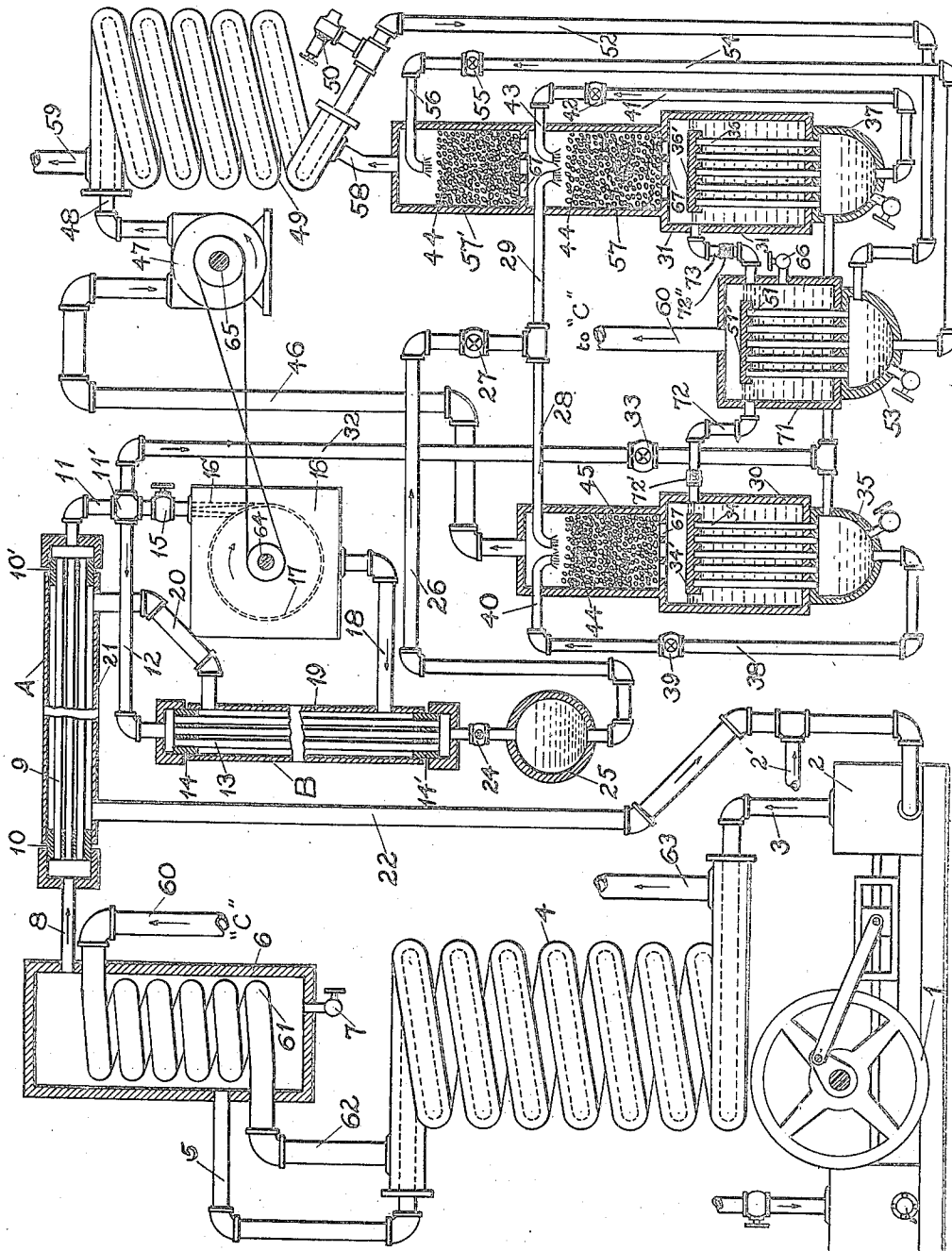


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 APPARATUS FOR LIQUEFYING AIR AND SEPARATING IT INTO ITS CONSTITUENTS.
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1,283,472.

