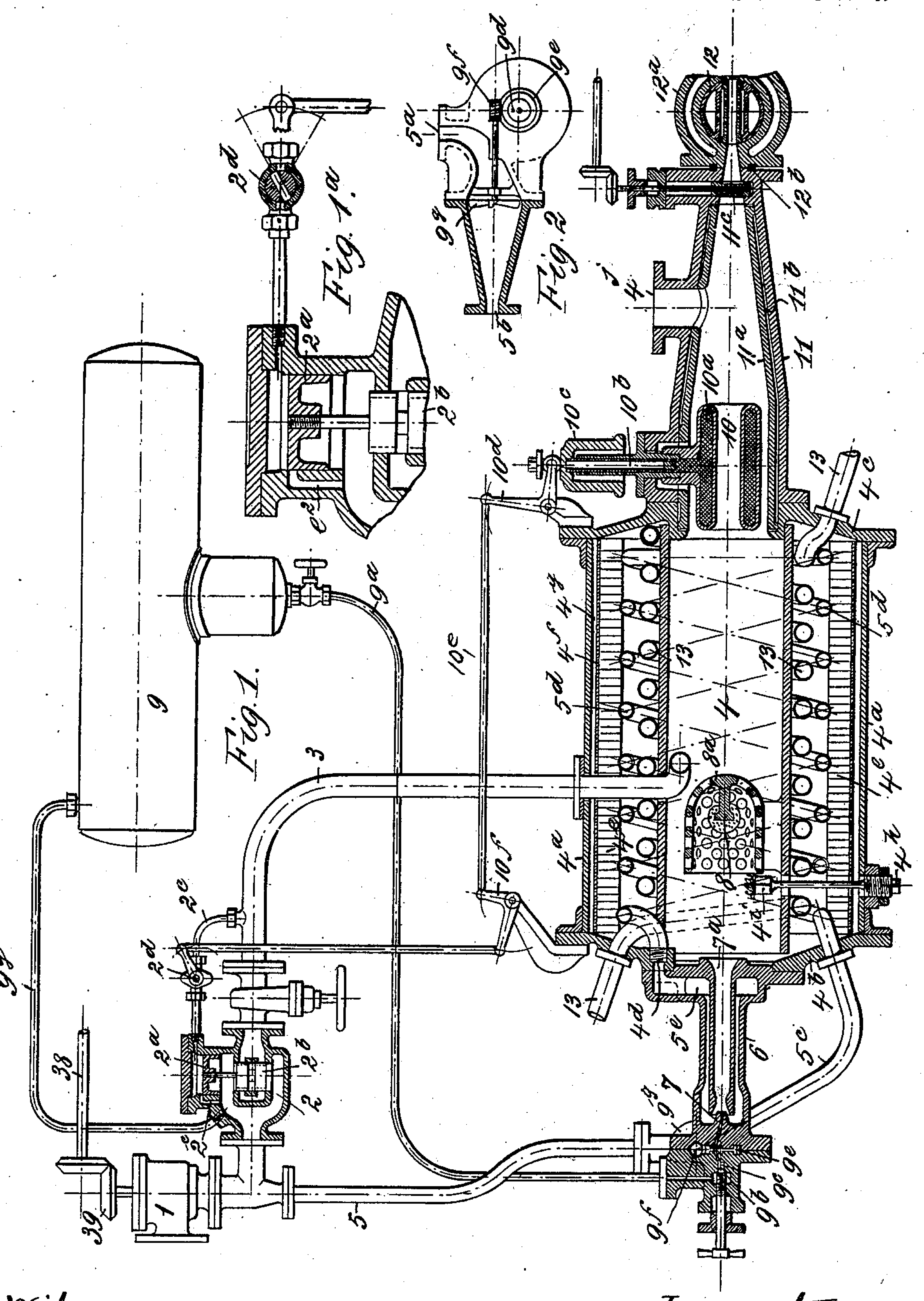
No. 660,996. **Patented Oct. 30, 1900.**

J. T. NICOLSON.

CALORIC ENGINE.

(Application filed June 6, 1900.)

