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Marshall Space Flight Center

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Automation of Bosch Reaction for CO_2 Reduction

One step in a scheme for the replenishment of oxygen necessary to sustain life in a space cabin is to collect the excess carbon dioxide exhaled by human inhabitants, and then to decompose the carbon dioxide into carbon and water by reaction with hydrogen in the presence of a catalyst. This is called the Bosch reaction. In a subsequent step the water is decomposed by electrolysis to obtain oxygen for replenishing the cabin air and hydrogen that is recycled through the Bosch reactor. The carbon is recovered as a powder for use if needed, or it can be jettisoned as waste.

The Bosch reaction has been used in the operation of ground based space cabin simulators wherein human subjects have lived for periods of two months or more. For these operations, the Bosch reaction was carefully monitored and controlled by human attendants outside

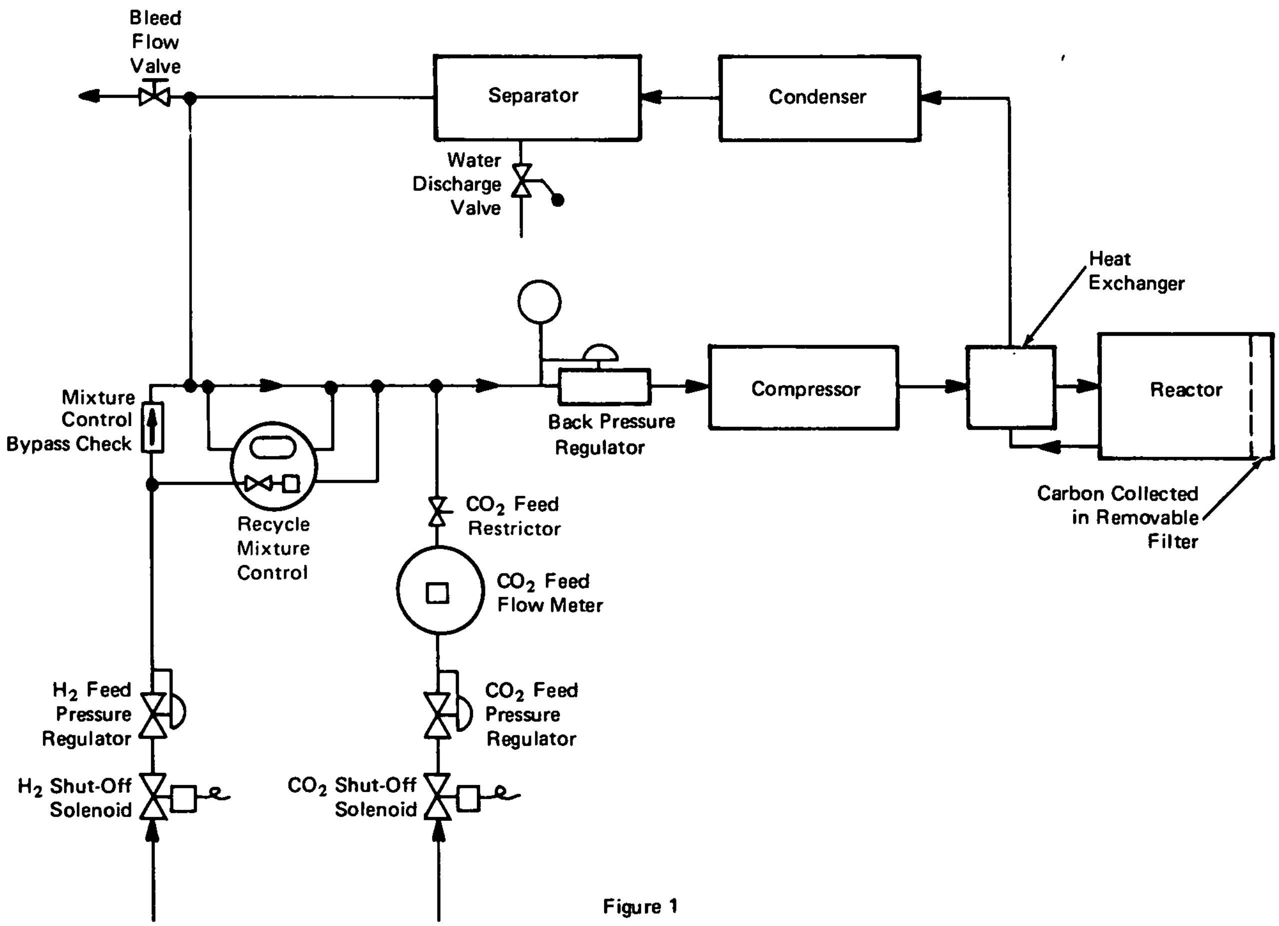

Figure 1

(continued overleaf)

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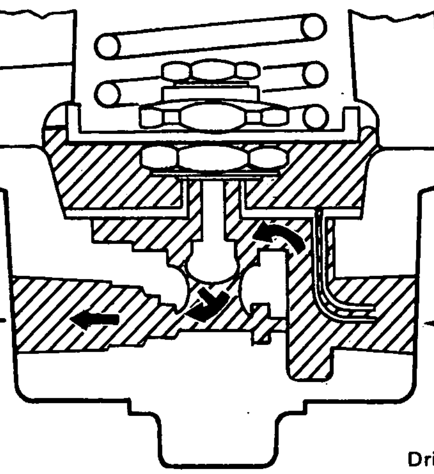

Figure 2

the cabin simulator. In the course of such monitoring, it was discovered that the reaction could be automated for self-regulation without constant adjustment by an attendant.

The reaction takes place at 867 to 978 K (1100 to 1300°F), but cannot be completed in a single pass because a water vapor equilibrium is approached. Therefore, a recycling system is required. This is a closed loop in which the carbon is accumulated within a catalyst cartridge for periodic removal, water vapor is removed continuously by condensation, and feed gases enter to replace the volume reductions due to the reaction and to water condensation and separation.

The primary factors influencing CO_2 conversion rates are reaction temperature, recycle gas mixture (hydrogen and carbon monoxide) ratios, reactor pressure, and recycle flow rate. An electrically powered heater and a thermocouple temperature sensor control rate excursions due to temperature variations. Excursions due to mixture ratio variations can be avoided by using infrared or thermal conductivity sensors for the composite mixture to control the relative input of H_2 and CO_2. Pressure variations influencing the process rate are prevented by feed gas pressure regulators. The process rate is immediately responsive to recycle flow rate and, within the capacity of the recycle flow compressor, can be varied over a wide range.

