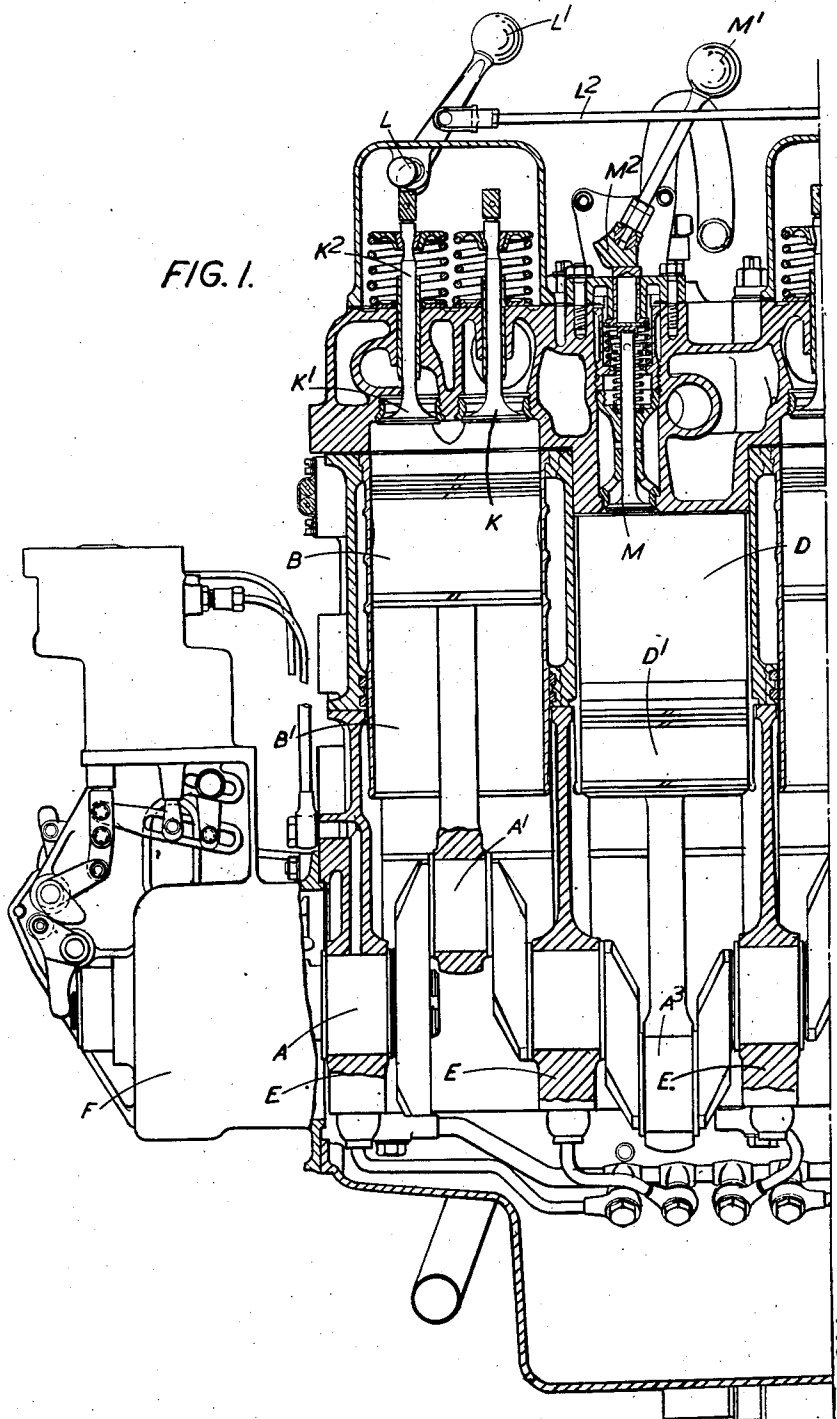
April 17, 1945. H. R. RICARDO 2,373,780

MULTISTAGE COMPRESSOR

Filed Sept. 16, 1942 4 Sheets-Sheet 1

FIG. 1.



