No. 688,004 Patented Dec. 3, 1901.

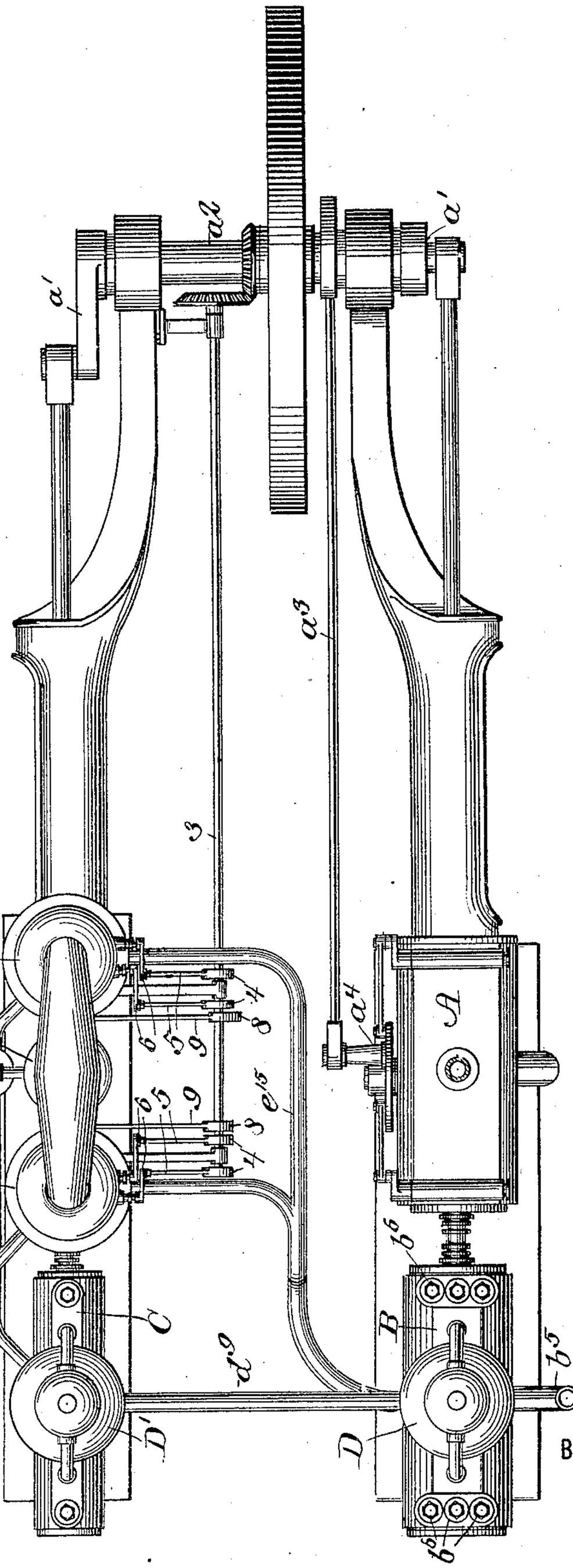
O. P. OSTERGREN.

LIQUEFACTION OF AERIFORM FLUIDS.

(Application filed Apr. 14, 1900. Renewed May 17, 1901.)

(No Model.) 4 Sheets—Sheet 1.

Fig. 1.



