H. F. FULLAGAR.

INTERNAL COMBUSTION ENGINE.

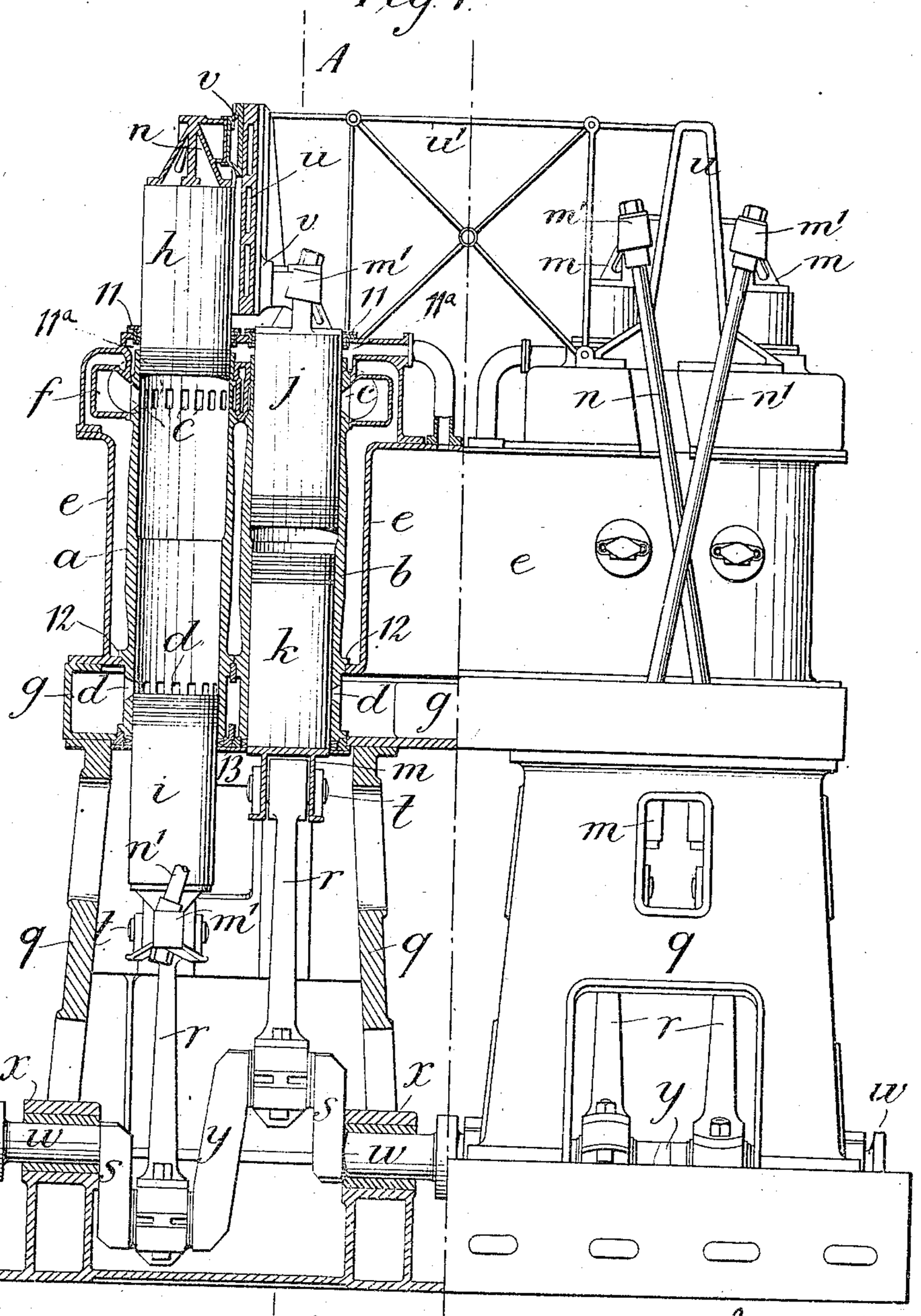
APPLICATION FILED NOV. 4, 1909.

995,857.

Patented June 20, 1911.

2 SHEETS—SHEET 1.

Fig. 1.



