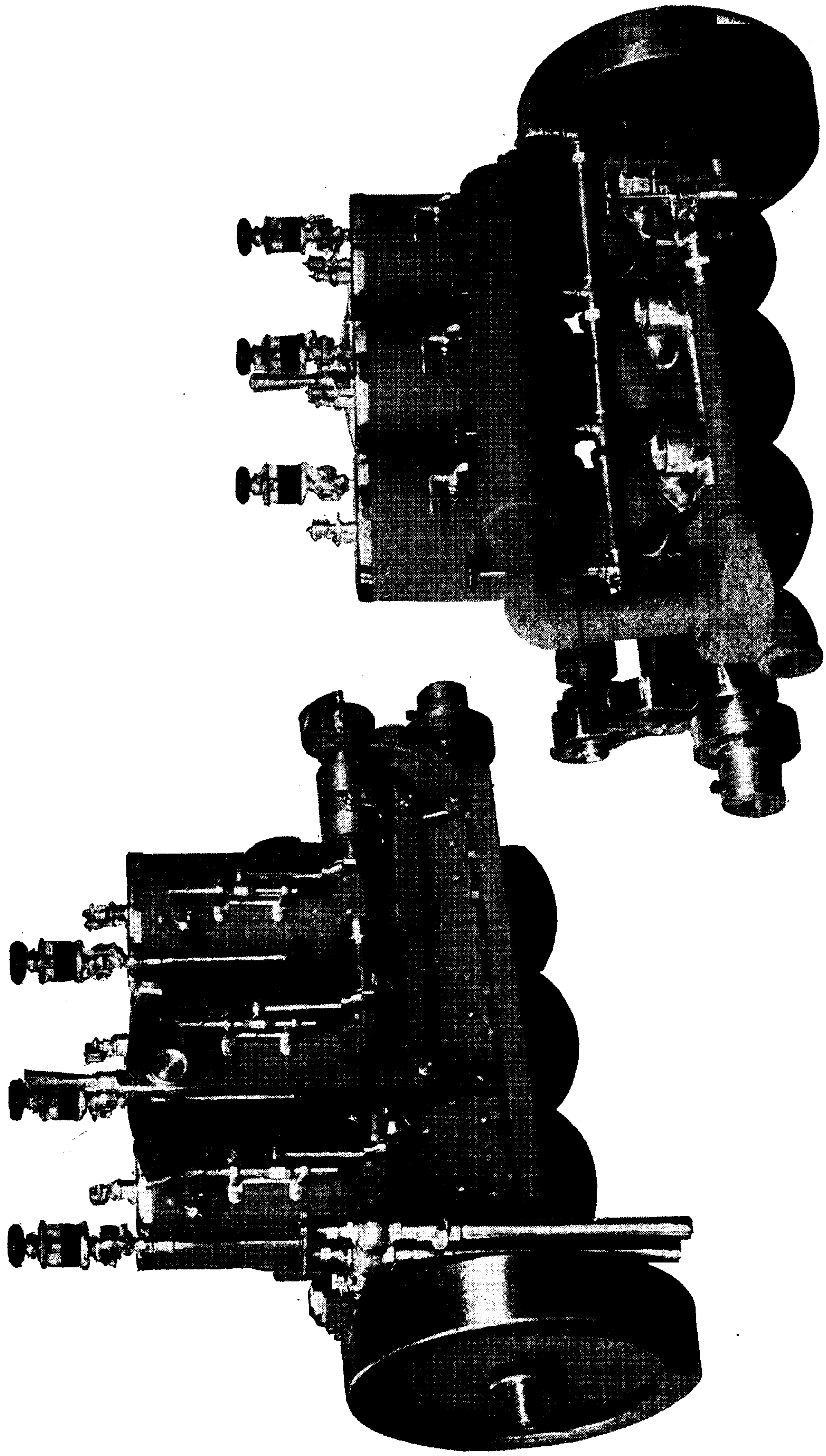


FIG. 309.—TRIPLEX TWO-CYCLE MOTORS, RIGHT AND LEFT SIDES.

be noted that the thrust bearing is of the ball bearing type. The ignition device is of the snap hammer adjustable type illustrated in detail in Fig. 305. The insulated spindle is made adjustable by

