B. V. NORDBERG.
COMPRESSED AIR POWER SYSTEM.
APPLICATION FILED JAN. 29, 1912.

1,231,051. Patented June 26, 1917.

3 SHEETS—SHEET 1.

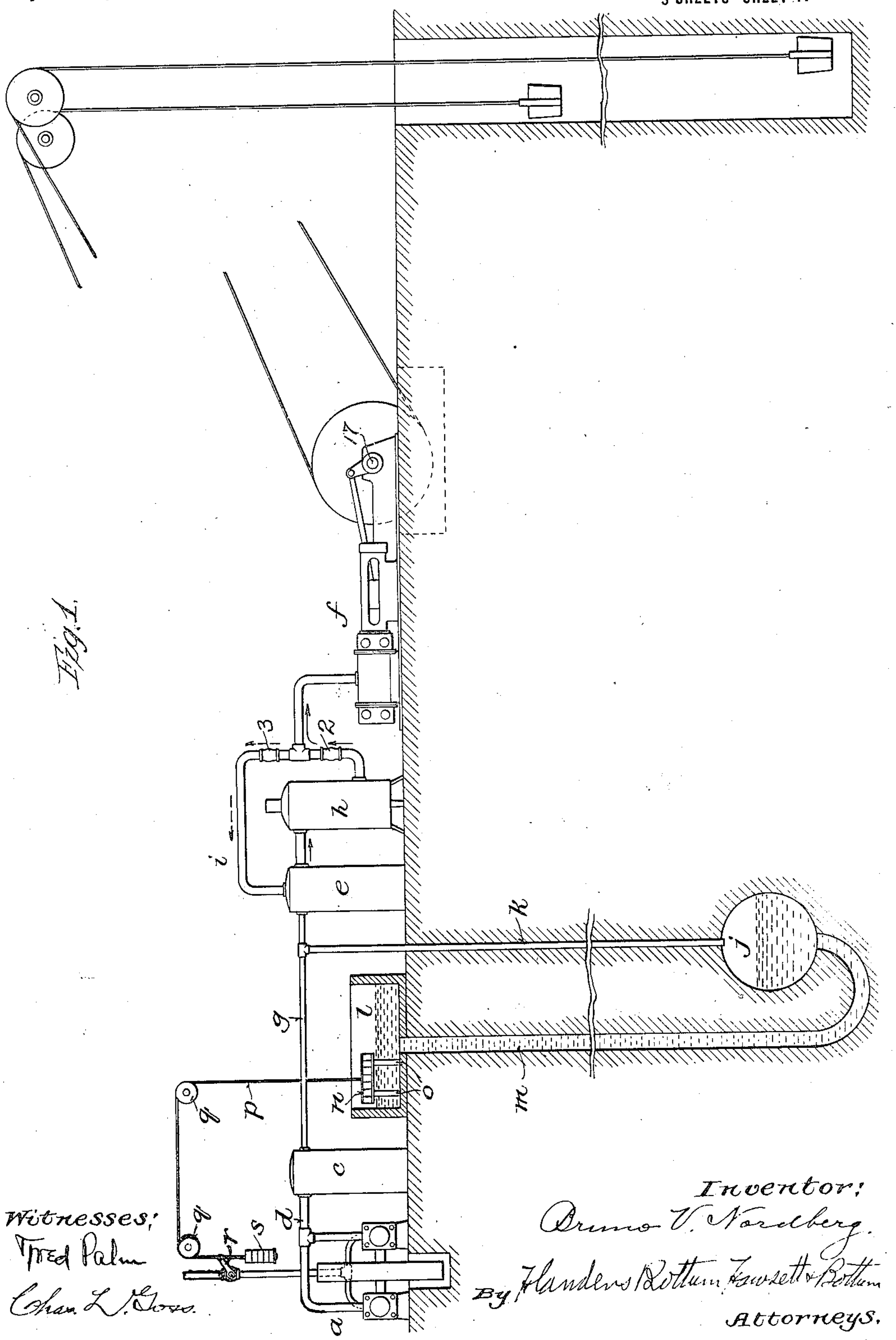

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Fig. 2.

