J. F. PLACE.

APPARATUS FOR LIQUEFYING AND SEPARATING ATMOSPHERIC AIR.

APPLICATION FILED FEB. 18, 1909.

1,123,588.

Patented Jan. 5, 1915.

2 SHEETS—SHEET 1.

Fig. 1.

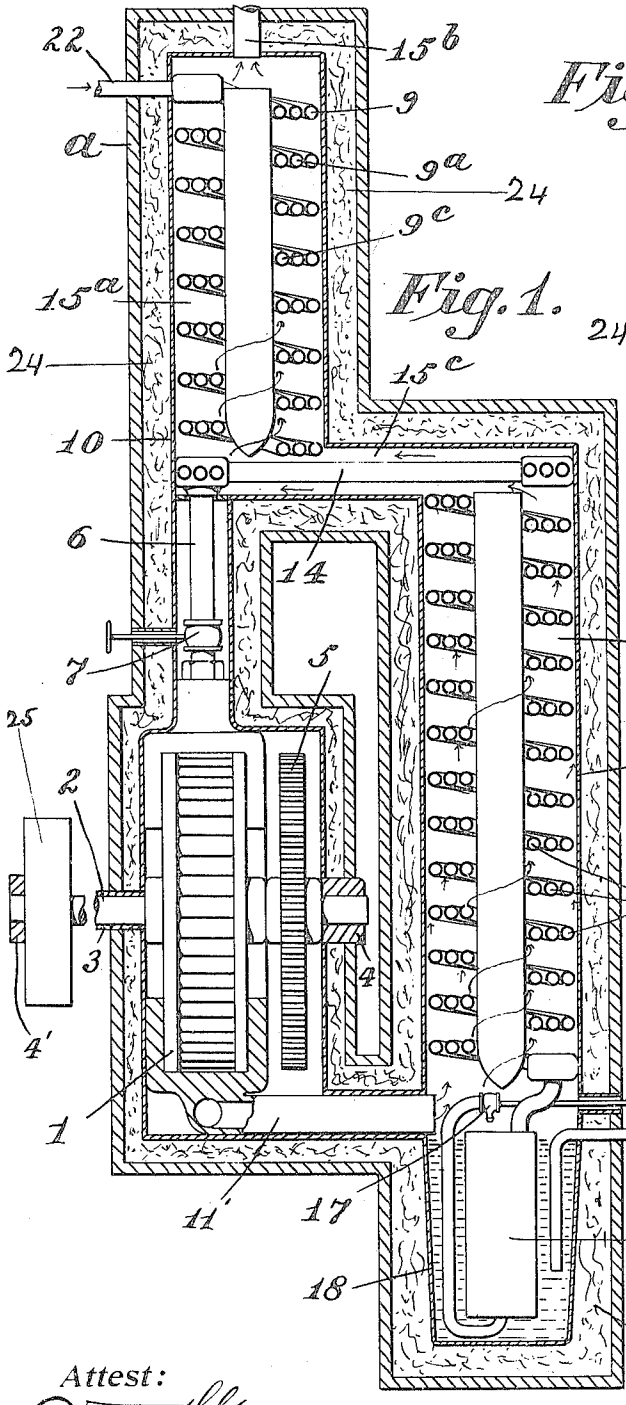
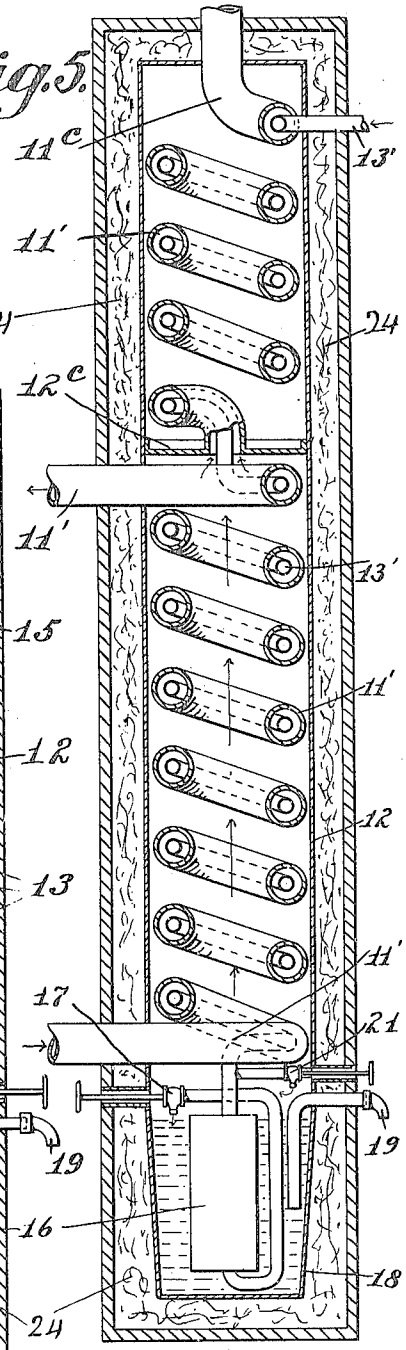


