

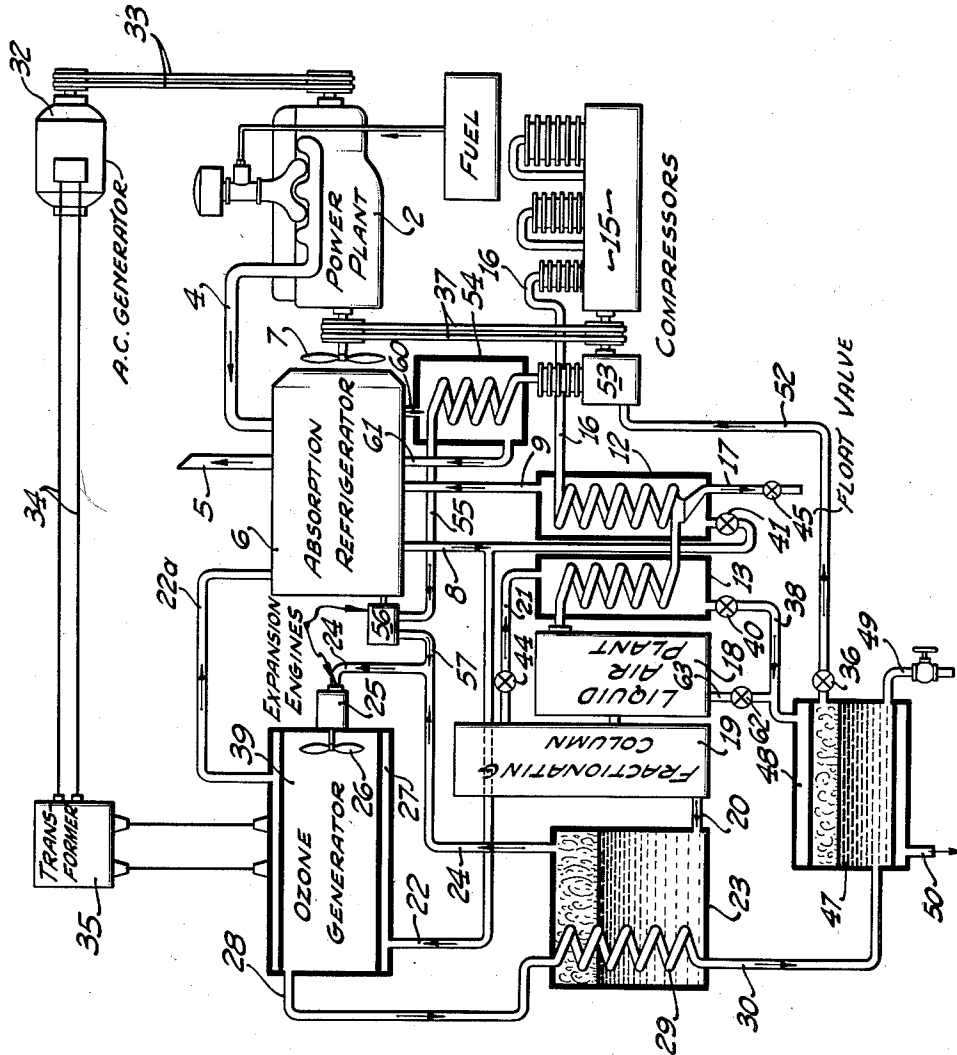
March 15, 1955

D. K. ALLISON

2,704,274

APPARATUS AND METHOD FOR PRODUCING LIQUID OZONE

Filed Oct. 25, 1946



DONALD K. ALLISON,
INVENTOR.

BY *Robert M. Lewis*
ATTORNEY.

1

2,704,274

APPARATUS AND METHOD FOR PRODUCING
LIQUID OZONE

Donald K. Allison, Washington, D. C., assignor of one-half to Robert W. Fulwider, Warren L. Patton, and William K. Rieber, Los Angeles, Calif., as tenants in common

Application October 25, 1946, Serial No. 705,698

23 Claims. (Cl. 204—176)

My invention relates generally to a combustant, and to method, and apparatus for producing the same. More particularly my invention relates to a combustant which is adapted particularly for use as an oxidizer for rocket fuels. Such fuels and oxidizers find their use in rocket missiles, aircraft, take-off assisting units, and the like.

It is a major object, then, of my invention to provide an oxidizer and a method and apparatus for producing the same which oxidizer shall be suitable for use in rocket engines and the like and which has a substantially higher B. t. u. per pound ratio than has been available heretofore.