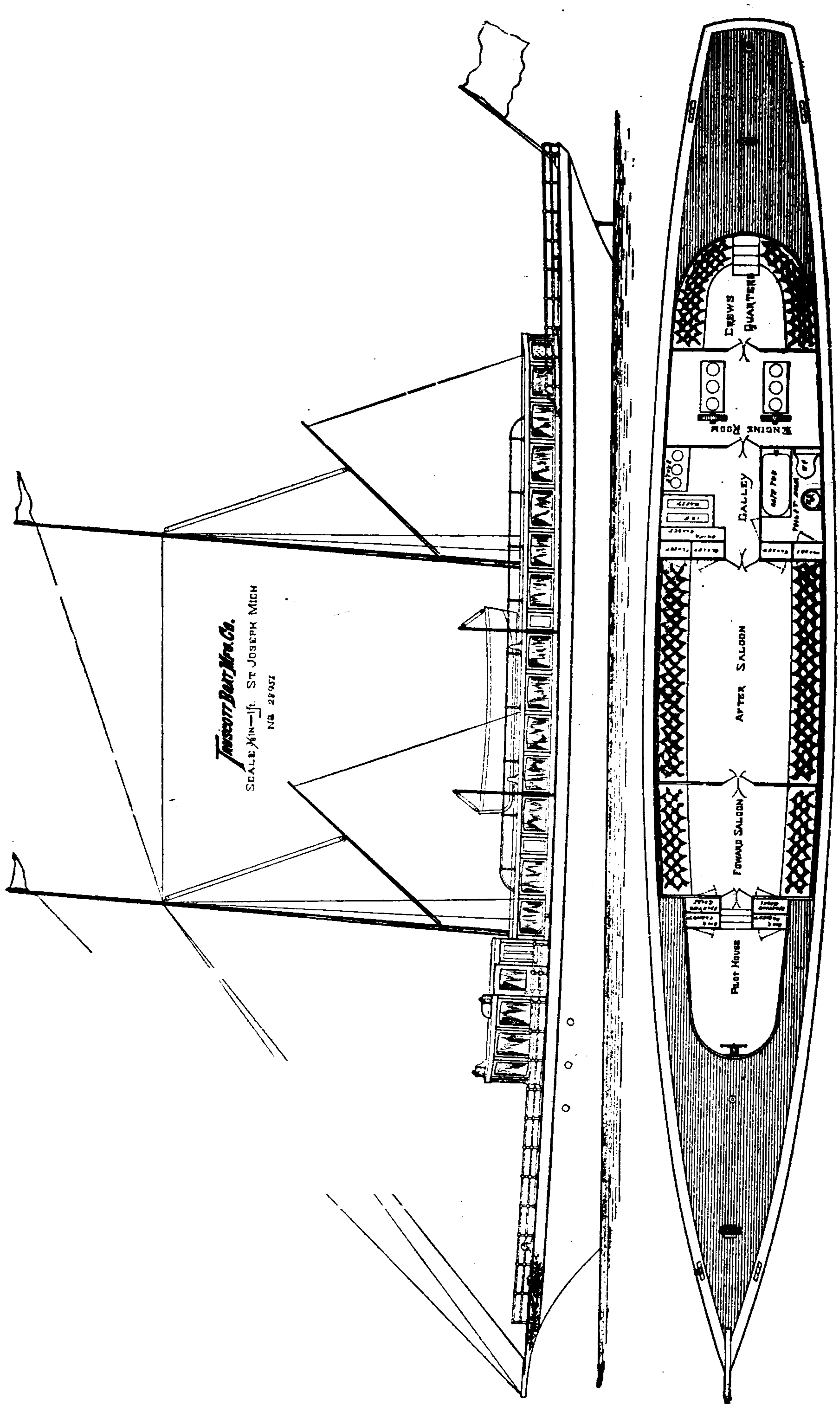


FIG. 310.—TRUSCOTT CRUISING SCHOONER, TWIN SCREWS AND MOTORS.