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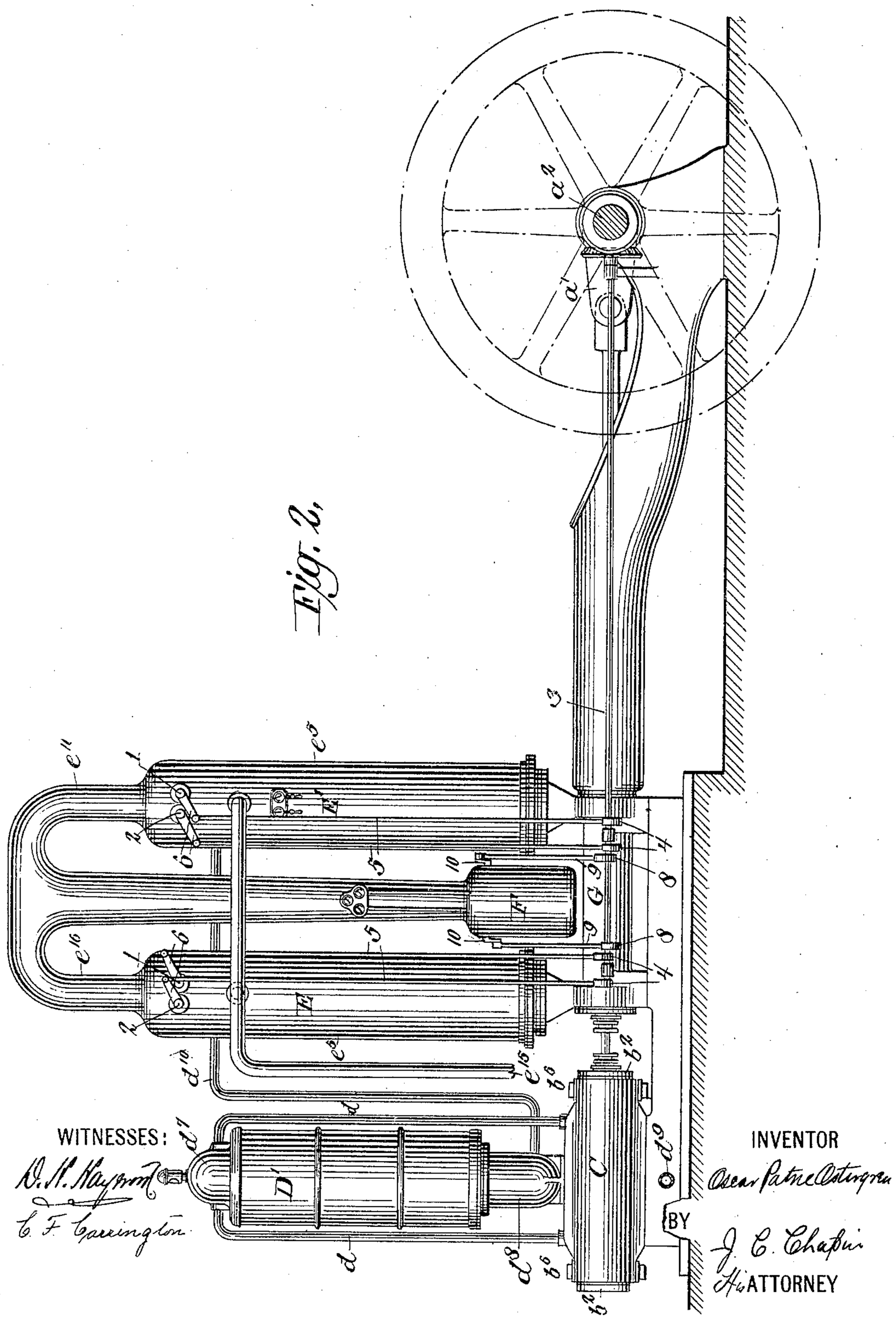
(No Model.) 4 Sheets—Sheet 2.

Fig. 2.



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(No Model.) 4 Sheets—Sheet 3.