It is another object of my invention to provide such an oxidizer which has a greater amount of available oxygen in a given volume of liquid than has been the case with previous oxidizers.

Still another important object of my invention is to provide apparatus for producing an oxidizer of the class described which is reasonably portable and which is capable of operating on ordinary fuel such as gasoline, distillate, and the like.

It is a further object of my invention to provide apparatus which is capable of producing a highly efficient oxidizer of the class described, using as raw materials and other expendable materials, only air and water.

It is a still further object of my invention to provide an oxidizer of the class described in the form of a liquefied gas which can be liquefied at a higher temperature than that required for oxygen (O_2).

The foregoing and additional objects and advantages of the invention will become apparent from the following detailed disclosure thereof, taken in connection with the attached drawings in which Fig. 1 depicts apparatus for carrying out the method of my invention to produce a propellant of the class described.

I have found liquid ozone to be a propellant meeting the above-stated requirements. By reason of the fact that triatomic ozone, (O_3) when it disassociates into diatomic oxygen (O_2), releases considerable energy, a propellant using liquid ozone as an oxidizer is considerably more effective than one using liquid oxygen (O_2).

The following is an example of the increase in released heat energy which is obtained by using ozone in place of oxygen. Methanol or methyl alcohol (CH_3OH), a fuel sometimes used in rockets, releases 10,270 B. t. u. per pound when oxidized. One pound of methanol requires approximately two pounds of oxygen for complete combustion. The foregoing proportion results in an overall efficiency of 3,423 B. t. u. per pound of the mixture of methanol and pure oxygen. As previously stated, ozone, upon disassociation, releases considerable heat energy the amount being approximately 1,295 B. t. u. per pound. If, then, the oxygen of the foregoing combustion re-action is replaced with ozone, an additional 862 B. t. u. are released upon the oxidation of one pound of the methanol-ozone mixture.

An additional advantage of liquid ozone over liquid oxygen as an oxidizer for rocket fuels, is occasioned by the differences in the specific gravity of the two liquids. The specific gravity of oxygen (O_2) is 1.118, whereas that of ozone is 1.784. Thus a given weight of ozone can be carried in a considerably smaller space than the same weight of oxygen, a saving of considerable importance in rocket missiles and the like.

Still another advantage of ozone is that due to its relatively higher boiling point than that of oxygen (O_2), it may be stored in relatively lighter containers than can

2

liquid oxygen since less pressure is required to maintain the ozone in a liquid condition. Similarly, less heat insulation is required to maintain ozone in a liquid condition at a given pressure, than is required for oxygen (O_2).

Liquid ozone has been produced heretofore only in experimental quantities and by laboratory procedures. When in the liquid state, ozone is highly explosive due to its tendency to disassociate into oxygen (O_2) when subjected to mechanical shock or when impurities, particularly organic matter, are introduced therein.

Having selected liquid ozone as a desirable oxidizer for rocket fuels, it is a still further object of my invention to provide apparatus for producing and liquefying ozone which apparatus shall be so constructed as to avoid the introduction of foreign matter into the liquid ozone and which shall not subject the gaseous or liquid ozone to mechanical shock such as that occasioned by passing the gas through a compressor.

Briefly described, the apparatus of my invention comprises a prime mover such as an internal combustion engine identified in the drawing by the reference character 2 which drives an A. C. generator 32 and a plurality of compressors 15 and 53. The waste heat energy contained in the exhaust gases of the prime mover are used to power an absorption refrigerator 6, the cooling coils of which are employed in a number of heat exchangers to be described in more detail hereinafter. One of the compressors 15 driven by the prime mover 2 is used to compress air for the purpose of producing liquid air by either the Claude or Linde process, both of which are well known in the art. Some of the liquid air produced by either of the foregoing processes is then passed into a fractionating column 19 and the nitrogen allowed to boil off. The nitrogen gas being relatively cool is mixed with non-fractionated liquid air and employed in another heat exchanger 13 which will also be described in more detail hereinafter. The liquid oxygen remaining in the fractionating column is passed into a combination heat exchanger and boiler 23. Gaseous oxygen (O_2) boiling off of the liquid oxygen in the boiler 23 is fed under pressure to an ozone generator 39 of the general class described in my previous Patent No. 2,405,728, patented August 13, 1946. A relatively high proportion of the oxygen passing through the ozone generator is converted into gaseous ozone (O_3) and the relatively ozone-rich ozone-oxygen mixture is then passed through a heat exchanger coil 29 situated in the boiler 23 above mentioned. The cooling effect of the liquid oxygen in the boiler 23, acting on the gaseous ozone, condenses it into a liquid which is then passed into a jacketed and cooled storage container 47. Such gaseous diatomic oxygen as is carried into the storage container with the liquid ozone is drawn off, compressed, cooled, expanded through an expansion engine, and fed back into the ozone generator along with the oxygen produced in the oxygen boiler.

