(No Model.) 2 Sheets—Sheet 1.

N. A. OTTO.

MOTOR ENGINE WORKED BY COMBUSTIBLE GAS.

No. 383,065. Patented May 15, 1888.

FIG. 1.

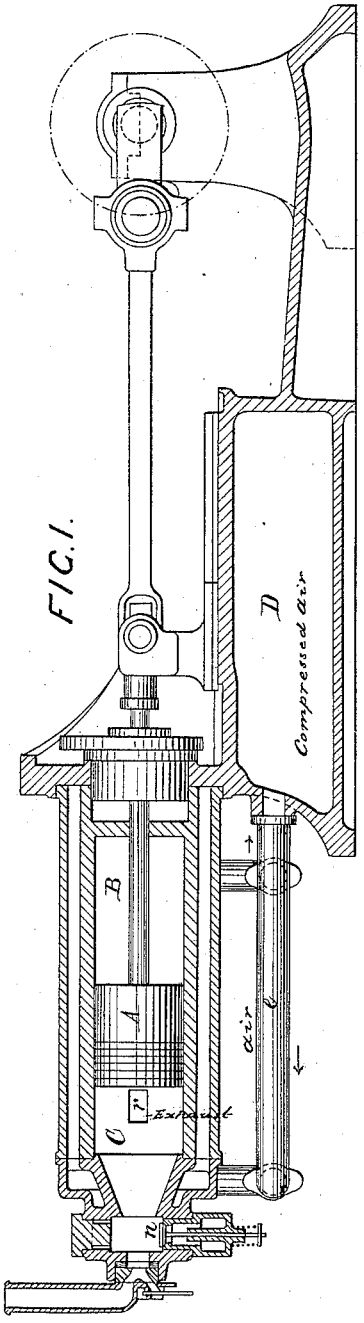
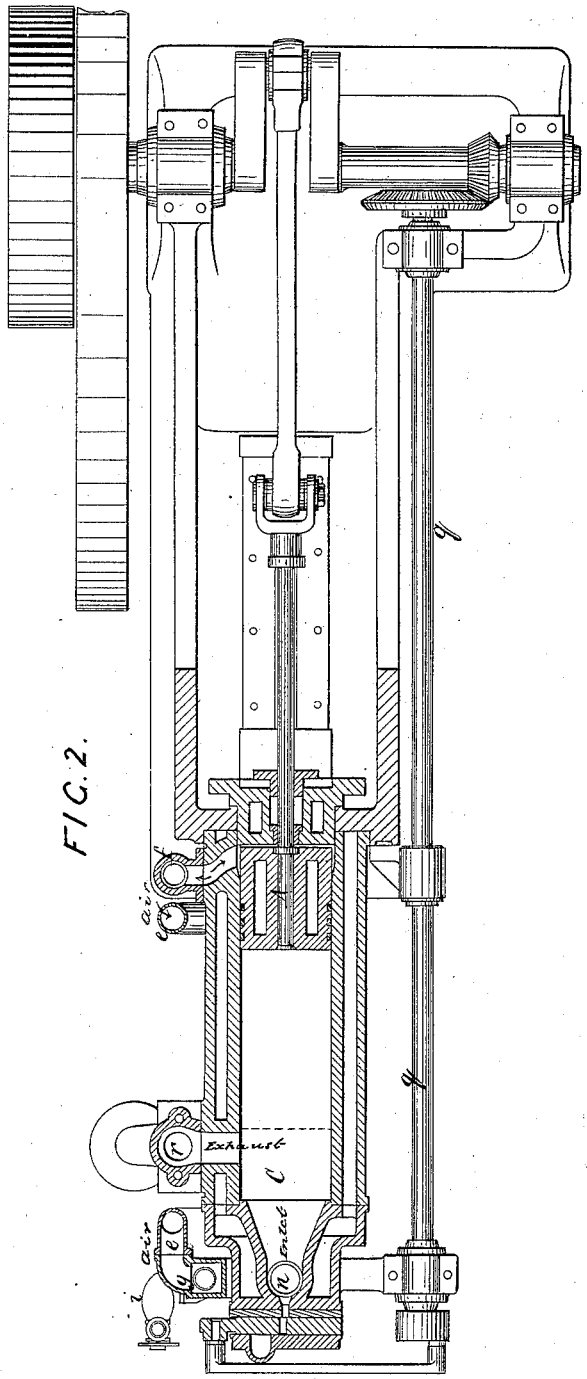


FIG. 2.