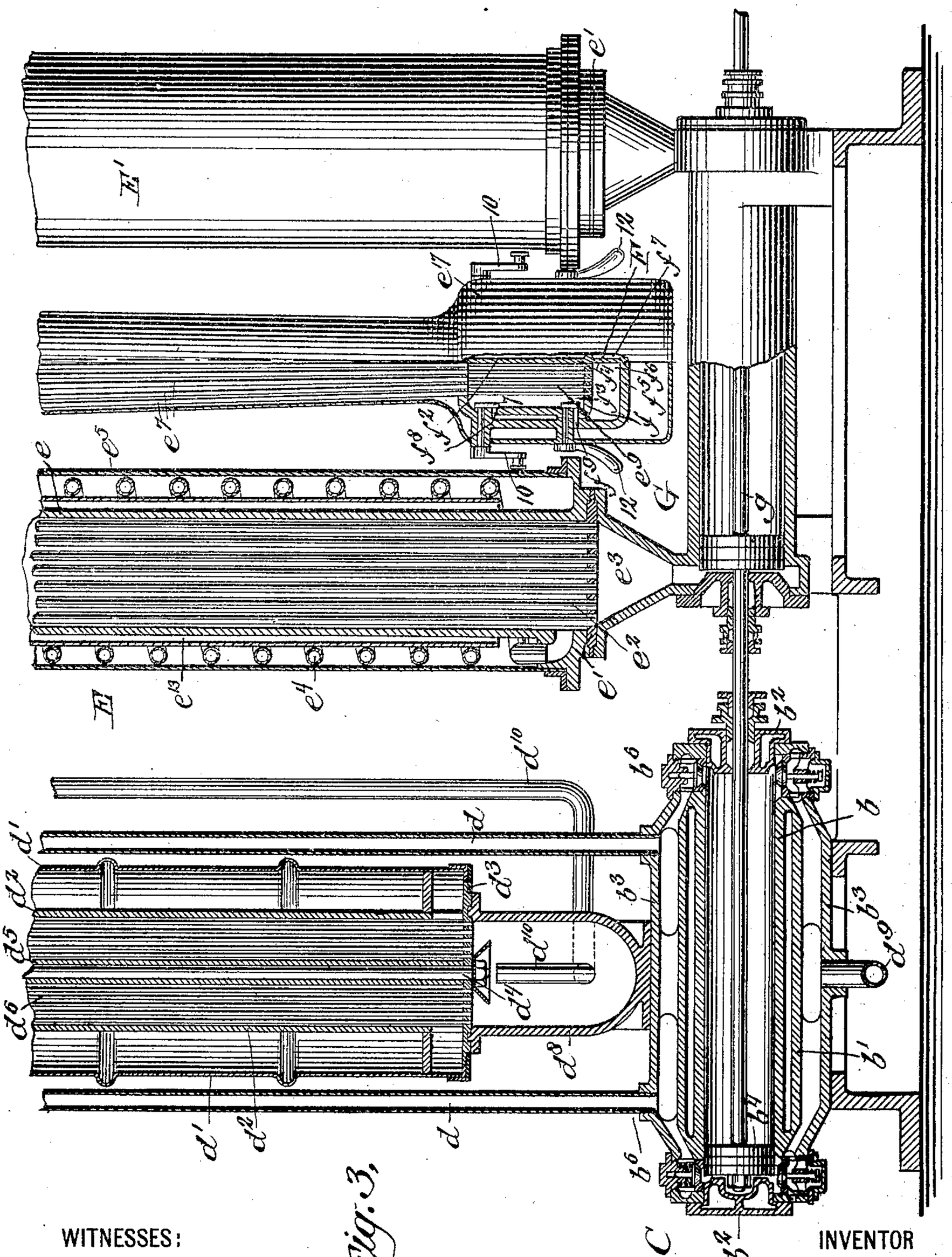

Fig. 3.