(No Model.) **4 Sheets—Sheet 1.**



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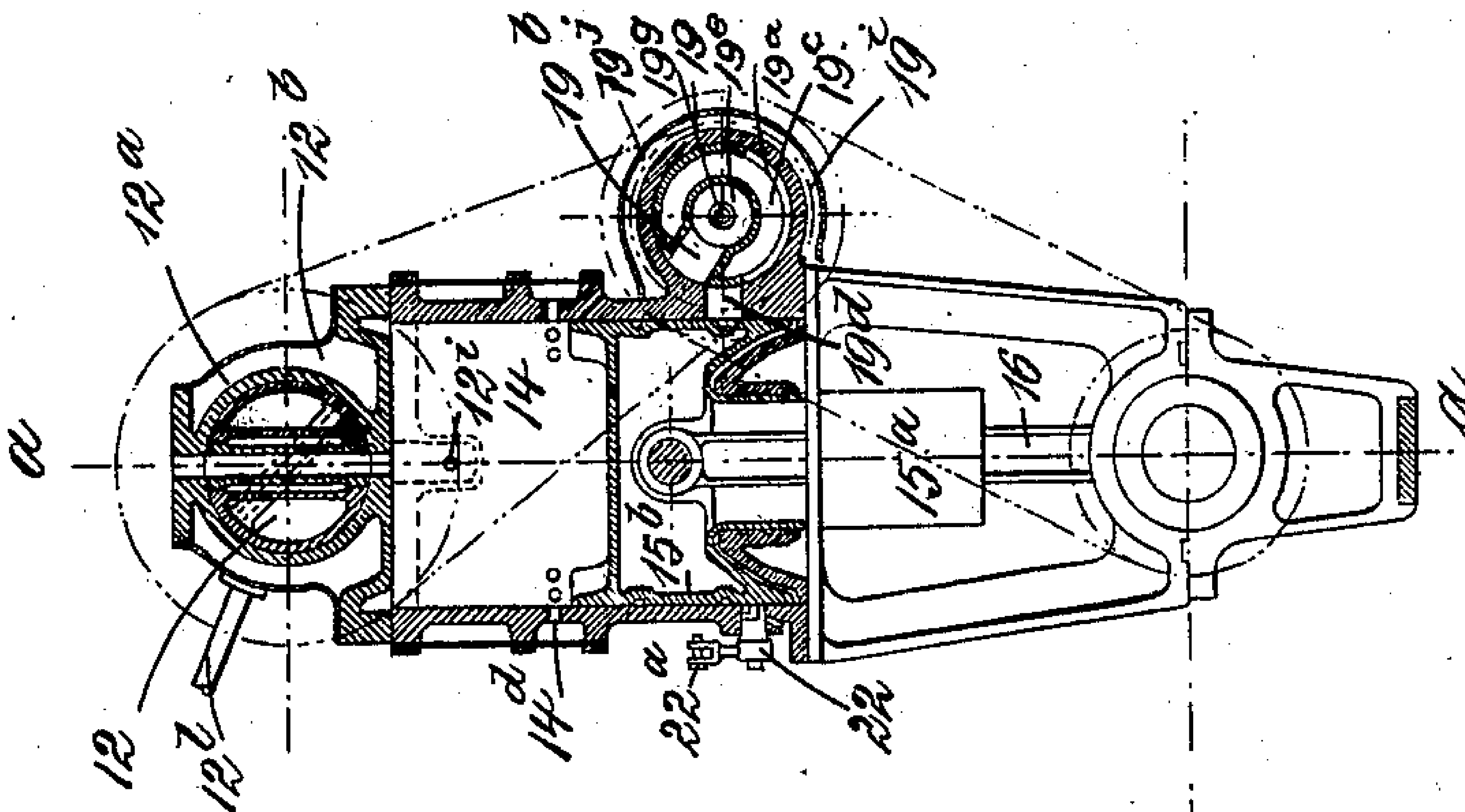

Fig. 4.

