H. F. FULLAGAR.

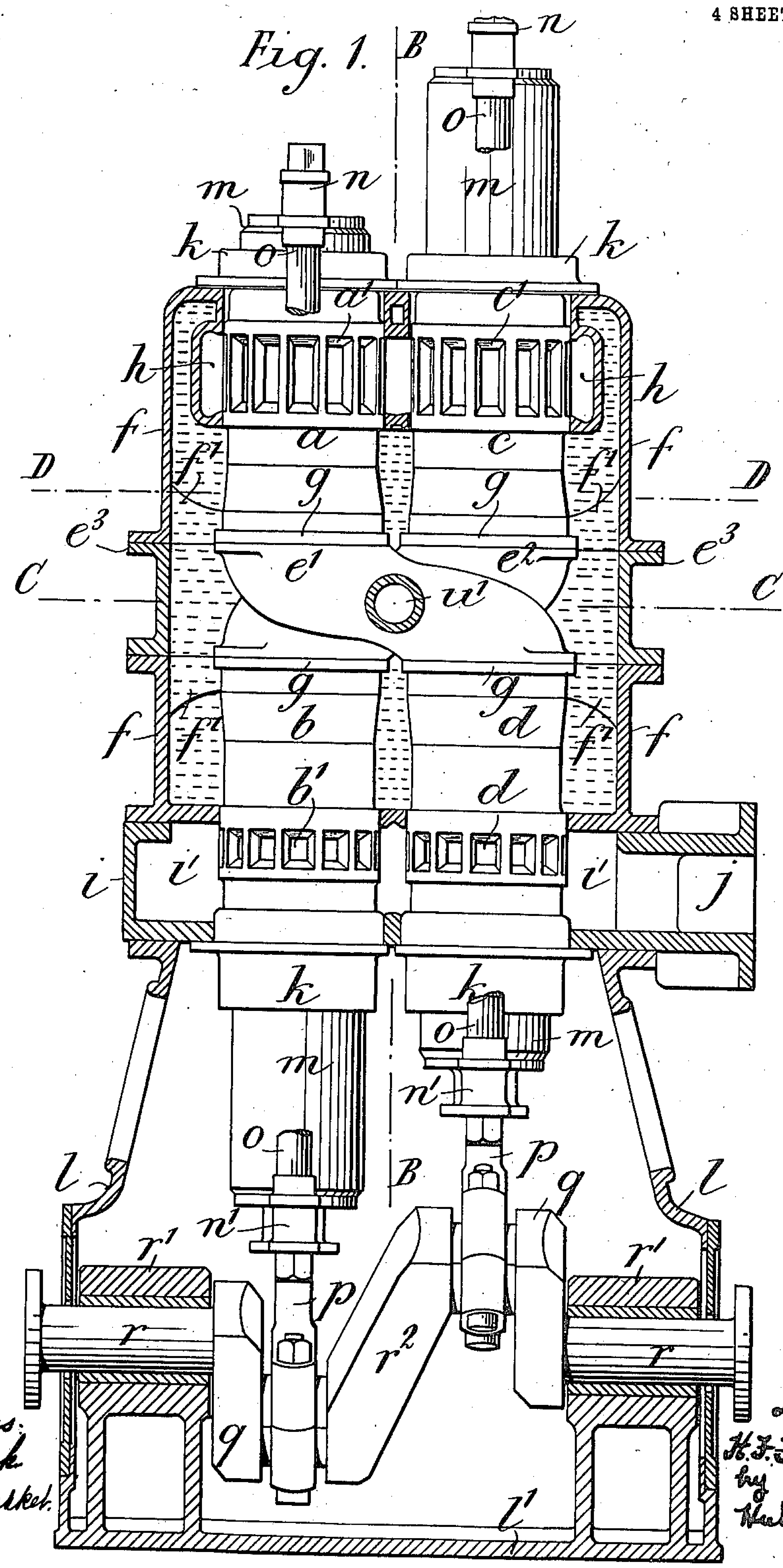
INTERNAL COMBUSTION ENGINE.

APPLICATION FILED NOV. 4, 1909.

995,858. Patented June 20, 1911.

4 SHEETS—SHEET 1.

Fig. 1.