INVENTOR
Harry R. Ricardo

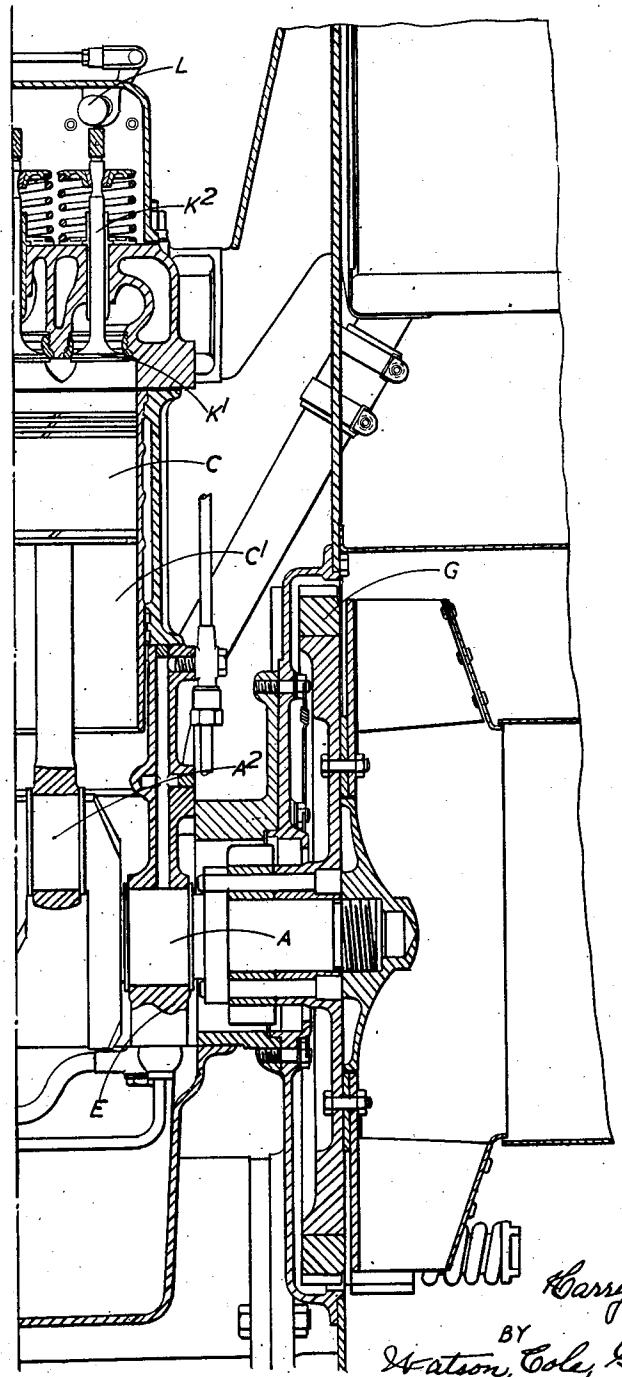
Watson, Cole, Grindle & Watson
ATTORNEY

April 17, 1945. H. R. RICARDO 2,373,780

MULTISTAGE COMPRESSOR

Filed Sept. 16, 1942 4 Sheets-Sheet 2

FIG. 1 (contd)



INVENTOR
Harry R. Ricardo
BY
Watson, Cole, Grindle & Watson
ATTORNEY

April 17, 1945. H. R. RICARDO 2,373,780

MULTISTAGE COMPRESSOR

Filed Sept. 16, 1942 4 Sheets-Sheet 3

FIG. 3.

