R. MEWES.

APPARATUS FOR LIQUEFYING AND SEPARATING GASES.

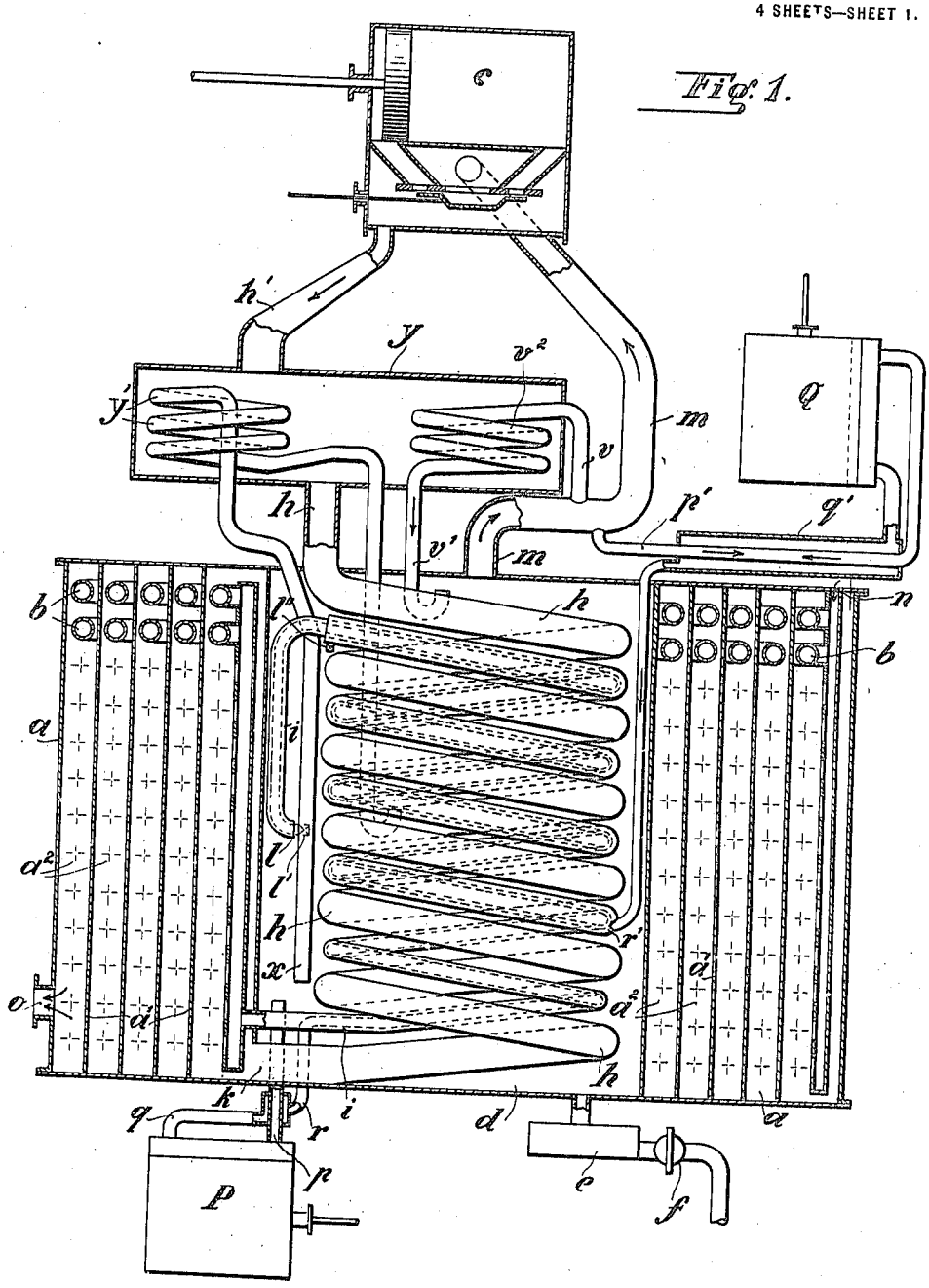
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1,215,957.

