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MECHANISM FOR LIQUEFYING AIR AND SEPARATING SAME INTO OXYGEN AND NITROGEN.

APPLICATION FILED NOV. 17, 1903.

978,935.

Patented Dec. 20, 1910.

2 SHEETS—SHEET 1.

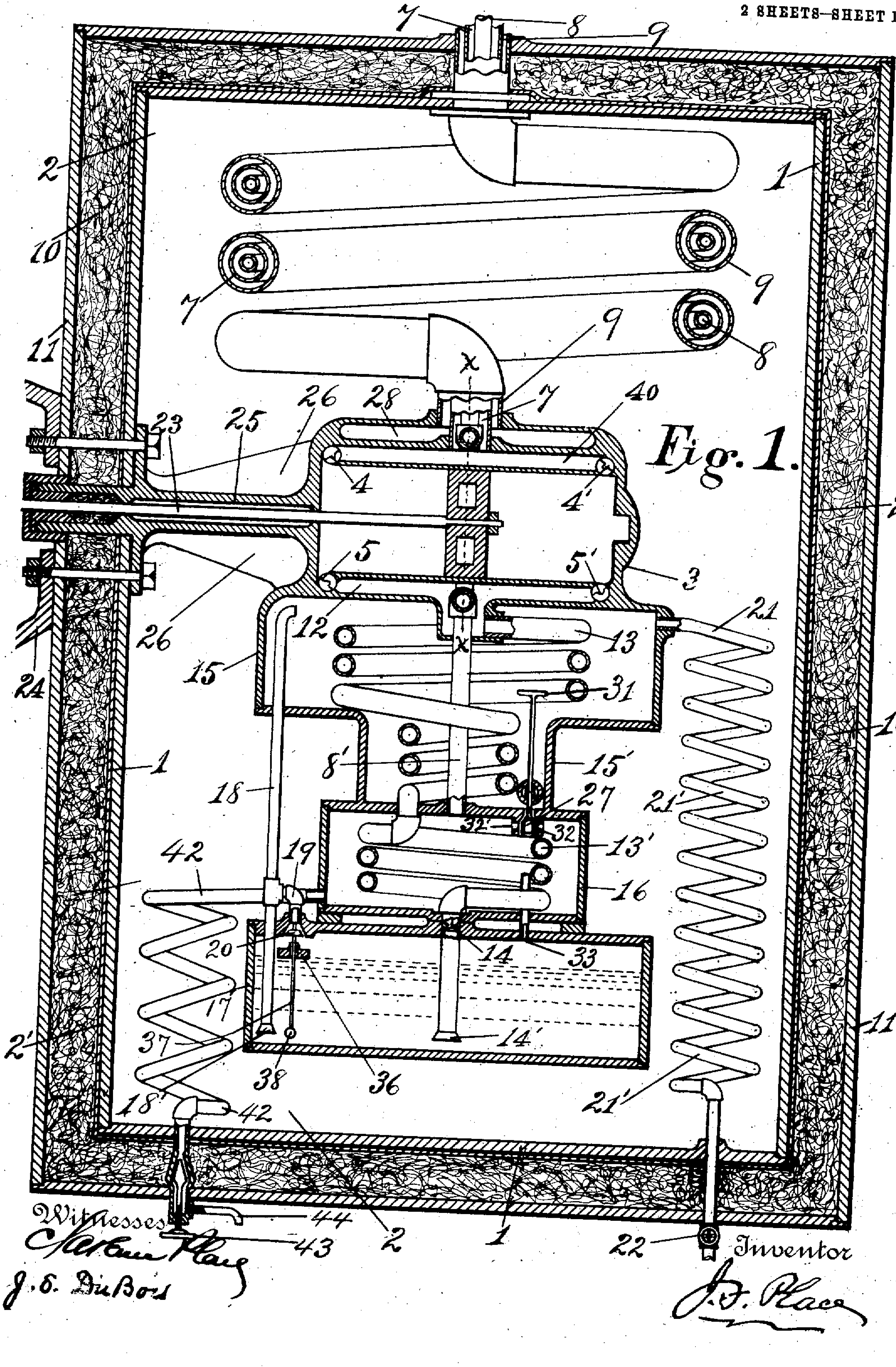

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Fig. 2.