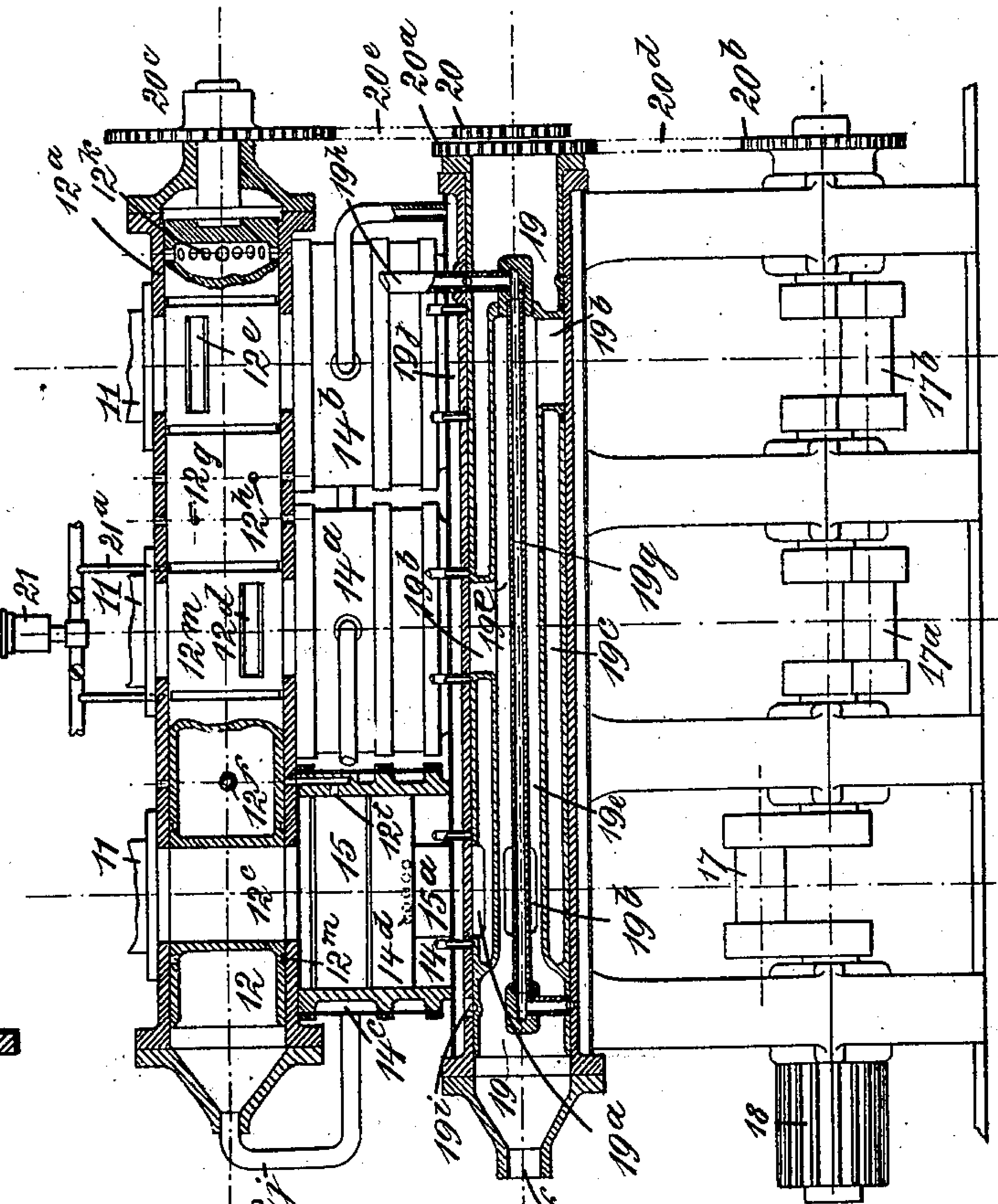

Fig. 3.

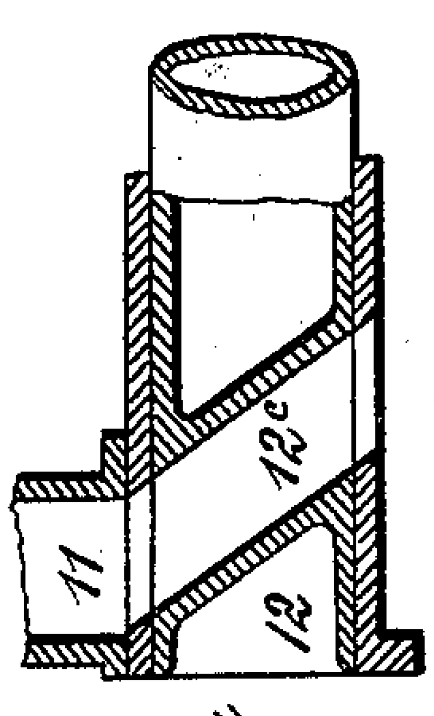

Fig. 3a.