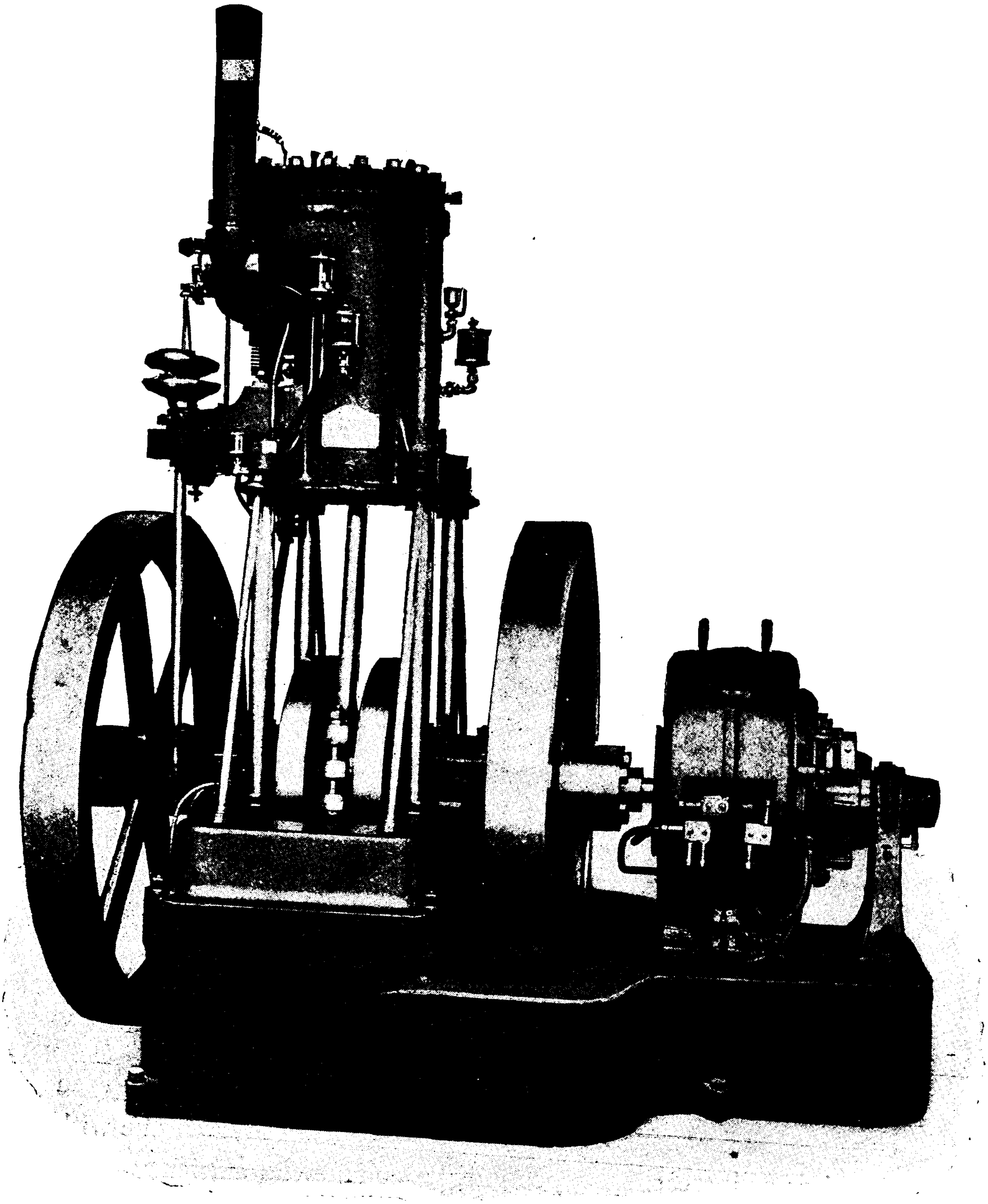


FIG. 311.—SECOR OIL ELECTRIC PLANT, STANDARD STEEL FRAME TYPE.

when the engine which needs neither boiler nor fireman can show an operating cost less than steam, combined with a performance and availability equal to steam, it will have a field of usefulness far greater than steam engines now occupy. Industrial statisticians no longer classing it among auxiliary powers, it will rank first among prime movers.

Experience has repeatedly demonstrated than an engine highly specialized, or improved in any one feature, is in less demand, commercially, than the ordinary gas engine. Such important advantages, for example, as the ability to use a better fuel than gasoline, or a considerable increase in thermodynamic efficiency, is rendered commercially abortive if accompanied by low mechanical efficiency, increased wear, imperfect regulation, increased vibration, or excessive weight; current engineering criticism suggested the desirability of simultaneous improvement along three distinct lines, each of these lines of course including special desiderata of supreme importance as determining factors in the problem of increasing the commercial efficiency of the internal combustion engine. Primarily, every element of mechanical inferiority must be eliminated; secondarily, the fuel flexibility should be increased and the engine adapted to use some low-cost and universally available fuel; and finally, if the performance in any particular is inferior to that of a high grade steam engine, it must be improved until it is fully equal to standard steam engine performance. The problem, therefore, which Mr. Secor attacked, was to produce an engine which should be equal mechanically to the steam engine, without being restricted to gas or gasoline for fuel, and which should also show such operative performance as would satisfy the most exacting conditions of industrial service.

The Secor Engine as a Machine.

As the basic idea of this engine was to include and harmoniously co-ordinate all factors essential to high commercial efficiency, it was considered important to combine in its design the elements of accessibility to working parts, compactness, durability, simplicity, strength, reliability, and reduced weight. Among the factors which have contributed to its remarkable success is the mechanical excellence of its design and construction. The design