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4 SHEETS—SHEET 1.

Fig. 1.



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4 SHEETS—SHEET 2.

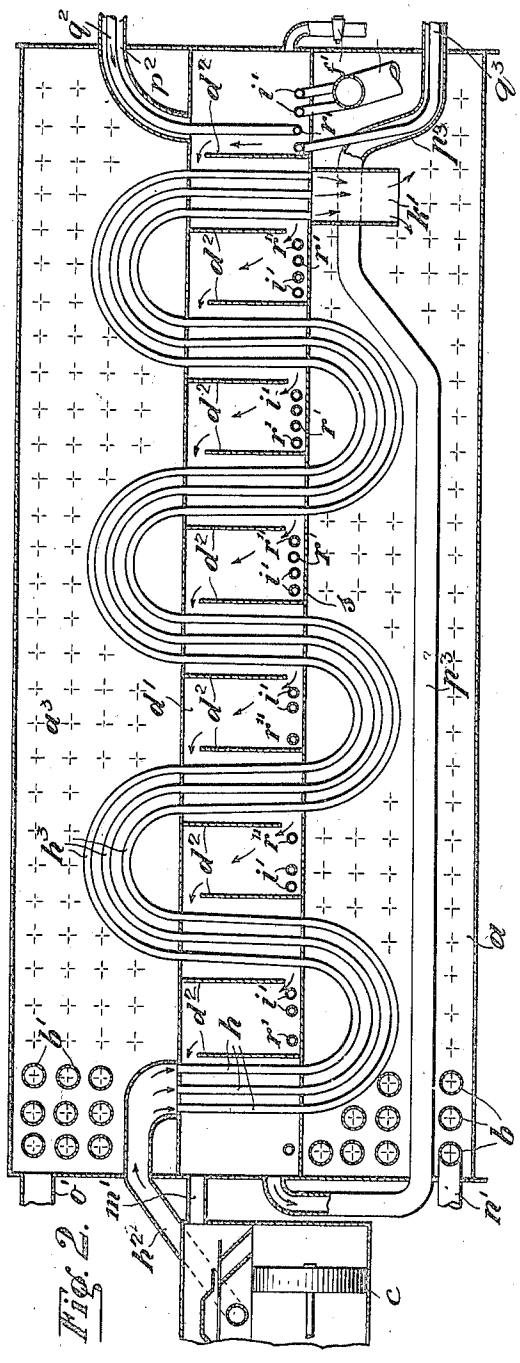


Fig. 2.

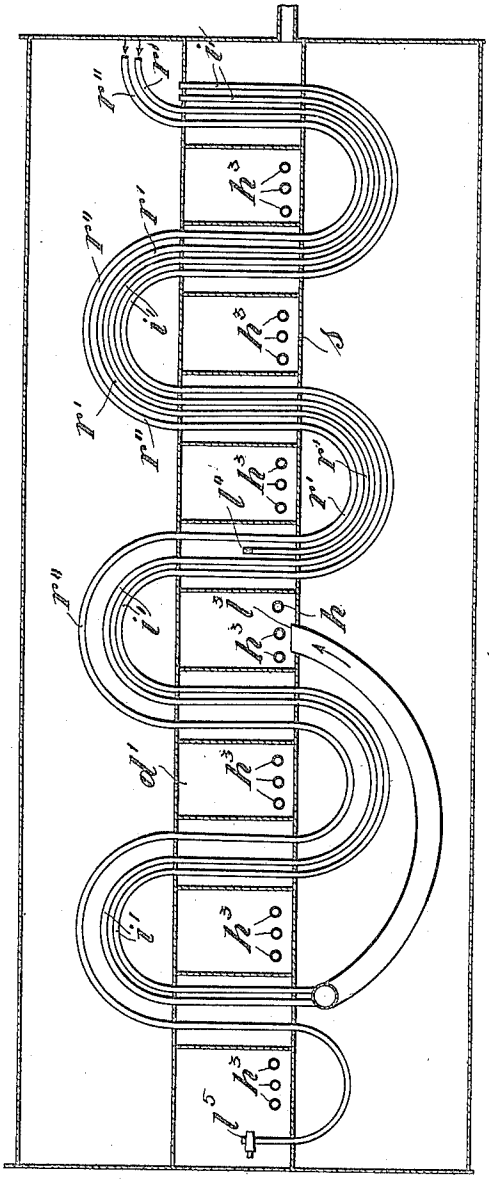


Fig. 3.