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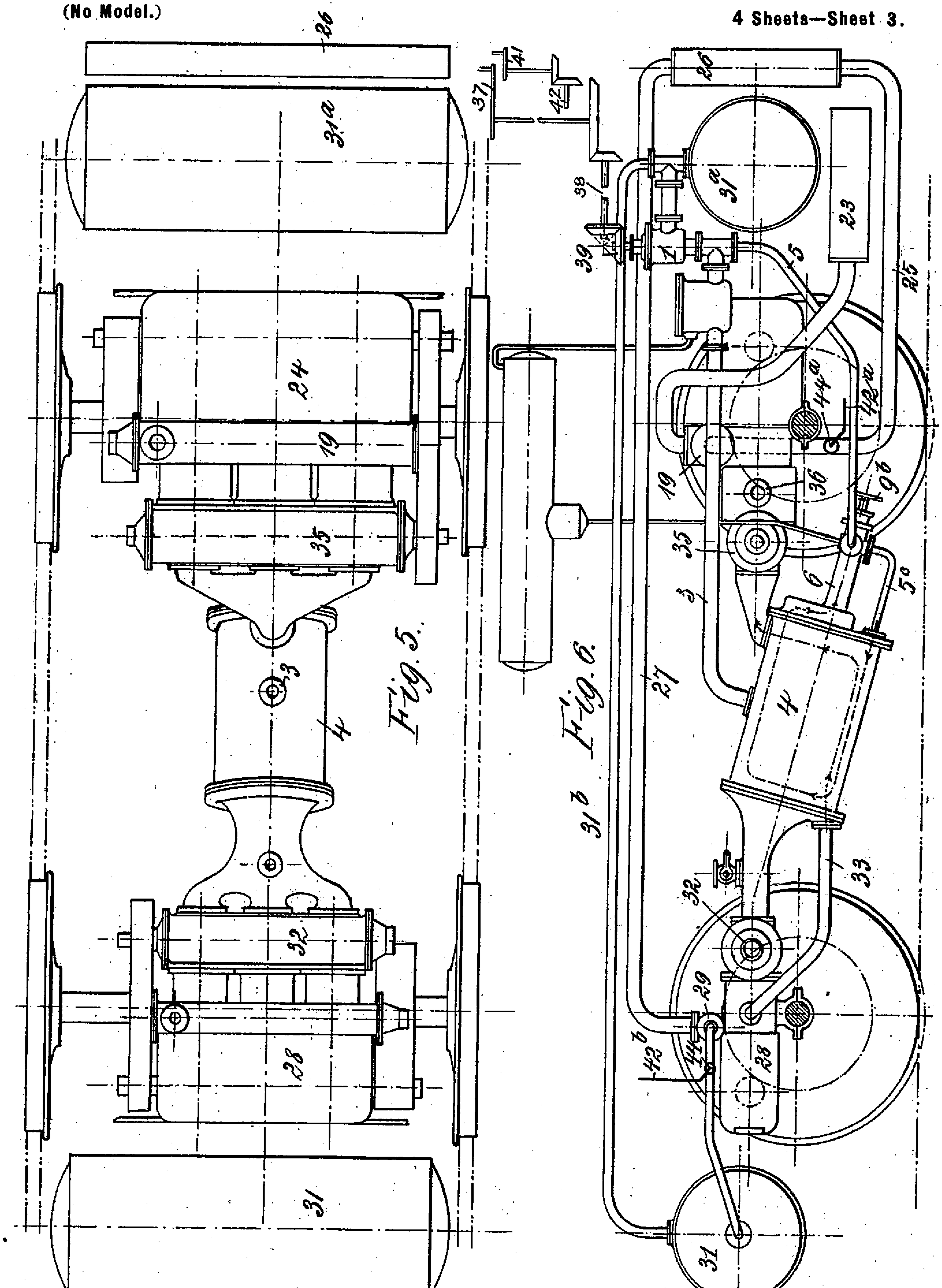