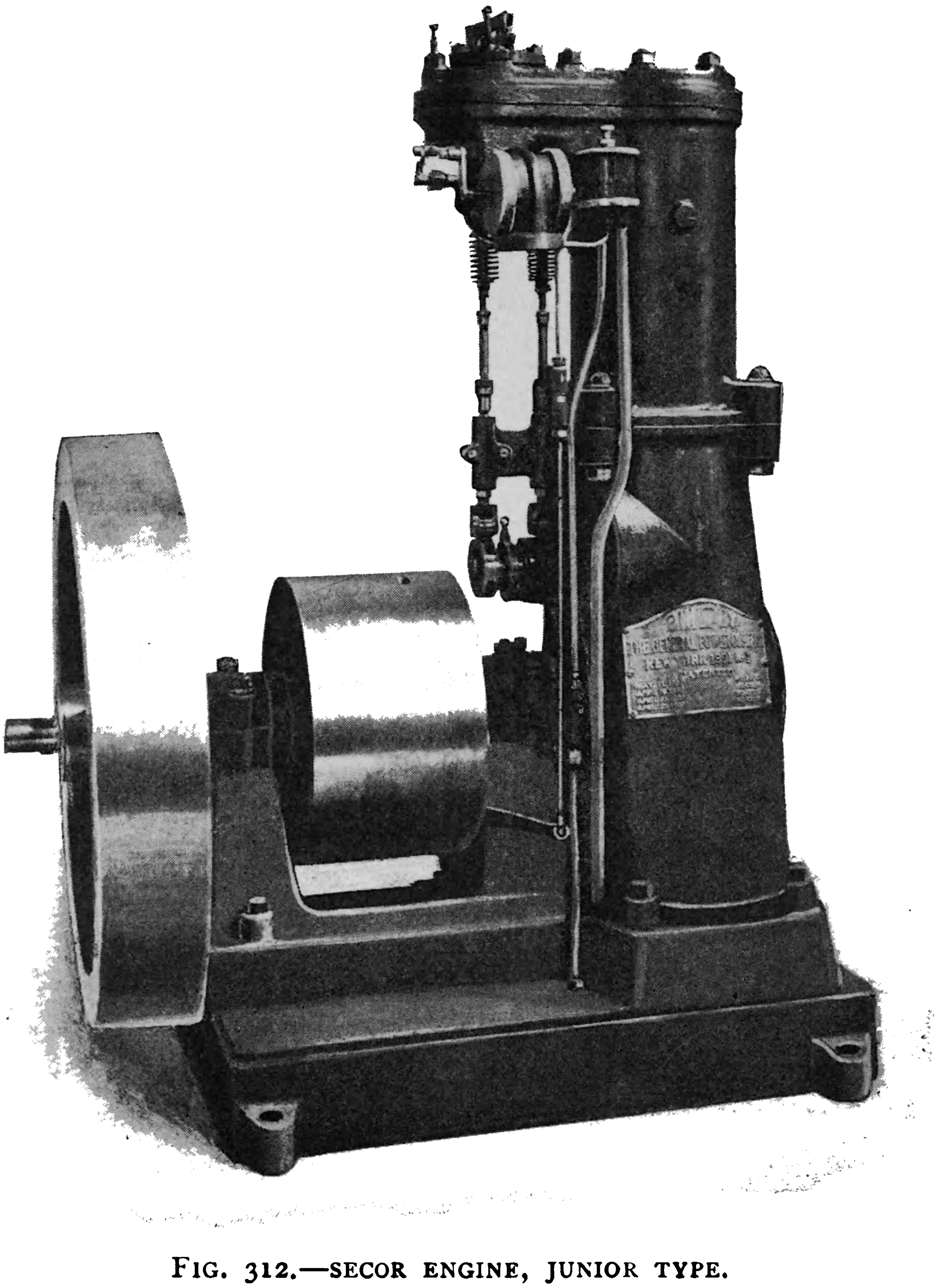


FIG. 312.—SECOR ENGINE, JUNIOR TYPE.

preferably adopted resembles somewhat the vertical marine type now being largely used in important stationary steam engine installations. The cylinder rests on columns of open hearth steel, diagonally braced by steel tension rods. The frame combines the maximum of strength with the minimum of weight, and although

battery is connected to a switch so arranged that the direction of the current through the igniting apparatus may be periodically reversed.

The Fuel Problem.

The discovery of petroleum in large quantities in Europe and America appears opportunely to supply the missing link which will render the internal combustion engine available for general use, inasmuch as commercial mineral oil, commonly known as kerosene, includes every essential quality of a satisfactory combustible. Considered solely as a fuel oil for the generation of power for industrial uses, kerosene is without a rival. It is the only known fuel combining the following advantages: (1) It is safe; (2) its cost is always low; (3) it is obtainable everywhere; (4) it possesses the highest thermodynamic value; (5) its chemical constitution is more constant than any other commercial hydrocarbon; (6) when stored for long periods or even exposed in open tanks it is not subject to change from varying temperatures or other atmospheric conditions. Kerosene, therefore, as a fuel combines the essential elements which are most important as contributing factors toward commercial efficiency in an engine. The commonly used fuels, city gas and gasoline, are totally unsuited for fuel, as they are variable in quality, costly and not everywhere obtainable.