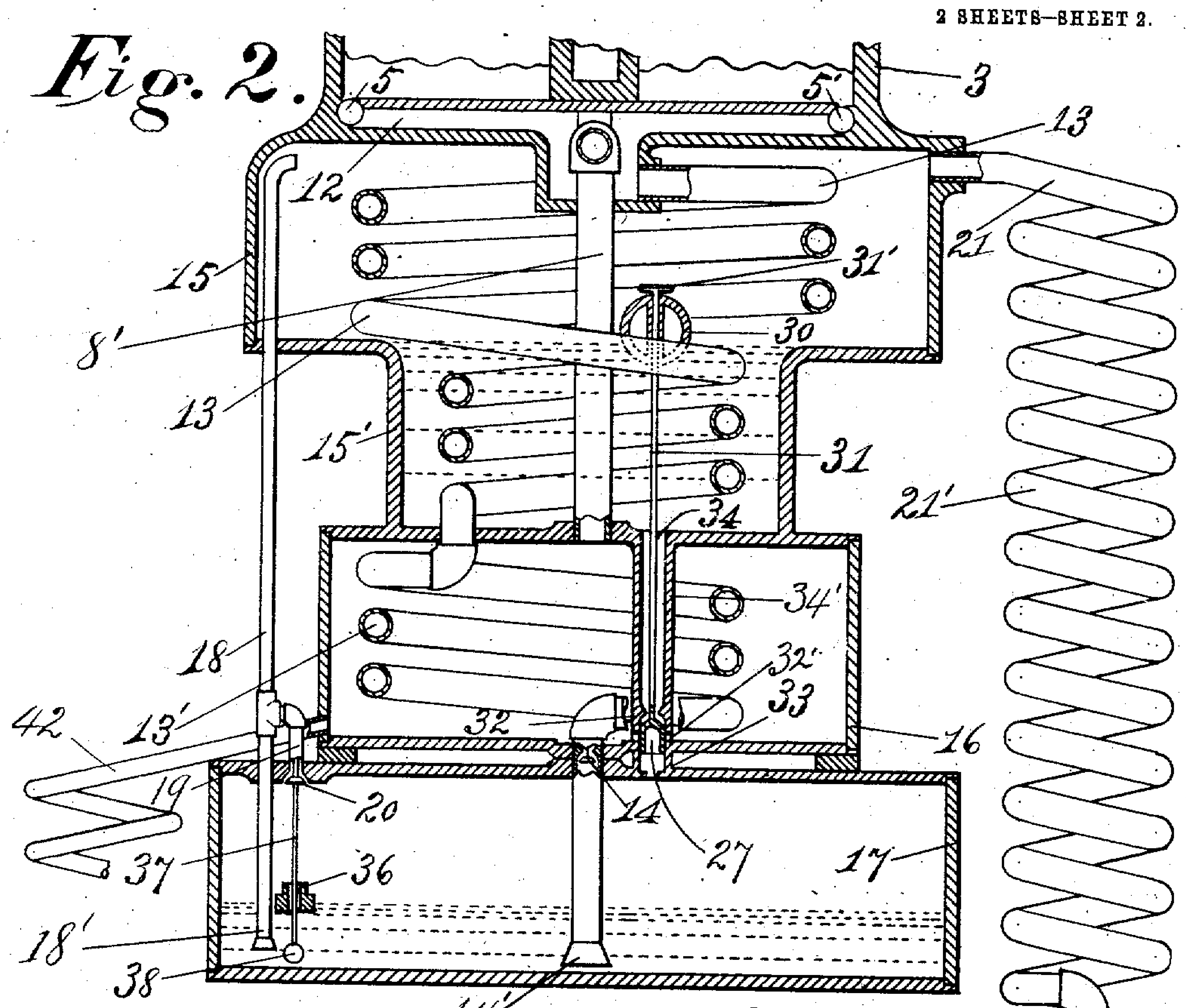