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APPARATUS FOR LIQUEFYING AIR AND SEPARATING IT INTO ITS CONSTITUENTS.

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Specification of Letters Patent.

Patented Nov. 5, 1918.

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To all whom it may concern:

Be it known that I, CHARLES F. CROMMETT, a citizen of the United States, and resident of Chelsea, in the county of Suffolk and State of Massachusetts, have invented certain new and useful Improvements in Apparatus for Liquefying Air and Separating It into Its Constituents, of which the following is a specification.

10 This invention relates to the liquefaction of atmospheric air and the separation of its oxygen and nitrogen. One of the objects of the invention is to produce oxygen gas and nitrogen gas at approximately atmospheric temperature and pressure; and the production of liquid air, liquid nitrogen, liquid oxygen, gaseous nitrogen and gaseous oxygen may also be accomplished by the methods and means hereinafter described.

20 The accompanying drawing, which is diagrammatic and conventional, illustrates partly in elevation and partly in section the apparatus herein described and claimed.

Referring to the drawing,—a machine which may be of any well-known type for compressing air to high pressure and cooling the same is represented conventionally at 1. Air is drawn into the cylinder 2 through an inlet pipe 2', and after being compressed and cooled the air is forced through a conduit 3, inner tube of concentric helical tube coils 4, conduit 5, drying chamber 6, conduit 8, and into a heat exchanger indicated generally at A. This exchanger 35 comprises a shell or casing 21 through which extend longitudinally thereof a plurality of tubes 9, preferably of copper, the tubes having their ends soldered in headers 10 and 10' fixed near the ends of the casing, the peripheries of the headers contacting with the internal side walls of the casing. The air upon entering the exchanger from the conduit 8 passes through the tubes 9 and out through conduit 11. At 11' is indicated a cross which deflects the compressed air so that it traverses three different paths. One portion of the air passes downwardly through a valve 15 and nozzle 16' into a turbine chamber 16 where the air is expanded and caused to propel a rotor similar to that shown in Patent No. 1,110,423, dated September 15, 1914. The air thus expanded is cooled, but its temperature remains above that required for the liquefaction of uncompress-
55 pressed air, the mechanical power developed

is conserved as hereinafter described, and the air from the chamber 16 is used as a refrigerant as follows. A second portion of the compressed air passes from the cross 11' through conduit 12 to an auxiliary heat exchanger B, the casing of which is indicated at 19. This auxiliary exchanger is similar to exchanger A, except that it is arranged vertically, being provided with headers 14 and 14' and copper tubes 13 affixed therein. The cooled and expanded air from the turbine chamber 16 passes through conduit 18 into the casing 19 of the exchanger B and surrounds the copper tubes therein, in which tubes compressed air of the second portion is under pressure, thereby chilling the compressed air and causing it to liquefy. When a quantity of liquid has accumulated at the bottom of the exchanger B it is allowed to pass through valve 24 into chamber 25. There will be sufficient pressure behind the liquid to force it from the chamber 25 through conduit 26, valve 27 and nozzles 28 and 29 into compartment 45 of a one-stage rectifier and lower compartment 57 of a two-stage rectifier, the valve 27 being so adjusted as to allow only liquid to pass therethrough. The expanded and cooled first portion surrounding tubes 13, after it has served by its coldness to liquefy the compressed air in said tubes, is led from the casing of exchanger B through conduit 20 and into the casing 21 of exchanger A, where it abstracts heat from the compressed air in tubes 9. The air is then led from the casing 21 through conduit 22 into compression chamber 2 for reuse.