The duty of the engine is to convert the potential energy of fuel into available mechanical power. The mechanism must perform the functions of receiving, transmitting and controlling mechanical energy resulting from recurring chemical reactions. Commercial efficiency demands that the control should be absolute and continuous, from the inception of kinetic energy to its transmission from the engine shaft as power. In fact, the control must precede the chemical reaction, for commercial efficiency requires that every element of uncertainty connected with the chemical operation of the engine be reduced to the utmost minimum, or abolished altogether. To achieve this control, and abolish uncertainty, all the conditions affecting the combustion must be subjected to positive and automatic mechanical control, so that it shall be impossible for them to vary without actual and sensible derangement of working parts. In proportion as this is accomplished, and only in proportion, does mechanical certainty take the place of conjecture, and reliability become a question merely of the number, intricacy and durability of the several parts. To utilize the heavy oils commercially is a difficult matter. In an engine working under the ordinary industrial conditions it is necessary to provide simultaneously for both correct combustion and satisfactory speed regulation. Under conditions purely academic, or nearly constant, no great difficulty is experienced in using kerosene either for illuminating or fuel purposes; but it has always been a difficult problem to vary the illumination of an oil lamp or the power of an oil engine without adversely affecting combustion. According to the usual method the fuel oil is supplied to a heated chamber, where it undergoes vaporization before entering the cylinder and partially mixing with the air, but it has been found impossible to design a vaporizer which will operate satisfactorily at all loads and under all conditions. If the temperature of the vaporizer is too low the oil cannot vaporize and the engine will finally stop, while on the other hand if the temperature is too high, partial decomposition of the oil takes place prematurely, causing the deposit of a carbon residue which after sufficient accumulation causes the vaporizer to work improperly; if by careful manipulation these two extremes are avoided, even a slight change in temperature will in some cases prevent correct regulation, inasmuch as any alteration whatever in temperature will increase or decrease the volume of oil vapor and thereby reduce or increase the thermal units contained in a given charge. Every form of vaporizer has some detracting feature which prevents accurate governing and perfect combustion, excepting when adjusted to constant conditions of weather and load.

In the Secor engine the fuel enters the cylinder in its liquid form, without pre-heating. The following postulates form the basis of the system of fuel supply:

a. It is desirable for the purpose of increasing the fuel flexibility to employ a system of fuel feed that can be easily adapted to suit either gaseous or liquid fuel.

b. To insure positive starting, the fuel supplying mechanism must *automatically* prevent the passage of any fuel to the motor cylinder, or any approach thereto when the engine is not in motion, regardless of the position assumed by the working mechanism at the time the engine ceases operation.

c. To insure positive starting, the fuel supplying mechanism should *automatically* furnish only the requisite supply of fuel during the "starting up" of the engine, always automatically avoiding an excessive supply whether the engine starts rapidly or slowly. The absence of this feature causes uncertainty in starting and may result in danger to the operator.

d. The fuel supplying mechanism should *automatically* insure absolute certainty of results during the continuous operation of an engine by preserving at all times the proper chemical relations between the fuel and the air which constitutes the explosive mixture from which the energy is derived. In order to obtain this result regardless of external weather conditions or internal load conditions it is necessary to provide for a more precise and homogeneous mixture than has heretofore been considered essential.

e. It was considered desirable to *automatically* provide for increased safety, by reducing to a minimum the quantity of liquid fuel at the engine or in the engine room, and in order to accomplish this the main fuel supply for the standard type of engine is contained preferably in riveted steel tanks placed below the engine in brick vaults or underground. The supply in the engine room is contained in a small reservoir attached to the engine itself and similar to the usual lubricating oil cup.

These postulates embodied in automatic methods of precision are covered by patents which include:

1. A fuel feed which is alternative, and which increases fuel flexibility by permitting the use of gaseous or liquid fuel as desired, by changing the fuel inlet valve, and which also provides

If a 25 horse power engine, for example, falls a little short of its rated power, or is inferior in other respects, it cannot operate continuously for 10 or 12 hours, 250 16 candle power lamps, each requiring 50 to 70 watts, nor furnish a commercially steady light, automatically and irrespective of the number of lamps thrown in or out of circuit, with economy, and without readjustment or undue wear or distress of any kind. Nor can it, like a steam plant, continue this for 20 years or more without requiring more than a nominal cost for "upkeep," unless it possesses all those elements which are combined in the best steam plant.

The ability to readily determine by means of electrical tests the load carried at any time by an engine operating electric light or power plants and to ascertain with absolute precision the speed regulation under varying loads, as well as the accurate check as to cost of operating afforded by a knowledge of the output in kilowatt hours and the corresponding cost of fuel and labor in the case of steam plants, has been found very convenient and useful in the evolution of this engine. The speed regulation under the electric tuning fork test is shown to be within one-third of one per cent under constant load. The Secor engine is therefore especially applicable for direct coupling to a dynamo for electric lighting or power service. Among the important advantages of the direct connected plants are the following:

1. The mechanism of these oil electric generating sets compares favorably in every detail with the best steam equipment. The single cylinder plants like steam plants are solid coupled, or else have continuous shafts from engine to dynamo.

2. These oil electric generators automatically produce electric light for isolated service from commercial kerosene oil at much less cost than is commonly charged by central stations for electric or gas light.

3. The Secor Solid Coupled Plants are self-regulating; no readjustment of rheostat being required when lights are turned on or off, the steadiness of E. M. F. is equal to the best steam engine performance.

4. The oil electric plants are now practicable for either direct or alternating current, operating as units, or in multiple.