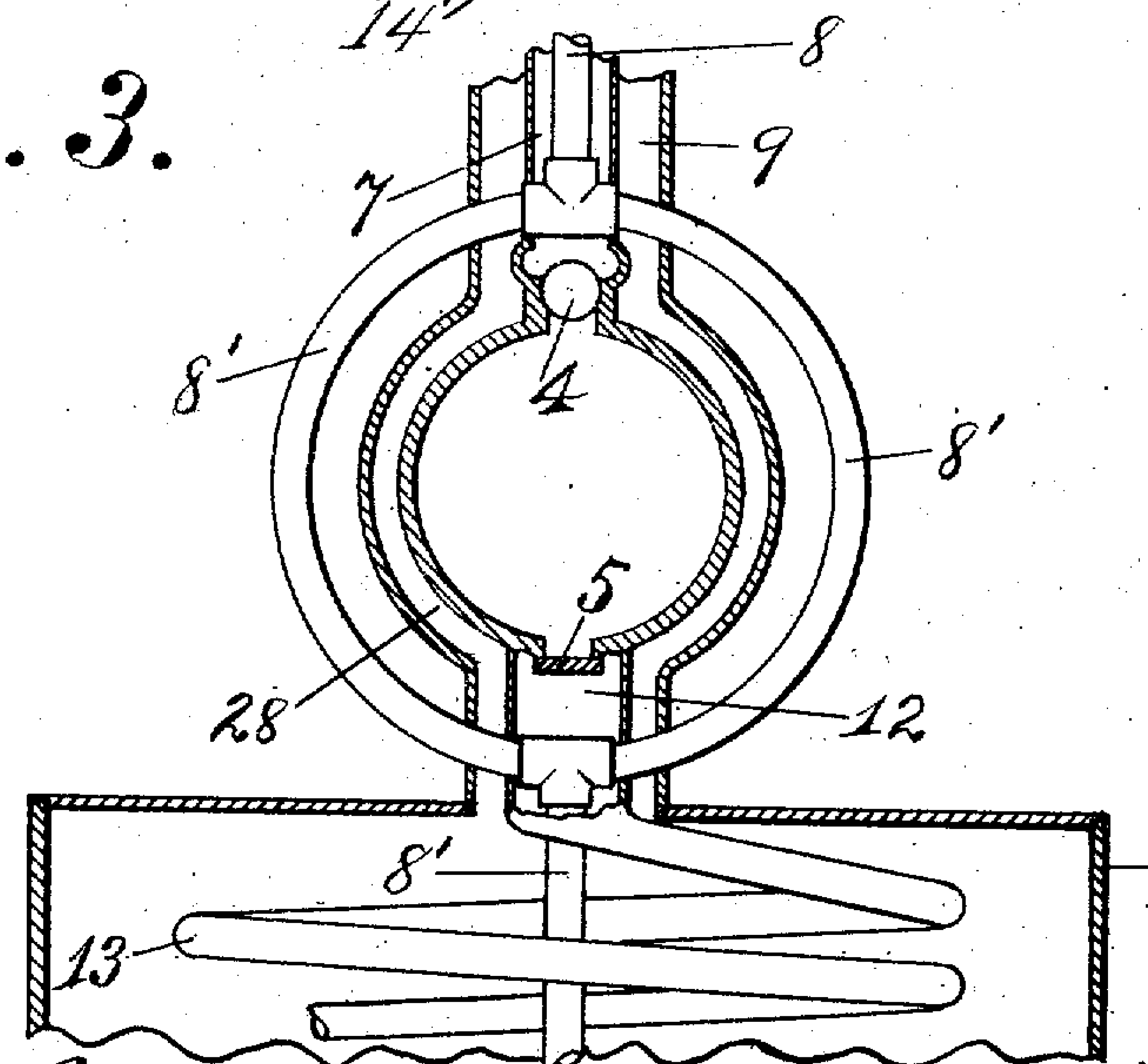