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Fig. 4.

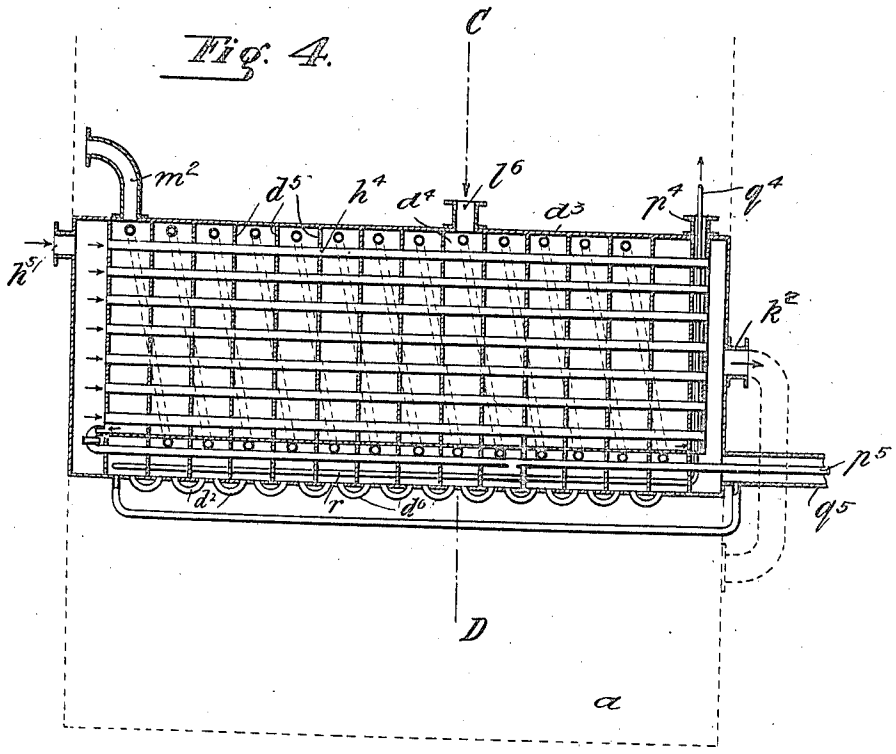
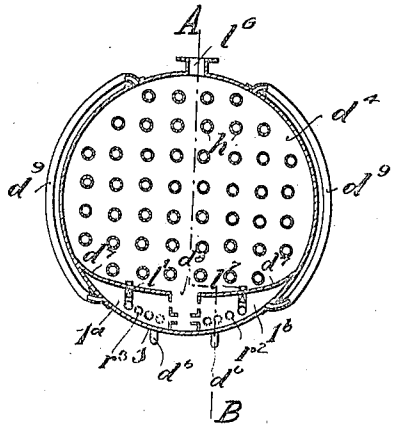


Fig. 5.