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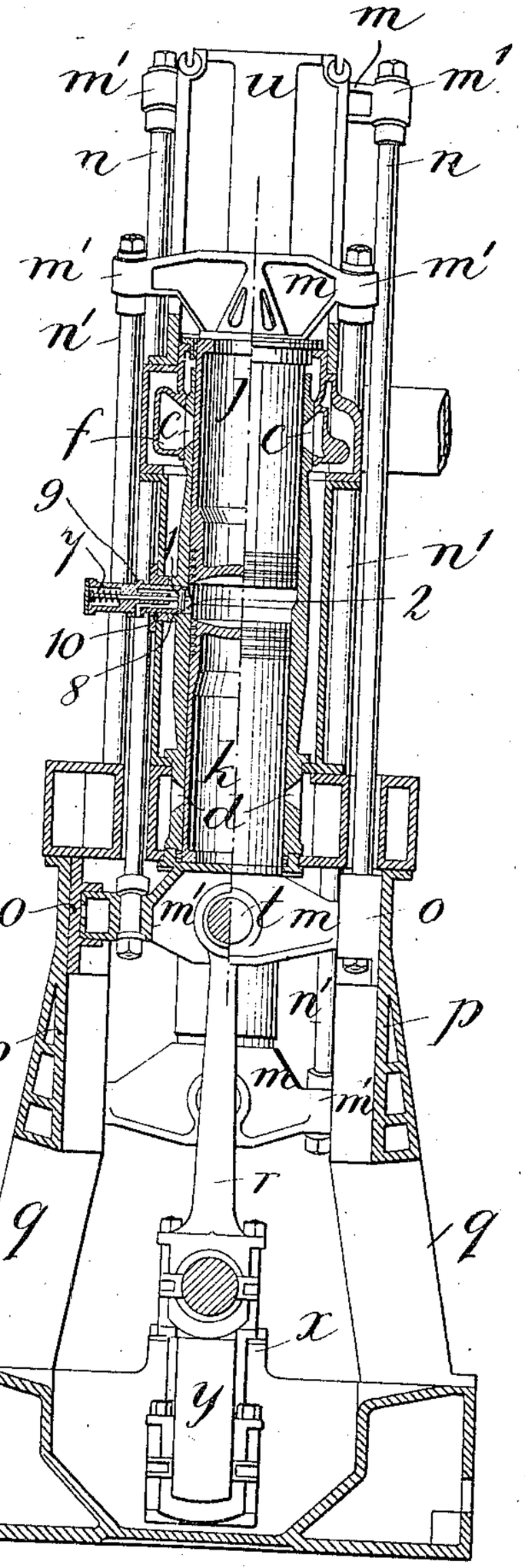
2 SHEETS—SHEET 2.

Fig 2.



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UNITED STATES PATENT OFFICE.

HUGH FRANCIS FULLAGAR, OF NEWCASTLE-UPON-TYNE, ENGLAND.

INTERNAL-COMBUSTION ENGINE.

995,857. Specification of Letters Patent. Patented June 20, 1911.

Application filed November 4, 1909. Serial No. 526,226.

To all whom it may concern:

Be it known that I, HUGH FRANCIS FULLAGAR, a subject of the King of Great Britain and Ireland, residing at Newcastle-upon-Tyne, England, have invented Improvements in or Relating to Internal-Combustion Engines, of which the following is a specification.

For many purposes for which reciprocating engines are employed, as, for, example, driving ships' propellers, motor vehicles and the like, it is necessary, in order that the engine may have sufficient flexibility in the matter of speed and be able to start and reverse promptly from any position of rest, that its crankshaft should receive separate impulses at several points of each revolution. Internal combustion engines as hitherto usually constructed are at a great disadvantage in this respect compared with steam engines, because, to obtain the same number of impulses per revolution, they require to have four times as many cylinders if of the usual four-stroke cycle single acting type, or twice as many cylinders if of the double acting type, entailing great cost and complication of valves, valve gear and other parts and also a large total amount of cylinder cooling surface compared with the power of the engines. Corresponding disadvantages obtain in the case of internal combustion engines working upon the two-stroke cycle as hitherto constructed.

