TO: KSI/Scientific & Technical Information Division  
Attention: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned U.S. Patents in STAR

In accordance with the procedures agreed upon by Code GP and Code KSI, the attached NASA-owned U.S. Patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No. : 3,771,959

Government or Corporate Employee : General Dynamics, Convair Div.

Supplementary Corporate Source (if applicable) : Northrop, M8, Plant, San Diego, CA

NASA Patent Case No. : LAR-16551-1

NOTE - If this patent covers an invention made by a corporate employee of a NASA Contractor, the following is applicable:

Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of column No. 1 of the Specification, following the words "... with respect to an invention of..."

Elizabeth A. Carter

Enclosure

Copy of Patent cited above
ABSTRACT

The catalyst cartridge has an inner cylindrical perforated wall and an outer cylindrical perforated wall concentric with the inner wall and spaced radially therefrom. One end of the cartridge is closed by a circular base. The other end of the cylindrical cartridge is closed by a circular covering having a central aperture therein for admitting a mixture of hydrogen and carbon dioxide gas through a supply pipe having an electric heater therein. The outer surface of the inner wall and the inner surface of the outer wall, and the inner surfaces of the base and cover caps are covered with a batting of quartz wool which encloses within the space defined a catalyst material or iron in the form of uniformly packed steel wool.

6 Claims, 4 Drawing Figures
Catalyst Cartridge for Carbon Dioxide Reduction Unit

Origin of the Invention

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 435; 42 U.S.C. 2457).

Background of the Invention

Field of the Invention

This invention relates generally to life support systems of the type utilized in space vehicles. One of the functions of the life support system in brief is to remove the carbon dioxide produced by crew members from the spaceship or spacesuit atmosphere, and to reclaim oxygen from the carbon dioxide. One known method for accomplishing this utilizes the Bosch process which catalytically reacts hydrogen with carbon dioxide to produce water and solid carbon. The water is then electrolyzed to yield hydrogen for reuse in the Bosch reaction and oxygen for the crew. In previously employed systems utilizing the Bosch reaction, there have been a number of difficulties encountered.

The primary problem which has prevented the full realization of the Bosch reaction in life support systems has been the prevention of any reaction in parts of the system where carbon deposits cannot be tolerated. In continuous removal reactors, migration of the carbon resulting from the reaction has not been successfully controlled and in batch removal systems, its migration from reaction zone or formation outside the reaction zone has not been prevented.

It is an object of this invention to provide a replaceable catalyst cartridge for a life support system utilizing the Bosch reaction for the reduction of carbon dioxide whereby total carbon containment is achieved within the desired reaction zone. It is also an object of this invention to guarantee that the carbon dioxide reduction takes place in the reaction zone only and that the product carbon formed in the reaction zone is retained within the reaction zone and does not migrate elsewhere in the system carrying catalytic material with it, thus preventing any carbon formation reaction taking place outside the reaction zone.

The Bosch catalytic reaction is carried out at temperatures generally in the range of 1,000° to 1,400°F and may be represented by the following overall chemical equation:

\[ 2\text{H}_2 + \text{CO}_2 \rightleftharpoons 2\text{H}_2\text{O} + \text{C} \]

The intermediate reactions which take place include the following:

\[ \text{CO}_2 + \text{C} \rightleftharpoons 2\text{CO} \]

\[ 2\text{H}_2 + \text{C} \rightleftharpoons 2\text{CH}_4 \]

which combined yield the following overall representation:

\[ x\text{H}_2 + y\text{CO}_2 \rightleftharpoons a\text{H}_2\text{O} + b\text{C} + c\text{CO} + d\text{CH}_4 \]

wherein \( x = 2y \) and \( a, b, c, \) and \( d \) are variable with time, temperature, pressure, and initial concentrations of the reactants.

Summary of the Invention

This invention comprises a catalyst cartridge particularly for utilization in a carbon dioxide reducing apparatus in a life support system for space vehicles. The catalyst cartridge includes an inner perforated metal wall, an outer perforated wall spaced outwardly from the inner wall, a base plate closing one end of the cartridge, and a cover plate closing the other end of the cartridge. The cover plate has a central aperture therein through which a supply line having a heater therein feeds a gaseous reaction mixture comprising hydrogen and carbon dioxide at a temperature from about 1,000°F to about 1,400°F. The outer surfaces of the internal wall and the inner surfaces of the outer wall are lined with a ceramic fiber lining material of sufficient thickness to prevent carbon formed in the reaction from passing through it. The portion of the surfaces of the base and cover plates defined within the inner and outer walls are likewise lined with ceramic lining, thus forming a complete enclosure lined with such lining. Contained within the enclosure of the housing is an iron catalyst for the reaction. The heated reaction mixture passes outwardly through the inner perforated wall and ceramic lining and over the catalyst. The solid carbon product formed is retained within the metal enclosure containing the catalyst. The water vapor and unreacted carbon dioxide and any intermediate products pass through the perforations of the outer wall. The reaction takes place outside the area containing the catalyst and any migration of the catalyst bearing carbon is prevented.