5. They are as easily installed and cared for in the smaller sizes as an ordinary house furnace.

6. They are more easily and quickly started and operated than any steam plant.

7. They are entirely reliable as generators of electricity for light and power.

8. They are simple, safe and remarkably compact.

The limited space required is a great advantage in crowded districts in cities, while the possibility of obtaining power or electric light from kerosene in the country, will open up an ever-widening sphere of usefulness. The cost of labor in a central station, and the unavoidable steam wastes as well as electric transmission loss, are all avoided by the new direct isolated system; the electric light is therefore no longer a luxury to be enjoyed only in homes of wealth located within the lighting area of a central station. *The Secor Oil Electric Isolated System Surpasses Ordinary Central Station Service in Quality and Cost of Light, as well as in Greater Availability.*

The Junior Oil Electric Plants consist of the Junior engines solidly coupled to multipolar electric generators, with complete switch boards and all instruments, and are made in several sizes from 25 lights upward. They carry sufficient oil in their own bases for an automatic supply of fuel for more than a night's run. In addition to electric lighting the smaller plants are available for light farm work, such as pumping water, ensilage cutting, churning, etc., and for such household uses beside electric lighting as charging storage batteries for electric carriages or launches, operating electric fans, etc. The Junior sets are therefore adapted to universal use in every possible situation, being easily installed and operated by local unskilled labor.

The General Power Company, No. 81 and 83 Fulton Street, New York City, are the sole manufacturers of the Secor engine in America.

PATENTS

Issued in the United States for Gas, Gasoline and Oil Engines and their appliances, from 1875 to July 1, 1902, inclusive.

—1875—

G. W. Daimler 168,623
J. Taggart 161,454
P. Vera 160,130

—1876—

J. Brady 176,588
A. de Bischop 178,121
T. W. Gilles 179,782

—1877—

J. Wortheim 192,206
R. D. Bradley 187,092
F. Deickman 195,585
N. A. Otto 194,047
Otto & Crossley 196,473

—1878—

J. Brady 200,970

—1879—

F. Burger 222,569; 222,660
J. H. Connelly 211,836
J. Robson 220,174
Wittig & Hees 213,539
G. W. Daimler 222,467

—1880—

E. Buss 226,972
L. Durand 232,808
C. Linford 232,987
A. K. Rider 233,804
Wittig & Hees 225,778
D. Clerk 230,470
G. W. Daimler 232,243

—1881—

E. Renier 247,741
C. J. B. Gaume 240,994
A. K. Rider 245,218
J. Robson 243,795
G. Wacker 242,401
N. A. Otto 241,707
J. Ravel 236,258

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C. G. Beechy 264,126
R. Hutchinson 253,709
A. P. Massey 260,587
T. McAdoo 253,406
P. Munsinger 266,304
L. C. Parker 269,813
C. M. Sombart 260,620
K. Teichman 269,163
H. Wiedling 259,736; 269,146
A. K. Rider 267,458
E. W. Kellogg 265,423
H. H. Burritt 258,884
W. H. Wigmore 260,513

—1883—

C. W. Baldwin 276,747; 276,748; 276,749; 276,750; 276,751; 287,897; 288,399; 290,310
J. Charter 270,202; 270,203
H. Denney 290,632
Eteve & Lallemont 272,130
J. A. Ewins 278,421
E. J. Frost 273,269
W. Hammerschmidt 288,632
Geo. M. Hopkins 284,555; 284,556; 284,557
G. M. & L. N. Hopkins 284,851
Jackson & Kirkpatrick 283,398
S. Marcus 286,030
H. S. Maxim 273,750; 279,657

J. Hodgkinson—J. H. Dewhurst 347,603
E. J. J. Lenoir 345,596
J. J. E. Lenoir 335,462
P. Murray, Jr 351,393; 351,394; 351,395
L. H. Nash 334,039; 341,934; 341,935
N. E. Nash 340,435
J. F. Place 348,998; 348,999
N. B. Randall 355,101
A. L. Riker 349,858
C. Sintz 339,225
H. & C. E. Skinner 335,971
R. F. Smith 345,998; 347,656
J. Spiel 349,464
S. Wilcox 343,744; 343,745
L. H. Nash 334,038; 334,040
E. Korting 346,374
J. H. Clark 353,402
C. E. Skinner 352,368; 335,970
F. Bain 354,881
C. W. Baldwin 352,796
N. A. Otto 350,077
H. Robinson 346,687
N. A. Otto 335,038
J. P. Holland 337,000; 335,629
A. K. Rider 349,983
G. Daimler 334,109
J. Spiel 349,369
G. Ragot & G. Smyers 350,769
L. H. Nash 334,041