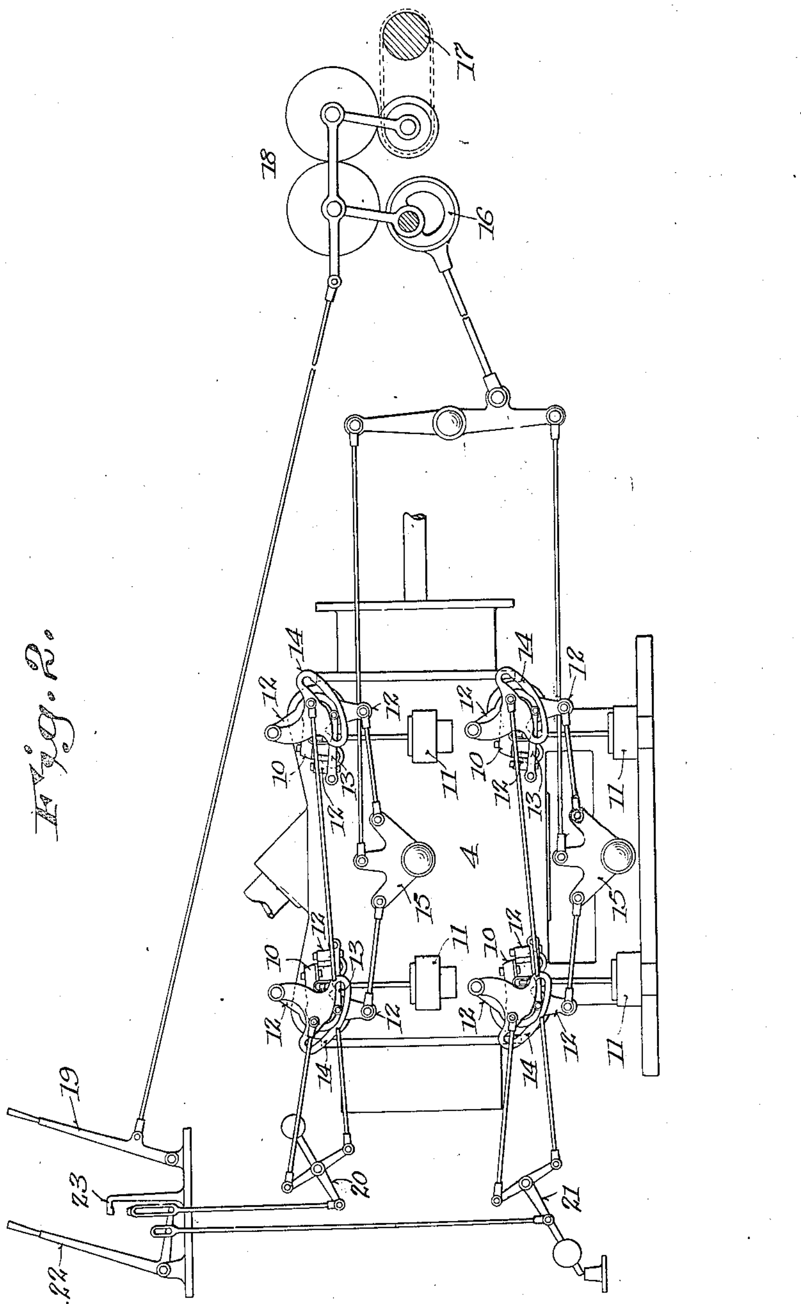

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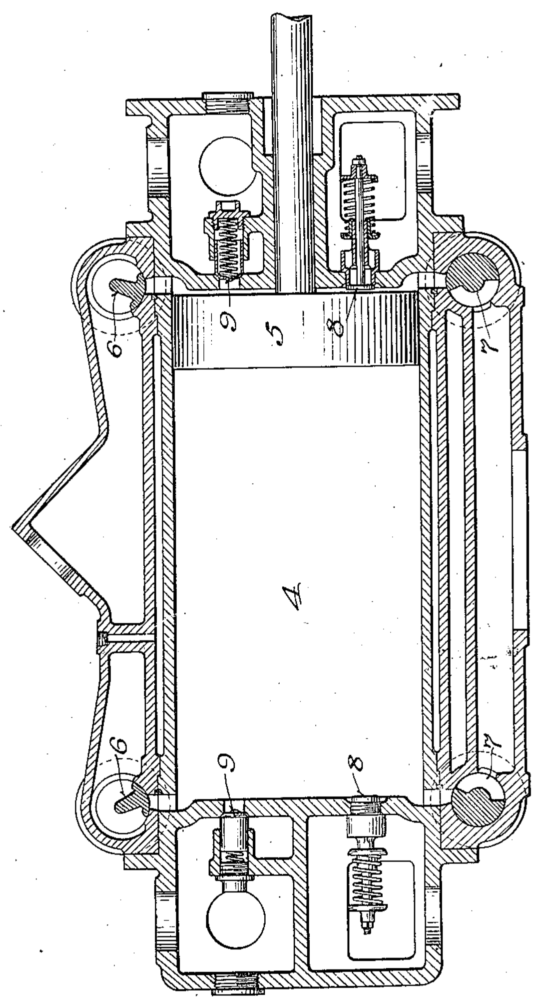
Fig. 3.



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UNITED STATES PATENT OFFICE.

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COMPRESSED-AIR POWER SYSTEM.

1,231,051. Specification of Letters Patent. Patented June 26, 1917.

Application filed January 29, 1912. Serial No. 674,056.

To all whom it may concern:

Be it known that I, Bruno V. Nordberg, a citizen of the United States, residing at Milwaukee, in the county of Milwaukee and State of Wisconsin, have invented certain new and useful Improvements in Compressed-Air Power Systems, of which the following is a specification, reference being had to the accompanying drawing, forming a part thereof.

This invention relates more particularly to compressed air systems upon which the demand for power as for example, in operating hoisting engines, fluctuates often within wide limits.

The main objects of the present invention are to equalize the load upon the air compressing plant of such a system; to enable a plant the capacity of which is equal to the average demand for power thereon to temporarily supply any and all excess or extraordinary demands to which the system may be subjected, such as peak loads in the operation of hoisting engines; and thus to admit of reducing the size of the air compressing plant and the cost of installing, operating and maintaining the same.

It consists in the construction, arrangement and combination of parts or elements for the accomplishment of these objects, as hereinafter particularly described and pointed out in the claims.

In the accompanying drawing like characters designate the same parts in the several figures.