When sufficient liquid from the nozzles 28 and 29 has passed downwardly from compartments 45 and 57 to chambers 30 and 31 therebeneath, the third portion of compressed air passing from cross 11' through conduit 32 to valve 33 is permitted to pass said valve, by which it is reduced in pressure, and it then passes into chambers 35 and 37. These chambers are arranged adjacent evaporating compartments 30 and 31 respectively, chamber 35 being provided with an upwardly extending series of copper tubes 34 and chamber 37 being provided with similar tubes 36. Tubes 34 are provided at their upper ends with a header 34' common to the series and serving as a closure. The tubes 36 are provided with a similar header 36'. The reduced-pressure air forced into the tubes 34 and 36 from

chambers 35 and 37 liquefies therein and is led from chambers 35 and 37 by conduits 38 and 41 respectively, liquid only being allowed to pass through valves 39 and 42 and flowing therefrom into compartments 45 and 57 into which other liquid air is flowing. The liquid in chambers 30 and 31 is evaporated by the comparatively warm compressed air undergoing liquefaction in tubes 34 and 36, and rises through ports 67, passing into rectifying chambers 45 and 57. The chambers 45 and 57 are provided with a content of pervious material 44, such as pebbles or lead shot, which offers impedance to the downflow of liquid and the upward flow of gas or vapor. As the vapor from the oxygenous liquid in chambers 30 and 31 passes upwardly it is brought into contact with the liquid flowing downwardly, this resulting in the reliquefying of the oxygen in the ascending vapor. The nitrogen gas passes above the inflowing liquid air and is carried from the one-stage rectifier through a conduit 46 by which it is led to a compressor 47 operated in any desired manner,—power-transmitting means, such as a chain or belt, mounted on a pulley or shaft 64 of the turbine 17 and conveying motion therefrom to the compressor through a pulley on shaft 65 being illustrated on the drawing. The nitrogenous gas is compressed to a degree ranging from three to five atmospheres and passes from the compressor into the inner tube of a coil 49 from which it passes downwardly to valve 50 in pipe 52. Here its pressure is regulated and the nitrogen gas is led through pipe 52 into chamber 53. Chamber 53 is provided with a series of copper tubes 51 extending upwardly into the chamber 71 and having at their upper ends a header 51' by which the ends of the tubes 51 are closed or sealed. The nitrogenous gas is forced upwardly into the tubes 51 from the chamber 53 and is liquefied. The nitrogenous liquid is under sufficient pressure to force it from the chamber 53 through conduit 54 to valve 55, which is so regulated as to allow only liquid to pass therethrough. From the valve 55 the liquid passes through nozzle 56 into the upper compartment 57' of the two-stage rectifier, this compartment being similar to the other rectifying compartments in that it contains a pervious material 44 and has ports 67 in its bottom wall. The unliquefied vapors in compartment 57, consisting of a large proportion of nitrogen and a small proportion of oxygen, are led to the upper compartment 57' through the ports 67 and are there subjected to a practically complete rectification by the nitrogenous liquid from the nozzle 56, the oxygen in the vapors being wholly condensed and the nitrogen remaining as a gas because of insufficiently low temperature to liquefy it. The liquid oxy-

gen thus condensed falls back into the compartment 57 and into chamber 31, while the practically pure nitrogen gas is passed from the top of compartment 57' through the conduit 58 which connects with the outer tube of the concentric tube coil 49. Here the nitrogen gas loses its heat in cooling the gas in the inner tube of said coil, and is discharged through conduit 59 by which it may be led to any suitable receptacle.

The oxygenous liquid is permitted to pass from the upper portions of chambers 30 and 31 through pipes 72 and 73, which are provided respectively with regulating valves 72' and 72'', into chamber 71, where the additional heating causes complete vaporization and the gas rises through conduit 60 (broken away as far as C at the left of the drawing for convenience of illustration) which connects with the coil 61 in drying chamber 6, where, because of the comparatively very low temperature of the oxygen gas, the moisture is literally frozen out of the compressed air passing through the chamber and falls to the bottom of the chamber, whence it may be removed on occasions when the apparatus is not operating, by means of the tap 7 at the bottom of the chamber, the size of the chamber being an effective preventive of its becoming clogged by ice. After the oxygen gas has left coil 61 it passes through conduit 62 into the outer tube of coil 4 where it chills the compressed air in the inner tube and is itself warmed. From the outer tube of coil 4 the gaseous oxygen is passed through conduit 63 at approximately atmospheric temperature and pressure to a suitable receptacle, not shown.

