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Cramer

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[54] **FAIL-SAFE LIQUID OXYGEN TO GASEOUS OXYGEN CONVERSION SYSTEM**

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[58] **Field of Search**..........................62/50–53; 128/203, 128/DIG. 27

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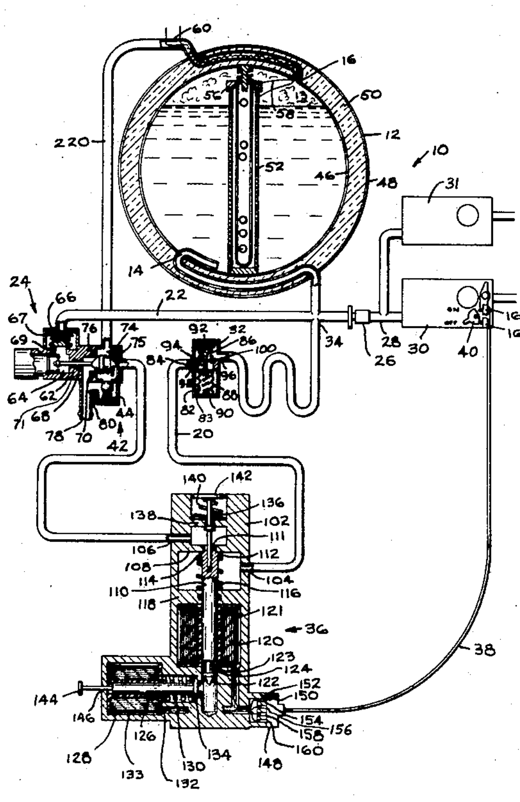
[57] **ABSTRACT**

A fail-safe system for supplying oxygen to a breathing regulator operated upon demand by a recipient. A liquid oxygen storage vessel has an outlet port connected to its inlet port through a build-up circuit. As the liquid oxygen flows through the build-up circuit it is converted from a liquid to a gas through the effect of thermal energy. As a result of the liquid to gas conversion, a high internal pressure is created in the build-up circuit. A pressure responsive member placed in the build-up circuit will interrupt the flow when the pressure reaches a predetermined value during the active operation of the system. A supply circuit connected to the build-up circuit transmits the oxygen as a gas to operate the breathing regulator. A first solenoid in response to an electrical signal controls a flow control valve connected in the build-up circuit. An operational switch on the panel regulator supplies the electrical signal to the first solenoid, opening the control valve. As the valve opens, a latching shaft controlled by a second solenoid engages a notch on the plunger of the flow control valve to hold the valve open. The flow control valve will remain open until an operational closing signal is communicated to the second solenoid. Upon receiving the signal, the second solenoid moves the latching shaft away from the notch permitting a resilient member to close the fluid flow outlet port to the build-up circuit. To prevent excessive pressure in the build-up circuit when the first solenoid closes the flow control valve, a by-pass valve is utilized to provide an escape to the atmosphere.