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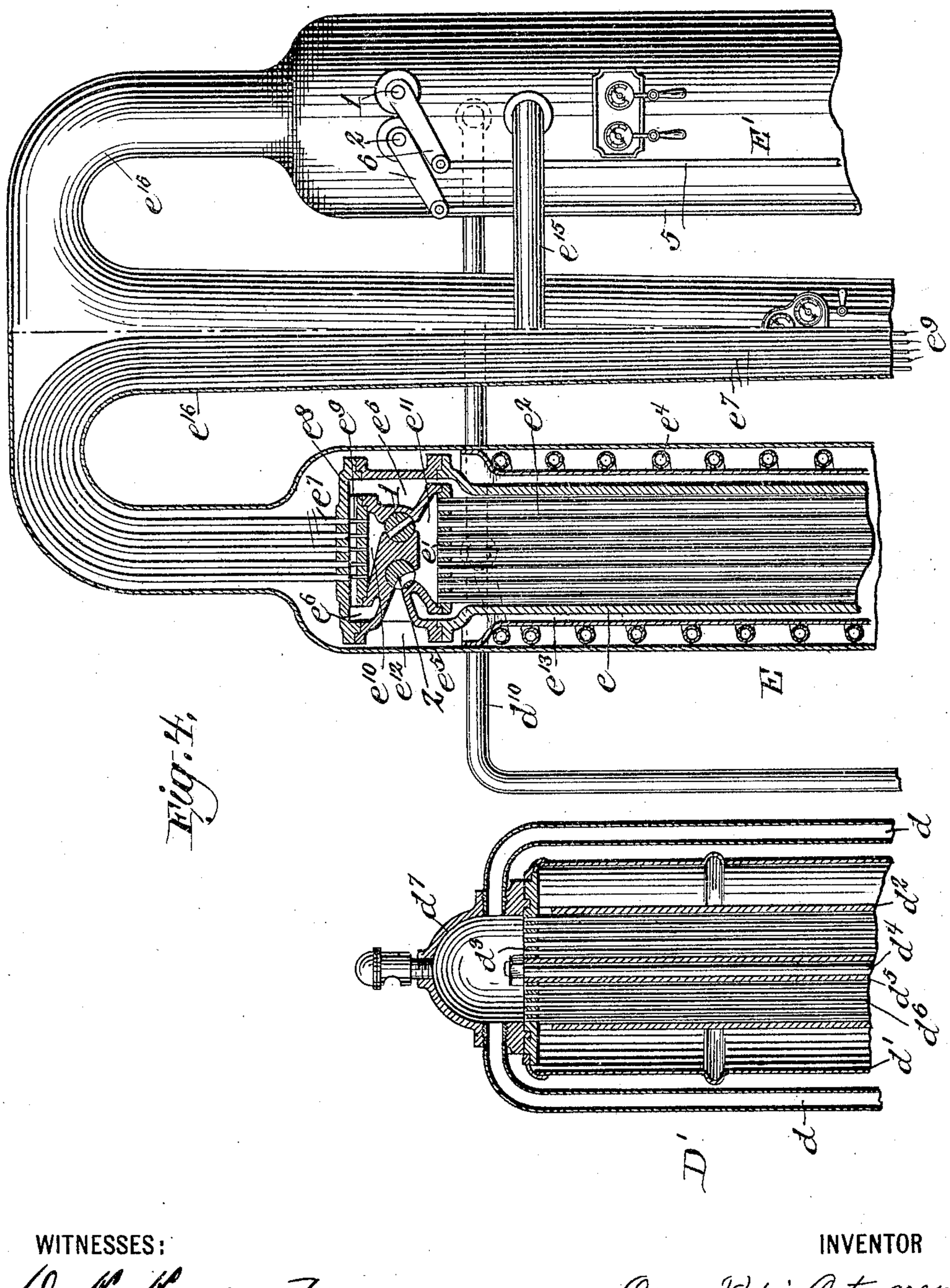

Fig. 4.

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OSCAR PATRIC OSTERGREN, OF NEW YORK, N. Y.

LIQUEFACTION OF AERIFORM FLUIDS.

SPECIFICATION forming part of Letters Patent No. 688,004, dated December 3, 1901.

Application filed April 14, 1900. Renewed May 17, 1901. Serial No. 60,747. (No model.)

To all whom it may concern:

Be it known that I, OSCAR PATRIC OSTERGREN, a citizen of the Kingdom of Sweden and a resident of the city, county, and State of New York, have invented certain new and useful Improvements in the Liquefaction of Aeriform Fluids, of which the following is a specification.

My invention relates to an apparatus for refrigerating or liquefying aeriform fluids or gases, and particularly atmospheric air.

I will describe an apparatus embodying my invention and then point out the novel features thereof in the claims.

In the accompanying drawings, Figure 1 is a top view, partly in horizontal section, of an apparatus embodying my invention. Fig. 2 is a view, partly in elevation and partly in vertical section, of the device shown in Fig. 1. Fig. 3 is a sectional view, partly in side elevation, on an enlarged scale, of the lower portion of certain parts shown in Fig. 2. Fig. 4 is a similar view of the upper portion of such parts.

Similar characters of reference designate corresponding parts in all of the figures.

A represents a power-cylinder or other suitable engine; B and C, compressors; D and D′, cooling devices for the air compressed in the compressors; E and E′, regenerators; F, a liquefier, and G a power-cylinder.