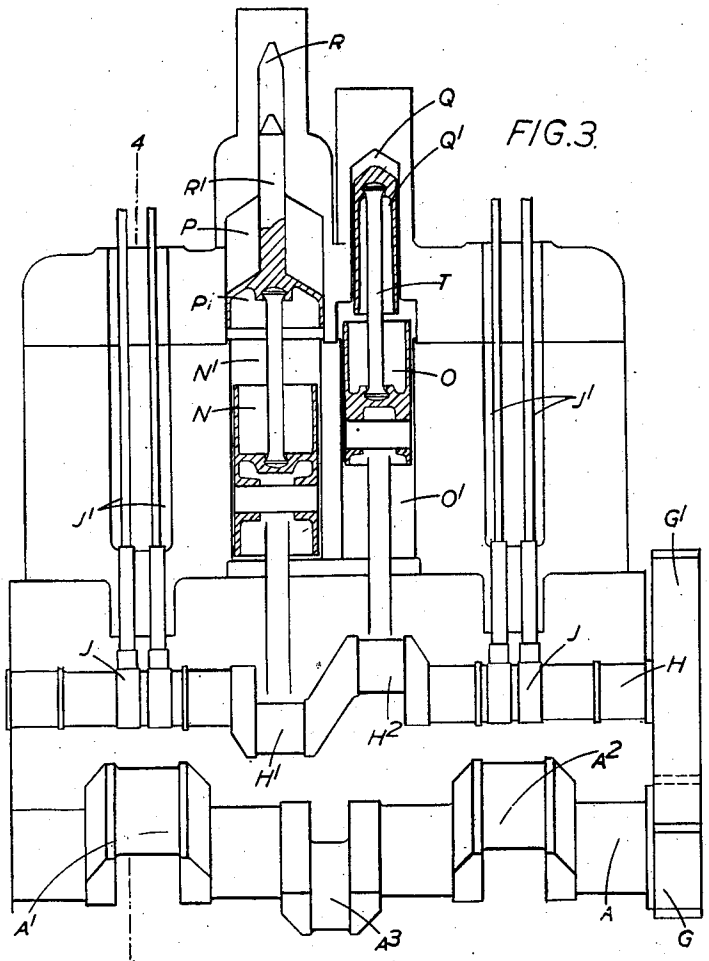
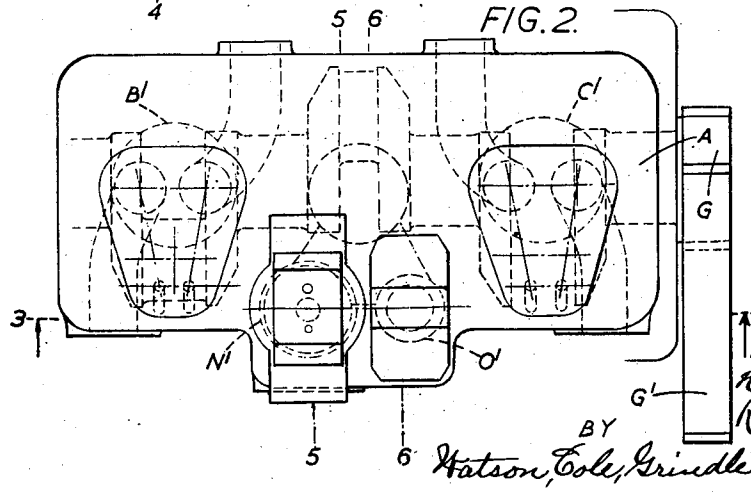


FIG. 2.



INVENTOR
Harry R. Ricardo

BY
Watson, Cole, Grindle & Watson
ATTORNEY

April 17, 1945. H. R. RICARDO 2,373,780

MULTISTAGE COMPRESSOR

Filed Sept. 16, 1942 4 Sheets-Sheet 4

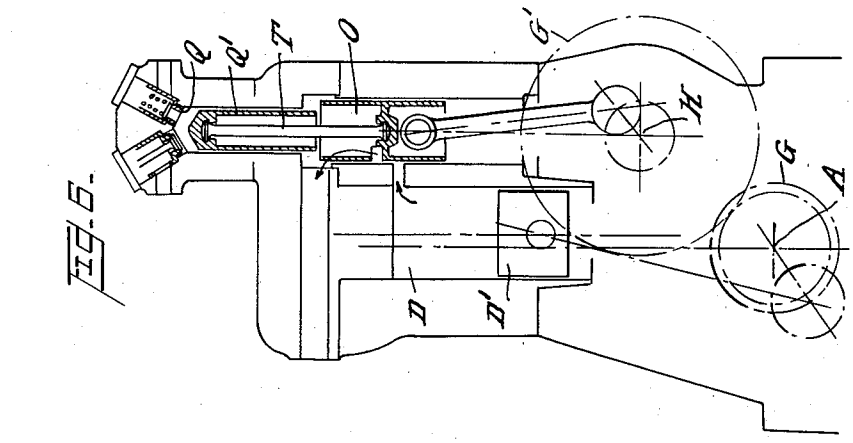


Fig. 6.