Fig. 3.



Witnesses

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MECHANISM FOR LIQUEFYING AIR AND SEPARATING SAME INTO OXYGEN AND NITROGEN.

978,935. Specification of Letters Patent. Patented Dec. 20, 1910.

Application filed November 17, 1903. Serial No. 181,498.

To all whom it may concern:

Be it known that I, JAMES F. PLACE, a citizen of the United States, and a resident of Glen Ridge, in the county of Essex and State of New Jersey, have invented certain new and useful Improvements in Mechanism for Liquefying Air and Separating Same into its Constituent Gases, Oxygen and Nitrogen, of which the following is a specification.

My invention relates to improvements in apparatus or mechanism for liquefying atmospheric air, and also for separating such liquid air into its constituent gases, oxygen and nitrogen, or commercial oxygen and commercial nitrogen.

The object of my invention is to reduce the cost of the production of liquid air, and also to reduce the cost of separating such liquid air into such commercial gases, and to make the fractional distillation, by which the separation of such commercial gases is obtained, a continuous operation.

In order that those skilled in the art may understand and make use of my invention, I will describe it by the aid of the accompanying drawings, in which,

Figure 1 is a view in vertical section of practically the complete apparatus. Fig. 2 is a view partly in vertical section, and on a larger scale, of the liquid air vaporizing vessel, in part, and of the oxygen vaporizing vessel, and liquid air reservoir, showing the automatic valves for filling the oxygen tank from the liquid air vaporizing vessel, after the nitrogen liquid has been separated from the liquid air by fractional distillation; and for automatically discharging the liquid air from the reservoir, and re-charging the liquid air vaporizing vessel. Fig. 3 is a transverse sectional view of the expansion engine cylinder on the line *x x* of Fig. 1, not showing piston.

Similar reference marks refer to similar parts throughout the several drawings.

The numeral 1 represents a suitable inclosure or case, which incloses the various parts preferably in a vacuum space 2; this is for the purpose of insulating such parts from the normal heat of the atmosphere, 2′ being an air tight covering to maintain said vacuum.

At 3 in Fig. 1, I show a reciprocating air-expansion engine. This engine should be provided with suitable cut-off valves, as at 4 and 4′, and also with suitable exhaust valves 5 and 5′,—all operated by suitable valve gear. In combination with this engine I have a counter-current heat interchanger, which comprises one high-pressure incoming conduit, or feed pipe 7 (which supplies the engine with "live" air, and which is fed from an outside compressor, or source of compressed air supply which has had the heat of compression and moisture removed therefrom by the mechanism shown in my U. S. Patent No. 711,525, or some other suitable and effective means), and two low-pressure outgoing conduits or pipes, 8 and 9, which carry outside the apparatus, one (9) the rich nitrogen and the other (8) the rich oxygen gases, which have been distilled from the liquid air in and by the apparatus as hereinafter described. The pipes or conduits comprising this interchanger, should be of considerable length and located or fixed in longitudinal juxtaposition with each other; the preferred construction is shown, one tube inside of another, and these two inclosed by a third—the whole thoroughly insulated from the heat of its environments by the vacuum space 2, and the dead air space filled with packings 10 of relatively low heat-conductivity, preferably inclosed or surrounded by the outer protecting case 11.

At 12 I show an exhaust chamber, which receives the expanded cold exhaust air from the engine as delivered from the exhaust valves 5 and 5′. The exhaust chamber is connected with and delivers to the condensing conduit or pipe 13, which is preferably in form of a helical coil and has an extension or continuation 13′, and at its delivery end is provided with a pressure-releasing or check valve 14.

At 15 I have a liquid air or nitrogen vaporizing vessel or receptacle, in which is located the helical condensing coil 13, said vaporizing vessel having preferably a downwardly projecting part 15′, of about one-fifth the size of the whole vessel; and at 16 I show an oxygen tank, or liquid oxygen vaporizing vessel; which is located preferably below the vaporizing vessel 15, and in which is located the extension helical condensing coil 13′.

At 17 is shown a liquid air reservoir, or receptacle for receiving and holding the liquid air as it condenses from the cold exhaust air in the pipes 13 or 13′ and is delivered through the valve 14. This reservoir is preferably made of somewhat larger capacity than the liquid air vaporizing vessel 15; and it is connected with the vaporizing vessel 15 by a tube 18 which tube is open at its delivery or upper end to the upper part inside of the vessel 15, so that any liquid air in the vessel 15 cannot run down the tube; and the lower end of this tube (18) is extended downwardly as shown, into the reservoir 17, at 18′ to near the bottom of said reservoir, so that no gas can pass up the tube so long as the liquid air therein is sufficient to seal or cover the lower end or mouth of the tube.

At 19 is shown a branch pipe, connecting the upper part inside the reservoir 17 with the tube 18 (outside the reservoir) through the valve 20, the operation of which will be explained farther on.

At 21 I show what I call my liquid air overflow pipe, for it serves as an outlet from the top of the liquid air vaporizing vessel 15, and allows any overflow or surplus of liquid air which may be delivered to said vaporizing vessel to pass into the pipe 21, from which it may be drawn off through the outside delivery cock 22; this overflow pipe is preferably made in form of a helical coil (21′), so as to give it considerable length, and thereby not only make it of larger holding capacity, but prevent the heat from being conducted from outside the apparatus into the vessel 15.