—1887—

J. Atkinson 367,496
C. W. Baldwin 368,444; 368,445
H. Campbell 367,184
J. Charter 356,447; 370,242
L. T. Cornell 359,920
F. W. Crossley 370,322
C. J. B. Gaume 374,056
F. W. Ofeldt 356,419
A Schmid—J. C. Beckfield 362,187; 371,793
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R. Van Kalkreuth 358,134
J. S. Wood 363,497
N. C. Bassett 359,552
T. Shaw 367,936
W. Gavillet—L. Martaresche 357,193
E. Korting 366,116
F. Von Martini 358,796
T. Backeljan 364,205
H. P. Holt—F. W. Crossley 370,258
N. A. Otto 365,701
F. W. Crossley—H. P. Holt—F. H. Anderson 363,508
B. F. Kadel 374,968

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H. T. Dawson 392,191
E. Delamare — Deboutteville, Reissue 10,951
H. Hartig 391,528
L. N. Hopkins 379,397
E. Korting 377,623
L. H. Nash 386,208; 386,210; 386,211
J. Noble 379,807
H. K. Shanck 376,212; 390,710
W. S. Sharpneck 391,486
C. Sintz 383,775
H. Skinner 389,608
R. F. Smith 377,962
G. W. Stewart 381,488
J. Bradley 386,233
J. R. Daly 392,109
L. H. Nash 386,214; 386,216; 386,212; 386,213; 386,215; 286,209
R. Bocklen 384,673
N. A. Otto 388,372
H. Williams 386,949
N. A. Otto 386,929
A. Rollason 391,338; 394,299
C. L. Seabury 393,080

—1889—

A. Schmid—J. C. Beckfield 403,294
J. J. R. Humes 400,850
C. W. Baldwin 407,320; 407,321

C. W. Baldwin	408,623
T. B. Barker	400,163
J. C. Beckfield	396,022
L. T. Cornell	406,263
W. E. Crist	417,471
H. J. Hartig	415,197
A. Histon	400,458
S. Lawson	399,907 399,908 402,749 402,750 402,751
J. Mathies	411,668
L. H. Nash	401,453 418,417
D. S. Regan	408,356
N. Rogers—J. A. Wharry	403,379
A. Schmid	396,238
C. Sintz	416,649
H. Tenting	402,363
W. von Oechelhaenser	417,759
C. White—A. R. Middleton	406,807
L. F. McNett	407,961
N. Rogers—J. A. Wharry	403,378
W. E. Crist	417,472
L. H. Nash	418,419
E. D. Deboutteville—L. P. C. Malandin	400,754 411,644
E. Capitaine	408,460
E. Korting	417,924
N. Rogers—J. A. Wharry	403,377 403,376
L. H. Nash	401,452
L. C. & B. Parker	401,204
E. Capitaine	408,459
I. F. Allman	411,211
N. Rogers—J. A. Wharry	403,380
J. C. Beckfield	417,624
S. Griffin	412,883
H. Hoelljies	408,483
L. H. Nash	418,418
E. Capitaine	406,160
C. S. A. H. Wiedling	398,108
J. J. Purnell	408,137
S. Wilcox	402,549
L. C. & B. Parker	403,367 405,795
W. J. Crossley	406,706
G. Daimler	418,112
J. Charter	415,446
N. A. Otto	407,234
M. V. Schiltz	399,569
A. Allmann—F. Küppermann	412,228
K. Gramm	415,908

—1890—

G. B. Brayton	432,260
W. D. & S. Priestman	430,038
E. Butler	423,214 437,973
H. Lindley & T. Browett	440,485
N. A. Otto	433,806 433,807
H. Campbell	428,801
G. McGee	432,638
J. Taylor	443,082
N. A. Otto	433,809 433,810 433,811 433,812 433,813 433,814 437,508 424,345
M. M. Barrett—J. F. Daly	434,695 430,504
F. Dürr	442,248
H. J. Baker	421,473
C. W. Baldwin	434,171
M. M. Barrett—J. F. Daly	430,505 430,506
J. C. Beckfield	432,720
J. C. Beckfield—A. Schmid	421,474 421,475 421,477
E. H. Gaze	437,776
J. Mohs	426 297
E. Quack	441,582
D. S. Regan (reissue)	11,068
A. Schmid—J. C. Beckfield	421,524
H. K. Shank	439,200
W. S. Sharpneck	441,028
C. Sintz	426,337
J. D. Smith	418,821
E. A. Sperry	433,551
J. R. Valentine—A. T. Grigg	425,116
C. W. Weiss	419,805 419,806
C. White—A. R. Middleton	438,209
J. J. Pearson—J. Kunze	428,858
G. H. Chappell (Rotary)	441,865
J. H. Eichler (Rotary)	442,963
G. E. Hibbard (Rotary)	424,000
W. S. Sharpneck (Rotary)	428,762
W. C. Rossney	420,169
E. F. Roberts	424,027
C. W. Baldwin	439,232
J. J. Pearson	426,736
J. W. Eisenhuth	436,936

J. W. Eisenhuth	430,310 430,312
G. B. Brayton	432,114
A. W. Schleicher—P. A. N. Winand	434,609
P. A. N. Winand—L. V. Goebbels	435,637
J. Roots	425,909
H. A. Stuart	439,702
N. A. Otto	437,507
C. von Lüde	435,439