Fig. 5.



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2 SHEETS—SHEET 2.

Fig. 2.

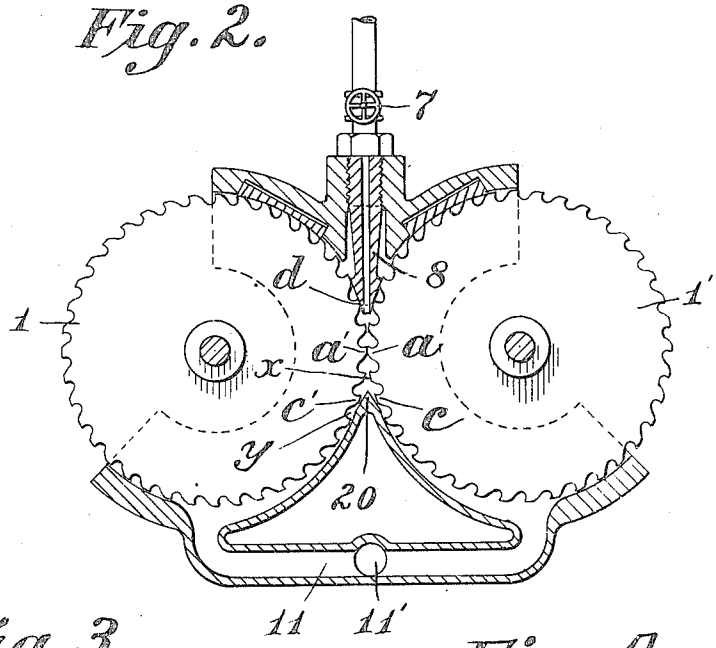


Fig. 3.

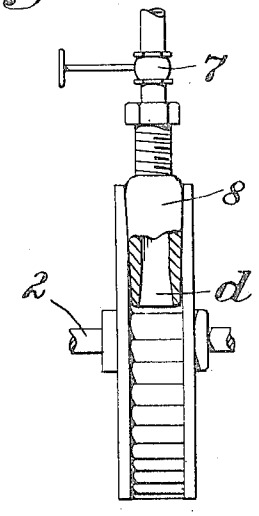
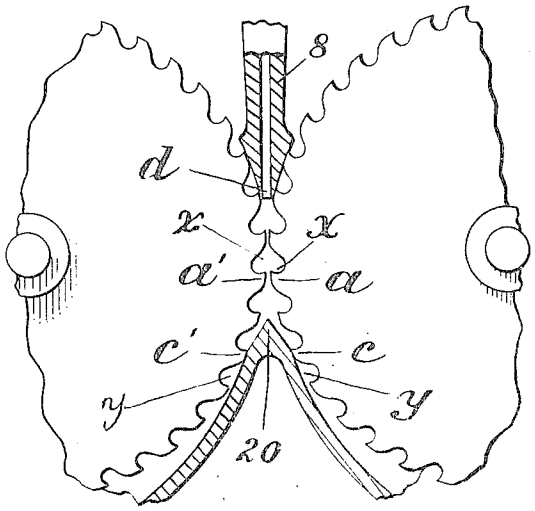


Fig. 4.



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UNITED STATES PATENT OFFICE.

JAMES F. PLACE, OF GLEN RIDGE, NEW JERSEY, ASSIGNOR TO AMERICAN AIR-LIQUEFYING COMPANY, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

APPARATUS FOR LIQUEFYING AND SEPARATING ATMOSPHERIC AIR.

1,123,588. Specification of Letters Patent. Patented Jan. 5, 1915.

Application filed February 18, 1909. Serial No. 478,736.