The novel feature is the use of a back pressure regulator (BPR) to maintain a constant feed-point pressure which can be achieved only when the process rate and feed rate are matched. The regulator accomplishes this by modulating the recycle flow rate which in turn modulates the process rate. In the closed system under normal feed supply conditions, a reduction in process rate due to adverse changes in temperature, pressure differential, mixture, etc., will tend to increase the total system pressure including that at the feed point. Within the capacity limits of the back pressure regulator and compressor, this tendency will be resisted by opening of the regulator to increase the recycle flow, and thereby, the process rate. If the process rate is too high, the feed-point pressure tends to fall causing the regulator to restrict recycle flow.

An effective control allowing the recycle flow to vary automatically, as required to maintain a constant process rate within the limits of compressor capacity, was obtained by installing a high-flow high-sensitivity back pressure regulator (BPR) in the recycle loop as shown in Figure 1. To increase its range of control, a flow bypassing hole was drilled in the regulator as shown in Figure 2. This hole was sized to pass the quantity of recycle flow needed for the desired process rate when the resistance to flow through the cartridge was at a minimum. This also prevented a complete blockage of flow during feed gas supply interruptions which caused the regulator to close.

Notes:

1. The information concerning this innovation may be of interest to the chemical processing industries.
2. Requests for further information may be directed to:
   Technology Utilization Officer
   Marshall Space Flight Center
   Code A&PS-TU
   Marshall Space Flight Center, Alabama 35812
   Reference: B72-10666

Patent status:

NASA has decided not to apply for a patent.

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