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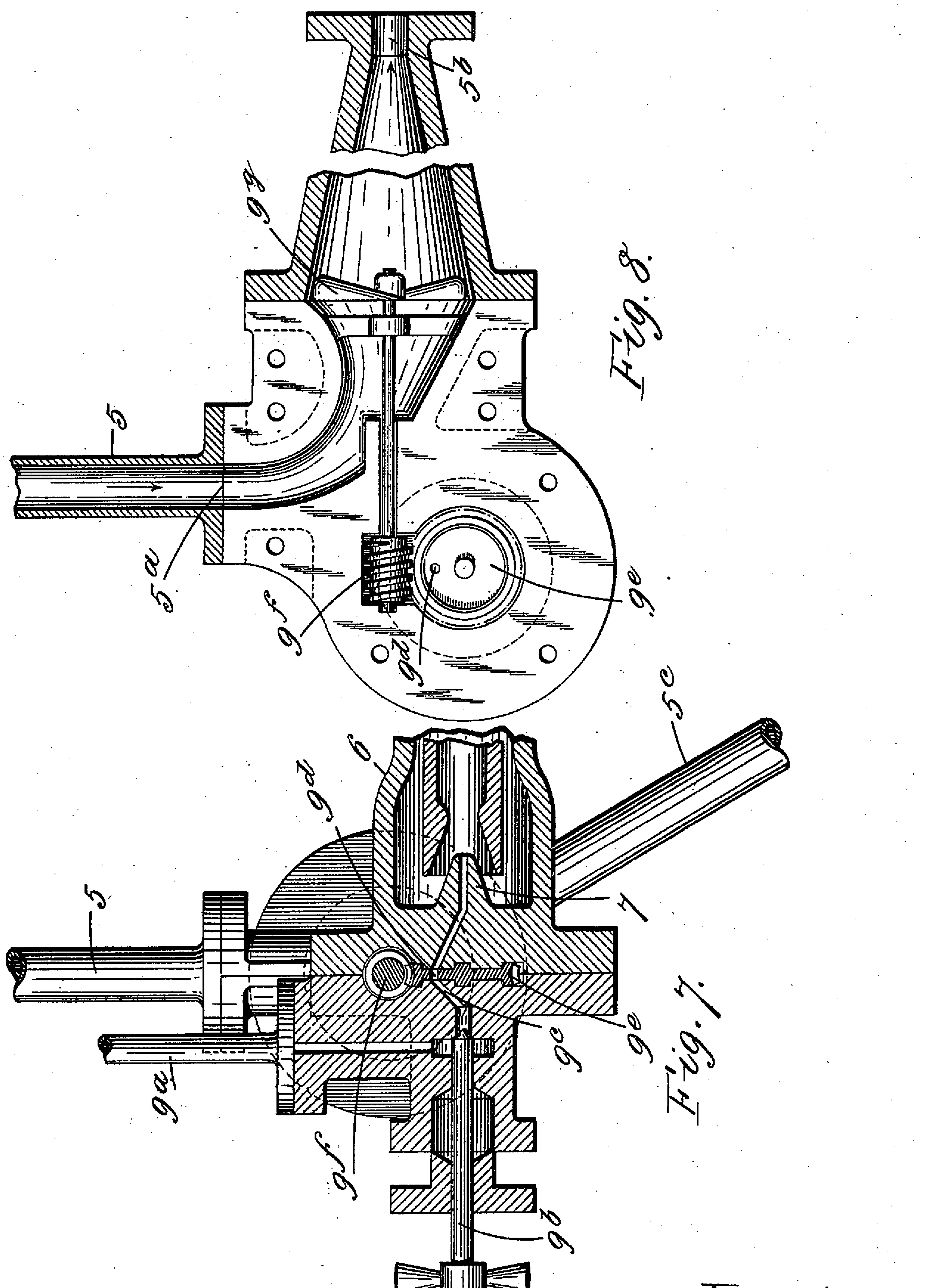

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CALORIC-ENGINE.

SPECIFICATION forming part of Letters Patent No. 660,996, dated October 30, 1900.

Application filed June 6, 1900. Serial No. 19,337. (No model.)

To all whom it may concern:

Be it known that I, JOHN THOMAS NICOLSON, D. Sc., a subject of the Queen of Great Britain, residing at Manchester, in the county of Lancaster, England, have invented certain new and useful Improvements in Joule Motors, of which the following is a full, clear, and exact description.

Joule in 1851 suggested the production of power by a scheme involving the use of compressed air, a heating receiver or furnace, and a motor, the motor being heated by heated compressed air from the receiver. A part of the work done by the motor was to have been employed to compress the air and the balance to have been utilized for driving any suitable mechanism. Since that date many others have devoted much time and attention to the development of the scheme; but mechanical difficulties have hitherto rendered fruitless all efforts to obtain commercial success. By my present invention these mechanical difficulties have been overcome, and the scheme proposed by Joule is thereby made generally available, and particularly in the production of power for utilization in the propulsion of tram-cars, autocars, and the like.