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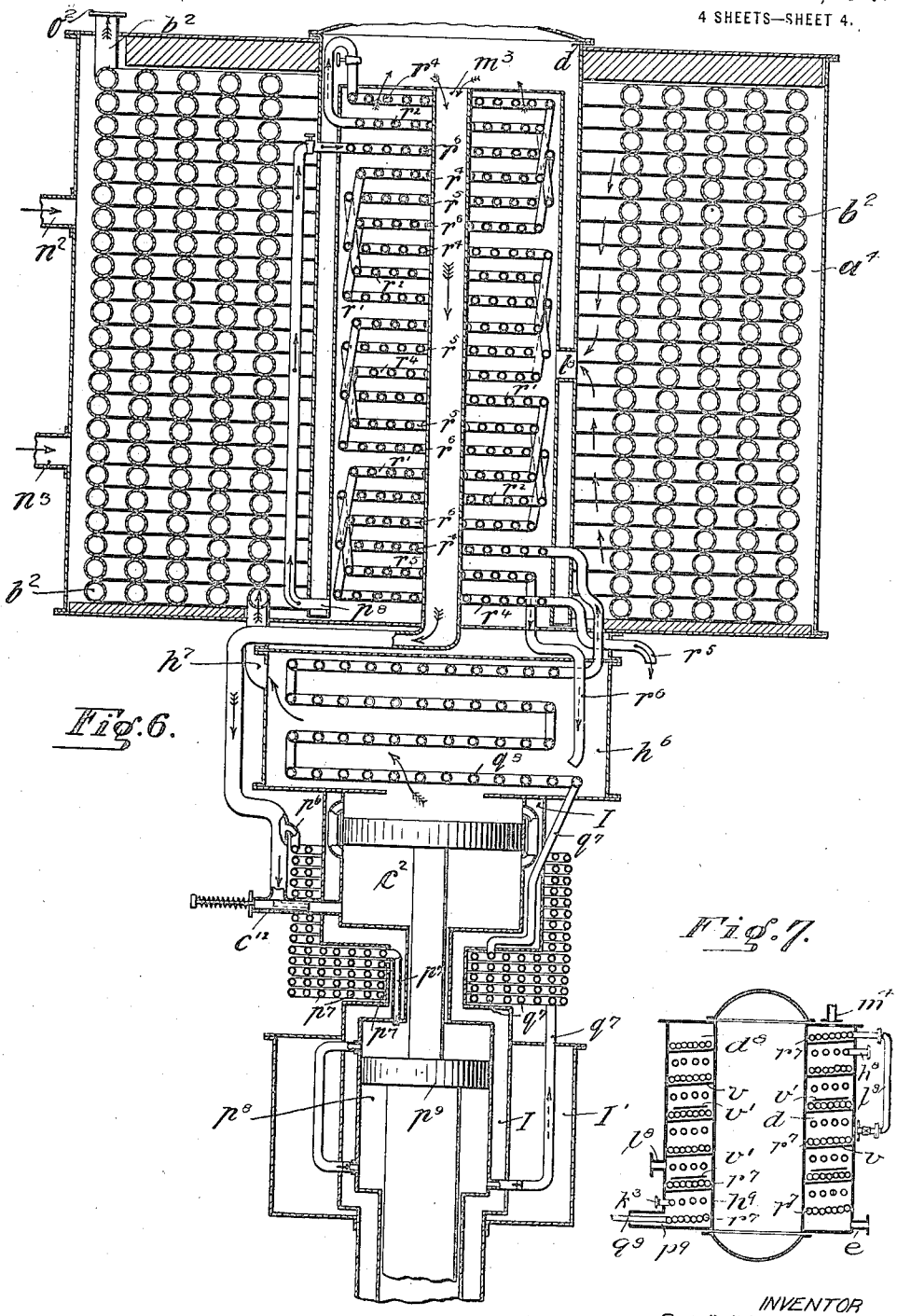


Fig. 6.

Fig. 7.

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UNITED STATES PATENT OFFICE.

RUDOLF MEWES, OF BERLIN, GERMANY.

APPARATUS FOR LIQUEFYING AND SEPARATING GASES.

1,215,957. Specification of Letters Patent. Patented Feb. 13, 1917.

Application filed October 7, 1915. Serial No. 54,601.

To all whom it may concern:

Be it known that I, RUDOLF MEWES, a subject of the King of Prussia, residing at Berlin, in the Kingdom of Prussia and German Empire, have invented new and useful Improvements in Apparatus for Liquefying and Separating Gases, of which the following is a specification.

My present invention relates to an improvement of the process for liquefying air and other gases described and claimed in my Patent No. 1,188,191 dated June 20, 1916.

In the cited application the cold gas mixture (for example oxygen and nitrogen) is alternately raised and lowered in temperature, and thus separated into its constituents by contact with coils containing relatively warmer and colder gases.

