NASA CASE NO. LAR 14398-1

PRINT FIG. 1 p- 9

## NOTICE

The invention disclosed in this document resulted from research in aeronautical and space activities performed under programs of the National Aeronautics and Space Administration. The invention is owned by NASA and is, therefore, available for licensing in accordance with the NASA Patent Licensing Regulation (14 Code of Federal Regulations 1245.2).

To encourage commercial utilization of NASA-owned inventions, it is NASA policy to grant licenses to commercial concerns. Although NASA encourages nonexclusive licensing to promote competition and achieve the widest possible utilization, NASA will provide the necessary incentive to the licensee to achieve early practical application of the invention. Address inquiries and all applications for license for this invention to **NASA Patent Counsel, Langley Research Center, Code 143, Hampton, Virginia 23665-5225.**

Serial No.: 07/736,985
Filed: 07-29-91 LaRC

(NASA-Case-LAR-14398-1) CONVERTING A CO2 ATMOSPHERE TO A HIGH-PURITY O2 SUPPLY Patent Application (NASA) 9 p N92-30098

Unclas
G3/25 0111096

NASA Case No. LAR 14398-1

## AWARDS ABSTRACT

## CONVERTING A $CO_2$ ATMOSPHERE TO A HIGH-PURITY $O_2$ SUPPLY


Planned exploration of Mars by human extravehicular activity in the early part of the next century (2007, 2009, 2011) may require techniques to produce oxygen for human consumption (and/or other applications) from the existing Martian environment. Mission outlines presently indicate a 220-day round trip with 30-day sojourn times, 20 days of which will be on the Mars surface. Clearly, it is desirable to provide a method of extracting environmental oxygen from existing sources, such as the oxide surface, the $CO_2$ ice, or the atmosphere itself, in order to alleviate the extensive requirement of sufficient oxygen necessary for such a long-term mission. Perhaps the most energy efficient approach would be the continual utilization of the six millibar $CO_2$ atmospheric surface pressure that exists on Mars.

The present invention provides a technique for conversion of an oxygen bearing gas such as a $CO_2$ atmosphere to that of a high-purity $O_2$ supply by the use of glow discharge dissociation that produces atomic oxygen and some molecular oxygen in the near vicinity of a hot silver or silver alloy membrane. The oxygen then adsorbs, dissolves and permeates the membrane to a downstream region where it thermally recombines to $O_2$ at the membrane surface and is pumped away and compressed in a storage volume. The pure oxygen can then be used for human consumption or other applications requiring $O_2$. An application of the invention is the conversion of the Martian atmosphere of $CO_2$ to a useful and breathable $O_2$ supply for astronaut consumption. There are also other applications, such as cabin atmosphere purification for the space shuttle or the Space Station Freedom. Also, there may be public interest where $CO_2$ is an unwanted byproduct that can be converted to useful $O_2$.

The novelty of the present invention resides in the conversion of an oxygen bearing gas, such as $CO_2$ atmosphere, to a high-purity $O_2$ supply by means of glow discharge dissociation of the oxygen bearing gas to produce atomic or molecular oxygen in proximity to a hot silver or silver alloy membrane, which serves to separate and direct the oxygen to a collection volume.



Inventor: Ronald A. Outlaw
Address: 98 Cove Road
Newport News, VA 23602
SS: [redacted]
Employer: NASA LaRC

Intial Evaluator: Billy T. Upchurch


Serial No.: 07/736,985
Filed: 07-29-91

# CONVERTING A $CO_2$ ATMOSPHERE TO A HIGH-PURITY $O_2$ SUPPLY

## Origin of the Invention

The invention described herein was made by a Government employee and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefor.

## Background of the Invention

### 1. Field of the Invention

This invention relates generally to a process for preparing oxygen from an oxygen bearing gas. More particularly, it relates to a process for converting an oxygen bearing gas, such as $CO_2$ atmosphere, to a high-purity $O_2$ supply by means of glow discharge dissociation of the oxygen bearing gas to produce atomic or molecular oxygen in proximity to a hot silver or silver alloy membrane, which serves to separate and direct the oxygen to a collection volume.

### 2. Description of the Background Art

Planned exploration of Mars by human extravehicular activity in the early part of the next century (2007, 2009, 2011) may require techniques to produce oxygen for human consumption (and/or other applications) from the existing Martian environment. Mission outlines presently indicate a 220-day round trip with 30-day sojourn times, 20 days of which will be on the Mars surface. Clearly, it is desirable to provide a method of extracting environmental oxygen from existing sources, such as the oxide surface, the $CO_2$ ice, or the atmosphere itself, in order to alleviate the extensive requirement of sufficient oxygen necessary for such a long-term mission. Perhaps the most energy efficient approach would be the continual utilization of the six millibar $CO_2$ atmospheric surface pressure that exists on Mars.