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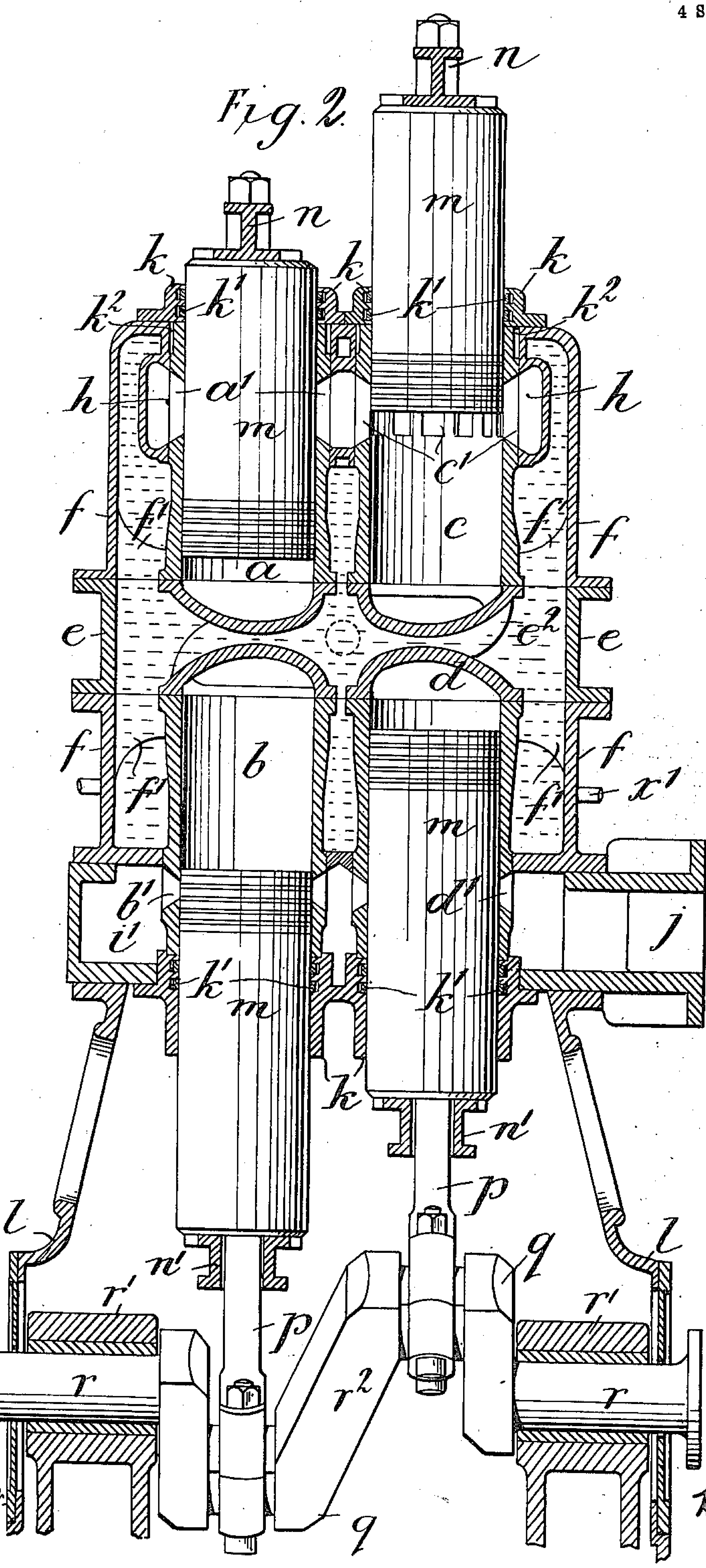
4 SHEETS—SHEET 2.

Fig. 2.