Now according to the present invention the raising of the temperature of the gas mixture in the separating chamber is also effected by gas at a higher pressure introduced in a coil and then expanded into the chamber and thus producing a very low temperature.

In the drawing several constructions of apparatus for carrying out the improvement are shown by way of example.

Figure 1 is a sectional outline of one construction in which the separating chamber is arranged in vertical position and is surrounded by a counter current apparatus;

Fig. 2 is a similar section of an apparatus working on exactly the same principle as that shown in Fig. 1, the separating chamber, however, being arranged horizontally, instead of vertically.

Fig. 3 is a section at right angles to Fig. 2;

Fig. 4 shows the sectional outline of another construction of the separating chamber on the line A—B in Fig. 5;

Fig. 5 is a section on the line C—D in Fig. 4;

Fig. 6 represents an apparatus something similar to that shown in Fig. 1, except that the gas compressed to a higher pressure is preliminarily cooled direct by the exhaust of the expansion engine and then enters a coil passing through the separating chamber. Other differences of this construction compared with that shown in Fig. 1 will be clear from the description given below;

Fig. 7 is a sectional outline of another construction of the separating chamber in annular form.

The apparatus shown in Fig. 1 comprises a counter current cooling apparatus a which surrounds a gas separating chamber d. The counter current chamber is divided by a spiral partition a' into a spiral passage a^2 containing a coil b. Into this coil low pressure air of 5–10 atm. is introduced at n which passes through the whole length of the coil and then enters a "heating" coil i which is arranged in the middle of the separating chamber d and terminates at l, so that the low pressure air passing through the coil i escapes into the chamber d. From the chamber d the air passes through the pipe m to the expansion cylinder c, from whence it passes through the pipe h' and chamber y to the cooling coil h which, like the coil i, is arranged in the middle of the chamber d, its separate windings being between the windings of the coil i. The lower end of the pipe h opens into the spiral passage a^2, so that the cold expanded air, after leaving the coil h, will pass through the passage a^2 in counter current to the air passing through the pipe b and it leaves said spiral passage at o, in order to pass to a vacuum pump, into the atmosphere, or to the suction side of the low pressure compressor which supplies air to the coil b at n, none of which are shown in the drawing, because they do not form part of the invention.

It will be clear that in the chamber d the air issuing from the pipe i will be partially liquefied, owing to its having been cooled, firstly in the coil b which is in contact with the cold expanded air passing through the passage a^2 after leaving the coil h, secondly by contact with the coil h in the chamber d. As a consequence, oxygen will have the tendency to collect at the bottom, and nitrogen will rise more to the top of the chamber d.

Now from the bottom end of the chamber d air rich in oxygen is drawn off through the pipe p to a high pressure compressor P with cooling mantle to carry off the heat of compression. In this compressor the air is raised to a higher pressure for example 40–60 atm. Thus highly compressed air at a temperature of —60° C., or more, returns through the pipe q and passes into the "heating" coil r, which is shown inside the coil i. The coil r extends through the entire length of the coil i and terminates in the throttling valve l', through which the highly compressed air escapes into the chamber d. It

will be clear that, owing to the high pressure of the air in the pipe r, it will be liquefied in this pipe, and on issuing from the valve l', it will have the tendency to expand and thus assist in lowering the temperature in the chamber d.

In the same way air rich in nitrogen is drawn off from the pipe m through the pipe p' and passes to a high pressure compressor Q by which the pressure is raised to a high pressure, for example 40–60 atm. The highly compressed air returns at a temperature of –60° C. or more through the pipe q' and enters the coil r' which is arranged to inclose the coils i and r for a portion of their length. The coil r' ends in the throttling valve l''. Through this valve the liquid nitrogen escapes into the chamber d, and, in escaping, expands, thus materially assisting in reducing the temperature. It will be understood that the throttling valves l' and l'' at the ends of the coils r and r' reduce the pressure of the air passing out of said coils.