The engine A is here shown as a steam-operated piston, the piston-rod being connected with a crank a', fixed on a shaft a^2, which is suitably journaled.

a^3 represents a pitman one end of which is fastened around an eccentric on the shaft a^2 and the other end of which is connected with a device a^4, employed for shifting the valves of the engine A. The piston-rod g of the power-cylinder G is also connected with the shaft a^2 and in a measure assists in rotating this shaft. The piston-rod g is also shown as being connected with the compressing-piston of the compressor C. This is not necessary, however, it being shown this way merely for convenience.

In the operation of the apparatus shown in the drawings the air or other gas to be liquefied is taken in at the compressor B. From there it passes through the cooling device D, and from the cooling device it passes into the compressor C. From the compressor C it passes through the cooling device D′ to the two regenerators and through the two regenerators into the liquefier. The compressed air or other gas from the liquefier passes out of it through separate conduits into the regenerators. As it enters these conduits it expands, and this expansion continues until the air or gas enters the regenerators, where further expansion takes place against a liquid. The gas does not pass out of the liquefier in a continuous stream, but only intermittently—that is to say, only a portion of the returning gas is expanded at a time. This permits of a greater expansion than if the return flow were continuous. Thus a greater cooling effect is obtained. This is due to the fact that each portion is allowed to expand in all directions to its greatest extent. Such a universal expansion could not take place if the flow of gas were continuous. The return of the compressed gas is also made alternately through each regenerator, so that at the same time that the intense coldness is being produced the piston in the cylinder G is being operated. The exhausted air after each expansion passes from the regenerators to the initial compressor to be again returned. It will therefore be seen that the gas or a part of it is sent through the apparatus or parts of it in a direction opposite to the incoming gas, and in different parts of the apparatus it is expanded to produce work and also an intense coldness. The incoming gas is therefore subjected to the intense coldness produced by the aforesaid expansion.

In the apparatus shown the two compressors, the two cooling devices, and the two regenerators are of substantially the same construction, so that the following description, which is of one of each of the compressors, cooling devices, and regenerators, will apply equally to both.

Referring now to the compressor C, it comprises a cylinder b and a jacket b', so arranged therearound as to leave a space through which a circulation of water is maintained. The heads b^2 of the cylinder are hollow, and the circulation of water is also maintained through them. Surrounding the jacket b' is a second jacket b^3 and so arranged therearound as to leave a space into which the

compressed gas is forced by the piston b^4. This piston is operated from the engine A. Atmospheric air or other gas is introduced into the cylinder b through a conduit b^5, in which a suitable check-valve is placed. As the piston b^4 is operated it compresses the air or other gas and forces it out of the cylinder past check-valves b^6, arranged at the ends of the cylinder, into the space or channels between the jackets b^3. From here it passes into two conduits d, which lead to the top of the cooling device D.

The cooling device D comprises, preferably, an outer cylinder d', an inner cylinder d^2, and heads d^3, all of which parts may be held together by a central bolt d^4. A tube or other casing d^5 is provided around the bolt d^4 and bears at each end against the heads d^3. The central portion of each head is provided with a number of openings, in which are secured a number of tubes d^6, through which the air passes from the top of the cooling device to the bottom. Water is circulated in the space between the two cylinders and between the spaces of the tubes d^6. The conduits d preferably lead into a dome d^7, provided at the top of the cooling device.

Provided at the bottom of the cooling device and connected therewith is a closed receptacle d^8, into which the compressed air enters after passing through the cooling device.

d^9 is a conduit one end of which is within the receptacle d^8, while its other end is connected with the inner cylinder of the compressor C. In the compressor C the air from the cooling device D is further compressed and forced out into and through the cooling device D'. From the cooling device D' the compressed air passes through a conduit d^{10}, which has branches, so that the compressed air may enter both regenerators E and E'.

The regenerator E comprises a cylinder e, a head e' at each end of the cylinder, which heads are provided with a number of openings in which a number of tubes e^2 are held, a chamber e^3 at the lower end of the cylinder e and with which the tubes e^2 communicate, and a chambered top. A spiral conduit e^4, which is connected at one end with one of the branches of the conduit d^{10} and at its other end with the interior of the cylinder e, is provided around the cylinder e, and a casing e^5 incloses the spiral. The spiral and casing also form part of the regenerator.