9 Claims, 1 Drawing Figure



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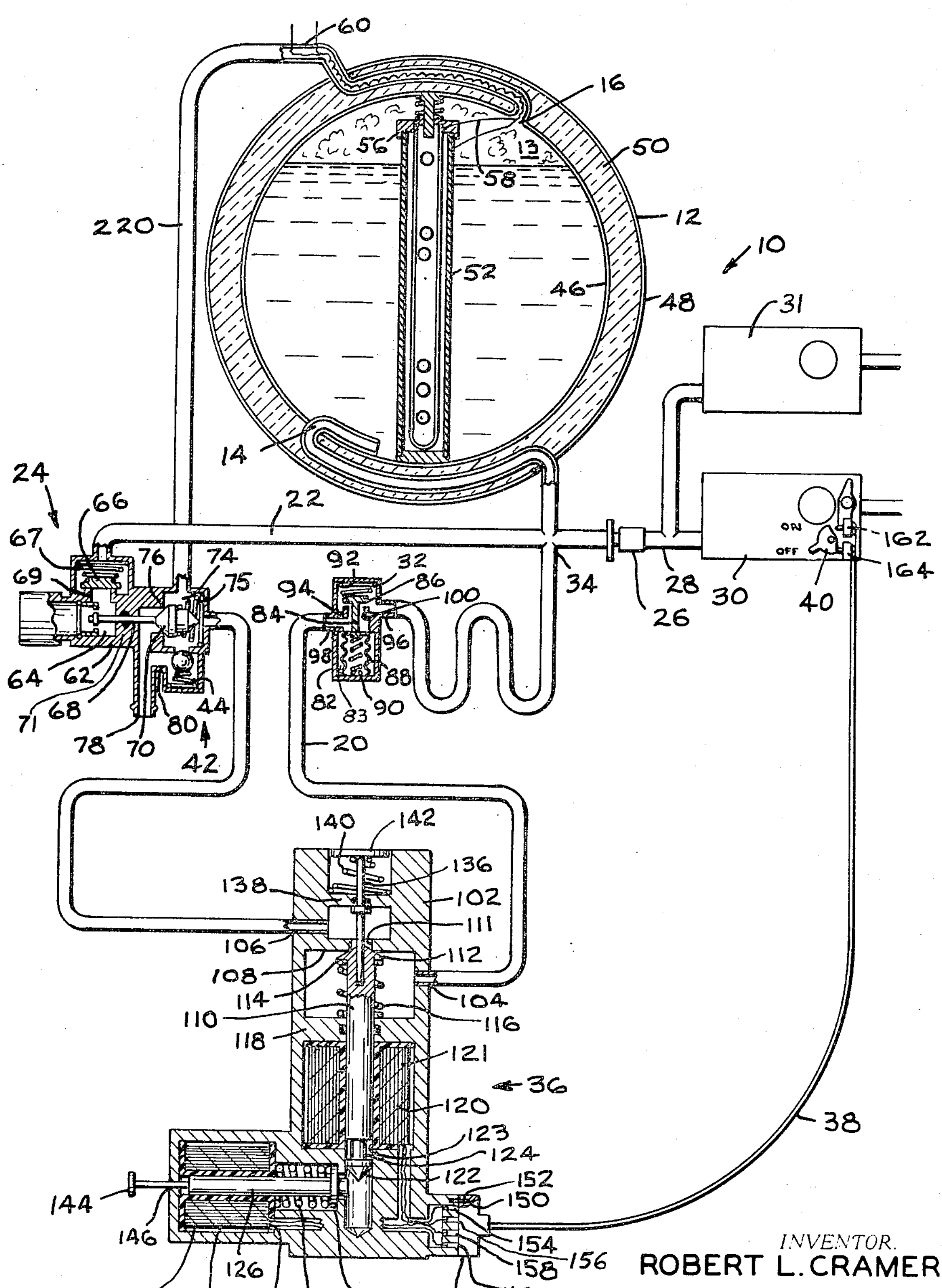

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FAIL-SAFE LIQUID OXYGEN TO GASEOUS OXYGEN CONVERSION SYSTEM

BACKGROUND OF THE INVENTION

Presently known liquid oxygen to gaseous oxygen systems have a pressure opening and closing valve whereby gas is drawn from the top of the storage container when the system pressure reaches a predetermined range of pressures. Pressure above this predetermined range is allowed to escape through a relief valve. Liquid oxygen trapped in the supply line during non-use is prevented from returning to the storage chamber by a check valve located between the pressure opening valve and the pressure closing valve. However, as this trapped liquid is converted to gas due to the thermal energy resulting in an increase in pressure in the system, pressurized gas above a predetermined value is lost through a relief valve. As the pressure in the system drops the pressure opening valve, permits fluid flow into the supply line to maintain an operating pressure at all times. Devices have been designed to prevent the pressure opening valve from operating, but require the operator to manually inactivate the pressure opening valve. If the operator inadvertently failed to engage this device, the oxygen supply would cycle to maintain the operating pressure with a resulting loss of oxygen as gas through the relief valve.

SUMMARY OF THE INVENTION

To reduce the loss of the oxygen during the stored or passive period, I have invented a liquid to gaseous oxygen conversion system having a flow control valve that is responsive to the ON-OFF toggle of a demand breathing regulator. The flow control valve is neither normally opened nor closed, but will remain in its intended position until an overt act on the part of the operator sends a signal indicating a desired change.