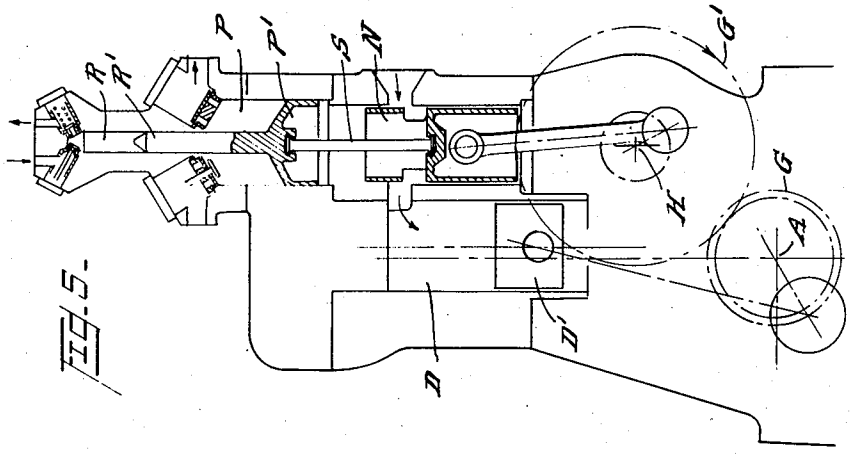


Fig. 5.

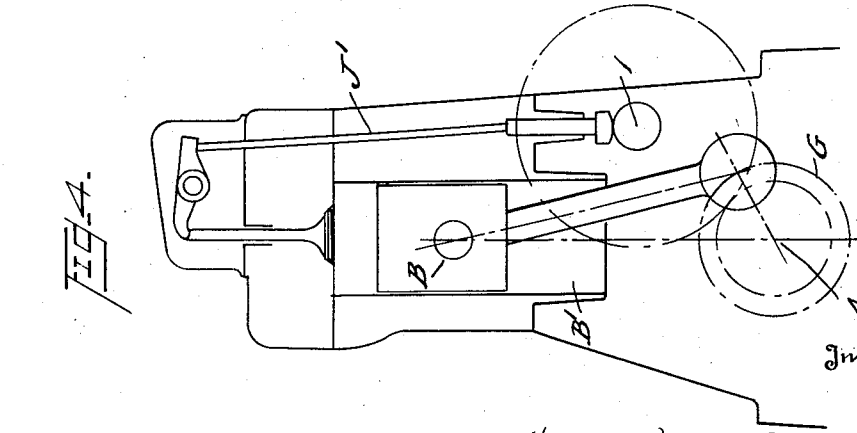


Fig. 4.

Inventor

Harry Ralph Ricardo

By Watson, Cole, Grindle & Watson

Attorneys

Patented Apr. 17, 1945 2,373,780

UNITED STATES PATENT OFFICE

2,373,780

MULTISTAGE COMPRESSOR

Harry Ralph Ricardo, London, England

Application September 16, 1942, Serial No. 458,548
In Great Britain September 29, 1941

6 Claims. (Cl. 230—184)

This invention relates to a multi-stage compressor of the reciprocating type combined with and driven by an internal combustion engine and has for its object to provide a compact and efficient construction.

According to this invention a crankshaft which is driven directly at high speed by the engine is combined with a second crankshaft which is driven from the high speed crankshaft at half its speed, and means are provided whereby the first stage of the compressor is directly operated by the first crankshaft while the valves of this stage are operated by the second crankshaft which also operates the second and subsequent stages of the compressor. The engine operates on the four-stroke cycle. The first crankshaft has two cranks at 360° and between them one crank at 180°, the two cranks at 360° being acted on by the pistons in the two cylinders of the engine while the intermediate crank at 180° operates the piston of the first stage of the compressor. The second crankshaft or layshaft which is driven by gearing from the first crankshaft operates piston valves which function for the first stage and also the pistons of the subsequent stages. With such an arrangement the first stage compression serves on the one hand to balance partially the torque reaction and on the other hand to complete the primary balance of the engine crankshaft.

In this construction as a result of the employment of the two crankshafts geared together to rotate at different speeds each piston in the first stage is reciprocated in its cylinder at a higher speed than the pistons in the cylinders of the subsequent stages.

It is to be understood that while in the arrangement described above only a single cylinder is indicated as being comprised in the first stage, there may be two or more cylinders in that stage with a corresponding number of cylinders in the higher stages. However, a construction in which there are two engine cylinders operating on the one high speed crankshaft which drives the first stage of the compressor, and two or three further stages operated by the second crankshaft in the manner indicated, constitutes a convenient and compact unit. Multiples of this unit may be combined and coupled together, or a similar, but larger unit structure may be employed comprising for example four engine cylinders operating on the same crankshaft by which the pistons in two separate first stage compressor cylinders are driven, the piston valves of these first stage cylinders together with the pistons of the higher stages being all driven from a second crankshaft driven at half speed from the first crankshaft.