My improved system consists in, first, compressing air to a high pressure by means of a compressor actuated by a hot-air motor; second, heating the air so compressed, and, third, the delivery of the hot high-pressure air to the motor and its utilization therein (*a*) for compressing the air and (*b*) for external work. The air to be compressed may be drawn either from the atmosphere or from a cooling-receiver into which the motor discharges. After compression it is delivered into a storage-receiver, whence it is led to a heating device, in which it may be heated to about 1,500° Fahrenheit before admission to the motor. If the motor is compound, the hot air may be first led to the high-pressure cylinder, thence to a reheater, and finally to the low-pressure cylinder and to the external air or a cooling-receiver for reuse.

I will describe my improvements with reference to the accompanying drawings, in which—

Figure 1 is a sectional elevation of my appliance for heating the air; Fig. 1^a, a partial section of the reducing-valve; Fig. 2, a cross-section through the burner; Fig. 3, a longitudinal section along the line *a a*, Fig. 4. Fig. 3^a is a transverse section of an alternative form of valve, showing a diagonal instead of a diametrical admission-passage through the same. Fig. 4 is a sectional elevation of the motor-compressor. Fig. 5 is a plan, and Fig. 6 an elevation, of the whole apparatus. Fig. 7 is a longitudinal section of the oil-injection apparatus drawn to a larger scale, and Fig. 8 is a cross-section of the same.

Referring to the apparatus for heating the compressed air, as illustrated by Figs. 1 and 2, the compressed air is supplied from its receiver to the main valve 1, which is controlled by the driver through suitable gearing or a system of links or levers. Beyond this valve the air-supply is divided, one part passing through the reducing-valve 2 and pipe 3 to the furnace 4 and the other part through the pipe 5 and the injection-burner 6 7. One function of the reducing-valve is to insure that the pressure of air supplying the burner shall be greater than that in the furnace, so that there shall be a constant flow or a tendency toward a constant flow from the burner. A suitable reducing-valve may be one of the known type, in which there is a floating piston 2^a, carrying in a cylinder below it a piston-valve 2^b. There is a small by-pass around the floating piston, which when the floating piston is in the position indicated in Fig. 1 puts the space above the piston into communication with the space below it. There is a further by-pass 2^c from the space above the floating piston to the pipe 3, this pipe being controlled by a valve 2^d between the reducing-valve and the by-pass junction. The amount of reduction of the pressure of the air passing to the furnace is governed by the weight of the floating valve 2^a and the piston-valve attached to it and by the pressures of the air above and below the floating valve. The pressure below the floating piston is sensibly the same as that supplied to the burner. The pressure of the air above the piston is the same as or greater than the pressure of the air in the furnace, according as the by-pass valve 2^d is opened or closed. When it is closed, the floating piston drops and its by-pass equalizes the pressure above and below it. At the same time the piston-valve 2^b drops and closes the passage to the furnace, so that the maximum quantity of air then goes through the burner and the maximum heating effect is produced. When the valve 2^d begins to open, it allows the pressure above the floating piston to become less than the pressure below it, and the piston thereupon rises, opening the piston-valve ports, diminishing the difference of pressure, and producing a reduction in the flow of air to the burner and a less consumption of oil in the furnace. When the valve 2^d is fully open, the valve-ports are wide open and but little oil is burned. The reducing-valve therefore not only produces a tendency to make the air flow through the burner, but controls it also when it is itself controlled through the valve 2^d. The flow of air through the furnace being divided between the burner and the pipe 3, the heat is under better control, since a greater flow through the pipe 3 reduces the temperature, and the reverse.

I overcome the great difficulty of getting a smokeless flame from oil fuel from a moderate-sized burner and the further difficulty arising from the clogging up of the oil-passages by the burner illustrated by Figs. 1 and 2. In the fairway 9^c, through which the oil passes to the injection-nozzle 7 of the burner, I arrange a small perforated disk 9^e, which has a toothed edge in gear with a small tangent screw 9^f, fixed on the spindle of a fan 9^g, which is contained in the passages 5^a and 5^b of the pipe 5. Hence the speed of rotation of the disk is proportional to the speed of the air passing to the burner. With this arrangement of oil-supply there is a divergence in the oil-passage if the disk be centrally arranged, and the passage is entirely closed by the disk; but if the disk be perforated, as at 9^d, in the line of passage oil will continue to flow so long as it takes for the perforation to travel across the passage, once in each revolution. Consequently an increase in air-flow to the burner is followed by an exactly-proportionate increase of oil-flow. The oil is contained in the reservoir 9, through which it passes to the burner by the pipe 9^a, where it is controlled by the valve 9^b. The reservoir 9 is in communication, through the pipe $9^{g\prime}$, with the compressed-air supply, so that it flows under that pressure. The air-supply pipe 5^c before finally reaching the burner 6 connects with the coiled pipe 5^d around the furnace 4, so that the air on its passage to the burner is highly heated. The air issues from the coil at 4^d to the space surrounding the injection-tube 7^a, into which it passes at the nozzle 7.