The piston rod 23 of the expansion engine (3) is connected with a connecting rod and crank, outside the apparatus, in the usual way, and the power of the engine may be used in helping to compress the air used in running the engine, or utilized in any other manner. The engine is fixed to the frame 24, and by the use of the long sleeve 25 around the piston rod, and of the strengthening ribs 26, the sectional area of conducting material for heat to pass in to the apparatus from its environments is reduced to the minimum. The liquid oxygen vaporizing tank 16 is connected with the liquid air vaporizing vessel 15, through the valve 27, which is operated automatically as hereinafter described. This oxygen vaporizing tank (16) has an oxygen vapor pipe 8′ which passes around the engine and is connected with and delivers, preferably, to the inner low-pressure pipe 8 of the counter-current interchanger. The liquid air distilling vessel (15) is connected with or is open to the passage 28 around the engine, preferably as shown in Figs. 1 and 3, which passage delivers to the outer low-pressure conduit 9 of the interchanger. It will thus be seen that all the cold gases or vapors distilled, from the liquid air charge in the liquid air vaporizing vessel 15, as well as all the oxygen gases or cold vapors from the liquid gas charge in the oxygen vaporizing tank 16, are passed out first around the engine, and then through the interchanger in a counter-current to the incoming compressed air supplied to the engine through the high-pressure or middle annular conduit 7 of the interchanger; in this way the normal heat of the compressed air in the supply pipe 7 is absorbed to the outgoing cold commercial nitrogen in conduit 9 and to the outgoing cold commercial oxygen in pipe 8, so that the initial temperature of the compressed air supplied to the engine is practically at the temperature of liquefaction, or so low that a considerable portion becomes liquefied as it is expanded and the heat of such expanded air is converted into work in the engine, and such liquid air is delivered to the exhaust chamber 12, and thence passes down by gravity into the coils 13 and 13′ and out through the pressure-releasing valve 14 into the reservoir 17.

Valve 27 is operated by a float 30 (Fig. 2), which slips up and down on the rod 31 fixed to the valve, but is prevented from getting off the rod by the cross bar 31′. At 32 I have a socket or casing to hold the valve 27 in place, and connected with this is the tube 33 which opens to the upper part (see Fig. 2) of the reservoir 17, so that any pressure in the reservoir 17 will act on the valve 27 and thereby close it. The float 30 will also close the opening 34, when all the liquid gas runs out of the vessel 15′; and this float will hold the valve closed by pressure against the cross bar 31′, whenever the liquid in the vessel 15 is at or above this cross bar.

In the preferred location of valve 27 as shown in Fig. 2 the opening 34 is connected through pipe 34′ and the ports 32′ with the oxygen vessel 16. In this way when the valve 27 drops by gravity the tube 34′ and vessel 16 are connected through the open ports 32′; and any liquid in the vessel 16 seals the ports 32′ so that the vapor therefrom or vaporized liquid rich in oxygen, cannot pass into the vessel 15′ through the tube 34′ but must pass up into the pipe 8′. The valve 20 in the reservoir 17 is also automatically operated; whenever the reservoir (17) is full of liquid, the float 36 which slides up and down on the valve rod 37, presses the valve to its seat; this causes a pressure to generate in the reservoir, and the valve (20) is held to its seat until all the liquid is forced up through the pipes 18′ and 18. As the liquid air level falls in the reservoir the float (36) falls also, and when practically all the liquid is out, the float (36) engages the lug 38, and pulls the valve open; its own weight keeps it open while the reservoir is being filled.

I am aware that attempts have been made to separate atmospheric air into its constituent gases; but such attempts have been usually confined to partially separating one gas from the other gas, while both are in the gaseous state, or else partially separating the gases during a continuous distillation and a continuous condensation—the vaporization of nitrogen and of oxygen going on both at the same time. In my apparatus, as preferably constructed, separate and successive charges of liquid air are distilled, separately, distinct as to time and quantity; and when the nitrogen of each charge is nearly distilled, the remaining liquid (which is practically liquid oxygen) of such charge is entirely removed or delivered by itself automatically into another and separate distilling receptacle, where it is vaporized by itself and the nearly pure oxygen gas therefrom (or what is known as commercial oxygen), is conducted into a separate conduit. The vaporization of the nitrogen from the liquid air charge in the first instance, and of the liquid oxygen or remainder of the charge in the second instance, are both effected by utilizing the latent heat of condensation of expanded air (but air at a higher pressure than the liquid charges) in a submerged condensing conduit or surface condenser, and causing such heat to be taken up as the latent heat of vaporization of the liquid air or liquid oxygen charges successively, thereby subjecting these liquid charges successively to fractional distillation. The heat of the incoming compressed air is absorbed by the outgoing cold vapors (both nitrogen and oxygen) by the well-known Siemens heat interchanger, in this case such interchanger being made with one incoming high-pressure pipe and two low-pressure outgoing pipes.