To all whom it may concern:

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

This invention relates to improvements in mechanism or apparatus for liquefying atmospheric air. It is equally as applicable to liquefying any other gases or gaseous mixtures; and in the case of air or other gaseous mixtures, may also be made to act as a partial separator of such mixtures.

The object of the invention is to simplify the process of air-liquefaction, and thereby lessen the cost of liquid air so that it and its constituent gases, oxygen and nitrogen, may be used commercially in the arts and industries. This object is attained in the manner and by the mechanism hereinafter described, reference being had to the accompanying drawings, in which—

Figure 1 is a general view, partly in vertical section, showing an end view of my improved impact air engine, or turbine, with the outside condenser or air-liquefying coils and sub-cooling liquid-air receiver, and in vertical section the thermal interchanger for cooling the compressed air supplied to both the turbine engine and the constant pressure liquefier, by the cold expanded air delivered from the turbine. Fig. 2 is a side view of my improved double air turbine, showing in vertical section the air nozzle and improved intermittent pressure-releasing turbine buckets, by which both the impact and expansion against external resistance of the compressed air, are utilized. Fig. 3 is a transverse view of the nozzle, partly in section, with an end view of the turbine, showing buckets. Fig. 4 is a side view of the turbine on a larger scale, with one of the outer plates and case removed—the buckets being shown in a slightly advanced position from that shown in Fig. 2. Fig. 5 shows a modification or a view in vertical section of the condenser or liquefier part of the apparatus when used as a combined air-liquefier and partial separator into nitrogen gas and oxygen liquid, of the air treated in same.

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

In Fig. 1 at 1 I show an end view of my improved air expanding turbine, showing at 2 the shaft inclosed in the insulating sleeve 3, supported in the bearings 4 and 4′. At 5 is shown the spur gear, by which the two parts or bucket wheels 1 and 1′ (see Fig. 2) are connected together. At 6 the compressed air nozzle feed pipe is shown, which supplies compressed air, through the throttle 7, to the nozzle 8, which delivers the same to the turbine buckets *a* and *a′*. (See Figs. 2 and 4.) The compressed air thus delivered to the turbine, comes from the high-pressure conduit, 9, 9^a and 9^c of the thermal interchanger 10. The air after expansion in passing over the turbine is delivered to the expanded air conduit 11, from whence it is delivered to the condenser 12. This air-liquefying condenser (12) consists preferably of the high-pressure liquefying triple coils 13, which are supplied with cooled compressed air by the transverse pipe 14, from the interchanger high pressure coils 9, 9^a and 9^c. By this preferred construction, a low-pressure helical passage 15 is formed in the condenser 12, which continues through the interchanger at 15^a, the two passages being connected by the horizontal passage or conduit 15^c. There is preferably a slight space allowed between the different helical coils 13, for passage of cold expanded air up through these coils, the same as shown between the coils 9, 9^a and 9^c. The coils 13 of condenser 12 may be designated as an outside still-air liquefier, for all of the air which enters the same through the pipe 14, is liquefied in the triple coil 13 without reduction of pressure, and falls by gravity into the submerged receiver 16. From here it is released by opening the liquid-releasing valve 17, and is delivered at substantially atmospheric pressure to the insulated low-pressure liquid-air holder 18. As the holder (18) becomes full, the liquid is delivered outside through the siphon spout 19. As the liquid air in the receiver 16 is released from a pressure of about 600 lbs. to the square inch, through valve 17, more or less of this liquid vaporizes as released, or such a percentage thereof as required, in order (by taking its latent heat of vaporization from the remaining liquid released) to lower its temperature from −220° F. (the temperature of liquefaction in the coils 13 and reservoir 16) to its boiling point −313° F. of

the liquid at substantially atmospheric pressure in the reservoir 18. After the holder 18 is filled with liquid air, then the temperature of such liquid will remain constant at about —313° F.; naturally, the receiver 16 being submerged in the liquid air in the holder 18, such liquid will absorb heat from the newly produced liquid air in the receiver 16, which, boiling at or above its critical pressure therein, has liquefied in the coils 13 at its critical temperature —220°. The liquid air in 16 will, therefore, become sub-cooled to the temperature of the released liquid air in the holder 18, or to —313°, so that when this newly produced and sub-cooled liquid air is released by valve 17, to substantially atmospheric pressure and delivered to the holder 18, there will be practically no evaporation thereof.