Witnesses.

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Atty.

(No Model.)

2 Sheets—Sheet 2.

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FIG. 3.

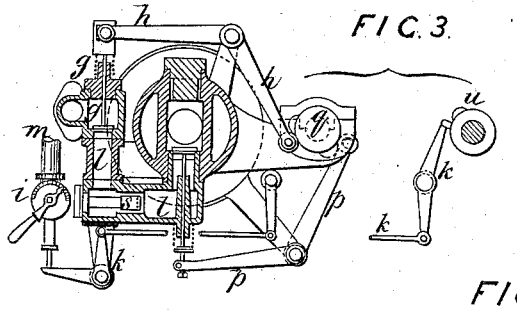


FIG. 5.

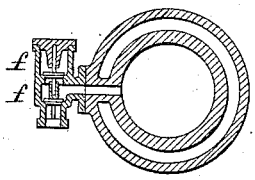


FIG. 4.

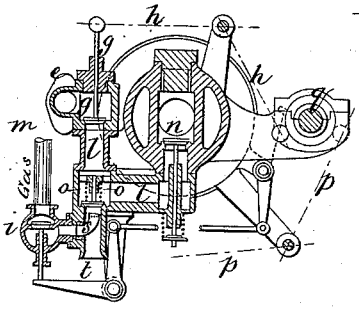


FIG. 6.

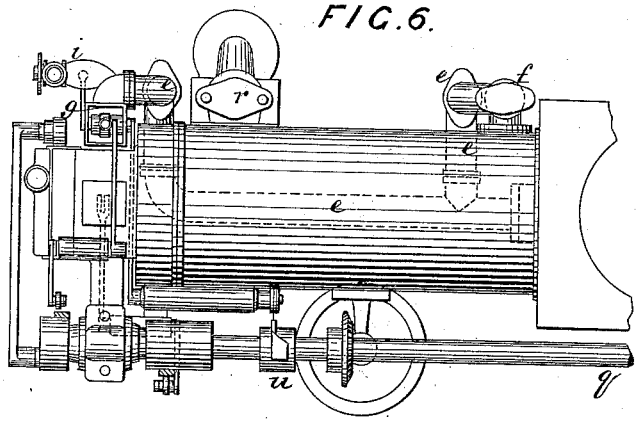
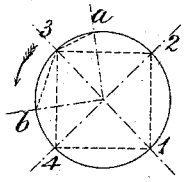


FIG. 7.



Witnesses.

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UNITED STATES PATENT OFFICE.

NICOLAUS AUGUST OTTO, OF COLOGNE, PRUSSIA, ASSIGNOR TO THE GAS MOTOREN FABRIK DEUTZ, OF DEUTZ ON THE RHINE, GERMANY.

MOTOR-ENGINE WORKED BY COMBUSTIBLE GAS.

SPECIFICATION forming part of Letters Patent No. 383,065, dated May 15, 1888.

Application filed September 26, 1887. Serial No. 250,734. (No model.) Patented in England August 23, 1887, No. 11,503; in Belgium September 3, 1887, No. 78,765, and in Italy November 10, 1887, XLIV, 176.

To all whom it may concern:

Be it known that I, NICOLAUS AUGUST OTTO, a citizen of Prussia, residing at Cologne, in the German Empire, have invented new and useful Improvements in Motor-Engines Worked by Combustible Gas, Vapor, or Spray, and Air, (for which I have obtained patents in Belgium, dated September 3, 1887, No. 78,765; Italy, November 10, 1887, Vol. XLIV, No. 176, and have made application for patent in Great Britain, which patent when granted will bear date August 23, 1887, No. 11,503,) of which the following is a specification.