Ordinarily an initial charge of liquid air may be provided in the distilling vessel 15, by passing it through the conduit 9; by use of the expansion engine, however, the apparatus may be made to produce its own initial charges of liquid air, and also to counteract any losses which may result from imperfect insulation, and to recover a good part of the power required to compress the air used. This engine is practically an air-liquefying engine, for I locate it between the interchanger and the liquid air vaporizing vessel (15), so that the engine takes the compressed air from the interchanger and exhausts into the condenser or submerged condensing conduit, which is located in or passes through both the successive liquid air charges in the liquid air vaporizing vessel (15) and the successive liquid oxygen charges in the liquid oxygen vaporizing receptacle (16). In this way the compressed air in the high-pressure conduit of the interchanger is practically cooled to the liquefying point before being expanded and made to do work in the engine, which feature insures liquefaction of the maximum amount in the engine; and the loss of heat converted into work cools the unliquefied remainder to the point of liquefaction before being subjected to the cooling action of the liquid charges.

In this class of machines for the separation of the gases by fractional distillation, any heat received by the liquid air or liquid oxygen charges from any other source than the latent heat of condensation of the compressed air supplied to the apparatus will cause a gradual diminution in quantity of the liquid air charge, and a "running down" of the machine. Cooling the compressed air before it enters the interchanger, as has been attempted in some cases, will not prevent this; but liquefaction of a portion of the compressed air, by conversion of its heat into external work by the engine, is a clear gain, and will effectually counteract such a result. In fact, the operation, with my apparatus as herein shown, will be continuous, and with ordinarily good insulation from outside heat a surplus of the liquid air will be produced over and above the amount evaporated in the vaporizing vessels. Provision is made, as will be noticed, for withdrawing from the system such surplus as produced, so that a uniform charge will at all times be delivered to the vaporizing vessel (15), and thus successively uniform charges of liquid oxygen will be delivered to the oxygen vaporizing tank (16) during the operation.

The operation of the apparatus is as follows: Compressed air from some outside source from which the moisture and the heat of compression have been removed, is supplied to the annular conduit (7) outside the apparatus (see Fig. 1). This passes down through the heat interchanger to the cut-off valve chamber (40) of the engine and is delivered to the engine through the cut-off valves 4 and 4′, and starts the engine, which is made to do some outside work; as the air is expanded in the engine, its temperature falls according to the amount of work done, and is then delivered from the exhaust chamber 12 to the condenser 13 and 13′, and passes thence to the reservoir 17 through the valve 14, which is set to open at a trifle less pressure than that of the exhaust or expanded air from the engine; thence it passes through the valve 20, and pipe 18 to the liquid air vaporizing vessel 15 and into the passage 28 around the engine, which connects with the outgoing outer conduit 9 of the interchanger. This expanded air being about 200 degrees colder than the first intake of incoming compressed air in the conduit 7, quickly absorbs the heat from such compressed air, so that the next following charges delivered to the engine are soon so cold that the temperature of the expanded charges in the engine fall below the condensation point, and are partially liquefied. This liquefied air drops by gravity from the exhaust chamber (12) down through the condensing conduits, 13, 13′, and passes through the pressure-releasing valve 14 with the expanded exhaust air which has not become liquefied, into the reservoir 17. As the engine continues to run, this reservoir (17) becomes filled with liquid air, and when it is full the float 36 engages the valve 20 and closes it; pressure quickly generates in the top of the reservoir 17 by vaporization of the liquid air and by passage of vapor through the pipe 14′ from the release valve 14, which pressure holds the vent valve 20 tightly to its seat, while the liquid air charge is forced up the siphon tube 18′ and 18 into the liquid air vaporizing vessel 15. The float 36 falls with the level of the liquid, and presses the lug 38, and pulls open the vent valve 20, when the pressure is released by passage of the vapor through valve 20 into vessel 15. The condensing conduit 13 being now surrounded by or submerged in the liquid air charge, the latent heat of the unliquefied but cold expanded exhaust air in the condenser (being under a suitable terminal pressure), is absorbed by and produces fractional distillation of the liquid air charge in vessel 15, and said exhaust expanded air in pipe 13 becomes totally liquefied. As the liquid air charge becomes vaporized, the nitrogen evaporates first and passes off through the passage 28, Fig. 3 (thus cooling and insulating the engine cylinder) into the outer interchanger conduit (9), and when about four-fifths of the charge has thus vaporized, or most of the nitrogen has evaporated, the float 30, Fig. 2, falls away from the cross-bar 31 and the valve 27 (being released from any pressure in the tube 33) falls down by gravity in the socket or case 32, and the whole remainder of the charge (now commercial liquid oxygen) in the vessel 15 runs down into the liquid oxygen vaporizing receptacle 16—the opening 34 then being closed by the float 30. The engine continuing to run, the cold exhaust air under the terminal pressure in the condensing conduit 13, unliquefied, now passes into the submerged coil 13′, and gives up its latent heat of condensation to the liquid oxygen, which becoming vaporized passes off up through the pipe 8′ into the outgoing pipe 8 of the interchanger; the liquid air vaporizing vessel 15 is then recharged from the reservoir 17, and the operation is repeated automatically—the commercial oxygen gas being collected from pipe 8, outside, and the nitrogen from pipe 9, outside.