The chambered top of the regenerator, above referred to, consists of a suitable casting in which a number of chambers are provided, into and out of which the compressed gas passes. The compressed gas passing out of the interior of the cylinder e enters a chamber e^6, and from the chamber e^6 the gas passes into a number of conduits e^7, which lead to the liquefier F. The ends of the conduits e^7 which communicate with the chamber e^6 are held in the top e^8 of the chambered top, and inclosed by the conduits e^7 are a number of conduits e^9, which also lead to the liquefier F. The conduits e^9 form a return for the compressed gas from the liquefier, and they conduct the gas to a chamber e^{10} in the chambered top. The chamber e^{10} is opened to a chamber e^{11} through a valve 1, which is operated in a manner to be hereinafter described. When the valve is in open position, the compressed air enters the chamber e^{11} and there expands against a liquid, preferably glycerin, which is contained in the tubes e^2 and the chamber e^3. The glycerin is kept at a high temperature, especially where the air expands. The chamber e^3 of each regenerator is in communication with one end of the power-cylinder. The volume of all the conduits is frequently less than the volume of the cylinder. The compressed air or other gas expanding against the liquid forces the liquid down into the cylinder G to move the piston. In its expansion against a movable liquid a cushion is afforded and the force of the impact is broken. The cooling effect of such an expansion is also much greater than an expansion against a stationary object, for as the liquid is moved a larger volume of space is provided in which the gas may expand. The liquid should also be of a higher temperature than that of the expanding fluid, and this higher temperature will be maintained through the friction of the moving liquid and its being brought into contact with the heat of the atmospheric air. The intense coldness of the expansion against the liquid will effect the incoming compressed gas to cool it.

It will be understood that each regenerator is complete in itself and that in the present instance each regenerator is adapted to drive the piston g in one direction only. It is obvious, however, that a single regenerator may be so arranged as to operate the piston g in both directions. I prefer, however, to use two regenerators and to alternately interrupt the return flow of the compressed gas, as the effectiveness of the machine is greatly increased.

After the expansion of the compressed gas in the regenerator it is allowed to escape through a valve 2 into a space e^{12}, formed by the chambered top and the adjacent part of the casing e^5. From this space it passes downward through a cylinder e^{13}, provided between the cylinder e and spiral, and escapes from said cylinder at the bottom thereof, which is adjacent to the lower end of the cylinder e. The exhaust-air then passes upward between the cylinder e^{13} and casing e^5 to an outlet and into a conduit e^{15} back to the compressor B.

The valves 1 2 on each regenerator are operated from a shaft 3, which is geared with the shaft a^2. Eccentrics 4 are provided on this shaft, and these eccentrics operate pitmen 5, which in turn operate arms 6, connected with the valves. The eccentrics 4 are so arranged on the shaft 3 that the valve 1 in one regenerator will be closed while the

same valve in the second regenerator is open. The same is true of the valves 2.

The casing e^5 is shown as being provided with an extension e^{16}, which leads to the liquefier F. The extension is mainly for the purpose of inclosing the conduits e^7 and e^9 of each regenerator. If desired, the extension e^{16} may be provided with an enlargement e^{17}, which incloses the liquifier F. The lower part of this enlargement is shown as serving the purpose of holding whatever gas may liquefy during the operation. Any form of decanting device may be connected therewith.

The liquefier F comprises a receptacle f, divided by a partition f^2 into two compartments f^3 f^4, and a second receptacle f^5, also divided by a partition into two compartments f^6 f^7. The partition f^2 may be extended to form the two compartments f^6 f^7. The compartments f^3, f^4, f^6, and f^7 communicate with each other through openings f^8, which are closed by valves 7. These valves are alternately operated from the shaft 3 by means of eccentrics 8, pitmen 9, and arms 10. The conduits e^7 of each regenerator are in communication with the compartments f^3 f^4, while the conduits e^9 are in communication with the two compartments f^6 f^7. The compartments f^6 f^7 are preferably of such a size as to permit expansion to take place in them before the gas enters the conduits e^9. The expansion then continues through the conduits e^9 and in the whole length of the regenerators. The compartments f^3 f^4 are in communication with the lower part of the enlargement e^{17} through openings f^9, controlled by hand-operated valves 12. These valves are opened to permit the liquefied gas which is formed in the compartments f^3 f^4 escaping into the lower part of the enlargement e^{17}. The gas will liquefy in these compartments as the coldest point in the apparatus.