The accompanying drawings, some of which are diagrammatic, illustrate by way of example a construction which may be used in carrying the invention into practice. In these drawings:

Figure 1, which is divided, is a sectional elevation in a vertical plane which includes the axis of the main crankshaft and the axes of the two cylinders of the engine and of the cylinder of the first stage of the compressor which is disposed between the engine cylinders.

Figure 2 is a diagrammatic plan of the engine and compressor.

Figure 3 is a part-sectional elevation on the line 3—3 in Figure 2 and looking in the direction of the arrows.

Figure 4 is a diagrammatic transverse section on the line 4—4 in Figure 3 the section passing through one of the cylinders of the engine.

Figure 5 is a similar transverse section on the broken line 5—5 in Figure 2.

Figure 6 is a similar view the section being taken on the broken line 6—6 in Figure 2.

Referring to Figure 1 the main or engine crankshaft A is three throw with the angular positions of the two cranks A^1 and A^2 of the power cylinders similar, that is at 360° and the intermediate crank A^3 at 180° with respect to the cranks A^1 and A^2, the crank A^3 actuating the piston of the first stage of the compressor. The two cranks A^1 and A^2 are acted on respectively by the two pistons B and C in the power cylinders B^1 and C^1 while between these cylinders lies the cylinder D of the first stage of the compressor with the piston D^1 therein which is coupled to the intermediate crank A^3. Bearings E are provided for the ends of the crankshaft A and also between the cranks A^1, A^2 and A^3. At one end of the crankshaft is mounted at F a centrifugal governor and on the other end is a gear wheel G which meshes with a gear wheel G^1 on the second crankshaft H which is thus driven from the main shaft A and at half the speed of the main shaft. It is convenient, as shown in Figures 4, 5 and 6, to place the second crankshaft H with its axis in a horizontal plane which lies above the horizontal plane in which lies the axis of the main crankshaft A. The crankshaft H is provided with two cranks H^1 and H^2 and it also carries the cams J by which are operated, through push rods J^1, the inlet and exhaust valves of the power cylinders B^1 and C^1.

The two engine cylinders B^1 and C^1 are of normal type and construction, the engine operating on the four-stroke cycle and either with spark

ignition or compression ignition. Poppet valves K, K^1 are provided and it is convenient to arrange means whereby the exhaust valves K^1 may be held off their seats on occasion. This may be effected by a cam L which when a hand lever L^1 is moved will act on the end of the valve spindle K^2, the cams operative on the two exhaust valves being coupled through a link L^2 so that they will be brought into action together. To facilitate starting, the cylinder D of the first stage is provided with a poppet valve M controlling a port in the head of the cylinder, the valve being normally kept on its seat by spring action, but by moving a hand lever M^1 a cam M^2 is caused to press on the end of the valve spindle and thus lift the valve off its seat, in this way preventing the compression of gas drawn into the cylinder as the crankshaft A is rotated.

As seen in plan in Figure 2 the cylinder D of the first stage appears between the two power cylinders B^1, C^1 of the engine with the valves N, O of the first stage in their cylinders N^1, O^1 and the cylinders P, Q and R of the higher stages towards one side of the first stage cylinder D. As mentioned these valves N, O are piston valves and they are arranged coaxial with the pistons P^1, Q^1 of the higher stages to which these valves are coupled by rods S, T each of which extends between the piston of the higher stage and a partition within the piston valve which is formed hollow. Conveniently the suction valve N is thus connected to the piston P^1 of the second stage, while the delivery valve O of the first stage is connected to the piston Q^1 of the third stage. The piston R^1 of the fourth stage is constituted by a plunger-like projection from the upper side of the piston P^1 of the second stage. The valves of the cylinders of the second, third and fourth stages are of a type which operates automatically.

An intercooler is preferably provided and arranged so that the air from the first stage passes through it before entering the cylinder of the second stage, and intercoolers may be employed between other stages and an aftercooler may be provided after the highest stage.