By my apparatus a very large portion of the heat of the compressed air used for liquefaction and separation disappears altogether by being transformed into work outside the apparatus; and thus there is that much less heat to be absorbed by the cold vapors derived from the charges of liquid being vaporized or distilled. Besides, a considerable portion of the air is liquefied in the engine by reason of its latent heat being converted into work, and all of the expanded exhaust air from the engine is cooled to the point of liquefaction, so that as it is subjected to the direct cooling action of the liquid charges there remains only the latent heat to be absorbed or taken up in order to produce total liquefaction. Thus the fractional distillation of the liquid charges is produced by the latent heat only derived from the cold expanded exhaust air, and this expanded air being at all times less in amount than the liquid charges to be vaporized if the insulation from outside heat is perfect, there will be a constant accumulation of the liquid charges equivalent to the amount liquefied in the engine.

By regulating or adjusting the cut-off valve-gear of the engine, an earlier or later cut-off may be given, and thus a higher or lower terminal pressure of the exhaust expanded air delivered to the condenser be obtained; in this way also a greater or less amount of the expanding charges may be liquefied in the engine, and delivered with the unliquefied expanded air to the condenser. The compression of the air used in the engine and the adjustment of the cut-off should be such as to insure a suitable terminal pressure and the required amount of condensation in the engine cylinder.

At 42 I have a discharge pipe from the oxygen vessel 16, by which through the valve 43 the liquid oxygen, or liquid rich in oxygen, can be drawn off if desired before it is allowed to vaporize; or the valve 43 may be set so that as fast as the liquid is dumped into vessel 16 from the residue in vessel 15′ by the automatic valve 27, it may be collected from the outside pipe 44 in any suitable insulated receptacle, such for instance as that shown in my U. S. Patent 707,634. In this way the liquid commercial oxygen may be put into air tight tanks, or drums, and as it absorbs heat and becomes of the temperature of its environments, it will vaporize into oxygen gas under pressure.

By regulating the cut-off valve gear of the expansion engine 3, the temperature and pressure of the exhaust products delivered to the chamber 12 and condensing conduits 13 and 13′, may be so regulated that partial or fractional condensation may be secured of the expanded air therein as delivered to the vessel 17 through valve 14 (see Fig. 2)—especially when the liquid commercial oxygen is drawn from the vessel 16 through pipe 42 and the valve 43, instead of being vaporized in said vessel and passed out through pipe 8′ and the interchanger as oxygen gas. In this way a liquid rich in oxygen may be delivered to reservoir 17 instead of liquid air, all the time; and naturally, after vaporization in vessel 15 of a portion of the charge therein, a liquid richer in oxygen will be left as the residue, in vessel 15′, and delivered to the tank 16, and either vaporized therein or drawn off if desired through pipe 42 and valve 43.

By providing the apparatus with an initial charge of liquid air, then a much lower pressure may be used in the engine, or only sufficient to make up for losses due to imperfect insulation.

Wherever the term "commercial oxygen" or "commercial nitrogen" is used herein or in the claims, it means and comprehends in either case a gas having oxygen or nitrogen in greater percentage or proportion than found in the atmosphere at normal condition.