All of the liquid air in holder 18 which does evaporate in sub-cooling the successive charges or the continuous supply of newly produced liquid air in the receiver 16, is utilized; for this cold vapor is conducted up through the passages 15, 15^c and 15^a, and helps to cool and liquefy the compressed air in the coils 9, 14 and 13, which air is maintained at a constant pressure at about its critical pressure, consequently it liquefies at —220°, and without giving out any latent heat of condensation.

In the liquefaction of air, as commonly produced, by what is known as the throttled-nozzle regenerative method, the results obtained are due to what is called the "Joule-Thomson effect," the familiar equation being

$$\frac{P-P'}{4}\ \frac{(289)^2}{T.}=$$

the fall in temperature in centigrade degrees; wherein T represents the absolute temperature of the compressed air before delivery to the nozzle, P the absolute pressure before expansion, or delivery to the nozzle, and P' the absolute pressure after expansion or delivery of the air from the nozzle. In this method, the frictional heat caused by the flow of air under great pressure through the throttled nozzle, nearly neutralizes the refrigerative effect of expansion; that frictional heat furnishes nearly all of the heat required for expansion of the air, which accounts for the small fall in temperature, shown in the equation.

The method shown in my U. S. Patent 895,192 is based on a different principle, that of conversion of heat of the compressed air into external work, by expansion in an air-expanding engine.

The method herein employed is partially a combination of both the above processes; the compressed air passes through the nozzle 8, but the friction and consequent generation of frictional heat, is practically eliminated, as the buckets *a* and *a'* intermittently oppose the flow of the column of air, and take the pressure thereof, so that the air is practically expanded against external resistance—the revolving buckets *a* and *a'* acting as a throttle without friction to the column of air during expansion. The fall in temperature of the air during expansion should, therefore, be augmented over and above the "Joule-Thomson effect," by a refrigerative effect equal to the external work done by the turbine.

It will be noticed that when the buckets *a* and *a'* are in the position shown in Fig. 2 the passage *x* for the air from the nozzle to the expanded-air conduit 11, is closed; and the buckets *c* and *c'* are in such position as to the spreader edge 20, that the passage *y* to the conduit 11 is open. But as the buckets move downward, when in the position shown in Fig. 4, the passage *x* aforesaid is open, and the passage *y* between the buckets *c* and *c'* and the projecting edge 20 is practically closed.

In the operation of the turbine, there is momentarily and intermittently successive points of time when the passages *x* and *y* are both open from the nozzle to the expanded-air conduit 11, thus insuring a continuous operation of the turbine.

In Fig. 5, I show a modification of the coils in condenser 12. The expanded air conduit is shown at 11'. This expanded air conduit in the drum 12 incloses the compressed air pipe 13' up to the top 12^c of the condenser drum 12; there it passes into and connects with the horizontal passage 15^c shown in Fig. 1. The vapor from the evaporating low-pressure liquid air in the holder 18 passes up through the center of the coils of the conduit 11' in the drum 12 into the conduit 11^c. In this way, compressed air from either the same or a different source may be admitted to the feed pipe 13' (Fig. 5) which passes down inclosed in conduit 11^c into and inclosed by the coils of conduit 11', and be delivered after liquefaction to the receiver 16. In this way by careful regulation of the temperature of the expanded air in conduit 11', partial liquefaction will take place in the coil 13'. The unliquefied portion may be released from valve 21, and passes up through the drum 12 (Fig. 5), thus being utilized, with the nitrogen vapor from the liquid at low pressure in holder 18, to help cool the incoming compressed air supplied to coils 13'. The gas which evaporates in the holder 18 is rich in nitrogen leaving the liquid in said holder rich in oxygen so that the liquid as drawn from the spout 19 is very largely liquid oxygen. Correspondingly, the gas delivered from the outlet 11^c of the low-pressure conduit 11' will be nearly all nitrogen gas. There is a further advantage in this construction of the apparatus when used for

producing oxygen liquid and nitrogen gas, that the compressed air admitted to the pipe 22 (Fig. 1) and used in the turbine may be used over and over in a closed circuit, the expanded air from the outlet 15^b being delivered direct to the compressor again; thus the expense of continuously drying this air will be avoided.

The system is supplied with compressed air, (which has been subjected to the usual process of drying) through pipes 22, or 13′ when the form of construction shown in Fig. 5 is used; and the turbine is made to do work by a belt from the wheel 25. The parts are insulated against circumambient heat by the packings 24.