Now this invention has for its object to produce an internal combustion engine each crank of which shall receive two impulses per revolution with only one cylinder for each crank, as in a steam engine, and which shall be of greater simplicity, contain fewer working parts, have lower working stresses, be more compact and be of less first cost than internal combustion engines of equal power as heretofore constructed. For this purpose an internal combustion engine according to the present invention comprises, as a unit, two open ended cylinders arranged parallel to one another in the same plane and each fitted with two plunger pistons, the four pistons in the two cylinders being interconnected so that they can be caused to work onto two cranks placed at 180° apart on a common crank shaft, or on two connected shafts, the arrangement being such that when the two pistons in one cylinder make their working outstroke they simultaneously impart impulses in opposite directions to the two cranks and directly cause the two pistons in the other cylinder to make their inward or compression strokes, these latter pair of pistons on afterward making their working out-stroke acting in like manner in opposite directions on the two cranks and simultaneously causing the first mentioned pair of pistons to make their inward and compression strokes. To attain this result the pairs of pistons in the two cylinders may conveniently be interconnected or cross connected by external diagonally arranged rods and by crossheads or their equivalent, the two pistons next the crank shaft being connected to the two cranks thereon by connecting rods jointed either to the pistons or to the corresponding crossheads.

By the construction described the negative work of compression is done entirely, or for the most part, directly from the pistons and independently of the crank shaft, and the pistons are cushioned at each end of the stroke by the compressed charges and the crank shaft thus further relieved of the stresses due to acceleration and retardation of the reciprocating parts. Also, four impulses are transmitted to the crank shaft through two cranks during each revolution and the two cranks can be arranged near together and be connected by a single web inclined to the axis of the crank shaft. Furthermore, the inertia of the pistons and the interconnecting side rods, due to their acceleration and retardation, has the effect of both equalizing the crank effort, by opposing the force of the explosion at the dead centers when ignition occurs, and of helping the force of explosion toward the outer end of the stroke when the explosion pressure is low, and, provided in the case of a vertical engine that the engine runs at such a speed that the acceleration toward the upper end of the stroke is greater than the acceleration of gravity, the effect of the inertia combined with that of the explosion, is to keep the side thrust on both the upper and lower pistons in a constant direction. In practice this is a feature of considerable importance as it tends to insure smooth running.

A twin cylinder engine having four cross connected pistons working onto two cranks on a common shaft as described, may be adapted to work as a two-stroke cycle engine or as a four-stroke cycle engine. In the former case, the exhaust of the hot prod-

ucts of combustion from the cylinders and the admission of air under pressure to sweep out the hot products and form part of the next charge are effected through ports formed in the cylinder walls near the opposite ends thereof and controlled by the pistons, all in a manner well understood. For a four-stroke cycle engine, the exhaust of the hot products and the admission of air and gas are effected through ports formed in the central portions of the cylinders and controlled by valves, also in a manner well understood.

In the case of a two-stroke cycle engine, which is the arrangement preferred, the air inlet ports of the several cylinders are preferably connected to a chamber that is common to them and supplied with air under pressure by a single high speed fan or a blower. The fuel inlet ports of the cylinders may be arranged near to the air inlet ports or at or near the center of the cylinders. When the fuel used is gas, a double acting pump is preferably used to supply definite measured quantities of the gas to the air in the cylinders to form the required explosive charges. When liquid fuel is used it may be injected by pumps in an ordinary way, suitable carbureters or vaporizers being of course provided according to the exact requirements of the fuel used.

Two-stroke internal combustion engines constructed as described are specially adapted for driving ships' propellers for the reason that by providing two or more units such as described having a common crank shaft and arranging the cranks of one unit at 90° (ninety degrees) to those of the other unit, where two units are used, or at 120° (one hundred and twenty degrees) to the other units when three units are used, separate impulses can be imparted to the crank shaft at a number of points in each revolution, thus providing considerable flexibility in the matter of speed and enabling the engine to be readily started from any position of rest and of being reversed, for which purpose compressed air may be employed.

Engines embodying the invention can be constructed in various forms. By way of example, a constructional form of a two-stroke internal combustion engine, suitable more especially as a marine or as a stationary engine will now be described with reference to the accompanying drawings, the said engine comprising two units, such as above referred to, that is to say, having four cylinders, two sets of interconnected pistons and a four-crank shaft.