To obtain low boil-off in the liquid to gaseous oxygen conversion system, the toggle of the regulator is placed in the OFF position. The toggle will remain in the OFF position until opened by the operator. A first solenoid of the flow control valve has an internal plunger resiliently biased toward an outlet port controlling flow through the build-up circuit. When the toggle is manually switched by an operator to the ON position, an electrical impulse is transmitted to energize the first solenoid. When the first solenoid is energized, the inner plunger will move away from the outlet port to permit fluid to flow through the build-up circuit. When the plunger of the first solenoid moves, a latching shaft of a second solenoid is engaged which holds the plunger in the opened position. When the toggle of the breathing rejector is switched to the OFF position, the second solenoid is energized pulling the shaft out of engagement and allowing the plunger to be seated, preventing fluid flow through the outlet port. Activation of the demand breathing regulator by an operator will insure operation conversion of the system until a subsequent deactivation of the breathing regulator, providing a fail-safe system uneffective by outside focus.

The flow control valve of the converter is provided with means for manual activation which will override the resiliently biased first solenoid, if power is not provided or unavailable. Thus, long standby or converter test outside the aircraft is possible when electrical power is unavailable.

It is therefore the object of this invention to provide a fail-safe liquid oxygen conversion to gaseous oxygen system having an activation switch integrally tied to a breathing regulator device.

It is another object of this invention to provide a fluid flow control valve with means to maintain its intended position in a manner unaffected by outside energy sources uncontrolled by an operator.

It is still a further object of this invention to provide means to manually activate a flow control valve to operate a liquid to gaseous conversion system.

These and other objects will become apparent to those who read this specification and view the drawing.

BRIEF DESCRIPTION OF THE DRAWING

The drawing shows a sectional view of a liquid oxygen to gaseous oxygen conversion system connected to a breathing regulator with an enlarged sectional view of a flow control valve operationally connected to the ON-OFF toggle of the regulator.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The liquid oxygen to gaseous oxygen conversion system **10** shown in the drawing includes a double walled storage vessel **12** having an inlet port **14** and an outlet port **16**. The inlet port **14** is externally connected to the outlet port through a build-up circuit **20**. The inlet port **14** is connected through a fill circuit **22** to a liquid oxygen supply adapter **24** and to connector means **26** in a supply circuit **28** going to a breathing regulator device **30**. A pressure responsive interrupting valve **32** is located in the build-up circuit **20** downstream from a supply circuit connection **34**. The interrupting valve **32** will open and close as the pressure in the build-up circuit **20** is reduced by withdrawal of gaseous oxygen through the breathing regulator **30**. Opening and closing the interrupting valve will assure that the pressure of the gaseous oxygen transmitted to the regulator **30** will remain within a predetermined pressure range. Downstream from the interrupting valve **32** is a flow control valve means **36** having an operational signal transmitting line **38** connected to the ON-OFF toggle **40** of the breathing regulator **30**. The flow control valve means **36**, upon receiving an operational signal when the toggle **40** is moved to the ON position, will permit fluid to begin to flow as a liquid through port **14**. As the liquid oxygen flows through the build-up circuit **20**, thermal energy converts the liquid to a gas resulting in an increase in internal pressure. The pressure in the build-up circuit will increase until the interrupting valve **32** becomes operational. As long as the toggle **40** remains in the ON position, the fluid will flow through the control means **36** thereby providing the regulator **30** with pressurized gaseous oxygen.

Upon moving the toggle **40** to the OFF position, control means **36** will stop the flow in the build-up circuit **20**. However, some fluid will remain in the build-up circuit **20** between the flow control valve means **36** and the gaseous outlet **16** of the storage vessel. This trapped liquid oxygen will continue to be converted to gaseous oxygen and build up a head within the build-up circuit **20** and the storage vessel **12**. By-pass means **42**, an integral part of the oxygen supply adapter **24**, contains a pressure opening ball valve **44** which permits excessive pressure to escape harmlessly into the atmosphere. Since liquid oxygen will continue to be converted to gaseous oxygen through the thermal energy penetrating the storage vessel **12**, the ball valve **44** will be operational as long as the fail-safe system is on standby.

In more particular detail the individual elements of the system could be constructed as follows to provide a fail-safe operational liquid oxygen to gaseous oxygen conversion system.