Brief Description of the Drawings

Referring to the drawings:

FIG. 1 is a schematic of a system utilizing the catalytic cartridge of this invention for the reduction of carbon dioxide by means of the Bosch reaction.

FIG. 2 is an end view of the catalyst cartridge of this invention.

FIG. 3 is a side sectional view of the catalyst cartridge of this invention, taken along line 3—3 of FIG. 2.

FIG. 4 is a perspective view of the assembled catalyst cartridge of this invention mounted on the end of the reactor case of the system of FIG. 1.

Description of the Preferred Embodiments

A system for reducing carbon dioxide to carbon and water utilizing the Bosch reaction is shown in schematic form in FIG. 1 of the accompanying drawings. There is shown a reactor 2 within which the catalyst cartridge 4 of this invention is mounted on the base 3 of the reactor 2. A mixture of hydrogen and carbon dioxide is fed to the system through feed line 6 which leads to a compressor 8. The compressor pumps the gases through feed line 10 to heat exchanger 12 wherein the mixture is heated to approximately reaction temperature and then from the heat exchanger 12 passes through supply line 14 to the reactor 2. The line 14 has an electric heater 16 in the end 15 which passes through the cover 40 into the center of the catalyst cartridge 4, as shown in FIG. 3. As represented by the heavy arrows 68, a mixture of reacted and unreacted gases passes from the catalyst cartridge 4 into the outer portion 5 of the reactor 2, and thereafter out through line 20 to heat exchanger 12. The gases comprise a mixture of hydrogen, methane, carbon monoxide, carbon dioxide, and water vapor. From the heat exchanger 12 the gases pass through line 22 to the water separator apparatus 24 which condenses the water vapor which then passes through line 26 to storage tank 27 and is thereafter treated electrolytically to yield hydrogen and oxygen. The oxygen is then resupplied to

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the rate of the process. A coarser grade of steel wool inches in diameter and eleven and three-quarters zone, flow channels would develop and adversely effect The cartridge in the above embodiment is about 7% activity, this diffusion causes fairly rapid deterioration 4 is positioned inside the reactor 2 with the supply line 2 by means of the brackets 70. Then the cartridge posited prior to build-up of a carbon block structure. put in place and fastened with the clips 50. The assem- shield is then removed and the base 38 with its liner 56 well 7 attached to the reactor 2 projects into the outer metal wall 30 and the cover 40 has a similar flange 41 extending over the other end of the wall 30. The cover 40 has a central aperture 42 through which the supply line 14 passes. A smaller aperture 44 in the cover 40 is provided for a cartridge thermocouple well 46 which extends into the space defined between the inner and outer cylindrical walls and the base and cover plates.

As shown most clearly in FIG. 3, the inner surfaces of the outer perforated wall 30, the outer surface of the inner perforated wall 34, and the inside surface of the base 38 and cover 40, are covered with a layer of ceramic wool bat as shown at 52, 54, 56, and 58, respectively. The preferred embodiment is quartz wool batting. Other suitable known ceramic fiber battings such as steel wool. If too coarse a form of iron is used, quartz wool liner for the base and inner and outer walls are non-catalytic in the reaction, and chemically unaf- fected by prolonged exposure to the reaction environ- ment. The selection of such materials is within the competence of those skilled in the art.

As indicated, the catalyst for the Bosch process is iron. The catalyst is preferably used in a fiber-like form such as steel wool. If too coarse a form of iron is used, there is less surface area and the process accordingly does not run efficiently.

The use of the steel wool as the source of the catalytic iron is desirable since it will readily support the Bosch reaction and remains uniformly distributed within the reaction zone of the catalyst cartridge, as well as providing support to retain the initial carbon de- posited prior to build-up of a carbon block structure. Since during the reaction process, iron diffuses into the resulting carbon product without losing its catalytic activity, this diffusion causes fairly rapid deterioration of a fine steel wool fiber. Should disintegration of the steel wool fiber occur before a sufficient amount of car- bon has formed to support the iron and to maintain a fairly uniform distribution throughout the reaction zone, flow channels would develop and adversely effect the rate of the process. A coarser grade of steel wool disintegrates more slowly and thus allowing time for the growth of the supporting carbon block.

In the embodiment shown, no 2 steel wool 60 is packed firmly into the enclosure defined by the inner and outer walls and the base and cover. As indicated by the heavy arrows in FIG. 3, the mixture of carbon dioxide, hydrogen gas and any recy- cled gases flows from the interior of the cartridge inner wall 34 through the perforations 36 thereof, and through the catalyst 60. As the reaction takes place, carbon deposits 66 begin to build up in the mesh of the steel wool catalyst 60. The water vapor resulting from the reduction of carbon dioxide in the reaction, to- gether with unreacted hydrogen, carbon dioxide, car- bon monoxide and methane, emerges from the car- tridge 4 as shown by the arrows at 68 after passing through the catalyst 60, the outer ceramic batting 52, and the perforations 32 in the outer wall 30.

