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(54) **Breathable gas delivery regulator.**

(57) A breathable gas delivery regulator (10) has a demand valve (15) which will open easily to substantially consistent efforts of a user throughout the pressure range of supply gas from a molecular sieve oxygen generator (not shown). The demand valve (15) is balanced by supply gas pressure and is operably connected, such as by a mechanical lever (29), with a pressure-responsive wall (27) of a demand-pressure sensing chamber (12) which is in fluid communication with a gas delivery outlet (17). Movements of the pressure-responsive wall (27) cause the demand valve (15) to move towards opening or closing and thereby regulate the flow of supply gas from a supply gas inlet (16) to the gas delivery outlet (17).

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Description of Invention

Title: "Breathable Gas Delivery Regulator"

THIS INVENTION relates to breathable gas delivery regulators and more particularly to such regulators of the demand type as are used in aircraft applications.

Regulators of this type, one such example being disclosed in U.K. - A-1,228,481, have been used to deliver oxygen or air-diluted oxygen, to aircrew members from oxygen sources that are arranged to supply gas at pressures generally in the range 485 to 1035 kPa (70 to 150 psi), which range provides ample pressure of gas to operate air entrainment means for obtaining dilution and permits ready usage of a flow demand valve that can satisfactorily employ supply gas to obtain its closing pressure.

However, a new generation of oxygen supply systems now beginning to emerge for use in aircraft, derives oxygen from the ambient air by passing air bled from an engine of the aircraft, through a simple on-board molecular sieve oxygen generator system (MSOGS) which delivers gas at pressures generally between 70 and 345 kPa (10 and 50 psi).

Early designs of on-board oxygen generator systems (OBOGS) were influenced by the existing aircraft oxygen installations and only considered as a replacement for the liquid oxygen converters or high pressure cylinder reservoirs, leaving the remainder of the installation in the aircraft unaltered, and were thought of solely in terms of reducing the operational logistics of providing liquid oxygen replenishment at airfields.

It is, therefore, understandable that a prime objective was then to obtain maximum oxygen concentration in the product gas supplied by an on-board oxygen generator (OBOG) for all conditions of flight; excessive oxygen concentrations in the product gas for a particular flight condition, being reduced by dilution downstream by the delivery regulator as in earlier manner. This required that the pressure of the product gas from an OBOG be increased prior to its supply to the regulator.

Our concept is to provide a complete on-board molecular sieve oxygen generating and delivery system for an aircraft, in which the constituent components are of optimum operating compatibility one with the other.

We have established that a molecular sieve oxygen generator (MSOG) can be controlled to deliver product gas having an oxygen concentration that is appropriate to the pertaining cabin altitude, such a system being disclosed in EP-A-0 046 369 (European Patent Application No. 81303677.9 filed 12th August, 1981). With an MSOG so controlled, there is no requirement for dilution of the product gas, so eliminating the need for the inclusion of means for entraining air into the delivery flow of the regulator associated with the MSOG. However, a problem arises with respect to demand valve operation in a regulator that will accommodate the lower range of supply gas pressure, particularly at its lower end towards 70 kPa (10 psi), available from an MSOG.

Demand valves in contemporary aviation demand-type oxygen regulators, which have supply pressures of 485 kPa (70 psi) and above, require the valve to lift by only a small amount in order to deliver the desired rate of gas flow. Although this is satisfactory for the highest gas pressure supplied by an MSOG, it is not so for the lower pressures in the range because to obtain the same desired rate of flow at these lower pressures for the same amount of valve lift, the valve must have a considerably larger than usual valve orifice: as the demand valve is held closed by supply gas pressure, a large orifice would give rise to excessively large valve clamping pressures at the higher pressures in the range.

Thus there is a requirement for a gas delivery regulator having a demand valve that opens easily to substantially consistent efforts of a user throughout the range of pressure of the gas supply from an MSOG.

According to the present invention a breathable gas delivery regulator having a supply gas inlet connected with a gas delivery outlet by way of a conduit arrangement which is closable by a demand valve, is characterised in that the demand valve is adapted for pressure balance by supply gas, and is in operable connection with a pressure-responsive wall of a demand-pressure sensing chamber having fluid connection with the gas delivery outlet.