Figure 1 is a diagrammatic view of apparatus embodying the invention; Fig. 2 is a side elevation on an enlarged scale of a variable capacity compressed air engine of the type shown in United States Letters Patent No. 926,819 issued to me July 6, 1909, and suitable for use in and as a part of the apparatus constituting the present invention; and Fig. 3 is an axial section on a still larger scale of a cylinder with an arrangement of valves suitable for such an engine.

In the operation of a hoisting engine the load is usually extremely variable or fluctuating, both in regard to individual trips and also to the distribution of the power over any given period of time. At each trip when the load is started, a certain amount of power must be applied to accelerate the hoist. This power is often two or three times greater than that required to balance the load. When the hoist has been accelerated or has attained the required speed, a less driving power can be applied to maintain the speed, and toward the end of the trip the power supplied for accelerating the hoist must be neutralized either by a brake or by a retarding power such for example as is described in the above mentioned patent.

A certain interval of time is required to load and unload the skips or cages connected with the hoist, during which time the engine remains idle and no power is consumed.

The hoisting is generally done during certain parts of the day, while during other parts of the day very little work is done with the hoisting engine except that necessary to lower the miners into and lift them out of the mine at the change of shifts.

Due to these conditions, the hoist is seldom in operation more than half of the time, and frequently much less. The result of this is that while, as in several instances within my knowledge, the effective work represented by the lifting of the loads averages per day one hundred horse power, the same work distributed over the actual time during which the hoist is in operation runs up to say, five hundred or six hundred horse power, while that represented by the heaviest individual trips or loads may run as high as from two thousand to three thousand horse power.