This invention relates to that description of gas-motor engines in which the firing of a combustible charge takes place once in every four strokes of the piston, such as that known as the "Otto" engine.

The present improvements have for their object to produce a greater development of power by the formation in the cylinder of an explosive mixture rich in gas and free from products of combustion, and also to produce an increased useful effect and saving in gas consumption by the expansion of the products of combustion. For this purpose the engine is so arranged that at the end of the expelling-stroke the portion of the gaseous products of combustion which would otherwise remain in the cylinder are expelled more or less entirely therefrom by the introduction of atmospheric air, to which charge of air is afterward admitted either pure combustible gas or a mixture of gas and air, the supply being cut off before the end of the suction-stroke. By this means on the following compression and working strokes a high degree of expansion, and consequently an increased useful effect, is obtained.

The power of the engine may be varied according as a greater or less quantity of combustible gas or gaseous mixture is admitted to the air in the cylinder, and according as the charge is admitted during a greater or less part of the suction-stroke so as to vary the degree of expansion.

In constructing the gas-motor engine for operating in the above-described manner the front end of the engine-cylinder is closed and is provided with a suction and delivery valve communicating, respectively, with the atmosphere and with a closed reservoir, so that at each forward stroke of the piston a charge of air is forced thereby at a certain pressure into the reservoir. A pipe leads from this reservoir to the back end of the cylinder, where it is provided with a valve, and where it communicates with the inlet-passage of the cylinder, also governed by a valve, both these valves being actuated by cams on a way-shaft revolving at half the speed of the engine-shaft. These valves are opened when the piston arrives near the end of its expelling instroke, so that the compressed air can then pass from the reservoir into the cylinder, expelling the remainder of the products of combustion through the open escape-valve as the piston completes its instroke, at the end of which the air in the reservoir will have sunk to about atmospheric pressure. The escape-valve being now closed, the piston commences its suction-stroke, and the valve of a gas-pipe leading into the inlet-passage being more or less opened, gas, together with a greater or less proportion of air admitted by the air-reservoir valve, is drawn into the charge of air contained in the cylinder. When the piston has performed a certain part of its outstroke, the gas and air valves are closed, so that as the piston completes its stroke the combustible charge in the cylinder is expanded below atmospheric pressure. At the commencement of the following instroke the combustible charge will first again attain atmospheric pressure, and will then be compressed to a greater or less degree on the completion of such stroke.

The accompanying drawings show the construction of a gas-motor engine operating according to my above-described invention.

Figure 1 is a longitudinal section of the engine. Fig. 2 is a sectional plan. Figs. 3, 4, and 5 show cross-sections. Fig. 6 is a part side view; and Fig. 7 is a diagram of the action.

The space B in the working-cylinder in front of the piston A is inclosed by a cover, as shown,

and serves as air-compressor, the air being drawn in on the instroke of the piston, and, after compression to a certain extent, forced into a reservoir, D, through pipe *e* and inlet and delivery valves *f f*, Fig. 5.