The operation of the apparatus is as follows: The engine A is started and the compressors B and C put in operation. Air or other gas is taken in at the compressor B and when it leaves the compressor it is under a certain pressure, (for example, eighty pounds.) It then passes through the cooling device D and from this cooling device to the compressor C. In this compressor the pressure is raised, to, say, three hundred pounds. The air under this pressure then passes through the second cooling device D' into the conduit d^{10} to both regenerators. The air under pressure then passes through the spiral of each regenerator, through the cylinder e of each regenerator into the chambers e^6, and from the chambers e^6 into the conduits e^7 to the compartments f^3 f^4. The valves are then alternately operated to permit an amount of compressed air to escape from the compartments f^3 f^4 into the compartments f^6 f^7. From the compartments f^6 f^7 the compressed air enters the conduits e^9 and into the chambers e^{10}. When the valve 1 of one regenerator is opened, the gas comes in contact with the glycerin and expands and greatly lowers in temperature, moving the piston g through the medium of the glycerin. After the air has been expanded the valve 1 closes and the valve 2 opens to permit the expanded gas to escape into the cylinder e^{13} and from out of this cylinder to the conduit e^{15}. While the exhaust is taking place in one regenerator the valve 1 in the second regenerator opens to permit the gas to expand in that regenerator. It will therefore be seen that as this operation continues intense coldness will be produced at each expansion until at last liquid air will be formed in the apparatus, which will collect in the compartments f^3 f^4. It will be noted that the extension e^{16} is open, so that vapors from the liquid air collected in the enlargement e^{17} will pass through the extension and casing into the cylinder e^{13} and out through the conduit e^{15}. This vapor tends to materially reduce the temperature of the incoming compressed air, and thereby materially aids in its liquefaction.

What I claim is—

1. In an apparatus for refrigerating and liquefying aeriform fluid, the combination of a compressor or compressors, a preliminary cooling device or devices for the compressed gas, regenerators in communication with said cooling device, each of said regenerators containing a liquid, a piston adapted to be operated by the liquid in each regenerator, a liquefier in communication with said regenerators, a return from said liquefier to each regenerator, which is adapted to have communication with the liquid in each regenerator, and means for alternately opening and closing each of said returns.

2. In an apparatus for refrigerating and liquefying aeriform fluid, the combination of a compressor, a preliminary cooling device or devices for the compressed gas, regenerators in communication with said cooling device, each of which contains a liquid, a piston adapted to be operated by the liquid in each regenerator, a liquefier in communication with each regenerator, a return from said liquefier to each regenerator, which opens into the liquid in each regenerator, and means for alternately opening the returns from the liquefier.

3. In an apparatus for refrigerating and liquefying aeriform fluid, the combination, with a compressor, of a preliminary cooling device for the compressed fluid, a regenerator in communication therewith, a liquefier, and a return from said liquefier to said regenerator, the said regenerator having a movable liquid therein against which the fluid expands upon its return from said liquefier.

4. In an apparatus for refrigerating and liquefying aeriform fluid, the combination, with a compressor, of a preliminary cooling device for the compressed fluid, a regenerator in communication therewith, a liquefier, a return from said liquefier to said regenerator, the said regenerator having a movable

liquid therein against which the compressed fluid expands upon its return from said liquefier, and means for interrupting the flow in said return.

5. In an apparatus for refrigerating and liquefying aeriform fluid, the combination of a compressor, a preliminary cooling device for the compressed fluid, a regenerator in communication therewith, said regenerator containing a liquid against which the compressed fluid expands on its return from a liquefier, a piston adapted to be operated by said liquid, a liquefier, a return therefrom to the regenerator, and means for interrupting the flow of fluid in said return.

6. In an apparatus for refrigerating and liquefying aeriform fluid, the combination of a compressor, a preliminary cooling device for the compressed fluid, a regenerator in communication therewith, said regenerator comprising a cylinder, a coil surrounding the same, and a number of pipes within the cylinder containing a liquid, a piston adapted to be operated by said liquid, a liquefier in communication with the coil and the interior of the cylinder, and with a liquid through a return, and means for interrupting the flow in said return.