In the apparatus shown in the above mentioned patent, expansion tanks are employed in which air can be stored so as to partially equalize the load. Since however, the pressure in these expansion tanks drops when air is drawn from them, only a part of the energy stored in the air in said tanks can be utilized. For instance, if the pressure in said tanks is one hundred pounds, it would not be practicable to draw therefrom a greater quantity of air than would reduce the pressure below say, eighty pounds, or that required to properly operate the engine. It follows therefore, that in the case assumed, only one-fifth of the total volume of the expansion tank or tanks is available for storage. Such expansion tanks are however, indispensable in connection with a system of hoisting engines, to take care of the sudden and great demands for air when the hoists are accelerated. The quantity of air required to meet such sudden and great demands is between five and ten times greater than that required when the hoist is up to speed, but the time during which such great quantity is required, is short, so that under these conditions an expansion tank is the proper device to use in connection with the hoist, and such tank should be located close to the hoist, so that the pipe system may not be overtaxed by such extraordinary demands for air.

In order however, to completely equalize the load or in order to render it possible for an air compressor the capacity of which is equal to the average consumption of all the hoists connected therewith to supply such extraordinary demands for air, the hydrostatic equalizing device herein shown and described has been devised.

Referring to Fig. 1 of the drawing, *a* designates an air compressor which may be driven by a steam engine or other motor. *c* is an expansion tank located close to the compressor and connected by a pipe *d* with the discharge chest thereof. *e* is another expansion tank located near a hoisting engine *f* and connected by a pipe *g* with the tank *c*. These expansion tanks *c* and *e* being located close to the compressor *a* and engine *f*, tend to equalize the pulsations and fluctuations of pressure due to the action of the compressor and the action of the engine, especially when the latter is subjected to sudden and extraordinary increase of load, and thus prevent consequent waste of energy and overtaxing the piping of the system.

The hoisting engine, which may be and preferably is, of the type described in the patent hereinbefore mentioned, is preferably connected with the tank *e* through a heater *h*, by which the air passing from the tank *e* to the engine is heated, while the compressed air discharged by the engine when it acts as a compressor to develop retarding power according to said patent, will be conducted into said tank around the heater through a branch pipe or bypass *i*.

The pipe connection between the engine *f* and the heater *h* is provided with a check valve 2, which closes toward the heater, and the branch pipe or by-pass *i* leading from said pipe connection back to the tank *e* is provided with a check valve 3, which closes toward the engine.

An air receiver *j* of large size, which when the conditions are such that it can be done, may be excavated in the rock formation below the surface, is connected at the top by a pipe or conduit *k* with the pipe *g*, or with a part of the compressed air system between the compressor and engine.

A water tank *l*, having a capacity equal to or as great as that of the air receiver *j* and located above the same, is connected at or near the bottom by a pipe or conduit *m* with the bottom or lower part of said receiver. The pipe or conduit *m* is preferably extended some distance below the receiver *j*, as shown, in order to prevent the escape of air therefrom and consequent loss of power in case the pressure in the system is increased sufficiently to displace all the water in said receiver.

The distance of the water tank *l* above the air receiver *j* is such that when the tank is filled with water the head to which the air in said receiver is subjected will balance the pressure, say eighty to one hundred pounds, necessary to operate the hoisting engine or other apparatus connected with the system and the size and shape of the tank and receiver are such that the water level in the tank will vary but little and hence the hydrostatic pressure on the air in the receiver will remain substantially constant, whatever the volume of water in the receiver may be.

Referring to Figs. 2 and 3, showing a compressed air engine of variable capacity, capable of developing greater power than can be supplied by the maximum capacity of the compressor *a*, and convertible at will from a motor into a compressor and vice versa, the engine comprises one or more cylinders 4, but one being shown in the present case. Each cylinder is provided, as shown in Fig. 3, with a piston 5, inlet valves 6, exhaust valves 7, automatic suction valves 8, and automatic discharge valves 9.