Following is a more detailed description of the apparatus just outlined. The prime mover 2 may be an internal combustion engine, a steam engine or any other suitable source of mechanical power preferably one in which heat is produced as a by-product. Such by-product heat as for example that contained in the exhaust gases of an internal combustion engine is delivered through a suitable duct 4 into the absorption refrigerator 6 in which heat is absorbed from the gases and operates in the conventional absorption refrigeration cycle whereby to cool a refrigerant for purposes to be described in more detail hereinafter. After having been cooled, the exhaust gases are emitted from the refrigerator through a suitable exhaust duct 5.

The power plant 2 is suitably coupled as for example by the V-belts 33 to an A. C. generator 32 and by other belts 37 to two compressors 15 and 53 one of which 15 is a multiple stage compressor capable of compressing air to a pressure in the neighborhood of 250 lbs. per square inch.

The A. C. generator delivers its electrical output through leads 34 to a high-voltage transformer 35 the secondary of which is suitably connected to an ozone gen-

erator 39 which will be described in more detail hereinafter.

Proceeding with the steps in the process which produce oxygen for delivery to the ozone generator 39, the elements of the apparatus will be described in the order of the gas flow through the apparatus starting at the multiple stage compressor 15. From the compressor 15, the compressed air is delivered through a duct 16 to coils in a heat exchanger 12. The heat exchanger 12 obtains its refrigerant from the absorption refrigerator 6 through suitable supply and return ducts 8 and 9, respectively. The purpose of the heat exchanger 12 is to cool the air to a temperature at or near the freezing temperature of the water therein for the purpose of removing substantially all of the moisture therefrom. As is well known in the art, when air is cooled well below the dew point the moisture contained therein is condensed out and in the present instance is drawn off through a duct 17 controlled by a float valve 45 or other suitable means adapted to withstand the relatively high air pressure in the coils of the heat exchanger 12.

From the heat exchanger 12 the compressed and relatively dry air is delivered to the coils of a precooling heat exchanger 13 in which the refrigerant is gaseous nitrogen obtained in a manner to be described hereinafter. The precooler 13 markedly reduces the temperature of the air, and at this reduced temperature it is delivered to a liquid air plant 18. The plant 18 may be either of the type operating on the Claude or on the Linde cycle or may be any other type of energy reduction plant capable of receiving highly compressed air, reducing the temperature below the critical temperature, and converting the air to a liquid. In the presently illustrated embodiment, the plant 18 operates on the Claude cycle wherein energy is removed from the air by allowing it to operate an expansion engine and is then circulated in heat exchange relationship with incoming air whereby to effect regenerative cooling which regenerative cooling is continued until condensation is effected.

The largest part of the liquid air produced in the plant 18 is delivered to a fractionating column 19 in which the pressure and temperature are so controlled as to allow the nitrogen constituent of the liquid air to boil off, but to prevent boiling of the oxygen constituent. The gaseous nitrogen produced in the fractionating column is delivered through a duct 21 and is used as a refrigerant as will be described in more detail hereinafter.

The relatively pure liquid oxygen produced in the fractionating column is delivered through a duct 20 to a boiler 23 and is heated by coils 29 to a point where it vaporizes at a controlled rate into gaseous oxygen (O_2) which is delivered at a pressure of approximately 100 lbs. per square inch through a duct 24 and through an expansion engine 25 to the ozone generator 39.

The ozone generator 39 is of the class described in detail in my previous patent above referred to and produces a relatively high percentage of ozone. The generator operates on the corona discharge principle the electrical power being delivered from the transformer 35 as previously described. A fan 26 driven by the expansion engine 25 effects forced recirculation of the oxygen through the corona discharge within the ozone generator whereby to greatly increase the efficiency thereof as described in my previous patent.