The valves and slide of the engine are worked by means of the way-shaft *g*, which makes one revolution for every two of the crank-shaft. The diagram of the piston's motion transferred to the crank-path of the way-shaft is shown at Fig. 7. From 1 to 2 combustion and development of power take place in the cylinder. From 2 to 3 the products of combustion are expelled. From 3 to 4 the charge of combustible mixture is drawn in, and from 4 to 1 it is compressed. On the expelling-stroke, before the piston has performed the whole of its stroke and is situated at a point corresponding with, say, the point *a*, Fig. 7, a cam on the way-shaft *q*, Fig. 3, opens the air-valve *g* by means of a lever, *h*, and the inlet-valve *n* by means of the lever *p*, whereupon the compressed air contained in the reservoir D passes through pipe *e* and passages *l l* and valve *n*, into the space C of the cylinder behind the piston, where it drives out the residual products of combustion through the discharge-valve *r*. When the piston has arrived at the end of its instroke, the pressure in the reservoir D will have sunk to that of the atmosphere, and the discharge-valve *r* is closed while the gas-inlet valve *i* is opened. The piston then by its outstroke draws gas in through pipe *s* among the air contained in the compression-space C, and with it any desired quantity of air, according as the air-valve *g* may be more or less opened or closed sooner or later. A variable degree of filling is obtained by cutting off the gas and air supply by closing the valves *g*, *i*, and *n* at any desired point of the stroke of the piston—such as, for instance, the point *b*—during the stroke from 3 to 4, Fig. 7. By the continued motion of the piston the charge in the cylinder is now expanded to a certain degree below atmospheric pressure, so that at the return stroke the charge is first brought back to atmospheric pressure and is then compressed in the compression-space. By this arrangement is attained, first, that the charge is freed as much as possible from combustion products, and consists of a comparatively rich gas-mixture containing the necessary quantity of oxygen for effecting perfect combustion, while, secondly, by cutting off the gas and air supply at any desired point of the suction-stroke any desired degree of expansion of the combustion-gases may be obtained during the working-stroke. The motor-engine can therefore be worked with any desired quantity of combustible mixture from the smallest possible charge up to the complete filling of the cylinder, according as the inlet-valve *n*, the air-valve *g*, and the gas-valve *i* are closed sooner or later.

As shown on the drawings, each engine may be worked with a definitely-fixed degree of expansion, the fixed cams on the way-shaft that actuate the valves *g* and *n* being so formed as to effect the closing of the valves at a definite point of the stroke corresponding to the curve 3 to 4, Fig. 7. With this arrangement the gas-inlet valve *i* is worked by a sliding cam with incline controlled by the governor, which either admits a larger or smaller quantity of gas or cuts off the supply entirely during one or more working-strokes, whereby the speed of the engine is regulated.

Instead of an inclined cam a straight cam may be used, the regulation being effected by causing the governor to move the cam to one side, so as not to open the gas-valve when the maximum speed is exceeded. The regulation of the engine may, however, also be effected by varying both the degree of expansion and the supply of gas, the time of closing the valves *g*, *n*, and *i* being varied simultaneously, for which purpose the cams that open the same are formed with steps or with an incline, and are shifted by the governor. In the arrangement shown at Fig. 3 the requisite air for forming the explosive charge is drawn in through the reservoir B; but it can also be drawn directly from the atmosphere through a branch pipe, *t*, Fig. 4, the air-valve *g* being in that case closed during the suction-stroke. The valve *o* opens automatically during the suction-stroke, so as to admit the required proportion of air and gas pass into the cylinder through the inlet-valve. The expansion of the cylinder-charge is in this case regulated by closing the gas-valve *i* and inlet-valve *n* at the corresponding point of the piston's stroke. This degree of expansion may be a fixed one by working the valves *g* and *n* by means of fixed cams of a determined length. The regulation of the engine is in this case effected by causing the governor to act upon the gas-inlet valve *i* in the before-described manner; but it may also be effected, as before described, by varying both the degree of expansion and the time of closing the gas-valve. The ignition of the charge can be effected in any known manner.

Instead of combustible gas, combustible vapor or spray may be employed, and the engine may be either vertical, horizontal, or inclined, and may have either one or several cylinders.

Having thus described the nature of my invention and the best means I know for carrying the same into practical effect, I claim—

In gas-motor engines working with a compression-space and with a cycle of four strokes, the method of replacing the residual products of combustion remaining in the cylinder at the end of the expelling-stroke by a combustible charge by first driving out the said products by means of a charge of atmospheric air and then drawing in a variable quantity of combustible gas with or without

admixture of air to mix with the said charge of air, the combined charge being partially expanded below atmospheric pressure during the suction-stroke and compressed during the return-stroke, substantially as herein described.

In testimony whereof I have signed my name to this specification, in the presence of two subscribing witnesses, this 3d day of September, A. D. 1887.

NICOLAUS AUGUST OTTO.

Witnesses:

GUSTAVE ALBERT OELRICHS,

MICHEL MÜLLER.