7. In an apparatus for refrigerating and liquefying aeriform fluid, the combination of a compressor, a preliminary cooling device for the compressed fluid, a regenerator in communication therewith comprising a cylinder inclosing a number of pipes which contain a liquid, and a coil surrounding the cylinder and opening into the interior thereof, a liquefier comprising a plurality of compartments which communicate through valved openings, a communication between the interior of the said cylinder and one of said compartments, and a communication between the other of said compartments and the said liquid, and means for interrupting the flow in said last-mentioned communication.

8. In an apparatus for refrigerating and liquefying aeriform fluid, the combination of a compressor, a preliminary cooling device for the compressed fluid, a regenerator in communication therewith, said regenerator having a passage through it for the compressed fluid, and a movable liquid against which the compressed fluid expands on its return from a liquefier, a liquefier with which said passage communicates, a return for the compressed fluid from said liquefier to the regenerator, a valve for opening said return to the liquid, a valve for permitting said expanded fluid to escape, and means for alternately opening and closing said valves.

9. In an apparatus for refrigerating and liquefying aeriform fluid, the combination of a compressor, a preliminary cooling device or devices for the compressed fluid, a plurality of regenerators in communication therewith, each of said regenerators having a passage through it for the compressed fluid, and a liquid against which the compressed fluid expands on its return from a liquefier, the liquefier with which said passage communicates, a return for the compressed fluid from said liquefier to each regenerator, a valve for opening each return to the liquid, a valve for permitting the expanded fluid to escape from each regenerator, means for alternately operating the said valves in pairs, and means for alternately opening the return to each regenerator from the liquefier.

10. In an apparatus for refrigerating and liquefying aeriform fluid, the combination of a compressor, a preliminary cooling device for the compressed fluid, a regenerator in communication therewith, and a liquefier in communication with said regenerator through two sets of conduits, the conduits of one set being inclosed by the conduits of the other set and one of which sets also forms a return, said liquefier comprising a plurality of compartments which are in communication with each other through a valved opening, and with which the sets of conduits communicate, one set with one chamber and the second set with the other chamber, and means for automatically intermittently operating said valve.

11. In an apparatus for refrigerating and liquefying aeriform fluid, the combination of a compressor, a preliminary cooling device for the compressed fluid, a regenerator in communication therewith, and a liquefier in communication with said regenerator through two sets of conduits, the conduits of one set being inclosed by the conduits of the other set and one of which sets also forms a return, said liquefier comprising three compartments, two of which are in communication with each other through a valved opening and with which the conduits communicate, one set of conduits with one of said two chambers and the other set of conduits with the second of said two chambers, and said third compartment being in communication with one of the said two through a valved opening, and means for automatically intermittently operating the first-mentioned valved opening.

12. In an apparatus for refrigerating and liquefying aeriform fluid, the combination of a compressor, a preliminary cooling device for the compressed fluid, a regenerator in communication therewith, said regenerator comprising an inner and outer cylinder and a coil intermediate the two cylinders and discharging into the inner cylinder, a liquid contained in pipes within said inner cylinder, a liquefier comprising two compartments in communication with each other through a valved opening, means for alternately operating said valve, conduits leading from the inner cylinder to one of the compartments, and a second set of conduits leading from the second compartment to the said liquid medium, a piston adapted to be operated by said liquid, and a casing inclosing said outer cylinder, conduits and two compartments.

13. In an apparatus for refrigerating and liquefying aeriform fluid, the combination of

a compressor, a preliminary cooling device for the compressed fluid, a regenerator comprising a coil which is connected with said cooling device, conduits communicating with said coil, a compartment in communication with said conduits, a second compartment in communication with said first-mentioned compartment, return-conduits inclosed by said first-mentioned conduits and in communication with said second compartment, a device containing a liquid medium with which said second-mentioned conduits are adapted to have communication, means for controlling said communication, and a piston adapted to be operated by said liquid.

Signed by me at New York, N. Y., this 10th day of April, 1900.

OSCAR PATRIC OSTERGREN.

Witnesses:
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C. F. CARRINGTON.