Efficiency of the ozone generator is also greatly increased by cooling the same. For this purpose a jacket 27 is provided which surrounds the generator 39 and into which is delivered refrigerant from the refrigerator 6 said refrigerant being at a temperature of approximately $-50^\circ C.$ and being delivered through duct 22 and returned through duct 22a.

A relatively ozone-rich mixture of oxygen and ozone is delivered from the ozone generator through a duct 28 to a coil 29 situated within the previously described boiler 23. Since the boiling point of oxygen is in the neighborhood of $-182^\circ C.$ and that of ozone is approximately $-112^\circ C.$, the effect of the heat exchange relationship between the coil 29 and the liquid oxygen (O_2) in the boiler 23 is such as to produce condensation of ozone within the coils 29 and also to boil the liquid oxygen as above described. While the pressure on the liquid oxygen in the boiler 23 raises the boiling point somewhat, this temperature is still considerably below the condensation point of ozone and hence liquefaction

takes place. Liquid ozone thus condensed is delivered through a duct 30 to a storage container 47 carrying with it such gaseous oxygen as was contained in the mixture delivered by the generator 39. The storage tank 47 is provided with a suitably valved exit duct 49 from which liquid ozone may be drawn off as desired. In order to prevent excessive pressures within the storage container 47, a jacket 48 is provided into which a mixture of relatively cold gaseous nitrogen and liquid air from the plant 18 is introduced. Such liquid air is delivered through a duct 63 and controlled by a throttling valve 62.

The pressure and temperature of the storage container 47 are so maintained that the ozone therein remains in a liquid state while the oxygen remains in a gaseous state. Such gaseous oxygen is delivered through a throttling valve 36 and a duct 52 to a single stage compressor 53 wherein it is compressed adiabatically until its temperature is approximately $-40^\circ C.$ whereupon it is delivered to a heat exchanger 54 which derives its refrigerant from the absorption refrigerator through ducts 60 and 61.

From the heat exchanger 54 the compressed oxygen is delivered through a duct 55 to an expansion engine 56. Hence it is delivered to a juncture with duct 24 and hence into the ozone generator 39.

The mechanical power delivered by the expansion engine 56 is employed to operate a refrigerant circulating pump in the absorption refrigerator 6.

Returning now to a description of the means employed to make use of the cold gaseous nitrogen delivered from the fractionating column, it will be remembered that a heat exchanger 13 is employed to precool the air delivered to the liquid air plant 18. Gaseous nitrogen is delivered through a duct 21 to a refrigerating tank of the heat exchanger 13. From this tank it is delivered through a throttling valve 40 and a duct 38 to a juncture with the liquid air duct 63 where it mixes with liquid air and is delivered to the jacket 48 of the storage container 47. From the jacket 48 the air and nitrogen mixture is exhausted into the air through an outlet port 50.

It will be seen from the foregoing description that the apparatus of my invention makes complete and efficient use of the power produced in power plant 2.

It is to be noted further that once the apparatus shown and described has been set in operation and the various heat exchangers have come to a point of equilibrium dependent on the rate of flow therethrough, the amount of air delivered by the compressor 15 is relatively small, being only that required to deliver the actual weight of liquid ozone collected in the storage tank 47 plus the nitrogen and air exhausted at the port 50. Relatively little oxygen is lost by the system since any which is not converted to ozone in the generator 39 is recirculated through the duct 52, the compressor 53, the ducts 55, 57 and 24 to the ozone generator 39, in the manner previously described.

This method of producing ozone which includes liquefying air or oxygen is highly effective since it removes all traces of moisture from the oxygen delivered to the ozone generator 39, hence greatly increasing the efficiency thereof.

In view of the interdependency between pressure and temperature of gases, it is to be understood that all temperatures and/or pressures mentioned herein are for purposes of illustration only and are not to be considered as critical to the operation of the apparatus except as defined in the appended claims. While the apparatus shown and described herein is fully capable of achieving the objects and providing the advantages hereinbefore stated, it is to be regarded as illustrative only. Hence I do not mean to limit myself to the specific form shown and described, but rather to the scope of the appended claims.