If desired, rich oxygenous liquid may be drawn from the container 71 through tap 66. Liquid air may be obtained by tapping chambers 37 or 35, and liquid nitrogen may be obtained by tapping chamber 53.

The apparatus described herein, with the exception of the air compressors, is to be thoroughly insulated from the heat of the atmosphere by means of any suitable insulation, such as wool or ground cork.

In the specification and claims the terms "compartment", "container" and "chamber" are non-interchangeable. By keeping this fact in mind, an understanding of the claims will be greatly facilitated.

I claim:

1. In an apparatus of the character stated, means for compressing and cooling air, means whereby the compressed air is divided into three portions, means whereby one of said portions is caused to liquefy the second portion, and means whereby the third portion is caused to evaporate the liquid produced from the second portion of said compressed air.

2. In an apparatus of the character stated,

means for compressing and cooling air, means whereby the compressed air is divided into three portions, means whereby one of said portions is caused to liquefy the second portion, and means whereby the third portion is caused to evaporate the liquid produced from the second portion of said compressed air and whereby the third portion is caused to liquefy.

3. In an apparatus of the character stated, means for compressing and cooling air, means whereby the compressed air is divided into three portions, means whereby one of said portions is caused to liquefy the second portion, means whereby the third portion is caused to evaporate the liquid produced from the second portion of said compressed air and the third portion is caused to liquefy, means whereby the liquids from the second and third portions are merged, and means whereby the nitrogen and oxygen in said liquids are separated.

4. In an apparatus of the character stated, means for compressing and cooling air, means whereby the compressed air is divided into three portions, means whereby one of said portions is caused to liquefy the second portion, means whereby the third portion is caused to evaporate the liquid air produced from the second portion of said compressed air and the third portion is caused to liquefy, means whereby the liquids from the second and third portions are merged, and means whereby the nitrogen and oxygen in said liquids are separated and gasified.

5. In an apparatus of the character stated, a one-stage rectifier, a two-stage rectifier, each of said rectifiers having therebeneath a container for liquid passing downwardly from said rectifiers, a plurality of liquefying chambers each of which is partly enveloped by one of said containers, each of said containers having communication with an auxiliary container, means for conducting compressed air to said chambers, means for delivering liquid from one of said chambers to the rectifying compartment of said one-stage rectifier, means for delivering liquid from the other of said chambers to the lower compartment of said two-stage rectifier, a compressor, means for operating said compressor, means for conducting gas from the top of said one-stage rectifier to said compressor, an auxiliary liquefying chamber having portions extending into said auxiliary container, means for delivering compressed gas from said compressor to said auxiliary liquefying chamber, means whereby liquid from said auxiliary liquefying chamber is delivered to the top compartment of said two-stage rectifier, a conduit whereby gas is conducted from said top compartment to a receptacle, said conduit being arranged so that gas passing therethrough is caused to cool gas from said

compressor, and a conduit for gas evaporated from said auxiliary container so arranged that said gas is caused to dry and cool compressed air while said gas is being conducted to a receptacle.

6. In an apparatus of the character stated, in combination, means for compressing and cooling air, means whereby said compressed air is divided into three portions, means whereby one portion of said compressed air is expanded and cooled and is caused to liquefy the second portion of said compressed air, a one-stage rectifier, a two-stage rectifier, each of said rectifiers having therebeneath a container for liquid passed downwardly from said rectifiers, said containers having communication with an auxiliary container, means for delivering liquid from said chambers to the rectifying compartment of said one-stage rectifier and to the lower rectifying compartment of said two-stage rectifier, a gas compressor, means for conducting gas from the top of said one-stage rectifier to said gas compressor, an auxiliary liquefying chamber having portions extending into said auxiliary container, a conduit to deliver gas from said compressor to said auxiliary chamber, means whereby liquid from said auxiliary chamber is delivered to the top compartment of said two-stage rectifier, a conduit whereby gas is conducted from said top compartment to a receptacle, said conduit being arranged so that gas passing therethrough is caused to cool the gas from said gas compressor, and a conduit for gas evaporated from said auxiliary container so arranged that said gas is caused to dry and cool compressed air while said gas is being conducted to a receptacle.