The furnace may be of steel, with dished ends 4^b and 4^c. On the end 4^c there is bolted the hot-air-exit pipe 11, which may have a protective lining 11^a and air-space 11^b. At the end of the air-pipe there is a sluice-valve 11^c, which is opened and closed simultaneously with the valve 1 through the agency of suitable gearing.

The valve 2^d, already described, may be operated by any suitable thermostat arranged in a position where it will be exposed to the heat of the heated air issuing from the furnace 4. As illustrated by the drawing Fig. 1, this thermostat 10 may consist of an annular chamber 10^a, filled with a fusible alloy. This chamber has a vertical cylindrical branch containing a plunger 10^b, on the top of which rests a heavy cap 10^c, connected by the links and levers 10^d 10^e 10^f with the handle of the valve 2^d. This valve is thus operated by the varying expansion of the fusible alloy under changes of temperature in the compressed air which may or may not be issuing from the furnace.

In Fig. 1, 12 represents a section through the cooled rotating plug-valve of the motor in the casing 12^a, which is connected with the pipe 11, a refractory non-conducting material 12^b being interposed in the joint. When the motor is compound, the air may be heated between the high and the low pressure cylinders by passing it through the pipes 13 13, connected with a second coiled pipe around the furnace 4. The flame from the burner may impinge upon a perforated cup 8^a, of refractory material, containing the stemmed protuberance 8, which becomes intensely heated and insures the ignition of the intermittent injections of oil. 4^f is a metal lining, 4^e is a refractory lining, and 4^g is an air-space acting as a heat-insulator. 4^h is a plug with a hollow end 4^i projecting into the furnace for the purpose of holding oil and a wick for lighting up at the start. Air at atmospheric pressure may be supplied to the interior of the furnace while lighting up through the branch 4^j in the pipe 11.

The motor and compressor are shown by Figs. 3 and 4. In the construction illustrated there are three cylinders; but any other convenient number may be employed. Each cylinder is fitted with a double-acting trunk-piston connected with the shaft by a connecting-rod in the usual manner. That end of the cylinder farther from the crank-shaft acts as the motor-cylinder and the nearer end as the compression-cylinder. By this arrangement a great economy in space and weight is effected and there is also a great reduction in frictional waste. The valves for both the compressors and the motors are of the rotary type. The rotating motor-valve 12 is shown in Fig. 3 to be constructed with straight through-ports leading direct from the pipe 11 to the inside of the cylinders 14 14^a 14^b. With these straight through-ports there is an admission twice for each revolution of the valve. If, however, the ports are made diagonally through the valve, as shown in Fig. 3^a, there may be an admission once only in each revolution. The ports are indicated at 12^c, 12^d, and 12^e. 12^f, 12^g, and 12^h show subsidiary exhaust-ports, and 12^i the exhaust-channel in one of the cylinders 14. The circulating water enters the valve 12 by the pipe 12^j

from the cylinder-jacket 14^c and leaves by the holes 12^k, escaping into the valve-casing jacket 12^b, and finally from the pipe 12^l.

One of the pistons and trunks is shown in elevation at 15 and 15^a in Fig. 3 and in section at 15^b in Fig. 4. The holes or slots 14^d constitute the main exhaust-ports of the motor-cylinders and are fully opened by the motion of the piston when close to the bottom or end of its stroke. By means of the subsidiary exhaust-port 12^i the back pressure is diminished to give efficiency and smooth running. 16 is one of the connecting-rods, 17, 17^a, and 17^b are the cranks, and 18 the main driving-pinion, fixed on the crank-shaft.