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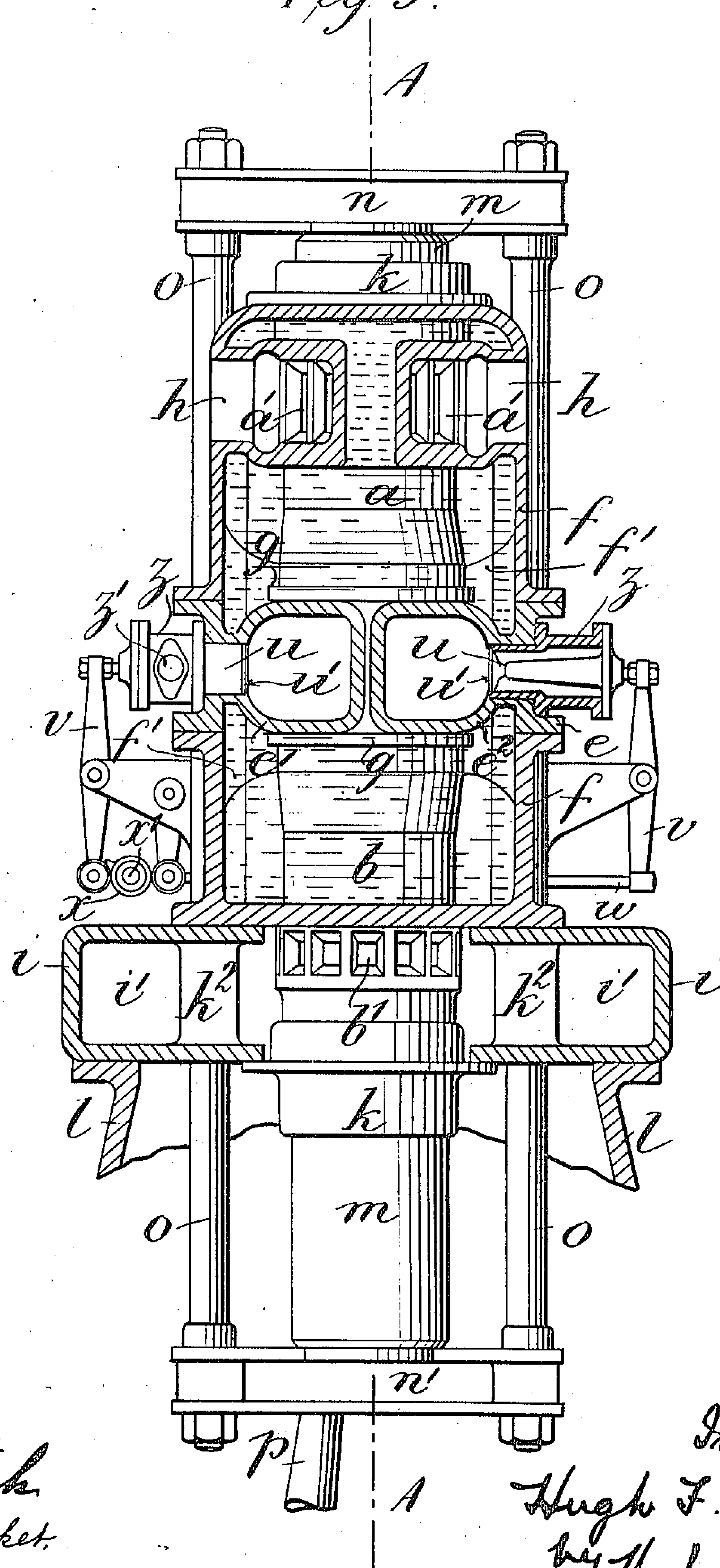
4 SHEETS—SHEET 3.

Fig 3.



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4 SHEETS—SHEET 4.

Fig. 4.