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

1. An apparatus for liquefying atmospheric air, comprising a nozzle and pipe for supplying compressed air thereto and a turbine air-engine, in combination with a constant-pressure outside liquefier, having a liquid-air discharging valve, and a gas adjustable escape valve; and means for conducting the cold expanded air from said turbine engine successively, first over said liquefier, and then over said pipe for supplying compressed air to said nozzle.

2. In an apparatus of the character described, the combination of a conduit for the passage of air compressed to or above its critical pressure, a rotary engine or air expanding turbine, a throttled nozzle valve connected with said conduit and delivering air to said rotary engine or air-expanding turbine, a constant pressure air liquefier having connection with said conduit, a release valve connected to said liquefier near its lower end, a constant high pressure liquefied gas receiver having a pressure releasing discharge valve, and means whereby said receiver may be submerged in the gas liquefied therein and discharged therefrom.

3. In an apparatus of the character described, the combination of a constant pressure liquefier, a rotary engine or air expanding turbine, a conduit for the passage of air compressed to or above its critical pressure, a throttled nozzle valve connected with said conduit and delivering a portion of the compressed air from said conduit to said rotary engine or air expanding turbine, and means for delivering the remaining portion of said compressed air to said liquefier.

4. In an apparatus of the character described, the combination of a constant pressure liquefier, a rotary engine or air expanding turbine, a conduit for the passage of air compressed to or above its critical pressure, a throttled nozzle valve connected with said conduit and delivering a portion of the compressed air from said conduit to said rotary engine or air expanding turbine, means for delivering the remaining portion of said compressed air to said liquefier where it is partially condensed, and means for releasing the uncondensed portion therefrom.

5. In an apparatus of the character described, the combination of a constant pressure liquefier, a rotary engine or air expanding turbine, a conduit for the passage of air compressed to or above its critical pressure, a throttled nozzle valve connected with said conduit and delivering a portion of the air from said conduit to said valve, means for delivering the remaining portion thereof from said conduit to said liquefier, means for partially liquefying the air in said liquefier, means for releasing from pressure the unliquefied portion of the air and thereby expanding the same, and means for utilizing the cold expanded air from said rotary engine or air expanding turbine and the cold expanded gases released from the liquefier to cool the incoming compressed air which is being supplied to the said rotary engine and to the said liquefier.

6. In an apparatus of the character described, the combination of a constant-pressure liquefier, a rotary engine or air expanding turbine, a conduit for the passage or air compressed to or above its critical pressure, a throttled nozzle valve connected with said conduit and delivering a portion of the air from said conduit to said rotary engine or air expanding turbine, means for delivering the remaining portion of said air to said liquefier where it is partially liquefied, means for releasing from pressure the unliquefied portion of said air and thereby causing an expansion of the same, and means for utilizing the cold expanded air from said turbine and the cold expanded unliquefied air from said liquefier to successively cool the air in the said liquefier and that supplied to the said rotary engine or air expanding turbine.

7. In an apparatus of the character described, the combination of a constant pressure air liquefier, a rotary engine or air expanding turbine, a conduit for the passage of air compressed to or above its critical pressure, a throttled nozzle valve connected with said conduit and delivering a portion of said compressed air to said rotary engine or air expanding turbine, means for delivering the remaining portion of the said compressed air from said turbine to said liquefier, means for subjecting the compressed air delivered to said liquefier to partial condensation, means for separating the liquid thus obtained from the remaining unliquefied air in the said liquefier, and means for releasing the said liquid from pressure and causing fractional distillation thereof.

8. In an apparatus of the character described, the combination of a counter-current thermal interchanger, including the conduit for the passage of air compressed to or above its critical pressure, means for cooling the air in said conduit, an air-expanding rotary engine, a throttle valve connected with the said conduit and delivering a portion of the air therein to said engine, a counter-current liquefier for liquefying a portion of the air which is supplied under a high pressure liquid gas receiver below said liquefier and connected thereto, the said receiver having a valve for releasing the liquefied air therefrom, the inlet to said valve being located inside of the said repressure thereto, the said liquefier having near its lower end a valve for releasing the unliquefied gaseous portion of the said air,

JAMES F. PLACE.

Witnesses:
JOHN S. SCHANTZ,
JAMES W. ANDERSON.