Further, a pipe x leads from the lower part of the chamber d, where oxygen, or air rich in oxygen, enters it, and this gas rises into the coil y' provided in the chamber y. As this chamber y is cooled by the expanded air coming from the cylinder c the gas in the coil y' will be liquefied and will be led by the other limb of the coil to the middle of the chamber d, where the pipe is bent around to form a liquid seal. In the same way a pipe v leads from m to the coil v^2 also provided in the chamber y, and the nitrogen, or air rich in nitrogen, which enters the pipe v, will be condensed in the coil v^2 and will be led by the pipe v' to the chamber d, where it will evaporate and produce cold. As shown in the drawing the pipe V′ is bent at its end to form a liquid seal, so that only liquid, and not gas can escape into the upper part of the chamber d, and by its evaporation lower the temperature. Circulation takes place in the coil V^2 because the temperature produced by the evaporation of the liquid at the upper part of chamber d is not as low as that in the chamber y.

As mentioned above, by the coil h the air or gas in the chamber d will be cooled, while the pipes i, r, r' will exercise a heating effect. By this alternate heating and cooling an alternate condensation and evaporation will be obtained, which results in a good separation of the constituent gases.

The liquid oxygen is collected in the receiver e and can be drawn off through the cock f.

It is to be understood that the chamber d is a rectification chamber, and it is impossible for gaseous oxygen to reach the top end of the chamber, because the temperature at the top is too low, owing to the cooling influence of the expanded air in the pipe h. The air liquefied in chamber d comes into contact with the pipes h and r' and is accordingly alternately heated and cooled. It is clear that this heating and cooling will have a rectifying influence. It will also be clear that, because no gaseous oxygen can reach the top of the chamber d owing to the low temperature at that part of d, only nitrogen will pass into the expansion cylinder c, and that the nitrogen on returning through the pipe h will exercise a very strong cooling action.

Figs. 2 and 3 show a horizontal apparatus working on the same principle as the vertical apparatus shown in Fig. 1.

a^3 is the counter current apparatus in which is provided the coil b', into which compressed air of about 5 to 10 atmospheres is fed at n'. After passing through the entire length of the coil b' the air passes into two coils i' of S-shape passing through the separating chamber d' and ending in a pipe l^3 which opens out into the middle of the chamber d'. The chamber d' is divided into a number of compartments by vertical partitions d^2, which however leave a space at the bottom and top respectively which will enable the air to pass from one end of the apparatus to the other. From the chamber d' the air passes to the expansion engine c through the pipe m', returning through the pipe h^2 which is divided into three cooling coils h^3 arranged at right angles to the coils i', ending in the pipe k', which opens into the counter current apparatus a. After passing through the chamber of the apparatus a^3 the air escapes through o' to the atmosphere, or to a suction pump, or to the suction side of the compressor supplying compressed air to the pipe b' at n'. The separating chamber d' can have a small incline from the expansion cylinder end downward to the opposite end. In any case however liquid oxygen will collect at the right end, and liquid nitrogen at the left end of the chamber d'. Oxygen or air rich in oxygen is drawn off through the pipe p^2 and compressed to a pressure of about 40–60 atm., whereupon it returns through the pipe q^2 and enters the "heating" coil r', which is arranged parallel to the coil i' and ends in the valve l^4, so that the highly compressed liquid oxygen expands into the chamber d'. From the opposite end of the chamber d' nitrogen is drawn off through the pipe p^3, and, after being compressed to about 50–60 atm., is returned through the pipe q^3, and enters the coil r'', which is also arranged parallel to the coil i, and ends in the valve l^5, through which the highly compressed liquid nitrogen expands into the chamber d'.

The liquid oxygen is drawn off through the cock f'.

In Figs. 4 and 5 another horizontal construction of the separating chamber is

shown, the relative position of the counter current cooling apparatus being represented in dotted lines.

According to this construction the separating chamber d^3 is composed of a number of parallel elements d^4 by the partitions d^5. The lower part or liquid chamber of each element is connected to the same chamber of the next element by a pipe d^6. In each element there is a partition d^7 having an opening d^8 in the middle, through which the liquid formed in the upper part of the element flows into the lower parts l^a, l^b. The partition d^7 prevents the gases evaporating in l^a and l^b from mixing with the gases in the chamber d^3. Above the level of the liquid in the chambers l^a, l^b a pipe d^9 is attached which leads to the top part of the next element. Transversely through all the elements d^4 pass the pipes h^4.