The liquid storage vessel **12** includes an inner container **46** and an outer container **48** separated by an insulating member **50**. A capacitance probe **52**, of a type described in U.S. Pat. No. 2,848,666, is held against the interior wall of the inner container **46** by a resiliently biased cap **56** adjacent the inlet port **14**. The electrical leads **58** of the capacitance probe **52** are carried through the gaseous port **16** and out of the storage vessel **12** through a hermetic opening **60** in the build-up circuit to an electrical gauge (not shown) for indicating the amount of liquid in the storage vessel **12**.

The supply adapter **24** includes a housing **62** having a supply chamber **64** with a spring controlled closure cap **66** overlying an opening **69** to the fill circuit **22**. A shaft **68** retained in a bearing wall **71** of the housing **62** has a bevelled face **70** extending into a by-pass chamber **74**. The bevelled face **70** is urged against an annular seat **76** surrounding an opening **78** to the atmosphere. An internal passage **80** from the opening **78** is connected to the by-pass valve **44**.

The interrupting valve **32** includes a housing **82** having a control chamber **83** containing a stem **84** with a face **86** on one end and a bellows member **88** on the other end. A spring **90** is located inside the bellows member **88** and acts on the stem **84** in opposition to a closure spring **92**. A wall **94** separates the inlet port **96** of the control chamber **83** from the outlet port **98**. Without pressure in the control chamber **83**, the bellows member **88** acts in conjunction with spring **90** to unseat face **86** from the opening **100** in wall **94**. As the pressure in the control chamber increases, the bellows member **88** will collapse and spring **92** will seat face **86** to close the flow between the inlet port **96** and the outlet port **98**. As the pressure across face **86** drops due to a demand for gaseous oxygen through the breathing regulator device **30**, spring **90**, aided by the force created by the pressure drop, will overcome spring **92** to again permit fluid to flow.

The flow control valve means **36** includes a housing **102** having a flow chamber with an inlet port **104** and an outlet port **106**. A wall **108** having a passage **111** is located adjacent the outlet port **106**. A plunger **110** with a beveled end **112** having a shoulder **114** for retaining one end of a resilient member or spring **116** is located in an axial line with passage **111** and is retained in a bearing wall **118**. The plunger **110** extends through the bearing wall **118** into a first solenoid **120**. The end **122** of the plunger **110** extending into the solenoid **120** has an annular notch **124** which receives the end of a holding shaft **126** when the solenoid **120** is energized and moves the plunger **110** away from passage **111**. A second solenoid **128** surrounds shaft **126**, with a resilient member **130** being caged between the end **132** of the solenoid and a shoulder **134** on the shaft to urge the shaft toward the notch **124**. Centrally located on the end of the plunger **110** is a T-shaped cylindrical shaft **136** which is sealingly retained in wall **138** of the housing **102**. A spring **140** rests against the wall **138** and acts on top portion **142** of the T-shaped cylindrical shaft **136** to aid resilient member **116** in sealing bevelled end **112** against wall **108** surrounding passage **111** to prevent fluid flow therethrough. A projection **144** attached to shaft **126** extends through an opening **146** in the housing **102** to permit manual release of the shaft from the notch **124** by compressing spring **130** to permit the shaft **126** to move.

A plug-in connector **148** has a key way **150** which receives a projection **152** located in the housing **102**. This will assure that the lead lines **154 – 156**, carrying electrical current to the first solenoid **120** when the toggle **40** is in the ON position **162** and the lead lines **158 – 160** carrying electrical current to the second solenoid **128** when the toggle **40** is in the OFF position **164** are not interchanged.

MODE OF OPERATION

When it is desired to fill the storage vessel **12** with a liquid, usually oxygen, a supply source is mated with adapter **24**. In connecting the supply source, the shaft **68** is pushed to the right compressing spring **75** and thereby communicating outlet **16** with atmosphere via conduit **220**, by-pass chamber **74** and opening **78**. The supply liquid being under pressure unseats cap **66** and flows through fill circuit **22** into the fluid inlet **14**. Connector means **26** includes a check valve (not shown) which prevents flow at this time to the regulator **30**, in addition, since the toggle **40** is in the OFF position **164**, flow through build-up circuit **20** is prevented by the plunger **110** being resiliently held against the housing surrounding passage **111**. During the fill process liquid flows into inlet port **14** and displaces gas in the inner storage vessel **46**. The displaced gas escapes through gaseous outlet **16**, through conduit **220** of the build-up circuit and the by-pass chamber **74** to harmlessly escape to the atmosphere. The amount of liquid in the storage vessel is monitered by the capacitive probe **52** and when sufficiently full, the storage source is disconnected from the supply adapter **24**. Upon disconnecting the supply source, resilient member **75** will seat bevelled face **70** against seat **76** and resilient member **67** will seat cap **66** on opening **69** to seal the liquid in the storage vessel **12**.