I claim:

1. In apparatus for producing liquid ozone: a compressor adapted to compress air above the critical pressure thereof; a liquid air plant including a precooler connected to the output of said compressor and adapted to liquefy air delivered by said compressor; a fractionating column connected to receive liquid air from said plant and adapted to separate the same into gaseous nitrogen and liquid oxygen; a boiler connected to said column at a point therein to receive said liquid oxygen, said boiler being adapted to maintain a pressure therein to

5

6

effect controlled boiling of said liquid oxygen whereby to deliver gaseous oxygen therefrom under pressure; an ozone generator connected by a conduit to said boiler to receive said gaseous oxygen and convert a substantial proportion thereof into gaseous ozone; and a heat exchanger element in said boiler connected to receive from said generator, gaseous ozone mixed with unconverted gaseous oxygen, said element being in heat exchange relation with said boiling oxygen whereby to liquefy said ozone while delivering the heat of condensation produced thereby to said boiling oxygen.

2. The apparatus of claim 1 further characterized by having a gas impeller in said ozone generator adapted to re-circulate gas therein and an expansion engine mechanically connected to drive said impeller and interposed in said generator conduit whereby to receive power from said oxygen gas delivered to said generator.

3. The apparatus of claim 1 further characterized by having a heat producing prime mover for said compressor and an absorption refrigerator of the type energized by a source of heat connected to receive heat from said prime mover and to refrigerate said compressed air whereby to remove the moisture therefrom prior to introduction thereof into said energy reduction plant.

4. The apparatus of claim 1 further characterized by having a cooled storage container connected to receive said liquid ozone from said heat exchange element and pressurized to maintain said liquid ozone in a liquid condition, and effect removal of gaseous oxygen therefrom.

5. The apparatus of claim 4 further characterized by having a second compressor interposed between said storage container and said generator, adapted to compress gaseous oxygen from said container, and connected to return said oxygen to said generator for recirculation.

6. Apparatus for producing liquid ozone which comprises: a liquid air plant including a compressor, precooling heat exchanger and condenser to produce liquid air; fractionating means connected to the output of said condenser to separate said liquid air into liquid oxygen and gaseous nitrogen; an ozone generator having means therein to receive gaseous oxygen and convert a substantial proportion thereof into ozone; and heat exchanger means connected to the output of said generator to receive gaseous ozone mixed with gaseous oxygen from said generator and further connected to receive liquid oxygen from said fractionating means, said heat exchanger means including compartments separated by a heat conducting barrier whereby to circulate said gas mixture and liquid in heat exchanging relationship to liquefy said ozone and vaporize said liquid oxygen, said last mentioned heat exchanger means being connected to deliver said vaporized oxygen to said generator.

7. The apparatus of claim 6 further characterized by having a storage container connected to said heat exchanger to receive a mixture of liquid ozone and gaseous oxygen therefrom and pressurized to maintain said ozone in a liquid state; and conduit means connected to deliver vaporized oxygen from said container to said generator.

8. The apparatus of claim 6 further characterized by having conduit means connected to deliver said gaseous nitrogen into heat exchange relationship with air in said precooling heat exchanger to precool said air prior to said condenser.

9. Apparatus for producing liquid ozone which includes: a heat engine; a refrigerator connected to, and powered by exhaust heat from said engine, said refrigerator including a circulating pump; a liquid air producing plant including a compressor mechanically connected to be driven by said engine, a precooler connected to receive the output of said compressor, and condensation means connected to said precooler; desiccating means connected to, and cooled by refrigerant from said refrigerator and including a conduit in heat exchange relationship with said refrigerant whereby to remove water from air delivered to said liquid air means; a fractionating column connected to the output of said plant and adapted to separate a portion of said liquid air into liquid oxygen and nitrogen; an ozone generator including an electric generator driven by said engine, said generator being connected to receive oxygen separated in said column and adapted to convert oxygen delivered thereto into gaseous ozone; a heat exchanger having one compartment connected to receive said liquid oxygen and gaseous ozone from said generator and a second compartment connected between said column and generator

to place said ozone in heat exchanging relationship with said liquid oxygen whereby to vaporize said oxygen prior to delivery to said ozone generator and to liquefy said ozone; a storage container connected to said heat exchanger to receive said liquid ozone; recovery means including a conduit and throttle valve therein connected to said storage means and adapted to collect unconverted gaseous oxygen therein, and deliver the same to said generator for recirculation therethrough; cooling means for said generator connected to receive refrigerant from said refrigerator for circulation therethrough; precooling means in said liquid air plant connected to said column to receive said nitrogen and adapted to effect circulation of said nitrogen in heat exchange relation with air in said plant to precool said air; cooling means in said storage means connected to receive nitrogen from said column and liquid air from said liquid air plant for circulation therethrough; a duct connected between said heat exchanger means and said generator to deliver oxygen from the former to the latter; means including a gas impeller driven by an expansion engine operatively connected in said duct adapted to effect forced recirculation of gas within said generator responsive to expansion of oxygen passing through said duct; a second expansion engine connected by a conduit to said recovery means and mechanically connected to said pump in said refrigerator to effect circulation of refrigerant in said refrigerator responsive to expansion of said recovered oxygen; and cooling means connected in heat exchange relation in said recovery means and further connected to receive refrigerant from said refrigerator and cool said recovered oxygen.