7. An apparatus of the character described comprising means for compressing and cooling air and dividing it into three portions; means for liquefying the first portion using the second portion as agent; and means for evaporating the first portion with the third portion as agent.

8. An apparatus of the character described comprising means for compressing and cooling air and dividing it into three portions; means for liquefying the first portion with the second portion as agent; and means for evaporating the first portion and liquefying the third portion.

9. An apparatus consisting of means for compressing and cooling air and dividing it into three portions; means for liquefying the first portion by the cooling power of the second portion; and means for evaporating the first portion by the heat of the third portion and at the same time liquefying the third portion; means for merging the first and third liquid portions, and separating the liquid mixture into liquid oxygen and nitrogen gas.

10. An apparatus of the character described comprising means for compressing and cooling air and dividing it into three portions; means for liquefying the first portion by the cooling power of the second portion; means for cooling said second portion by expanding it through a motor machine; and means for evaporating said first portion by the heat of the third portion of compressed air.

11. An apparatus of the character described comprising means for compressing air to relatively high pressure, means for cooling and drying said air, and dividing it into three portions; means for liquefying the first portion by the cold produced from the expansion of the second portion; and means for progressively evaporating said first portion by the heat of the third portion, and means for reducing said third portion to a relatively low pressure.

12. An apparatus of the character described comprising means for compressing, cooling and drying atmospheric air, and dividing it into three portions; means for liquefying the first portion by the second portion, said second portion being provided with means for its expansion in a motor machine; means for evaporating partially or wholly the first portion by the heat of the third portion and at the same time liquefying the third portion progressively; means for merging the liquids from the first and third portions; and means for separating the liquid mixture into gaseous oxygen and nitrogen.

13. An apparatus of the character described comprising a one-stage rectifier, a two-stage rectifier, each rectifier being provided with a container for liquid passing downwardly from said rectifiers, a plurality of liquefying chambers, which are partly enveloped by said containers, and each of said containers connecting with an auxiliary container; means for conducting air under pressure to said chambers; means for delivering liquid from one of said chambers to the one-stage rectifier; means for delivering liquid from the other of said chambers to the two-stage rectifier; a compressor with means for operating it; means for conducting the gaseous mixture issuing from the one-stage rectifier to said compressor; an auxiliary liquefying chamber partly enveloped by said auxiliary container; means for delivering compressed gas from said compressor to said auxiliary liquefying chamber; means whereby liquid from said auxiliary liquefying chamber is delivered to the two-stage rectifier; a conduit whereby gaseous nitrogen issuing from the top of the two-stage rectifier is conducted to a receptacle, said conduit being so arranged that gas passing therethrough is caused to cool gas from said compressor; and a conduit for

gaseous oxygen issuing from said auxiliary container so arranged that said gaseous oxygen is caused to dry and cool compressed air while being delivered to a receptacle.

14. In an apparatus of the character described, means for delivering liquid air to the rectifying compartment of a one-stage rectifier and to the lower compartment of a two-stage rectifier; means for evaporating the liquid falling from said compartments in containers therebeneath, whereby gaseous mixtures are caused to rise through said compartments; means whereby a portion of the oxygen of said gaseous mixtures is reliquefied by being saturated with liquid air delivered to said compartments; means for compressing, cooling and liquefying the nitrogenous gas issuing from the one-stage rectifier; means for conducting the nitrogenous liquid formed to the upper compartment of said two stage rectifier, whereby it is re-gasified by the ascending gaseous mixtures; and means for warming the nitrogen gas issuing from the two stage rectifier before delivering it to a receptacle.