Accordingly, a primary object of the present invention is to provide a high purity supply of oxygen from an oxygen bearing gas such as a carbon dioxide atmosphere.

Another object of this invention is to use glow discharge to dissociate the molecules of an oxygen bearing gas such as carbon dioxide into atomic oxygen in conjunction with a hot permeable silver or silver alloy membrane within the glow discharge, which dissolves and separates the atomic oxygen, followed by recombining the atomic oxygen into oxygen molecules and subsequent compression and storage thereof.

Other objects and benefits of the present invention will become apparent to those of skill in the art, upon consideration of the following disclosure.

## Summary of the Invention

The present invention provides a technique for conversion of an oxygen bearing gas such as a $CO_2$ atmosphere to that of a high-purity $O_2$ supply by the use of glow discharge dissociation that produces atomic oxygen and some molecular oxygen in the near vicinity of a hot silver or silver alloy membrane. The oxygen then adsorbs, dissolves and permeates the membrane to a downstream region where it thermally recombines to $O_2$ at the membrane surface and is pumped away and compressed in a storage volume. The pure oxygen can then be used for human consumption or other applications requiring $O_2$. An application of the invention is the conversion of the Martian atmosphere of $CO_2$ to a useful and breathable $O_2$ supply for astronaut consumption. There are also other applications, such as cabin atmosphere purification for the space shuttle or the Space Station Freedom. Also, there may be public interest where $CO_2$ is an unwanted byproduct that can be converted to useful $O_2$.

Brief Description of the Drawings

For a more complete understanding of the present invention, including its objects and attending benefits, reference should be made to the Description of the Preferred Embodiments, which is set forth in detail below. This description should be read together with the accompanying drawing, wherein:

FIG. 1 is a schematic showing the process of the present invention as carried out in a suitable apparatus; and

FIG. 2 is a plot of downstream oxygen pressure vs. time for an actual experiment employing the process of the present invention.

Description of the Preferred Embodiments

Referring now to FIG. 1, a schematic of the process of the present invention is shown. As an example of an oxygen bearing gas, a flow of $CO_2$ 10 from a carbon dioxide atmosphere is inlet into chamber 11 with the aid of pump 12 at a rate to maintain an optimum pressure thereof at about 0.5 to 1 Torr for facilitating glow discharge. A voltage of about 380 volts DC in this geometry is applied at electrode 13 to create glow discharge 14 which dissociates the $CO_2$ by electron impact as follows to form a partial pressure of atomic oxygen:

$$CO_2 + e^- \rightarrow CO + O + e^-$$

or

$$CO + e^- \rightarrow C + O + e^-.$$

However, as in understood by those of skill in the art, a glow discharge may be effected by other suitable means, such as radio frequency, microwave energy or laser energy, among others, and atomic oxygen may be produced from the $CO_2$ by a mechanism other than electron impact dissociation. The atomic oxygen formed can recombine to form $CO_2$, $O_2$ and other oxygen bearing gases, but can also adsorb and dissolve in silver membrane 15, which is located in proximity to the glow discharge and kept at a temperature between about 400 and 800°C by means of heater 16, ultimately permeating to a vacuum interface in downstream region 17, where the atomic oxygen thermally recombines on the surface of membrane 15 to form $O_2$ and subsequently desorbs. As is also understood by those of skill in the art, other oxygen bearing gases may be employed, such as $N_2O$ or $NO_2$, among others. Permeable silver membrane 15 may be silver metal or advantageously a silver alloy having a thickness of less than about $10^{-2}$ cm, which thickness is capable of supporting a pressure differential across the membrane. By means of transfer pump 18 the desorbed $O_2$ is pumped away from downstream region 17 to maintain as low a concentration of $O_2$ therein as possible in order to provide the necessary concentration gradient, as is understood by those of skill in the art. The pumped away $O_2$ is compressed into storage tank 19 to provide an adequate pressure of oxygen for functional utilization. Following adsorption and dissolution of atomic oxygen into silver membrane 15, the concentration gradient across the membrane serves as the driving force to transport the atomic oxygen to the downstream side, where the oxygen atoms recombine and desorb into the low pressure region. At this point they are removed to storage tank 19 by transfer pump or compressor 18. The downstream side 17 is at a significantly lower pressure than the upstream side, thus maintaining the oxygen concentration gradient.

FIG. 2 shows the results of an actual experiment employing the process of the present invention in which the temperature of a permeable $Ag_{0.95}Zr_{0.05}$ membrane was kept at 650°C, and the $CO_2$ atmosphere was maintained at 0.5 Torr. As shown in FIG. 2, application of the DC field as detailed above creates a glow discharge, which supplies oxygen to the permeable silver membrane, whereupon a mass spectrometer detected $O_2$ signal goes up by several orders of magnitude and reaches a steady-state level.