10. The method of producing liquid ozone which includes the steps of: compressing and cooling air to produce liquid air; fractionating said liquid air to separate said liquid air into gaseous nitrogen and liquid oxygen; passing said liquid oxygen into a boiler whereby to vaporize same; thereafter passing said vaporized oxygen through a corona discharge whereby to ozonize said oxygen; and thereafter passing said ozonized oxygen in heat exchange relation through said boiler whereby to transfer heat from said ozonized oxygen to said liquid oxygen, liquefy ozone in said ozonized oxygen, and vaporize said liquid oxygen.

11. The method of claim 10 further characterized by thereafter collecting said liquid ozone in a container and passing said nitrogen in heat exchange relation past said container whereby to cool said liquid ozone.

12. The method of claim 10 further characterized by thereafter collecting said liquid ozone and the unconverted oxygen therewith in a container; passing said nitrogen in heat exchange relationship past said container whereby to cool said ozone; and collecting said unconverted oxygen from said container and re-passing said unconverted oxygen through said corona discharge to further ozonize said oxygen.

13. Apparatus for producing liquid ozone which comprises: a liquid air producing plant; fractionating means connected to receive liquid air from said plant and separate said liquid air into liquid oxygen and gaseous nitrogen; an ozone generator having means therein to receive gaseous oxygen, to convert a substantial proportion of said oxygen into ozone, and to deliver a gaseous mixture of oxygen and ozone; and a heat exchanger having gas receiving and liquid receiving chambers separated by a heat conducting barrier, said gas receiving chamber being connected to said generator to receive said gaseous mixture therefrom and said liquid receiving chamber being connected to said fractionating means to receive said liquid oxygen therefrom and place the same in heat exchange relationship with said gaseous mixture whereby to vaporize said liquid oxygen and condense the ozone from said gaseous mixture, said liquid receiving chamber being further connected to said generator to deliver said vaporized oxygen to said generator.

14. In apparatus for producing a liquid ozone from liquid oxygen: an ozone generator adapted to receive gaseous oxygen, convert a portion of said oxygen into ozone, and deliver a gaseous mixture of oxygen and ozone; a heat exchanger having two enclosed chambers separated by a heat conducting barrier; means communicating a first of said chambers with the input of said generator and the other of said chambers with the output of said generator; and means to deliver liquid oxygen to said first chamber whereby said oxygen vaporizes in said

first chamber, vaporized oxygen is delivered to said generator, said gaseous mixture is delivered to said other chamber, said ozone portion of said mixture is condensed in said other chamber, and the heat released by said condensation is delivered through said barrier to vaporize said liquid oxygen.

15. The apparatus of claim 14 further characterized by having means including a collection chamber connected to said second heat exchange chamber to collect the oxygen portion of said gaseous mixture, said collection means being connected to deliver said gaseous oxygen to said generator for repassage therethrough.

16. The apparatus of claim 15 further characterized by having a compressor connected between said collecting chamber and generator to compress said gaseous oxygen prior to said repassage through said generator.

17. The apparatus of claim 16 further characterized by having a precooling heat exchanger connected between said compressor and generator to cool said compressed oxygen prior to repassage through said generator.

18. The method of producing liquid ozone which includes the steps of: pre-cooling and compressing air to produce liquid air; fractionating said liquid air to separate the same into relatively cool gaseous nitrogen and liquid oxygen; passing said gaseous nitrogen in heat transfer relationship past said air to pre-cool the same as aforesaid; passing said liquid oxygen into a boiler whereby to vaporize the same; thereafter passing said vaporized oxygen through a corona discharge whereby to ozonize said oxygen; and thereafter passing said ozonized oxygen in heat exchange relation through said boiler whereby to transfer heat from said ozonized oxygen to said liquid oxygen, liquify ozone in said ozonized oxygen, and vaporize said liquid oxygen.