During the passive or standby period, thermal energy will be transferred through wall **48**, insulating member **50** and wall **46** to cause the liquid oxygen to boil and then be converted to gaseous oxygen. As the pressure in the chamber **13** builds up, this same pressure being present in conduit **220** will unseat resiliently held ball valve **44** of means and permit the gaseous oxygen to travel through passage **80** and opening **78** to harmlessly escape to the atmosphere.

To check the operation of the storage vessel **12** prior to attaching the regulator device **30**, T-shaped cylindrical shaft **136** is pushed manually until spring loaded shaft **126** engages notch **124**. Fluid will now be permitted to flow in build-up circuit **20** until the pressure acting on bellows **88** causes it to collapse thereby permitting spring **92** to seat face **86** and close opening **100**. As long as the pressure at the junction **34** in the build-up circuit remains constant the pressures across the interrupting valve **32** will prevent further flow in the build-up circuit **20**. With any further pressure build-up in circuit **20** fluid is allowed to escape through by-pass valve means **42** to prevent damage to the system. To release the plunger **110** from its held open position, projection **144** is pulled to overcome resilient member **130** thereby disengaging the shaft **126** from notch **124**. Upon disengaging the shaft from the notch, resilient members **116** and **140** will again seat plunger **110** on the housing around passage **111** to prevent fluid flow from the inlet port **104** to the outlet port **106**.

Upon joining the regulators to the supply circuit **28** through connecting means **26**, the check valve contained therein is opened permitting liquid oxygen convertible to gaseous oxygen under pressure to be supplied to the breathing regulator device **30**. The intensity of the pressure varies with the pressure in the build-up circuit created by thermal energy in the liquid to oxygen conversion. If fluid flow in the build-up circuit has been interrupted or prevented prior to connecting the breathing regulator device **30**, then the initial gaseous oxygen supplied will be at a minimal pressure.

When the operator desires to place the breathing regulator device in operation, toggle switch **40** is placed in the ON position **162**. In the ON position **162** electrical energy is transmitted through leads **154 – 156** to the first solenoid **120**. When the coil **121** is energized, the plunger **110** becomes magnetized and the mutual action of the field in the solenoid on the poles created of the ends **112** and **122** of the plunger **110** cause the plunger to move within the solenoid. This moving force becomes zero only when the magnetic centers of the plunger **110** and the solenoid **120** coincide. The maximum uniform pull to overcome the resiliently biasing closing members **116** and **140** occurs when the end of the plunger **122** is located within the bore **123** of the solenoid **120**. As the plunger **110** moves in the solenoid **120**, the bevelled end **122** slides along the end of shaft **126** partially compressing spring **130**. When the plunger **110** approaches the center of equilibrium with the solenoid **120**, shaft **126** snaps into groove **124**. This latching will occur almost instantaneously after the toggle **40** has been switched to the ON position **162**. To prevent the solenoid from heating, a conventional timing device (not shown) will stop the flow of electrical energy to the coil after a predetermined period of time. With plunger **110** locked open, fluid flow will be permitted from inlet port **104** to outlet port **106** without hinderance. As the flow of liquid oxygen progresses from the liquid port **14** to the gaseous port **16**, heat will have converted all the liquid to a gas resulting in an increase in line pressure. When the pressure in the build-up circuit reaches a predetermined value, the interrupting valve means **32** will close. The pressure across the seat face **86** of the interrupting valve means **32** will prevent flow in the build-up line until the differential is sufficient to overcome the resilient members **92**. Through this interrupting valve means, the pressure of the oxygen supplied to the breathing regulator device **30** will remain within a predetermined range.