In a preferred embodiment of the invention the pressure balanced demand valve is of poppet-type and comprises a poppet valve-head connected by a spindle to a spool portion.

Preferably the poppet-type demand valve is adapted for pressure balance by counteracting areas exposed to supply gas pressure, the counteracting areas being provided by an end face area of the spool portion and the opposed closed face area of the poppet valve-head which is coupled to the end face area of the spool portion by a spindle.

In a preferred embodiment of a regulator in accordance with the present invention, grooves in a manner forming a labyrinth seal are provided on the circumferential surface of the spool portion of the poppet-type demand valve and means are provided for venting leakage of supply gas past the labyrinth seal. The vent means may comprise a vent chamber which is spanned by a plain length of the spool portion.

In order that safety pressure, i.e. a small positive gas pressure in the cavity of an aviator's breathing mask to prevent ingress of toxicants around the face seal, may be maintained continuously, it is convenient to hold the poppet valve open sufficiently to provide this condition by preloading the valve by direct, or substantially direct, application of a resilient force, preferably by a spring, or alternatively, by preloading the pressure-responsive wall by a resilient force which is transmitted to the valve by way of a mechanical member which provides for operable connection between the pressure-responsive wall and the valve.

In one breathable gas delivery regulator in accordance with the invention, and suited for use by an aviator, the pressure-responsive wall of the demand-pressure sensing chamber is common to a breathing-pressure control chamber having a barostatically-controlled outlet, the two chambers being interconnected by an orifice-controlled bleed path. Conveniently the orifice-controlled bleed path may be provided in the pressure-responsive wall.

Preferably outflow from the barostatically-controlled outlet may pass to another outlet which is closable by a push button which is spring-loaded into an open position.

A pressure-compensated relief valve may be included for relieving excessive delivery gas pressure at a predetermined value relative to breathing-pressure control chamber pressure which is itself directly related to cabin pressure.

The invention will now be further described by way of example and with reference to the accompanying drawing which shows a schematic section of a breathable gas delivery regulator on the longitudinal axis of a demand valve forming part of the regulator.

Referring to the drawing, a demand type oxygen delivery regulator 10 for use by an aviator comprises a body 11 containing three fluidly interconnected pressure chambers comprising a demand-pressure sensing chamber 12, a breathing-pressure control chamber 13 and a cabin-pressure sensing chamber 14. The body 11 also provides a housing for a demand valve arrangement 15; this housing includes an oxygen supply inlet 16 and a delivery outlet 17 that is directed into an outlet tube 18.

The demand valve arrangement 15 includes a poppet-type demand valve member 19 comprising a valve-head 20 which is carried by a spindle 21 from a spool 22. The spindle 21 is arranged to span the chamber formed by the supply inlet 16 whilst the effective areas of the spool 22 and the valve-head 20, exposed to inlet pressure, are the same. The delivery outlet 17 provides a valve seat 23 onto which the valve-head 20 is urged to close by a compression spring 24. Optionally, a helical plug type spring adjuster (not shown) is provided for adjustment of the spring 24. The spool 22 is arranged to project into the demand-pressure sensing chamber 12 and is provided on its circumferential surface with grooves in a manner forming a labyrinth seal 25. The plain portion of the spool 22 on the low pressure side of the labyrinth seal 25 spans a vent chamber 26 in the regulator body 11 whereby leakage of supply gas past the labyrinth seal 25 is dissipated without affecting the balance of the valve.

The demand-pressure sensing chamber 12 is fluidly connected to the outlet tube 18 and is separated from the breathing-pressure control chamber 13 by a pressure-responsive wall in the form of a pressure-responsive flexible diaphragm 27 which is provided with an orifice 28 in order to permit a small flow to pass from one chamber to the other. The centre of the diaphragm 27 is attached to one end of a valve operating lever 29 which is arranged to rock about its appropriately formed opposite end within a location 30 in a wall of the demand-pressure sensing chamber 12. Intermediate of its ends the lever 29 is provided with a pad 31 which contacts the projecting end of the spool 22. A compression spring 32 is arranged axially of the spool 22 and is held between a location on the lever 29, behind the pad 31, and a spring adjuster 33 that is adjustable from outside the regulator body 11. The chosen adjustment is such that when the pressure-responsive diaphragm 27 is in the null position, the valve-head 20 is held off the valve seat 23, against the closing pressure exerted by the other compression spring 24, sufficient to maintain a positive pressure (safety pressure) of 250 Pa (1 in/WG) in the outlet tube 18 and thus in an aviator's breathing mask (not shown) connected to the tube 18.