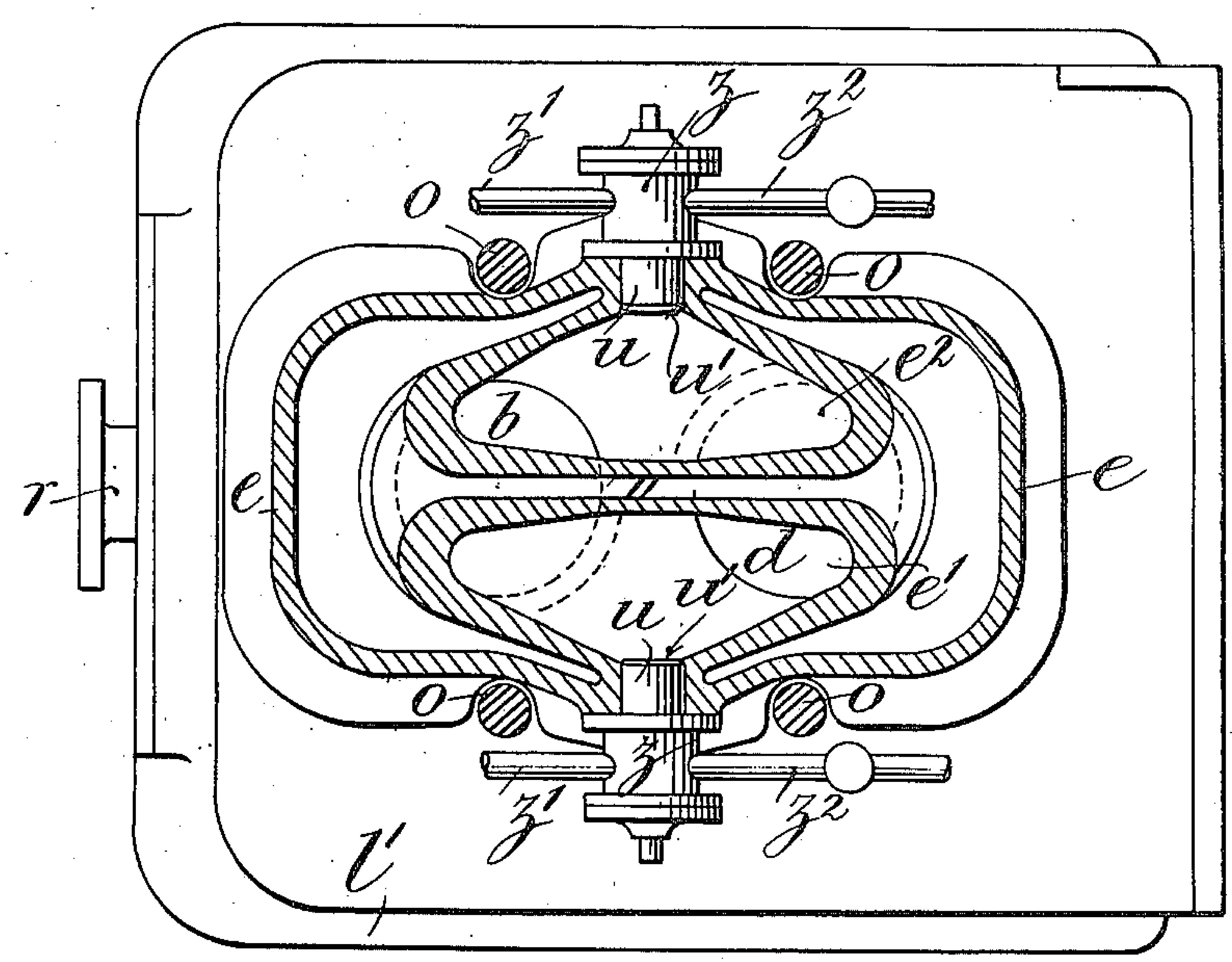
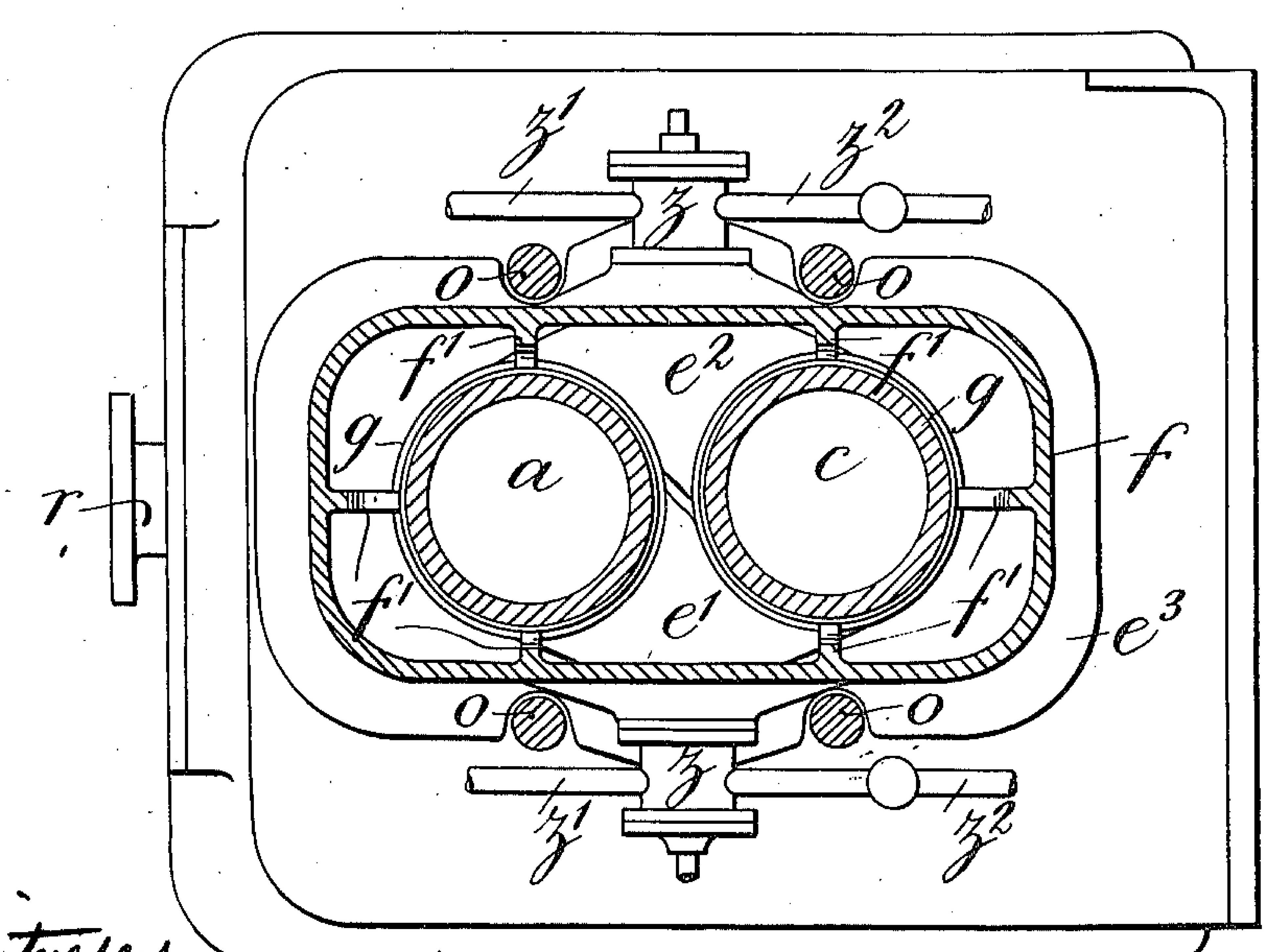