In these drawings, Figure 1 shows the engine partly in side elevation and partly in vertical section, corresponding to the line A A of Fig. 2, while Fig. 2 shows it partly in vertical cross section on the line A^1 A^1 of Fig. 1 and partly in end elevation.

In this example, each unit comprises two vertical cylinders *a* and *b* each open at both ends and having a ring of exhaust ports *c* intermediate of its length but disposed nearer the upper end than the lower, and also a ring of air inlet ports *d* intermediate of its length but nearer the lower end than the upper. The two cylinders are housed within a casing *e* (or casings), constituting a water jacket, the upper part of which is provided with a suitable passage or chamber *f* to receive and conduct away the exhaust products from the two cylinders, and the lower part of which is similarly provided with a chamber or passage *g* in communication with the air inlet ports *d* of the cylinders. The air chamber or passage *g* is common to the two units and is preferably connected to the same source of air supply which, for convenience, may be a blower or a single or compound fan of any well known type, driven independently by an electric motor or otherwise. The two cylinders *a* and *b* are provided with four pistons of hollow trunk type arranged to overrun the ports *c*, *d* in the cylinders in proper sequence, *h* and *i* being the upper and lower pistons respectively in cylinder *a*, and *j* and *k* the upper and lower pistons respectively in cylinder *b*. Each of the pistons has fixed thereto a cross head *m*, or equivalent, that of piston *h* being connected by a pair of external diagonal rods *n* to that of piston *k*, and that of piston *j* being similarly connected by another pair of external diagonal rods n^1 to that of piston *i*, the two rods *n*, n^1 at each side of the engine being arranged to cross each other, as shown. The upper cross heads *m* may each be formed, as shown, by a bar or beam the ends of which are adapted, as by forming them with eyes m^1, to have fixed thereto the upper ends of two of the four interconnecting diagonal rods *n*, n^1. The lower cross heads *m* are each provided with slippers *o*, or equivalent, arranged to work between guides *p* on the engine framing *q* and with eyes m^1 to which the lower ends of the corresponding pair of diagonal rods *n* or n^1 are fixed. Each of the two connecting rods *r* for the two cranks *s* may, as shown, conveniently be jointed to a pin *t* mounted in bearings in the corresponding cross head *m* which is connected to the corresponding piston *i* or *k* in such a manner, as by bolts, that it can be readily detached therefrom when necessary. At the upper part of the casing *e* is a centrally arranged upward extension or guide *u* the opposite sides of which serve as lateral bearing surfaces for slippers *v* on the cross heads *m* of the upper pistons *h* and *j* during the working of the engine. The two extensions *u* may be suitably stayed together as by a frame u^1. The guides *p*, through the lower cross heads *m* and slippers *o*, serve to take

the lateral thrusts due to the connecting rods r and to the oblique side rods n, n^1, while the upper guides or extensions u serve to take any positive or negative thrust on the slippers v that may exist, for which purpose the guides or extensions u may be formed with vertical grooves in which the slippers work. At all but slow speeds, however, the acceleration of the upper pistons h and j and their cross heads m, together with the fuel pressure on the said pistons, is sufficient to keep the side rods n, n^1 always in tension and the slippers v always pressing in one direction, namely inward against the guides or extensions u. The pressures of the opposing slippers v to a certain extent neutralize each other but the stay rods constituting the frame u^1 serve to give greater stiffness to the guides u. The crank shaft w has only two main bearings x for each pair of cranks s, so that there is no center bearing between the cranks constituting each separate pair of cranks which, as shown, are arranged near together and connected by a single web y which may be inclined to the axis of the shaft as shown. The cranks of one unit are arranged at right angles to those of the other unit. The framing q of the engine can be of any desired type but an inclosed type is preferred, with forced lubrication for the bearing surfaces.