A primary consideration of the process of the present invention is how rapidly the atomic oxygen can permeate the heated silver membrane. This is controlled primarily by the temperature, the upstream oxygen pressure, the thickness of the membrane and the silver microstructure. As is understood by those of skill in the art, the thickness should be as small as possible for most efficient transfer; however, it must be large enough so that the membrane is capable of maintaining a pressure differential across it. If the membrane is a thin film of silver covering a porous plug, the thickness can be reduced significantly. Another possibility is the employment of nanocrystals, which have a large grain boundary diffusivity resulting in an increase of permeability.

What is claimed is:

# CONVERTING A $CO_2$ ATMOSPHERE TO A HIGH-PURITY $O_2$ SUPPLY


## Abstract of the Disclosure

A $CO_2$ atmosphere or any other oxygen bearing gas is converted to a high-purity $O_2$ supply by in-letting a flow of $CO_2$ from the atmosphere into a closed container, which is equipped with a means for creating a glow discharge or other method for dissociation in proximity to a permeable silver membrane kept at a temperature between about 400 and 800°C. A glow discharge is created to dissociate the $CO_2$ to form a partial pressure of atomic and molecular oxygen. The oxygen produced is allowed to adsorb, dissolve as atoms, permeate the silver membrane to a vacuum interface in a downstream region thereof, where the atomic oxygen thermally recombines on the surface of the membrane to $O_2$ and desorbs: $O + O \rightleftarrows O_2$. The desorbed $O_2$ is pumped away from the downstream region to maintain as low a concentration of $O_2$ in the downstream region as possible. The pumped away $O_2$ is then compressed into a storage volume to provide an adequate pressure of oxygen for functional utilization.