15. In an apparatus of the character described, means for delivering liquid air to the rectifying compartment of a one-stage rectifier and to the lower compartment of a two-stage rectifier; means for evaporating liquid falling from said compartments in containers therebeneath, whereby gaseous mixtures are caused to rise through said compartments, means whereby a portion of the oxygen of said gaseous mixtures is reliquefied; means for compressing, cooling and liquefying the nitrogenous gas issuing from the one-stage rectifier and means for conducting the nitrogenous liquid formed to the upper compartment of said two-stage rectifier, whereby the remaining oxygen of the ascending gaseous mixture is reliquefied and the nitrogenous mixture is at the same time gasified; and means for warming the nitrogen gas issuing from the two-stage rectifier.

16. In an apparatus of the character described, means for compressing, cooling and drying air and dividing it into three portions, means for liquefying the first portion by the cooling power of the second portion; means for delivering the first portion liquid to a one-stage rectifier and a two-stage rectifier; means for evaporating liquid falling from said rectifier in containers thereto attached by the heat of the third portion of compressed air, whereby the third portion is liquefied, and gaseous mixtures are caused to rise through said rectifiers; means for reliquefying a portion of the oxygen of said gaseous mixtures by the rectifying power of the liquid from the first and third portions of compressed air; means for compressing, cooling and liquefying the nitrogenous gas issuing from said one-stage rectifier; means for conducting the nitrogenous liquid

formed to the upper compartment of said two-stage rectifier, whereby the remaining oxygen of said gaseous mixture rising from the lower compartment is re-liquefied, and the nitrogenous liquid is progressively vaporized; and means for warming the nitrogen gas issuing from the two-stage rectifier before delivering it to a receptacle.

17. In an apparatus of the character described, means for compressing, cooling and drying air and dividing it into three portions; means for liquefying the first portion by the cooling power of the second portion; means for delivering the first portion liquid to the rectifying compartment of a one-stage rectifier and the lower compartment of a two-stage rectifier; means for evaporating the first portion liquid progressively in containers attached to said rectifiers by the heat of the third portion of compressed air, whereby said third portion is progressively liquefied and gaseous mixtures are caused to rise through said rectifiers; means whereby a portion of the oxygen of said gaseous mixtures is re-liquefied by contact with the liquids from the first and third portions of compressed air; means for compressing, cooling and liquefying the nitrogenous gas issuing from the one-stage rectifier; means for conducting the nitrogenous liquid formed to the upper compartment of said two-stage rectifier, whereby the remaining oxygen in the ascending gaseous mixture is re-liquefied and the nitrogenous liquid is at the same time progressively vaporized; means for warming the nitrogen gas produced by rectification before delivering it to a receptacle; and means for drying and cooling compressed air by the cooling power of the gaseous oxygen produced by rectification before delivering said gaseous oxygen to a receptacle.

18. An apparatus of the character described comprising means for delivering liquid air to the rectifying compartment of a one-stage rectifier and to the lower rectifying compartment of a two-stage rectifier; means for evaporating liquid falling from said compartments in containers therebeneath; means whereby gaseous mixtures are caused to rise through said compartments; means whereby a portion of the oxygen of said gaseous mixtures is re-liquefied by bringing other liquid into contact with said gaseous mixtures; means for compressing and cooling the nitrogenous gas issuing from the one-stage rectifier; means for liquefying it in a chamber partially enveloped by an auxiliary container communicating with said other containers, whereby the oxygenous liquid in said auxiliary container is gasified; means for conducting the nitrogenous liquid formed to the top compartment of said two-stage rectifier, whereby its nitrogen content is re-gasified by the ascending gaseous mixture; and means for warming the nitrogen

gas issuing from said two-stage rectifier before delivering said nitrogen gas to a receptacle.