Fig. 5.



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UNITED STATES PATENT OFFICE.

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

INTERNAL-COMBUSTION ENGINE.

995,858. Specification of Letters Patent. Patented June 20, 1911.

Application filed November 4, 1909. Serial No. 526,227.

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.

This invention relates to internal combustion engines of the type wherein four pistons operate in four connected cylinders so that each explosion operates on two oppositely moving non-alined pistons. It has hitherto been proposed to effect this operation by the use of four cylinders placed side by side in tandem pairs, closed at their inner ends and communicating by cross passages. It has further been proposed to operate such an engine on the four stroke or the two stroke cycle.

The present improvements relate to means for producing a practical and efficient internal combustion engine of the type referred to by avoiding the fluid friction in the cross passages, the excessive cooling surface, the large combustion chamber volume and the large negative work resulting from the use of a high pressure of air for scavenging, which have heretofore prevented the production of a successful engine of the kind referred to. For this purpose according to the present invention, in lieu of using four cylinders closed at their inner ends and cross connecting them by means of narrow passages of a length comparable to the diameter of the cylinders, as heretofore proposed, there are employed, in effect, two long double cylinders each with two pistons, the two cylinders being placed as close together as possible and twisted about one another by a half turn for a short portion at the middle of their length so as to obtain as nearly as possible the cylinder conditions of the well known Oechelhauser type of engine—the part of the cylinder which serves as the combustion chamber being so twisted as to give a free connection between the upper and lower portions without any sudden change of area and direction, the volume of the twisted portion being reduced if necessary to that proper to act as a combustion chamber between the two pistons, whereby cooling losses are also reduced, while the through area is kept as large as possible so as not to impede the flow of the scavenging air.

With a single pump supplying air at a more or less constant pressure, it is highly important, in order to reduce negative work, that the pressure should be as low as possible and considerably less than the maximum pressure produced by separate intermittent pumps. According to the present invention an air pressure of from two to four pounds per square inch only is used, and in order that the scavenging and cooling action of such air shall be as great as possible during the relatively short portion of the revolution during which the ports are uncovered by the pistons, the half twist above mentioned is formed so as to give a smooth and uninterrupted connection between the upper and lower portions of the cylinder. In this way the correct combustion chamber volume is obtained with the minimum cooling surface and the minimum of obstruction to the exhaust gases and scavenging air.

By the use of cylinders closely twisted together as described, it is possible to avoid the use of a bearing between contiguous cranks, since the impulses, positive or negative, being at all times equal and opposite and nearly in the same plane, produce a nearly perfect turning couple. It is further possible to surround both cylinders by a common water jacket part of which being formed in one piece with the twisted portion, serves, in conjunction with the framing of the engine, to support the reaction due to explosions and to relieve the cylinders of tensional stress.

For many purposes for which flexibility of speed is required, with power to start and reverse, it is necessary to combine two or more such units capable of imparting several impulses per revolution, and in such cases it is of obvious advantage to employ the two-stroke in place of the four-stroke cycle, because the output from the cylinders is nearly doubled, while a single air pump or fan can be made to supply all the cylinders.