The rotary compressor-valve 19 has three suction-ports 19^a and three discharge-ports 19^b. The air for suction enters at 20 through the chain-wheels 20 and 20^a or alternately by a branch pipe and passes along the annular channel 19^c and through the three ports 19^a by way of the inlet-port in the cylinder 19^d. The discharged air delivered through the ports 19^b passes along the central cavity of the valve 19^e and out through the branch 19^f. Cooling-water is supplied along the pipe 19^g, entering at 19^h and leaving at 19^i by way of the casing 19^j. The valves are positively rotated, the compressor-valve by the chain-wheels 20^a and 20^b and a connecting-chain and the motor-valve by the chain-wheels 20 and 20^c and a connecting-chain. The wheel 20 is fast with the wheel 20^a, and consequently moves therewith. Lubrication of the motor-valve is provided for by recesses, such as 12^m, turned on the valve and being in communication with a lubricator 21 through the tube 21^a. Each of the lubricators may have its upper interior in communication with the compressed-air reservoir through a pipe 21^b. The bottoms of the compressor-cylinders communicate through the cocks 22, of which there is one for each cylinder. These cocks can be simultaneously opened and closed by a common link connected at 22^a, so as to put them into communication or to isolate the cylinders. When the motor is started, these cocks are opened, with the result that no compression takes place and the whole of the work of the motor is utilized in starting the vehicle. After the motors have come well into action the cocks are closed and compression commences.

In the general arrangement illustrated by Figs. 5 and 6, 23 is a filter, through which air enters the compressor-valve 19. After being compressed in the cylinder 24 it is discharged, through the pipe 25, into the cooling-reservoir 26, whence it passes by way of the pipe 27 to the next stage compressor 28 through the valve 29. From this compressor it is discharged at its highest pressure to the reservoirs 31 and 31^a, connected by the pipe 31^b, which is in communication with the main valve 1, whence its course to the furnace 4 has already been described. After leaving the furnace the hot air passes to the high-pressure motor-cylinder 28 through the rotary valve 32, is discharged through pipe 33, to be reheated in the coil 13, Fig. 1, whence it passes by the pipe 34 to the low-pressure motor-cylinder 24 through its valve 35, and is finally discharged through the pipe 36. By means of the starting-handle 37 and the shaft 38 giving motion to the bevel-wheels 39 the driver is enabled to open the stop-valve 1. The cocks 22, Fig. 4, are then opened, arresting compression. As soon as the motor is well started the cocks 22 are closed. A braking action may be introduced by increasing the pressure of the air on the discharge side of the compressors. This may be done by means of equilibrium-valves 44 and 44^a, operated by the handle 41 and the connecting-rods 42, 42^a, and 42^b. In the general arrangement the compression is shown to be effected in two stages; but three or more may be employed, thus dividing this work.

Having now described my invention, I declare that what I claim is—

1. The combination of a plurality of low-pressure motor-compressors, a plurality of high-pressure motor-compressors, a furnace for reheating the air between the high-pressure and the low-pressure motors, a receiver in which the air is cooled between the low-pressure and the high-pressure compressors, a second receiver for the fully-compressed air a furnace for heating the fully-compressed air, a reducing-valve through which the high-pressure air is supplied to the last-named furnace, and pipes connecting the said parts with each other, substantially as described.

2. In an apparatus of the class described, the combination with the furnace for heating the compressed air, of a reducing-valve intercalated between the furnace and the source of compressed air the said reducing-valve having a floating piston with a chamber above it, a thermostat, a tube connecting the reducing-valve chamber with the air-pipe on the furnace side of the valve, and a cock in the connecting-tube controlled by the thermostat, substantially as set forth.

3. In an apparatus of the class described, a main valve controlling the admission of the compressed air, a furnace provided with a liquid-fuel burner for heating the compressed air, a reducing-valve intercalated in a passage from the main valve to the interior of the furnace, and a tube coiled around the furnace and communicating at one end with the liquid-fuel burner and at the other end with the main valve, substantially as set forth.

4. In an apparatus of the class described, a plurality of motor-compressors each containing a trunk-piston connected with a common crank-shaft, a rotary valve admitting compressed air to the side of each piston away from the trunk, a rotary compressor-valve adapted to work synchronously with the motor-valve controlling the admission to and delivery from the trunk side of the cylinder, a

pipe communicating through branches with the trunk side of each cylinder, a cock intercalated in each of the branch pipes, a link by which all the cocks can be opened and closed simultaneously, and an air-heating furnace communicating on one side with the compressed-air supply and on the other side with the motor-valve, substantially as set forth.

5. In an apparatus of the class described, a furnace provided with a liquid-fuel injector-burner, a perforated cup containing an axial stemmed projection therein, a thermostat in the furnace-outlet for controlling the air-supply, a removable oil and wick holder for lighting up, and a coil around the furnace for preliminarily heating the compressed air, substantially as set forth.

In witness whereof I subscribe my signature in presence of two witnesses.

JOHN THOMAS NICOLSON.

Witnesses:
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ARTHUR MILLWARD.