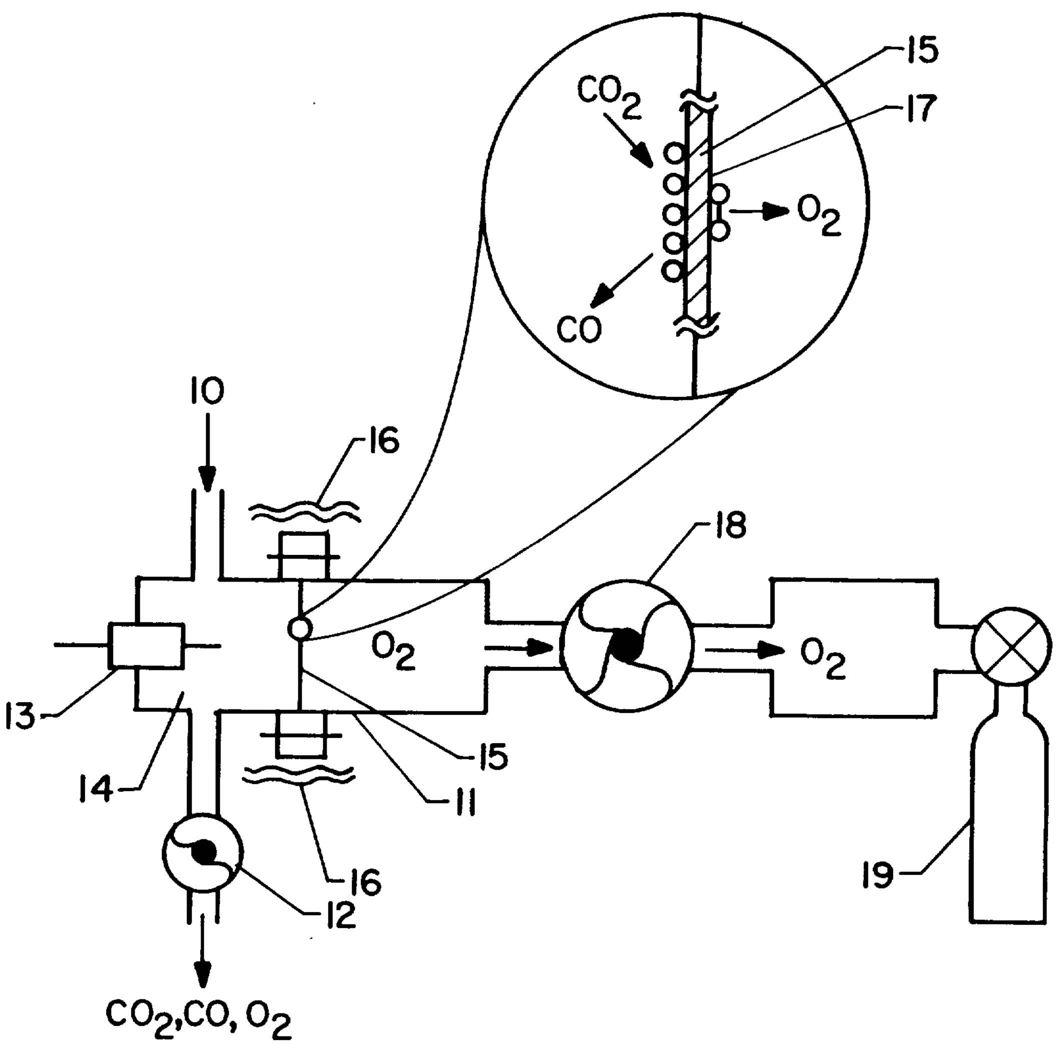


FIG. 1

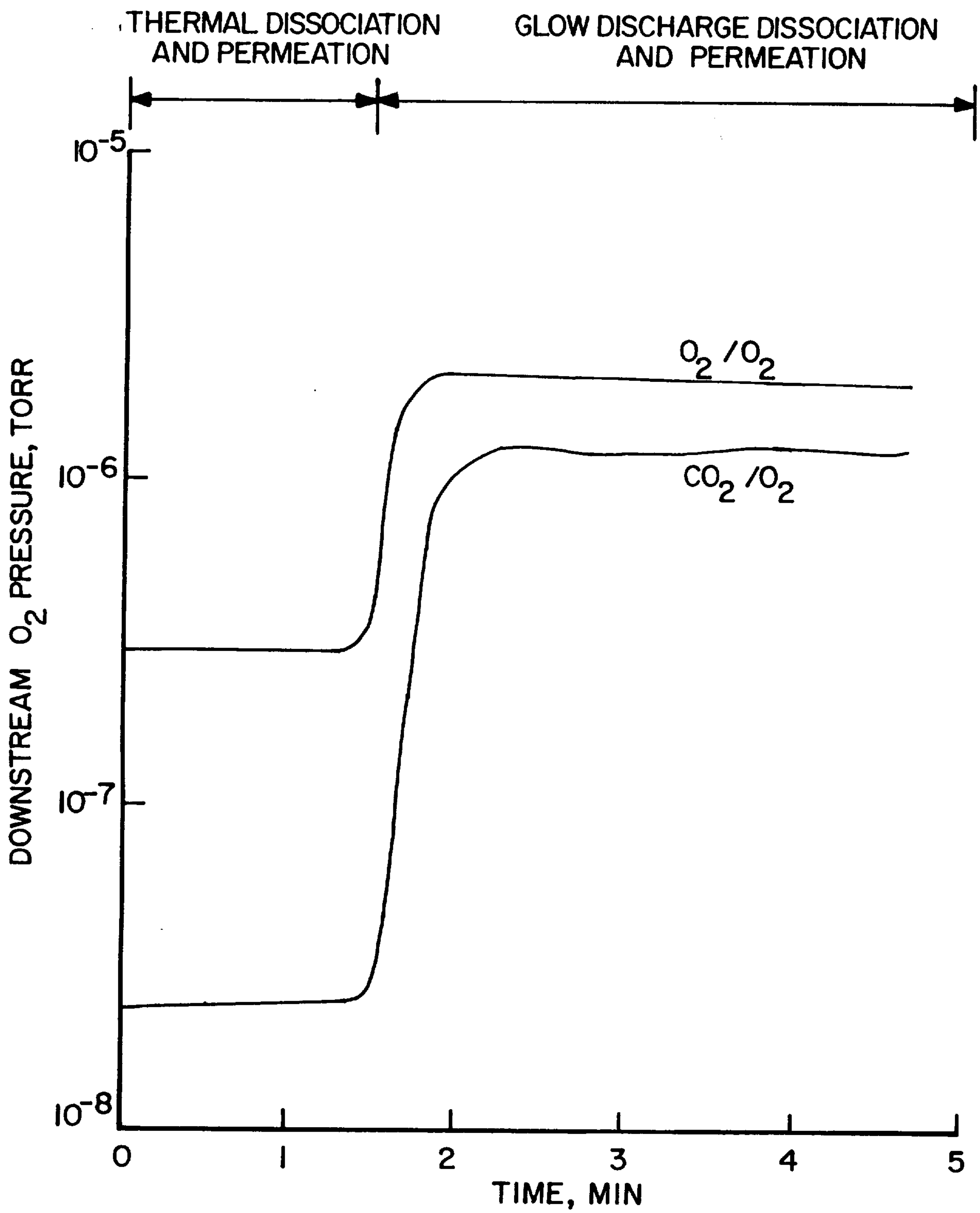
THERMAL DISSOCIATION AND PERMEATION
GLOW DISCHARGE DISSOCIATION AND PERMEATION
$10^{-5}$
$10^{-6}$
$10^{-7}$
$10^{-8}$
DOWNSTREAM $O_2$ PRESSURE, TORR
$O_2/O_2$
$CO_2/O_2$
0
1
2
3
4
5
TIME, MIN

FIG. 2