In operation the low pressure air of 5–10 atm., after passing through the counter current apparatus a, enters one of the elements d^4 at l^6 near the middle of the whole series. The air passes out of the end element d^4 through the pipe m^2 to the expansion cylinder not shown in Figs. 4 and 5, because the arrangement will be clear from Figs. 1 and 2. The expanded air returns through the pipe h^5 and then passes through the pipes h^4 from one end of the apparatus to the other and is then conducted by the pipe k^2 to the counter current apparatus a.

From the right end of the apparatus oxygen or air rich in oxygen is drawn off through the pipe p^4 to a compressor by which it is raised to a pressure of about 40–60 atm. and returned through the pipe q^4, which leads to the coil r^2 in the compartment l^b. After leaving the coil r^2 the air enters one of the middle elements d^4 through a cock l^7.

From the left end of the apparatus nitrogen or air containing but little oxygen is drawn off through the pipe p^5 to a compressor, by which it is raised to about 40 to 60 atm. and then returned through the pipe q^5, from which it enters the coil r^3. On leaving the coil r^3 the gas enters one of the middle chambers d^4 through a cock l^8.

The apparatus represented in Fig. 6 operates on the same principle as that shown in Fig. 1, but the construction is somewhat different.

The counter current cooling apparatus a^4 with its coils b^2 surrounds the separating chamber d^7, but the low pressure air is not fed into the coil b^2, as in Fig. 1, but into the spiral passage formed by the windings of said coils b^2 touching each other. Said low pressure air enters at n^2, n^3, that is, at two different points, in order to well distribute it. After passing through the spiral passage formed by the windings of the coils and thus being cooled, it passes through the opening l^8 into the separating chamber d^7. Here the nitrogen naturally rises and the oxygen sinks, owing to the extremely low temperature. The air rich in nitrogen, in other words, containing but little oxygen, passes through the pipe m^3 to the expansion cylinder c^2, the entrance to said cylinder being controlled by the valve c^{12}. The air entering the cylinder c^2 is expanded and then escapes through the chamber h^6 and pipe h^7 into the coil b^2, through which it passes, in order to escape at o^2. In this construction the expanded air from the cylinder c^2 does not exercise any cooling effect in the separating chamber d^7, because it is led direct into the counter current cooling device. From the pipe m^3 a pipe p^6 is branched off which is wound into the form of a coil p^7 surrounding the expansion engine and its connection with the compressor. After leaving the cooling pipe p^7 the air passes into the upper end of the compressor p^8. By the upward motion of the piston p^9 this air is forced to the lower end of the compressor cylinder and by the return motion of the piston it is compressed to 40 to 60 atm. and leaves the compressor through the coil q^7 from whence it passes through the coil q^8 which leads into the coil r^4. This coil leads to the top of the chamber d^7 and then returns through the coil r^5, in order to escape out of the pipe r^6 into the chamber h^6, from whence it passes through the coil b^2 to o^2. The oxygen collecting in the bottom part of the chamber d passes through the pipe p^8 to the coil r^6 which is subjected to the intense cold given off by the coils r^4, r^5. The liquid oxygen formed will issue through the pipe r^5.

The expansion cylinder is shown with a single insulating jacket I and the compressor with a double insulating jacket I, I'.

The separating chamber shown in Fig. 7 has an annular form and is divided by the spiral plate v into one continuous annular passage. In the passage so formed the spiral pipes h^8 and r^7 are provided. The low pressure air of 5 to 10 atm. is introduced into the spiral passage at l^8 and passes off at m^4 to an expansion engine, for example of the kind shown in Fig. 1. After being expanded the air is fed to the coil h^8 at h^9 and passes through the whole length of this coil, in order to pass off at k^3 into the counter current device. At the bottom end of the spiral chamber d^8 the oxygen or air rich in oxygen is drawn off through the pipe p^9 and compressed to a high pressure, whereupon it is returned through the pipe q^9 and enters the coil r^7. After passing through the whole length of the coil r^7, the high pressure air is led to the middle of the chamber d^8 through the pipe l' in which a throttling valve is provided, as shown in the drawing. The oxygen liquefied in the chamber d^8 flows

over plates v' to the bottom of the spiral passage formed by the spiral plate v and in flowing along the spiral plate v it cools the high pressure air in the pipe r^7. The liquid oxygen is drawn off through the pipe e^2.