When the internal combustion engine comprises two units, each constructed as described, the two cranks of one unit are arranged at an angle of 90° (ninety degrees) to those of the other unit. When the engine comprises three units, the cranks of the several units are arranged 120° (one hundred and twenty degrees) apart.

One construction of a two-stroke cycle internal combustion engine according to the invention, suitable more especially for marine or land purposes, comprises two units, such as above described, that is to say, having four pairs of tandem cylinders and a four-crank shaft. One unit of such an engine, with adjuncts common to both units, is illustrated, more or less diagrammatically, in the accompanying drawings whereof—

Figure 1 shows the cylinders and other parts in elevation and the water jacket and other parts in central vertical section; Fig. 2 shows the engine in vertical section on a line corresponding to A A of Fig. 3; Fig. 3 is a side elevation with part in vertical section on a line corresponding to B B of Fig. 1, and Figs. 4 and 5 are horizontal sections on the lines C C and D D respectively of Fig. 1.

In this example, each unit comprises an upper pair of vertical cylinders *a* and *c*, open at both ends and having a ring of exhaust ports a^1 and c^1 respectively intermediate of their length but disposed nearer the upper ends than the lower; a second and lower pair of vertical cylinders *b* and *d*, also open at both ends and having a ring of air inlet ports b^1 and d^1 respectively intermediate of their length but nearer the lower ends than the upper, and a junction piece *e* that forms the twisted portions of the complete double cylinders hereinbefore described and serves to cross-connect adjacent ends of the non-alined cylinders, namely, cylinders *a* and *d* and cylinders *b* and *c* and form therewith two short combustion chambers e^1 e^2. Thus the cylinders *a* and *d* form with the twisted portion e^1 of the junction piece *e* connecting them, one double cylinder, and the cylinders *b* and *c* with the twisted portion e^2 of the junction piece *e* connecting them, a second double cylinder, these two double cylinders being, as shown, situated as close together as possible and twisted around each other at their center as hereinbefore described. As will be seen the twisted portions or passages e^1, e^2 of the junction piece which form compression and combustion chambers, coincide at their ends, in shape and dimensions with the ends of the cylinder portions to which they are connected and are made of large cross sectional area throughout their length and have smooth curved guiding surfaces between their ends so as to enable fluid to flow directly through them without causing eddies, that is to say, to allow of stream line flow of the fluid, so as to minimize fluid friction and loss of energy and enable air of low pressure to be used for scavenging purposes. Surrounding the cylinders is a rigid casing *f* formed of flanged parts between which flanged portions e^3 of the junction piece *e* are arranged and to which they are securely fixed, as by bolts.

The casing *f*, together with the flanged portions e^3 of the junction piece *e*, constitute a water jacket that surrounds the cylinders and also the twisted portions e^1 e^2 of the double cylinders formed in the junction piece. The flanged parts of the casing *f* are formed internally with ribs or extensions f^1 recessed to receive external flanges *g* on the adjacent inner ends of the cylinders *a*, *b*, *c*, *d* and hold the same firmly in place, such inner ends of the cylinders and adjacent parts of the ribs or extensions being made flush, or nearly so, with the surfaces of the upper and lower flanged parts of the casing *f*. The upper and lower surfaces of the junction piece *e* are also made flat so as to bear against the flat surfaces on the inner ends of the cylinders and on the flanged parts of the casing *f*. The arrangement is such that upon bolting or otherwise securing the flanged portions of the casing *f* and junction piece *e* together, the inner ends of the cylinders will be firmly secured in place and caused to make a fluid tight joint, it may be with the aid of packing, with the junction piece *e*, and that by removing the upper part of the casing *f* the cylinders *a* and *c* can be readily removed and by then removing the junction piece *e*, the cylinders *b* and *d* can be readily removed. The upper part of the casing or jacket *f* is provided with a suitable passage or chamber *h* to receive and conduct away the exhaust products from the cylinders. The lower part of the casing or jacket *f* forms, in conjunction with a separate casting *i*, a chamber or passage i^1 in communication with the air inlet ports b^1 and d^1 of both of the lower cylinders of the unit, the two air chambers or passages i^1 of the two units being connected together to form a single chamber provided with a common inlet *j* connected by a pipe to the same source of air supply which preferably consists of a high speed fan or a blower of any well known type driven independently by an electric motor or otherwise, and arranged to supply air at a pressure of say for example from two to four pounds per square inch. The upper end portions of the upper cylinders *a* and *c* extend tightly through the exhaust chamber or passage *h* and are free to expand upward, while the lower ends of the lower cylinders *b* and *d* extend tightly through the air inlet chamber or passage i^1 and are free to expand downward, the cylinder ends in each case terminating adjacent to glands *k* that are carried by the upper part of the casing *f* and by the casting *i* and are provided with packing rings k^1 through which the pistons work. The combined cylinders, twisted center portions, water jacket or casing and air chamber are supported by the engine framing or standards *l* carried by the base plate l^1 of the engine.