I do not confine myself to the particular construction shown of either the interchanger or the case, nor of the vaporizing vessels and reservoir, nor of the expansion engine and its parts, nor of the condensing conduit or condenser, nor as to the automatic devices and other parts. All such parts should be of such suitable material and such suitable construction, so as to best serve the requirements in order to secure the results sought to be obtained as herein set forth.

I am aware that the separation of air into its constituents nitrogen and oxygen by the fractional distillation of liquid air, is not new; and I am also aware that the liquefaction of air by expanding the same against resistance in an air engine, and cooling the incoming supply fed to the engine by the exhaust therefrom, is in theory not new. But the cooling of compressed air supplied to an engine, by the products of distillation of liquid air, and the liquefaction of the expanded exhaust air from an engine by causing heat to pass therefrom to liquid air—or the evaporation of liquid air by heat derived from the expanded exhaust air of higher pressure from an engine—are I believe new and original with me; and, therefore, such devices and mechanism as herein shown, or any similar devices for utilizing these novel functions herein described, are new and original with me. I am also aware that the distillation of separate charges of liquid air intermittently, is not new in theory; but the distillation intermittently of separate charges of liquid air by the devices and in the manner and for the purposes herein shown, is new; and the distillation of said separate charges of liquid air intermittently and automatically is new. And the evaporation of the residue of separate charges of liquid air, after partial fractional distillation, or the evaporation of liquid oxygen, or substantially liquid oxygen, by heat derived from cooled compressed air, about to be liquefied, is new; and especially is it new and original with me to evaporate separate and intermittent charges of either liquid air, or liquid nitrogen or liquid oxygen, by heat derived from the expanded air of higher pressure exhausted from an air expansion engine—which is supplied with and operated by compressed air cooled before expansion in said engine by the cold gaseous products of said evaporation. So also, so far as I know, it is new and original with me, to arrange devices to draw off and utilize for purposes outside the apparatus, the surplus liquid air produced therein, and the surplus liquid oxygen, or products of distillation of liquid air, therefrom, while in liquid form. Therefore the devices and combinations herein shown and described produce valuable results not heretofore attained, and are new and useful improvements.

Having thus described my invention what I claim as new and original and desire to secure by Letters Patent, is:—

1. The combination of an air-liquefying reciprocating expansion engine with a liquid-air vaporizing vessel, means for automatically supplying said vessel with intermittent charges of liquid air, and means for liquefying the exhaust air from said engine by the fractional distillation of said automatically delivered intermittent charges of liquid air in said vessel; and a receiver for said liquefied exhaust air, arranged to maintain said exhaust air in heat-interchanging relation with the intermittent charges of liquid air.

2. The combination of an air-liquefying reciprocating expansion engine with a liquid-air vaporizing vessel, means for automatically supplying said vessel with intermittent charges of liquid air and for liquefying the exhaust air from said engine by the fractional distillation of said automatically delivered intermittent liquid-air charges; a receiver for the liquefied air arranged to maintain said exhaust air in heat-interchanging relation with the intermittent charges of liquefied air, and means for cooling the compressed air supplied to said engine by the products of said distillation.

3. In an apparatus for liquefying air and separating the same, the combination of a liquid-air evaporating vessel, with a reciprocating air-expanding engine, having an exhaust conduit within said evaporating vessel and means for automatically supplying said vessel with intermittent charges of liquid air of less pressure than the expanded air in said exhaust conduit.

4. In an apparatus for liquefying air and separating the same into its constituent

gases, the combination of a liquid-air evaporating vessel with a reciprocating air-expanding engine having an exhaust conduit within said evaporating vessel, and means for automatically supplying said vessel with intermittent charges of liquid air previously liquefied as aforesaid in said exhaust conduit.

5. The combination of a low-pressure liquid-air evaporating vessel, with a reciprocating air-expanding engine, means for automatically evaporating by fractional distillation intermittent charges of low-pressure liquid air in said vessel by heat derived from the exhaust air of higher pressure from said engine during the process of liquefaction thereof, and means for automatically delivering intermittent charges to said vessel of low-pressure liquid air previously liquefied as the exhaust air from said engine as aforesaid.

Signed at New York, in the county of New York and State of New York, this 16th day of May A. D. 1903.

JAMES F. PLACE.

Witnesses:
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J. E. DU BOIS.