Most importantly, there is no migration of catalyst- bearing carbon outside of the reaction zone. The reac- tion takes place entirely within the confines of the reaction zone defined by the quartz wool batting in the car- tridge and the migration of carbon and catalyst to other parts of the system is prevented, thus eliminating reac- tion in other parts of the system and subsequent clog- ging of the system by carbon deposits.

The metal surfaces of the catalytic cartridge, reactor, and heat exchanger must be non-catalytic under the re- action conditions of the Bosch reaction, that is, the high temperatures and reducing atmosphere. Selection of such materials is within the purview of those skilled in the art.

In the above embodiment, the base 38 and the cover 40 of the cartridge are spun from type 321 stainless steel. The inner and outer walls 34 and 30 are rolled and welded from type 304 stainless steel, perforated with 3/32 inch holes on 5/32 inch centers. All apertures are punched prior to plating. The parts are then plated with an electrolytic nickel strike followed by 1 to 2 mils of electropolished nickel. The thermocouple well 46 is alloy 122 phosphorous-dioxidized copper and the cover clips 50 are Inconel X-750. The reactor body 2 and other parts which are exposed to high temperature gases are made 321 stainless steel with electrolytic nickel strike, 1 mil of electropolished nickel, 4 mils of nickel electroplate.

The thermocouple well 46 is inserted in the aperture 44 in the cover 40 and locked to the cover 40 with a pressfit copper retaining washer 45. The cover 40 is fastened to the outer wall 30 with the clips 50. The quartz wool liner for the base and inner and outer walls is then inserted. All liners are held temporarily in place by a sheet metal shield while the steel wool catalyst is added. The steel wool should be packed uniformly with special attention given to the region around the ther- mocouple well 46 in order to eliminate any voids which would lead to channeling of the reaction gases. The shield is then removed and the base 38 with its liner 56 put in place and fastened with the clips 50. The assem-bled cartridge 4 is then secured to the end 3 of the reac- tor 2 by means of the brackets 70. Then the cartridge 6 is positioned inside the reactor 2 with the supply line 14 projecting through the aperture 42 of the cover 40 into the area enclosed by the inner wall 34. The ther- mocouple well 7 attached to the reactor 2 projects into the cartridge thermocouple well 46.

The cartridge in the above embodiment is about 7% inches in diameter and eleven and three-quarters
What is claimed is:

1. A replaceable cylindrical catalyst cartridge for use in a life support system utilizing the Bosch reaction for the reduction of carbon dioxide comprising:

   a housing,

   said housing including an inner tubular perforated wall, an outer tubular perforated wall spaced outwardly from said inner perforated wall, and a base closing one end of said housing,

   a cover closing the other end of said housing, said cover being provided with a centrally located aperture having a smaller cross-section than that of said inner perforated wall for admitting a carbon dioxide reaction mixture,

   a layer of ceramic fiber covering the outer surface of said inner wall, the inner surface of said outer wall, and the inner surfaces of said base and said cover defined between the ends of said inner and outer walls, and

   a catalyst contained within the space defined by the inner and outer walls, and said base and said cover, said catalyst having the inherent physical property characteristic of catalyzing the reduction of carbon dioxide to carbon and water in the presence of hydrogen and in the temperature range of 1,000°-1,400°F.

2. A catalyst cartridge as claimed in claim 1 wherein said catalyst is an iron catalyst in the form of activated steel wool.

3. A replaceable catalyst cartridge comprising an inner cylindrical perforated wall, an outer cylindrical perforated wall spaced radially from said inner perforated wall, a circular base closing one end of said cartridge, a circular cover closing the other end of said cartridge, said cover having a centrally located aperture therein through which a gaseous reaction mixture comprising carbon dioxide and hydrogen may be admitted, said inner wall, outer wall, base, and cover each being comprised of metal and having the inherent physical property characteristic of being non-reactive in a reducing atmosphere at temperatures up to 1,400°F, a layer of ceramic fiber covering the outer surface of said inner wall, the inner surface of said outer wall, and the inner surfaces of said base and said cover defined between the ends of said inner and outer walls, and an iron catalyst contained within the space defined by said inner and outer walls and said base and said cover.

4. A cartridge as claimed in claim 3 wherein said iron catalyst is in the form of steel wool.

5. A cartridge as claimed in claim 4 wherein said ceramic fiber is in the form of quartz wool batting.

6. A cartridge as claimed in claim 5 wherein said steel wool has been activated by etching with dilute hydrochloric acid.