The pistons *m*, of hollow trunk type, are arranged to overrun the exhaust ports a^1, c^1 and the air inlet ports b^1, d^1 in their cylinders in proper sequence and are coupled by external cross-heads n, n^1, and side rods o, the lower pistons working through connecting rods p on to the adjacent cranks q. The crank shaft r has only two main bearings r^1 for each pair of cranks q, so that there is no center bearing between the cranks constituting each separate pair of cranks which are arranged near together and connected by a single web r^2 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 l of the engine can be of any desired type but an inclosed type, as shown, is preferred with forced lubrication for the bearings.

The combustible portion of the explosive charge may be forced into the cylinders by means of pumps driven in any convenient manner by the engine and adapted to deliver definite measured quantities of gaseous fuel into each double cylinder during the proper portion of each revolution. 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 inlet ports b^1 or d^1 of each twisted double cylinder, it is sometimes preferred to employ a single valve u arranged to control a gas port u^1 opening into each combustion chamber or twisted portion e^1 or e^2 of a double cylinder, so that each unit includes only two valves which can, as shown in Fig. 3, be arranged on opposite sides of the engine and be operated by a system of levers or levers v and rods w, under the control of cams x upon a shaft x^1 driven by the engine. Gas is admitted to each valve box or chamber z through an inlet z^1. The gas ports controlled by the valves u can also be used to admit compressed air, supplied to each valve box or chamber z through a valve controlled pipe z^2, to the cylinders for the purpose of starting or reversing the engine. When the valves u are removed, the ports u^1 serve to give access to the twisted portions e^1, e^2 of the said cylinders for the purpose of inspection and cleaning.

In action, when an explosion occurs in the combustion chamber forming the twisted portion e^1 or e^2 connecting the upper and lower parts of a twisted double cylinder, say b—c, two equal impulses are produced which form a turning couple on the crank shaft r. As the pistons m of this double cylinder approach the ends of their outstroke, the upper piston in cylinder c first overruns the corresponding exhaust ports c^1 and reduces the products of combustion to atmospheric pressure. Continued movement in the same direction then causes the lower piston m in cylinder b to overrun the corresponding air inlet ports b^1, whereupon air under pressure, say from two to four pounds per square inch, rushes in and sweeps the contents of the double cylinder b—c through the exhaust ports c^1, cooling the cylinder walls and the ends of the pistons and interposing a cushion of air between the exhaust products then escaping and the next charge to be ignited, thus securely guarding against pre-ignition of the new charge and back firing. On the return stroke of the pistons m in cylinders b and c, caused by the explosion of the charge in the combustion chamber e^1 of the second twisted double cylinder, say a—d, the air inlet and exhaust ports b^1 and c^1 in the first double cylinder b—c are successively closed by the said pistons and the said cylinder left charged with air, the combustible gaseous portion of the charge is introduced into the air in the cylinder, either just before or just after the air ports b^1 are closed, and the charge compressed by the pistons through the action of the said explosion in the other double cylinder a- -d and afterward ignited. As the engine, composed of two units such as described, has four pairs of pistons m and four cranks q, the crank shaft r will receive eight impulses during each revolution.

The arrangement of the air supply chamber or passage i^1 shown, effectually precludes leakage of gas into the engine room past the lower pistons m, while by admitting a small supply of air into the space k^2 below the glands k and packing rings k^1 of the upper pistons m, leakage of gas past these upper pistons can be prevented.

The pistons and cylinders, instead of being of equal diameter, as shown, may, in some cases, be of unequal diameter in which case the impulses on the cranks will not of course be equal, but if the upper cylinders are the larger in diameter, the difference will serve to partly relieve the main bearings of the weight of the moving parts. 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 double cylinders arranged close together and twisted at their central portions about one another by a half turn so that the two outer straight portions of each cylinder are brought into line with those of the other cylinder, substantially as set forth.

2. An internal combustion engine, comprising two double cylinders constituted by

separated cylinder portions arranged side by side and a separate junction piece common to all the cylinder portions and formed with twisted explosion chambers that extend one around the other and at the ends, coincide in shape and dimension with the ends of the cylinder portions and throughout their length are adapted to stream line flow so as to freely cross connect the cylinder portions in pairs.