An 'on/off' lever arrangement 34 includes a shaft that projects through a wall of the regulator body 11 and carries a sprag-arm 35 within the demand-pressure sensing chamber 12 and a manually operable lever 36 externally of the regulator 10. The arc of movement of the sprag-arm 35 takes it into and out of engagement with the valve operating lever 29 so that when in engagement the effect of compression spring 32 is negated whereby the valve-closing spring 24 causes the valve to seat and prevents wastage of oxygen during non-use of the regulator.

The breathing-pressure control chamber 13 is provided with a large outlet port 37 in one wall which, on its outer side within the cabin-pressure sensing chamber 14, provides a seat 38 for a valve-head 39 that is mounted on an aneroid capsule 40. The capsule 40 is carried on an adjusting screw 41 which projects through an outer wall of the sensing chamber 14. Discharge from the sensing chamber 14 is enabled by an outlet 42 which is normally open, but can be closed by a spring loaded push button 43 to provide a test facility.

A pressure-compensated relief valve 44 is mounted on the outlet tube 18 of the regulator and comprises a valve head 45 carried on a flexible diaphragm 46. The valve is connected so as to be responsive to gas pressure in the breathing-pressure control chamber 13 by way of a duct 47 and is arranged, by inclusion of a light spring 48, to relieve when pressure in the outlet tube 18 is, say, 125 Pa (0.5 ins WG) above that in the control chamber 13.

The duct 47 is branched and connects also with a pressure-relief valve 49 that is arranged to open when a predetermined maximum pressure, say, 4.5 kPa (18 ins WG) occurs in the breathing-pressure control chamber 13. This pressure is determined by the maximum altitude at which the aircraft is expected to operate; in this example 15250 m. (50000 feet).

In operation of the demand type breathable gas regulator 10, when supply gas is available at the inlet 16, the demand valve member 19 responds to the inhalatory and exhalatory phases of a user aviator's breathing cycle by way of movement of the pressure responsive diaphragm 27. Breathing cycle pressure exists in the outlet tube 18 and in the fluidly connected demand-pressure sensing chamber 12, being sensed by the diaphragm 27. The diaphragm 27 is drawn in a downward direction, as viewed in the drawing, during inhalation so as to deflect the valve operating lever 29 to rock within its terminal location 30 and move the valve member 19 to the right as viewed in the drawing from the preset slightly open valve-head 20 position, that gives the safety pressure condition, to a full flow state giving a rapid maximum flow response feeding breathable gas into the outlet tube 18. Because the valve member 19 is pressure balanced by the supply gas pressure the spring force providing safety pressure and valve closure can be small, thereby allowing a substantially consistent response characteristic of the valve over the entire operating pressure range of an associated MSOG (not shown). Exhalation causes a cessation of flow through and consequent pressure build-up in the outlet tube 18 and in the chamber 12 to an extent where the diaphragm 27 is raised above its null position and the valve operating lever 29 is moved to a position enabling the valve-head 20 to move to its nearly closed position giving safety pressure as described, until the cycle is repeated.

Breathable gas bleeds from chamber 12 to ambient by way of the orifice 28 in the sensing diaphragm 27, the breathing-pressure control chamber 13, the large outlet port 37 thereof, and the cabin pressure sensing chamber 14 and its outlet 42.

With increasing cabin altitude (decreasing ambient pressure) from, say, 12000 m. (40000 feet) the aneroid capsule 40, which contains a compression spring (not shown), becomes expanded to carry its valve-head 39 towards engaging the valve-seat 38 and restricting the flow through the large outlet port 37, thereby developing increasing pressure in the breathing-pressure control chamber 13 and, consequently, an increasing closing pressure on the diaphragm 46 of the relief valve 44, and an increasing pressure in the outlet tube 18 and in the aviator's breathing mask (not shown). As the cabin altitude returns to 12000 m. the capsule 40 contracts and this restriction of the large outlet port 37 is progressively removed.