In all the above examples exclusively air has been mentioned, but it is clear that not only air, but also other gases can be treated in the same way, and the claims are meant to include apparatus for liquefying and separating socalled permanent gases of all kinds.

What I claim and desire to secure by Letters Patent of the United States is:—

1. The described apparatus for liquefying and separating the components of air, which comprises in combination, a counter current device for cooling air of low pressure, a separating chamber, a coil inside said chamber to which the low pressure cooled air is fed, said coil opening into said chamber, a pipe connecting said chamber with the expansion cylinder, a second coil in said chamber, a pipe connecting said second coil with the exhaust of said expansion cylinder, a suction pipe for air rich in oxygen, a high pressure cooled compressor connected with said suction pipe, a third coil in said separating chamber, a force pipe connecting said high pressure compressor with said third coil, and a throttling valve at the end of said third coil, substantially as, and for the purpose, set forth.

2. The described apparatus for liquefying and separating the components of air, which comprises in combination, a counter current device for cooling air of low pressure, a separating chamber, a coil inside said chamber to which the low pressure cooled air is fed, said coil opening into said chamber, a pipe connecting said chamber with the expansion cylinder, a second coil in said chamber, a pipe connecting said second coil with the exhaust of said expansion cylinder, a suction pipe for air rich in oxygen, a high pressure cooled compressor connected with said suction pipe, a third coil in said separating chamber, a force pipe connecting said high pressure compressor with said third coil, a throttling valve at the end of said third coil, a suction pipe for air containing little oxygen, a second high pressure cooled compressor connected with said suction pipe, a fourth coil in said separating chamber, a force pipe connecting said second high pressure compressor with said fourth coil, and a throttling valve at the end of said fourth coil, substantially as, and for the purpose, set forth.

3. The combination with a chamber in which air is liquefied by being led under low pressure through said chamber in counter current to expanded cold air, of a pipe containing high pressure air arranged in counter current to said expanded air and opening out into said chamber, substantially as, and for the purpose, set forth.

4. The combination with a chamber in which air is liquefied by being led under low pressure through said chamber in counter current to expanded cold air, of a pipe containing high pressure air rich in oxygen arranged in counter current to said expanded air and opening out into said chamber, substantially as, and for the purpose, set forth.

5. The combination with a chamber in which air is liquefied by being led under low pressure through said chamber in counter current to expanded cold air, of a pipe containing high pressure air rich in oxygen arranged in counter current to said expanded air and opening out into said chamber, and a pipe containing air comparatively rich in nitrogen arranged in counter current to said expanded air and opening out into said chamber, substantially as, and for the purpose, set forth.

6. The combination with an expansion cylinder of a chamber, a coil in said chamber, a pipe connecting said coil with the exhaust of said cylinder, a second coil in said chamber and arranged adjacent to said first coil and containing low pressure air, a third coil in said chamber and adjacent to said first and second coils and containing high pressure gas, a fourth coil in said chamber also containing high pressure gas said second, third, and fourth coils all opening out into said chamber, and a pipe connecting said chamber with said expansion engine, substantially as, and for the purpose, set forth.

7. The described apparatus for liquefying air and separating its components, comprising in combination, a chamber to which low pressure cooled air is fed, a coil in said chamber, a high pressure cooled compressor, a pipe connecting the top end of said chamber with the inlet port of said compressor, a second pipe connecting said coil with the outlet side of said compressor, a further coil arranged in said chamber, and a pipe leading from near the bottom of said chamber and communicating with said last mentioned coil, substantially as set forth.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

RUDOLF MEWES.

Witnesses:

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HENRY HASPER.