3. An internal combustion engine, comprising two pairs of cylinders arranged side by side, a junction piece arranged between and connected to the cylinders and formed with passages or combustion chambers freely cross connecting the cylinders in pairs, and means connecting the junction piece to the engine frame independently of the cylinders.

4. An internal combustion engine, comprising two double cylinders constituted by separate cylinder portions arranged side by side, a separate junction piece common to all the cylinder portions and formed with explosion chambers that are twisted around one another and which at the ends, coincide in shape and dimension with the ends of the cylinder portions and throughout their length are adapted to stream line flow so as to freely cross connect cylinder portions in pairs, and a water jacket connected to the junction piece.

5. An internal combustion engine, comprising two double cylinders constituted by cylinder portions arranged side by side, a junction piece formed with explosion chambers that are twisted around one another and which at the ends coincide in shape and dimensions with the ends of the cylinder portions and throughout their length are adapted to stream line flow so as to freely cross connect the pairs of cylinder portions, and a water jacket connected to the junction piece and also to the engine frame independently of the cylinders.

6. An internal combustion engine comprising two double cylinders constituted by cylinder portions arranged side by side, a junction piece formed with explosion chambers freely cross connecting the pairs of cylinder portions, and water jacket portions connected to the junction piece and through which the cylinder portions are axially movable.

7. An internal combustion engine, comprising two double cylinders constituted by cylinder portions arranged side by side and having piston controlled inlet and exhaust ports, a junction piece with passages cross-connecting such cylinder portions in pairs, a water jacket portion formed upon the junction piece, a water jacket portion having an exhaust chamber common to the exhaust ports of certain of the cylinder portions and connected to one side of the water jacket portion of the junction piece, a second water jacket portion connected to the opposite side of the water jacket portion of the junction piece and a casting connected to the second water jacket portion and having an air inlet chamber common to the air inlet ports of the remainder of the cylinder portions.

8. In an internal combustion engine, the combination with two pairs of cylinders arranged side by side, of a junction piece with passages freely cross connecting such cylinders in pairs, connected pairs of pistons, one of the pistons of each pair being arranged in one of the cylinders of a connected pair of cylinders and the other piston of the pair being arranged in one of the cylinders of the other pair of cylinders, a pair of oppositely arranged cranks and means for connecting each pair of pistons to a corresponding crank.

9. In an internal combustion engine, the combination with two pairs of cylinders arranged side by side, of a junction piece with passages freely cross connecting such cylinders in pairs, connected pairs of pistons, one of the pistons of each pair being arranged in one of the cylinders of a connected pair of cylinders and the other piston of the pair being arranged in one of the cylinders of the other pair of cylinders, a pair of contiguous oppositely arranged cranks, bearings outside said cranks, and means for connecting each pair of pistons to a corresponding crank.

10. An internal combustion engine unit comprising two cylinders arranged side by side and each having a series of outlet ports near its outer end, two other cylinders arranged side by side and each having a series of air inlet ports near its outer end, a junction piece formed with twisted combustion chambers freely cross connecting the cylinder portions of opposite pairs, gas ports communicating with such combustion chambers and means for controlling such ports, a water jacket portion integral with the junction piece, a water jacket portion connected to the last named water jacket portion and formed with a chamber common to the exhaust ports of the two first mentioned cylinders, a casting forming an air inlet chamber common to the air inlet ports of the two last mentioned cylinder portions and a water jacket portion connecting said air inlet chamber to the water jacket portion of the junction piece.

11. An internal combustion engine unit, comprising two upper cylinders arranged side by side and each having a series of outlet ports near its outer end, two lower cylinders arranged side by side and each having a series of air inlet ports near its outer end, a junction piece formed with twisted combustion chambers freely cross connecting the upper and lower cylinder portions in pairs,

gas ports communicating with such combustion chambers and means for controlling such ports, a water jacket portion integral with the junction piece, a water jacket portion connected to the last named water jacket portion and formed with a chamber common to the exhaust ports of the two upper cylinders, a casting forming an air inlet chamber common to the air inlet ports of the two lower cylinders, a water jacket portion connecting said air inlet chamber to the water jacket portion of the junction piece, said casting supporting the cylinders, junction piece and water jacket, a crank chamber upon which said casting is secured, a crank shaft having two oppositely arranged cranks connected by a web common to them, and two pairs of pistons arranged in co-axial pairs of the cylinders and connected to the respective cranks.

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

HUGH FRANCIS FULLAGAR.

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