As shown in Fig. 2, the inlet and exhaust valves 6 and 7 are provided with manually adjusted and controlled operating and releasing gear, comprising closing arms 10 fixed on the valve stems and connected with dash pots 11, which constantly tend to close the valves, oscillatory opening arms 12 mounted concentrically with the valve stems, trip arms 13 pivotally mounted on the arms 12 and adapted by engagement with the arms 10 to open the valves, and cams 14 pivotally mounted on the arms 12 and engaging with the trip arms 13. The arms 12 are actuated by wrist plates 15 and an eccentric 16 which may be connected, as shown, with the crank shaft 17 of the engine by reversing gear 18 manually adjusted by a suitable device such as a lever 19.

The cams 14 are connected with weighted trip levers 20 and 21, which are connected with and manually operated and controlled by a lever 22 or other suitable means.

When the lever 22 and the valve releasing mechanism are adjusted as shown in Fig. 2, compressed air will be admitted to the expanding end of the cylinder and exhausted from the other end of the cylinder during nearly the full stroke of the piston, the inlet and exhaust valves 6 and 7 being opened and held open by the valve gear.

When the lever 22 is moved to the left, the inlet valves 6 will be released and closed earlier in the stroke of the piston, thereby gradually reducing the volume of air admitted to the cylinder and hence reducing the driving or accelerating power applied to the engine until further movement of the upper trip cams 14 by the weighted lever 20 is arrested by a stop 23, in position to prevent the opening of said valves and the further admission of compressed air into the cylinder, the exhaust valves continuing to function as before.

A further movement of the lever 22 in the same direction, shifts the trip lever 21 and turns the lower cams 14 into position to release the exhaust valves 7 and permit them to close, at first near the end of the stroke of the piston, thereby converting the engine from a motor into a compressor.

The continued movement of the lever 22 in this direction effects an earlier closing of the exhaust valves, thereby gradually increasing the work and the retarding or braking effect to which the engine is subjected without waste of power, until at the limit of the movement of said lever to the left the cams 14 reach a position in which they will not open said valves.

The movement of the lever 22 backward to the right effects a reversal of the foregoing operations, gradually reducing the work or retarding effect on the engine functioning as a compressor, then converting the engine from a compressor into a motor and then gradually increasing the driving or accelerating power applied to the engine functioning as a motor.

When the engine operates as a motor and the valve gear is adjusted for early release of the inlet valves 6, the automatic suction valves 8 operate to prevent expansion of the air in the cylinder below atmospheric or exhaust pressure and thus avoid waste of power, and when the engine operates as a compressor both the suction and discharge valves 8 and 9 operate, as more fully explained in said Letters Patent No. 926,819.

In the operation of the apparatus, when compressed air is drawn therefrom at a greater rate than the compressor *a* which runs at an approximately constant speed, can supply, the excess is taken from the receiver *j*, and as the pressure in said receiver is slightly lowered, the water from the tank *l* flows through the pipe or conduit *m* into said receiver. It is obvious that with this arrangement it is possible to draw on the whole storage volume of the receiver *j*, which if it is made large enough, will render it possible to operate the compressor *a* at a constant speed and still supply the hoisting engine *f* and other apparatus connected with the system with whatever power they may require for their operation.

To control the operation of the compressor and prevent waste of power, the tank *l* is provided with a float *n*, which normally rests on the supports *o*, and this float, which may be in practice made in the form of a heavy raft of logs or timbers, so that it will not be sensitive to friction, but will act with considerable power when lifted by a rise of the level of the water in said tank, may control the supply of steam or other power by which the compressor is actuated or the volume of air compressed by a compressor of variable capacity, such for instance, as is shown and described in Patent No. 900,418 issued to me October 6, 1908.

In the drawing the float is shown as connected by a rope *p* passing over sheaves *q* with a lever *r* which controls the supply of steam to the compressor engine. A counterpoise *s* attached to the rope *p*, keeps it stretched taut and acts upon the lever *r* in opposition to the weight of the float *n*, which is much greater than that of the counterpoise. The float may be connected with mechanism for varying the capacity of the compressor, such as that shown in Patent 900,418 above mentioned. The connections of the float are so adjusted that when it rests in its normal position on the supports *o* it will allow the compressor to run at full capacity, but whenever the level of the water rises sufficiently to lift the float, it will reduce the speed or capacity of the compressor, thus operating as a safety device and preventing escape and loss of air pressure when the hoisting engine is shut down or the consumption of compressed air ceases for a considerable length of time.