As before stated, the combustible portion of the explosive charge, conveniently derived from a suction gas producer plant, is arranged to be supplied in definite measured quantities, for which purpose two double acting pumps may be employed driven for example by means of side levers from the engine crank shaft, or from cranks on a shaft connected to or forming an extension of the engine crank shaft. While it is possible by timing the pump pistons to dispense with means for positively operating gas valves, or even to avoid cylinder valves altogether by injecting the gas through a port above the air ports d, it is sometimes preferred to employ a single valve 1 arranged to control a gas port 2 located at the center of the length of each cylinder a and b so that each unit includes only two valves which can be operated by any suitable means. The gas admission valves 1 can be made comparatively small and balanced and be loaded with springs 7 and each of them with its seat 8 is preferably mounted in a box or holder 9 that can be easily and quickly fixed in a hole or passage 10 in the central portion of the cylinder a or b, or a lateral extension thereof. Through each hole or passage 10, when the corresponding valve 1 is removed, access can be gained to the corresponding cylinder. The gas ports 2 controlled by the valves 1 can also be used to admit compressed air, supplied to the valve boxes or holders g through valve controlled pipes to the cylinders a and b for the purpose of starting or reversing the engine.

In action, an explosion occurs at the center of each cylinder a and b in turn, producing, through the pistons, say h and i, of cylinder a and the corresponding side rods n, n^1, two approximately equal impulses which form a turning couple on the crank shaft w and at the same time cause the other pair of pistons, say j, k, to which the said rods are connected, to move toward each other and compress the charge between them. As the pistons h and i approach the end of their outstroke, the upper one, viz. h, first overruns the exhaust ports c in cylinder a and reduces the products of combustion to atmospheric pressure. Continued movement in the same direction then causes the lower piston i to overrun the air inlet ports d of cylinder a, whereupon air under pressure, say from two to four pounds to the square inch, rushes in, sweeps the contents of the cylinder through the exhaust ports c, cooling the cylinder walls and ends of the pistons and interposing a cushion of air between the exhaust products then escaping and the next charge, thus securely guarding against pre-ignition of the new charge and back firing. On the return stroke of the said pistons h and i, caused by the explosion of the charge in cylinder b and consequent outward movement of the pistons j, k therein, the inlet and exhaust ports d and c respectively in cylinder a are successively closed, the cylinder left charged with air, the combustible gaseous portion of the charge immediately introduced into the air, either before or just after the air ports d are closed, and the charge compressed by the pistons h, i through the action of the explosion in cylinder b, and afterward ignited. As the engine, composed of two units, as described, has four pairs of pistons m and four cranks s, the crank shaft w will receive eight impulses during each revolution.

The arrangement of the air supply chamber or passage g shown, effectually precludes leakage of gas into the engine room past the lower pistons i, k, while by admitting a small supply of air into the space 11^a below the check rings or glands 11 of the upper pistons h, j, leakage of gas past these upper pistons can be prevented.

The holes in the eyes m^1 on the upper cross heads m, which take the oblique rods n n^1, are slotted out vertically so that when the nuts are removed from such rods, the cross heads and upper pistons h, j can be readily lifted out of the cylinders without removing the rods, and the lower pistons i, k can then be drawn up through the cylinders after unbolting them from their cross heads.

The cylinders a and b are formed at their lower portions with flanges 12 that bear upon the bottom of the water jacket e. They

are held down by bolts which may also hold up the lower glands or junk rings 13. The upper ends of the cylinders are a sliding fit through the exhaust chamber *f* so that they are free to expand upward.

The upper pistons may, with advantage, be made of somewhat larger diameter than the lower ones so that the difference in pressure on the two sets of pistons may help to support the moving parts and thus relieve the main bearings *x* of a portion of the weight of such parts. This construction also allows of the lower pistons being more readily withdrawn through the upper portions of the cylinders when this may be desired.

The details of construction of engines such as described can be variously modified. Thus, the upper slippers *v* and guides *u*, or the lower slippers *o* and guides *p*, or both, may, in some cases, be replaced by trunk guides forming, virtually, upward extensions of the cylinders against which the upper or lower pistons, in the form of trunks, directly bear; the opposing faces of the pistons *m* may be made concave so as to reduce the ratio of surface to volume of the clearance space, and the relative position of the air inlet and the exhaust ports may be reversed.

The engines instead of being arranged as vertical engines, as shown, may sometimes be arranged as horizontal engines.