19. The method of producing liquid ozone which includes the steps of: pre-cooling and compressing air to produce liquid air; fractionating said liquid air to separate the same into relatively cool gaseous nitrogen and liquid oxygen; passing said gaseous nitrogen in heat transfer relationship past said air to pre-cool the same as aforesaid; passing said liquid oxygen into a boiler whereby to vaporize the same; thereafter passing said vaporized oxygen through a corona discharge whereby to ozonize said oxygen; thereafter passing said ozonized oxygen in heat exchange relation through said boiler whereby to transfer heat from said ozonized oxygen to said liquid oxygen, liquify ozone in said ozonized oxygen, and vaporize said liquid oxygen; collecting said liquid ozone and the unconverted oxygen therewith in a container; passing said nitrogen from its point of heat transfer with said air past said container in heat exchange relationship therewith whereby to cool said ozone while permitting vaporization of said unconverted oxygen therewith; and collecting said unconverted oxygen from said container and repassing the same through said corona discharge to further ozonize the same.

20. In apparatus for producing liquid ozone from liquid oxygen: an ozone generator adapted to receive gaseous oxygen, converted portion of said oxygen into ozone, and deliver a gaseous mixture of oxygen and ozone; a heat exchanger having two enclosed chambers separated by a heat conducting barrier; means communicating a first of said chambers with the input of said generator and the other of said chambers with the output of said generator; means to deliver liquid oxygen to said first chamber whereby said oxygen vaporizes therein, vaporized oxygen is delivered to said generator, said gaseous mixture is delivered to said other chamber, said

ozone portion of said mixture is condensed in said other chamber, and the heat released by said condensation is delivered through said barrier to vaporize said liquid oxygen; a collection chamber connected to said other chamber to collect a mixture of liquid ozone and gaseous oxygen therefrom; and cooling means for said collection chamber adapted to maintain said ozone in a liquid state while permitting escape of said gaseous oxygen therefrom.

21. The apparatus of claim 20 further characterized by having said container connected to the input of said generator whereby to deliver said gaseous oxygen from said container to be converted therein as aforesaid.

22. Apparatus for producing liquid ozone which comprises: a liquid air producing plant including a pre-cooler; fractionating means connected to receive liquid air from said plant and separate said liquid air into liquid oxygen and gaseous nitrogen; means connected to deliver said gaseous nitrogen to said pre-cooler to act as a coolant therein; an ozone generator having means therein to receive gaseous oxygen, to convert a substantial proportion of said oxygen into ozone, and to deliver a gaseous mixture of oxygen and ozone; and a heat exchanger having gas receiving and liquid receiving chambers separated by a heat conducting barrier, said gas receiving chamber being connected to said generator to receive said gaseous mixture therefrom and said liquid receiving chamber being connected to said fractionating means to receive liquid oxygen therefrom and place the same in heat exchange relationship with said gaseous mixture whereby to vaporize said liquid oxygen and condense the ozone from said gaseous mixture, said liquid receiving chamber being further connected to said generator to deliver said vaporized oxygen to said generator.

23. Apparatus for producing liquid ozone which comprises: a liquid air producing plant including a pre-cooler; fractionating means connected to receive liquid air from said plant and separate said liquid air into liquid oxygen and gaseous nitrogen; means connected to deliver said gaseous nitrogen to said pre-cooler to act as a coolant therein; an ozone generator having means therein to receive gaseous oxygen, to convert a substantial proportion of said oxygen into ozone, and to deliver a gaseous mixture of oxygen and ozone; a heat exchanger having gas receiving and liquid receiving chambers separated by a heat conducting barrier, said gas receiving chamber being connected to said generator to receive said gaseous mixture therefrom and said liquid receiving chamber being connected to said fractionating means to receive liquid oxygen therefrom and place the same in heat exchange relationship with said gaseous mixture whereby to vaporize said liquid oxygen and condense the ozone from said gaseous mixture, a collection chamber connected to receive a mixture of condensed ozone and gaseous oxygen from said gas receiving chamber; and conduit means to deliver said nitrogen from said pre-cooler after heat transfer therein, into heat transfer relation with said collection chamber whereby to maintain said condensed ozone in a liquid state while permitting escape of said gaseous oxygen therefrom.

References Cited in the file of this patent

UNITED STATES PATENTS

65	2,337,474	Kornemann et al.	Dec. 21, 1943
	2,398,201	Young et al.	Apr. 9, 1946
	2,404,778	Allison	July 30, 1946