—1891—

A. Harding	452,520
I. F. Allman	453,071
J. Charter	455,388
B. H. Coffee	446,851
P. T. Coffield—C. H. Poxson	456,284
E. W. Evans	452,568
J. Fielding	450,406
M. A. Graham	445,110
O. Kosztovits	448,924
G. W. Lewis	451,621
E. Narjot	448 989
B. C. Vanduzen	448,597
G. J. Weber	449,507 444,031
M. M. Barrett	452,174
M. M. Barrett—J. F. Daly	463,435
D. D. & J. T. Hobbs	460,070
F. W. Lanchester	459,403 459,404 459,405 465,480
L. G. Wolley	450,091
J. S. Connelly	457,459 457,460
V. Loutsky	460,241
P. Neil—A. Janiot	462,447
H. Williams	457,020
B. C. Vanduzen	448,386
P. C. Sainsevain	461,802
G. Roberts	446,016
F. S. Durand	455,483
H. Schumm	458,073
H. Lindley	450,771
E. Kaselowsky	463,231
G. W. Lewis	451 620
A. Rollason—J. H. Hamilton	456,505 456,853 457,332
O. Lindner	453,446
L. Kessler	451,824
D. S. Regan	448,369

—1892—

J. Joyce	480,019
B. Stein	478,651
D. Best	484,727
J. Charter	472,106
J. A. Charter	473,293 477,295
H. T. Dawson	466,331
E. W. Evans	488,165
J. W. Raymond	488,483
H. Warden	486,143
J. Wehrschmidt	484,168
C. W. Weiss	473,685
S. Withers—D. S. Covert	487,313
H. Schumm	488,093
E. I. Nichols	480,272
H. Schumm	482,202
A. Niemezyk	480,737
G. W. Weatherhogg	480,535

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F. E. Tremper	495,281 503,016
J. S. Bigger	491,403
F. Cordenons	500,754
J. Foos—C. F. Endter	494,134
C. J. B. Gaume	501,881
W. W. Grant	497,239
C. F. Hirsch—A. Schilling	507,436
D. D. Hobbs	506,817
G. E. Hoyt	502,255 510,140
S. Lawson	498,476
G. W. Lewis	511,535
W. von Oechelhaeuser — H. Junkers	508,833
C. W. Pinkney	499,935 504,614 505,327 511,158
J. W. Raymond	491,855
C. Sintz	509,255
C. V. Walls	498,700
H. A. Weeks—G. W. Lewis	511,478
W. H. Worth	504,260
H. W. Tuttle	510,213
D. Best	496,718
C. W. Weiss	492,126
A. Niemczyk	508,042
C. B. Wattles	509,981
E. Delamare — Deboutteville — L. Melandin	511,593

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G. W. Roth.................... 552,263
W. R. Campbell................ 550,742
B. W. Grist................... 545,125
J. Robison.................... 532,098
P. Burt—G. McGhee...... 550,674
G. W. Roth.................... 539.923
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F. Mayer..................... 549,677
F. W. Ofeldt................. 538,694 / 540,757
W. Lorenz.................... 535,837
J. Robison................... 532,097 / 532,100

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J. F. Duryea................. 557,469
J. F. Daly & W. L. Corson..... 557,493
G. E. Hoyt....... 561,890
A. A. Hamerschlage........... 561,886
G. F. Eggerdinger and G. R. Swaine..................... 561,774
G. W. Lamos.................. 562,307
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J. M. Worth.................. 559,017
G. L. Thomas................. 558,749
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E. Kasalowsky................ 559,290
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A. J. Pierce................. 564,643
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H. Swain..................... 564,769
J. Robison................... 565,033
R. E. Olds—M. F. Bates....... 565,786
B. Wolf...................... 566,263
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H. Ebbs...................... 566,300
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H. Van Hoevenburgh........... 567,928
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F. C. Olin................... 569,386 / 569,564
H. A. Winter................. 569,530
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M. W. Weir................... 569,694
T. von Querfurth............. 569,672
R. E. Olds................... 570,263
E. J. Pennington............. 570,440 / 570,441

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L. Gathman	570,470
E. Prouty	570,500
C. W. Pinkney	571,239
C. A. Kunzel, Jr	571,447
G. W. Lewis	571,534
F. C. Olin	571,495
E. Rappe	571,498
M. Blakey	571,966
J. F. Duryea	572,051
E. E. Ludi	572,209
E. Capitaine	572,498
F. J. Rettig	573,296
F. E. Culver	573,209
S. M. Balzer	573,174
J. Charter, Jr	573,762
G. S. Tiffany	573,628
M. F. Underwood	574,183
J. W. Eisenhuth	574,311

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F. Burger	576,430
F. C. Southwell	575,812
J. Walrath	577,898 578,377
L. Benier	579,378
H. S. Bristol	575,326
T. W. Cohen	575,878
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