The pressure-compensated relief valve 44 ensures that pressure in the outlet tube 18 and in the breathing mask (not shown) will relieve should the pressure therein reach a value of 125 Pa (0.5 ins. WG) greater than the pertaining control-pressure in chamber 13; whereas the pressure-relief valve 49 will relieve when the breathing-pressure control chamber pressure reaches the predetermined pressure of 4.5 kPa(18 insWG) which is slightly above that of the maximum desired control pressure which is appropriate to the minimum cabin pressure the regulator must satisfy.

The push-button 43 provides a manual test facility for checking, before flight, that the aviator's breathing mask (not shown) is fitting correctly and that there are no appreciable leaks in the oxygen delivery system fed from the regulator 10. By closing the push-button 43, with oxygen being supplied to the regulator, the venting to ambient of safety pressure bleed is prevented until the breathing-pressure control chamber pressure reaches the pressure at which the pressure-relief valve 44 opens.

In most prior art regulators, safety pressure gas flow into the breathing-pressure chamber is taken from the gas supply to the demand valve and is controlled by a very small orifice. In the regulator of the present invention, because the demand valve member 19 itself is arranged to deliver the safety pressure flow, the gas flow into the breathing-pressure control chamber 13 is taken from the demand-pressure sensing chamber 12 by way of the relatively large orifice 28 which is less likely to become obstructed than the fine orifices of the prior art regulators.

Where required, a follower diaphragm (not shown) may be accommodated to maintain the volume of the breathing-pressure control chamber 13 constant during movement of the pressure responsive diaphragm 27, the follower diaphragm being exposed to cabin pressure on its outer surface and to the pressure in the breathing-pressure control chamber on its inner surface.

CLAIMS

1. A breathable gas delivery regulator (10) having a supply gas inlet (16) connected with a gas delivery outlet (17) by way of a conduit arrangement which is closable by a demand valve (19), characterised in that the demand valve is adapted for pressure balance by supply gas and is operably connected with a pressure-responsive wall (27) of a demand-pressure sensing chamber (12) having fluid connection with the gas delivery outlet.

2. A breathable gas delivery regulator as claimed in Claim 1, further characterised in that the demand valve is of poppet-type comprising a poppet valve-head (20) connected by a spindle (21) to a spool portion (22).

3. A breathable gas delivery regulator as claimed in Claim 2 further characterised in that the poppet-type demand valve is adapted for pressure balance by counteracting areas exposed to supply gas pressure and comprised by an end face area of said spool portion and an opposed closed face area of the poppet valve-head.

4. A breathable gas delivery regulator as claimed in Claim 2 or Claim 3, further characterised in that a labyrinth seal (25) is provided on a circumferential surface of the spool portion and means are provided for venting leakage of supply gas past the labyrinth seal.

5. A breathable gas delivery regulator as claimed in Claim 4, further characterised in that said vent means comprises a vent chamber (26) which is spanned by a plain length of said spool portion.

6. A breathable gas delivery regulator as claimed in any preceding claim, further characterised in that said demand valve is operably connected to said pressure-responsive wall by a mechanical member (29).

7. A breathable gas delivery regulator as claimed in any preceding

claim, further characterised in that resilient means (32) preload said demand valve towards an open position.

8. A breathable gas delivery regulator as claimed in any preceding claim, further characterised in that said pressure-responsive wall of said demand-pressure sensing chamber is common to a breathing-pressure control chamber (13) having a barostatically-controlled outlet (37), said demand-pressure sensing chamber and said breathing-pressure control chamber being interconnected by an orifice-controlled bleed path.

9. A breathable gas delivery regulator as claimed in Claim 8, further characterised in that said orifice-controlled bleed path comprises an orifice (28) in said pressure-responsive wall.