Internal combustion engines constructed and operating as described can be variously modified to adapt them for different services and for use with various kinds of gaseous and liquid fuels, the arrangement hereinbefore described being merely given as an example of engine suitable for marine or land use and using gaseous fuel of good quality.

What I claim is:—

1. An internal combustion engine comprising two cylinders arranged side by side, two oppositely movable pistons in each cylinder, and coupling rods connecting each piston in one cylinder to the oppositely situated piston in the other cylinder.

2. An internal combustion engine comprising two cylinders arranged side by side, a co-acting crank shaft, two oppositely disposed pistons in each cylinder adapted to move in opposite directions, means connecting one piston in each cylinder to the crank shaft and means connecting the remaining piston in each cylinder with the first named piston in the other cylinder.

3. An internal combustion engine comprising two cylinders arranged side by side, two oppositely disposed pistons in each cylinder between which pistons an explosive charge is adapted to be compressed and fired and means comprising rods arranged obliquely to the axes of the cylinders connecting each piston of one cylinder with the oppositely situated piston of the other cylinder whereby an explosion in any one cylinder produces an outward movement of the pistons in such cylinder and a simultaneous inward movement of the pistons in the other cylinder.

4. An internal combustion engine comprising two cylinders arranged side by side and each having air inlet ports near one end and exhaust ports near the other end, two pistons in each cylinder controlling respectively the air inlet and exhaust ports and rods arranged obliquely to the axes of the cylinders cross connecting the pistons so that while the pistons in one cylinder simultaneously move outward to uncover the exhaust and inlet ports, the pistons in the other cylinder move inward and cover the corresponding inlet and exhaust ports of such other cylinder.

5. An internal combustion engine comprising two cylinders arranged side by side, two oppositely moving pistons in each cylinder, crossheads connected to the outer ends of said pistons and arranged transverse to the plane of the engine crankshaft and rods directly connecting the crosshead of each piston to the crosshead of the oppositely situated piston of the other cylinder.

6. An internal combustion engine comprising two cylinders arranged side by side, two pistons in each cylinder, cross connecting rods arranged obliquely to the axes of the cylinders, crossheads coupling the rods to the pistons, a crank shaft having oppositely arranged adjacent cranks connected by a common web, and connecting rods between said cranks and one of each of the cross connected crossheads and rods.

7. An internal combustion engine comprising two cylinders arranged side by side, two pistons in each cylinder, cross connecting rods arranged obliquely to the axes of the cylinders, crossheads coupling the rods to the pistons, slippers on the crossheads, and stationary guides against which the slippers work.

8. An internal combustion engine comprising two cylinders arranged side by side, two pistons in each cylinder, cross connecting rods arranged obliquely to the axes of the cylinders, crossheads coupling the rods to the pistons, slippers on the crossheads, stationary guides against which the slippers work, a crank shaft having oppositely arranged adjacent cranks connected by a common web, and connecting rods between said cranks and connected crossheads and one of each of the cross rods.

9. In an internal combustion engine, cylinders, pistons in each cylinder, cross connecting rods arranged obliquely to the axes of the cylinders and crossheads coupling the rods to the pistons, said crossheads having portions slotted out parallel to the axes of

the cylinders to enable the crossheads to be removed in the direction of such axes without bodily removing the rods.

10. An internal combustion engine comprising two vertical cylinders arranged side by side, two oppositely movable pistons in each cylinder and means comprising rods arranged obliquely to the axes of the cylinders and transversely arranged crossheads connecting each piston of one cylinder with the oppositely situated piston of the other cylinder, the upper piston in each cylinder being of greater diameter than the lower piston.

11. An internal combustion engine comprising two cylinders arranged vertically side by side, two oppositely movable pistons in each cylinder, the upper piston in each cylinder being of larger diameter than the lower one, means comprising rods arranged obliquely to the axes of the cylinders and transversely arranged crossheads connecting each piston of one cylinder with the oppositely situated piston of the other cylinder, a co-acting crank shaft having two oppositely arranged cranks and a connecting rod between each crank and one of the sets of oblique rods and cross heads.

Signed at Newcastle-on-Tyne, England, this eighteenth day of October 1909.

HUGH FRANCIS FULLAGAR.

Witnesses:

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FRED H. DUKE.