19. An apparatus of the character described comprising means for delivering liquid air to a one-stage rectifier and a two-stage rectifier; means for evaporating the liquid falling from said rectifiers in containers thereto attached by liquefying air under more or less pressure in chambers partially enveloped by said containers; means whereby gaseous mixtures are caused to rise from said containers and to pass upward through said rectifiers; means for delivering the liquid air from said chambers into the compartments in which other liquid air is being delivered; means for compressing the nitrogenous gas issuing from the one-stage rectifier; means for cooling said nitrogenous gas by passing it through a coil immersed in nitrogen gas which is on its way to a receptacle; means for liquefying the cooled and compressed nitrogenous gas in an auxiliary chamber immersed in an auxiliary container communicating with said other containers; means whereby the oxygenous liquid in said auxiliary container is progressively evaporated; means for conducting the nitrogenous liquid from said auxiliary chamber to the upper compartment of said two-stage rectifier, whereby its nitrogen content is progressively vaporized by the ascending gaseous mixture; and means for cooling and drying compressed air to be used in the process by the cold oxygen vaporized in said auxiliary container, while said oxygen gas is being conducted to a receptacle.

20. In an apparatus of the character described, means for delivering liquid air to a one-stage rectifier and a two-stage rectifier; means for evaporating said liquid air progressively in containers attached to said rectifiers; means for reliquefying a portion of the oxygen of the gaseous mixtures arising from said containers by liquid air delivered to said rectifiers; means for collecting the liquid oxygen formed in an auxiliary container communicating with said other containers; means for compressing and cooling the nitrogenous gas issuing from said one-stage rectifier; means for delivering the nitrogenous liquid formed to the upper compartment of said two-stage rectifier, whereby the oxygen content of the gaseous mixture passing through said two-stage rectifier is reliquefied; and means for utilizing the cooling power of the nitrogen gas issuing from two-stage rectifier before delivering it to a receptacle.

21. In an apparatus of the character described, means for delivering liquid air to a one-stage rectifier and a two-stage rectifier; means for evaporating said liquid in containers attached to said rectifiers; means for reliquefying a portion of the oxygen of the

gaseous mixtures issuing from said containers by contact with liquid air delivered to said rectifiers; means for collecting the liquid oxygen formed in an auxiliary container communicating with said other containers; means for compressing and cooling the nitrogenous gas issuing from said one-stage rectifier; means for liquefying it in a chamber immersed in said auxiliary container; means for delivering the nitrogenous liquid formed to the top compartment of said two-stage rectifier; means whereby the remaining oxygen in the gaseous mixture rising from the lower compartment of said two-stage rectifier is reliquefied; means for utilizing the cooling power of the nitrogen gas produced to cool nitrogenous gas which is to be liquefied; and means for utilizing the cooling power of the oxygen gas to cool and dry compressed air to be used in the apparatus.

22. An apparatus of the character stated in combination, means for compressing, cooling and drying air; means whereby said air is divided into three portions; means whereby one portion of said air is expanded and cooled and caused to liquefy the second portion; a one-stage rectifier, a two-stage rectifier, each rectifier having therebeneath a con-

tainer for liquid passing downwardly from said rectifiers and said containers communicating with an auxiliary container, all of said containers being provided with liquefying chambers; means for delivering liquid from chambers attached to the one and two-stage rectifiers to their respective rectifier; a compressor; means for conducting the gaseous mixture issuing from the one-stage rectifier to said compressor; a conduit to deliver the compressed gaseous mixture from said compressor to the liquefying chamber of the auxiliary container; means for delivering liquid from said liquefying chamber of the auxiliary container to the two stage rectifier; a conduit whereby gaseous nitrogen is conducted from said two-stage rectifier to a receptacle; said conduit being so arranged that the gaseous nitrogen passing there-through is caused to cool the gaseous mixture from said compressor; and a conduit for gaseous oxygen evaporated from said auxiliary container so arranged that said gaseous oxygen is caused to dry and cool compressed air while said gaseous oxygen is being conducted to a receptacle.

In testimony whereof I have affixed my signature.

CHARLES F. CROMMETT.