In the operation of the apparatus disclosed and claimed in this application, after establishment of the air pressure which balances the water column, nearly the whole quantity of stored compressed air which has been delivered from the compressor, is available for use in meeting the widely varying demands of the engine *f*. In establishing and maintaining that condition substantially the same power must be used as that required to establish and maintain the average pressure in the air reservoir of the aforesaid Letters Patent No. 926,819, but in the present case the foundation pressure used immediately in the operation of the engine, is not that of an elastic fluid, but is that of a moving incompressible body, the water column in the tank *l* and conduit *m*, which, when the air pressure against which it acts falls, will occupy a corresponding space in the total space for compressed air, preventing more than a slight fall in air pressure. Therefore, variations in the use of compressed air will not materially change the pressure against which the compressor must operate, the load upon the compressor is always perfectly equalized, and any required quantity of air within the capacity of the receiver *j* can be used in the engine without material change in the pressure of air supplied.

In the apparatus of said Letters Patent No. 926,819, the volume of stored air is constant, while the pressure varies widely, whereas in the present system the pressure of the stored air is substantially constant, while the volume varies within wide limits.

In the adaptation of the apparatus to varying conditions to meet different requirements, the construction and arrangement of its component elements may be changed accordingly without affecting the principle and mode of operation of the equalizing device and without departure from the scope of the invention.

I claim:

1. In a compressed air power system the combination with a compressed air engine of an air compressor, an air receiver connected with the discharge of the compressor and having a manually controlled connection with the engine, and an open water tank located above and having a constantly open and unobstructed connection with the air receiver, said receiver and tank being so constructed, arranged and connected that a quantity of compressed air equal to the entire volume of the receiver may be drawn therefrom at an approximately constant pressure.

2. In a compressed air power system the combination with a compressed air engine of an air compressor, an air receiver connected with the discharge of the compressor and having a manually controlled connection with the engine, and an open water tank having an unobstructed and constantly open connection with said air receiver and located at such a distance above the same as is required to maintain a hydrostatic pressure approximately equal to the normal discharge pressure of the compressor.

3. In a compressed air power system, the combination of an air compressor, a compressed air engine of variable capacity connected with the compressor and capable of developing greater power than can be directly supplied by the maximum capacity of the compressor, an air receiver of large capacity connected with the compressed air supply conduit between the compressor and engine, and an open water tank having an unobstructed and constantly open connection with said receiver and located above the same at a sufficient distance to balance the normal working pressure in the system.

4. In a compressed air power system the combination of an air compressor, a compressed air engine connected with the compressor, an air expansion tank in the connection between the compressor and engine, an air receiver connected with the air conduit between the compressor and engine, and an open water tank located above and having an unobstructed and constantly open connection with said receiver.

5. In a compressed air power system the combination with a compressed air engine of an air compressor, an air receiver connected with the discharge of the compressor and with the engine, an open water tank located above and having a constantly open connection with said receiver, and a float in said tank adapted when the water rises above a certain level therein to reduce the volume of air discharged by the compressor.

6. In a compressed air power system the combination with a compressed air engine of an air compressor, an expansion tank in communication with the discharge of the compressor and connected with the compressed air driven engine, an air receiver connected with the discharge of the compressor and with the engine, and an open water tank of as great capacity as the receiver located above the same and connected with the lower part thereof by an unobstructed and constantly open conduit extending below the receiver.

7. In a compressed air power system, the combination of an air compressor, a compressed air engine, an expansion tank supplied with air from the compressor and supplying compressed air to the engine to drive the latter, an air receiver connected with the compressed air conduit between the compressor and engine to supply compressed air to the engine when the demand thereof exceeds the capacity of the compressor and expansion tank, and a hydrostatic device coöperatively connected with the air receiver to equalize the pressure therein proportionately to withdrawal of air therefrom.

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

BRUNO V. NORDBERG.

Witnesses:

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Frank E. Dennett.