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

1. In a multi-stage compressor of the reciprocating type the combination of an internal combustion engine with a crankshaft driven thereby, at least one cylinder with piston therein constituting the first stage of the compressor which is directly operated by the engine crankshaft, a second crankshaft with means whereby it is driven from the engine crankshaft at half the speed of the latter, inlet and delivery valves for this first stage with means by which these valves are actuated by the said second crankshaft, at least one cylinder with piston therein constituting a subsequent stage of the compressor and means whereby any such subsequent stage is operated by the said second crankshaft, and valves for the said internal combustion engine with means whereby they are actuated by the said second crankshaft.

2. In a multi-stage compressor of the reciprocating type the combination of an internal combustion engine having at least two cylinders and operating on the four-stroke cycle, a crankshaft having at least two cranks at 360° with one crank between them at 180° the two cranks at 360° being acted on by the internal combustion engine, at least one cylinder with piston therein constituting the first stage of the compressor and operated by the said crank at 180° between the cranks on the crankshaft which are acted on by the internal combustion engine, a second crankshaft with means whereby it is driven from the said engine crankshaft at half the speed of the latter, inlet and delivery valves for the first stage of the compressor with means by which these valves are actuated by the said second crankshaft, at least one cylinder with piston therein constituting a subsequent stage of the compressor and means by which any such subsequent stage is operated by the said second crankshaft, and valves for the said internal combustion engine with means whereby they are actuated by the said second crankshaft.

3. In a multi-stage compressor of the reciprocating type the combination of an internal combustion engine with a crankshaft driven thereby, at least one cylinder with piston therein constituting the first stage of the compressor which is directly operated by the engine crankshaft, a second crankshaft with means whereby it is driven from the engine crankshaft at half the speed of the latter, at least two cylinders with pistons therein constituting subsequent stages of the compressor and operated by separate cranks on the said second crankshaft, inlet and delivery valves for the said first stage with means whereby these valves are actuated by the said second crankshaft, and valves for the said internal combustion engine with means whereby they are actuated by the said second crankshaft.

4. In a multi-stage compressor of the reciprocating type the combination of an internal combustion engine with a crankshaft driven thereby, at least one cylinder with piston therein constituting the first stage of the compressor which is directly operated by the engine crankshaft, a second crankshaft with means by which it is driven from the engine crankshaft at half the speed of the latter, at least two cylinders with pistons therein constituting subsequent stages of the compressor and operated by separate cranks on the said second crankshaft, inlet and delivery valves for the said first stage these valves being piston valves which are coaxial with and connected to the pistons in the said cylinders of the subsequent stages and thus are actuated by the said second crankshaft, and valves for the said internal combustion engine with means whereby they are actuated by the said second crankshaft.

5. In a multi-stage compressor of the reciprocating type the combination of an internal combustion engine having at least two cylinders and operating on the four-stroke cycle, a crankshaft having at least two cranks at 360° with one crank between them at 180° the two cranks at 360° being acted on by the internal combustion engine, at least one cylinder with piston therein constituting the first stage of the compressor and operated by the said crank at 180° between the cranks on the crankshaft which are acted on by the internal combustion engine, a second crankshaft with means by which it is driven from the said engine crankshaft at half the speed of the latter, at least two cylinders with pistons therein constituting subsequent stages of the compressor and operated by separate cranks on the said second crankshaft, inlet and delivery valves for the first stage these valves being piston valves which are coaxial with and connected to the pistons in the said cylinders of the subsequent stages and thus actuated by the said second crankshaft, and valves for the said internal combustion engine with means by which they are actuated by the said second crankshaft.

6. In a multi-stage compressor of the reciprocating type the combination of an internal combustion engine having at least two cylinders and operating on the four-stroke cycle, a crankshaft having at least two cranks at 360° with one crank between them at 180° the two cranks at 360° being acted on by the internal combustion engine, at least one cylinder with piston therein constituting the first stage of the compressor and operated by the said crank at 180° between the cranks on the crankshaft which are acted on by the internal combustion engine, a second crankshaft with two cranks at 180° and gearing by which this crankshaft is driven from the said engine crankshaft at half the speed of the latter, at least two cylinders with pistons therein constituting subsequent stages of the compressor, piston valves which function as inlet and delivery valves for the first stage these valves being connected to and acting as crossheads for the said pistons in the cylinders of the subsequent stages and being actuated by the cranks on the said second crankshaft, and valves for the said internal combustion engine with means by which they are actuated by the said second crankshaft.

HARRY RALPH RICARDO.