10. A breathable gas delivery regulator as claimed in Claim 8 or Claim 9, further characterised in that a pressure-compensated relief valve (44) is provided at or near said gas delivery outlet and is adapted to relieve excessive delivery gas pressure at a predetermined valve relative to breathing-pressure control chamber pressure.

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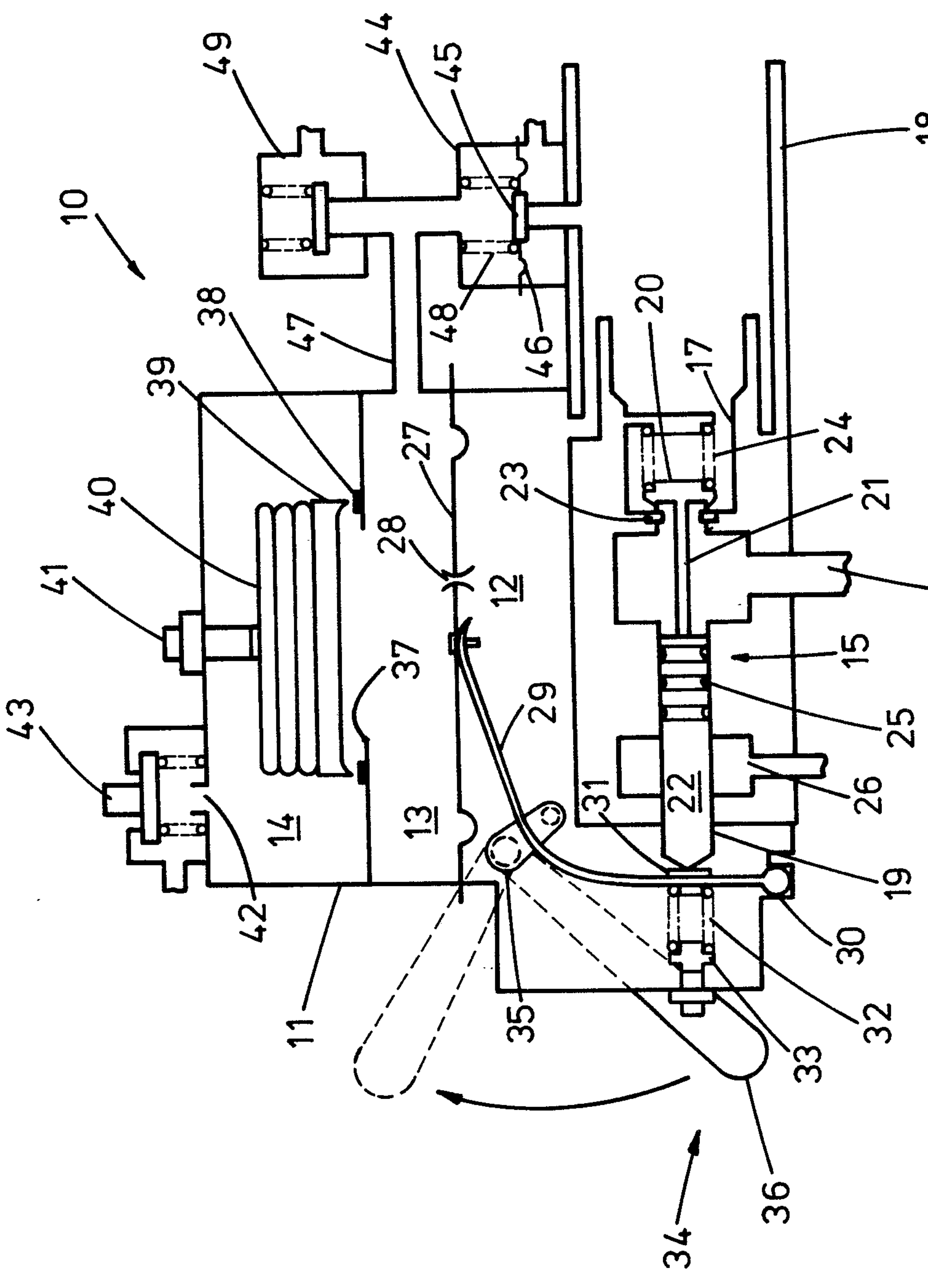
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