If electrical power failure should occur, operation of the liquid oxygen to gaseous oxygen conversion system will be unaffected since the solenoid plunger **110** and shaft **126** could be mechanically positioned and remain so until an overt act on the part of the operator repositions them. During a power failure if it be desired to return the system to a passive stage, projection **144** could be pulled out to permit the resilient members **116** and **140** to seat plunger **110** and close passage **111** to thereby prevent fluid flow.

With electrical energy available, the operator switches toggle **40** to the OFF position **164** at the end of an active period to stop the flow of gaseous oxygen through the breathing regulator device **30**. Simultaneously with the toggle **40** in the OFF position, electrical energy is transmitted through leads **158** and **160** to the second solenoid **128** to energize the coil **133**. When coil **133** is energized, a magnetic flux will occur pulling shaft **126** out of contact with the notch **124** thereby permitting the plunger to be resiliently closed and stop fluid flow in the build-up circuit **20**. After a predetermined period of time, the electrical energy which is supplied the coil **133** of the second solenoid, is terminated and the flow control means inactivated.

Once the operator shows a need for oxygen the system is not subject to power failure in the electrical system since the flow of liquid oxygen in the build-up circuit is controlled by the latched solenoid control valve **36** tied to the toggle **40** of the breathing regulator device **30**. Through the manual override devices **142**, for the first solenoid, and **144**, for the second solenoid, a means is provided to shut the system down after a power failure, to activate the system without power and to perform a test on the connector prior to installation in the system without the regulator. In addition, the number of breathing regulator devices **30** and **31** can be varied to meet the requirement of the number of breathing systems required for the occupants of an airplane, but the operation of the liquid oxygen connection to gaseous oxygen is controlled by the master breathing regulator **30** connected to the flow control valve of the liquid oxygen to gaseous oxygen conversion system.

I claim:

1. A fail-safe system for supplying a gas to a regulator in a breathing system in response to a breathing demand of an operator, said system comprising:

a liquid storage vessel having a liquid port and a gaseous port;

a pressure build-up circuit connecting said liquid port to said gaseous port, the liquid in said storage vessel being converted from a liquid to a gas by thermal energy upon flowing from said liquid port to said gaseous port through said build-up circuit;

a supply circuit with a connection connected to said build-up circuit and said regulator, said supply circuit converting said liquid to a gas, said supply circuit delivering said gas to said regulator at a rate necessary to maintain a physiological level for said operator;

pressure responsive means located in said build-up circuit downstream from said supply circuit connection for interrupting the flow of said liquid in said build-up circuit when the fluid pressure therein caused by the liquid to gas conversion reaches a predetermined value, said pressure responsive means thereby correspondingly limiting the pressure of the gas transmitted to said regulator through said supply circuit;

by-pass means located in said build-up circuit for venting excessive fluid pressure in said liquid storage vessel to atmosphere; and

control means located in said build-up circuit downstream from said pressure responsive means, said control means being latched to an opened position for permitting fluid flow in said build-up circuit to create a fluid pressure therein in response to an electrical operational signal being communicated from said regulator.

2. The fail-safe system, as recited in claim **1**, wherein said control means includes:

a housing having a chamber located therein with an inlet port connected to said pressure responsive means and an outlet port connected to said pressure build-up circuit leading to said gaseous port of the storage vessel;

a plunger retained in a bearing wall in said chamber, said plunger having a valve face on one end and a notch on the other end;

first resilient means secured to said plunger for urging said valve face into sealing engagement with a seat of said housing to prevent fluid flow from the inlet port to the outlet port; and

first solenoid means surrounding said plunger having an electrical circuit connected to an activation section of an operational switching means for said regulator, said first solenoid moving said face away from said seat upon energization by said electrical operational signal.

3. The fail-safe system, as recited in claim **2**, wherein said control means further includes:

a shaft retained in a bearing wall adjacent the other end of said plunger; and

second resilient means secured to said shaft for urging one end of said shaft toward said plunger, said one end of the shaft engaging the notch end of said plunger to hold the valve face away from the seat upon deactivation of said first solenoid means.

4. The fail-safe system, as recited in claim **3**, wherein said control means further includes:

second solenoid means surrounding said shaft having an electrical circuit connected to a deactivation portion of the switching means of said regulator, said second solenoid means receiving an electrical signal from a deactivation section of said switch member being operated upon by an operator, said electrical signal causing said second solenoid means to move said shaft away from said plunger permitting said first resilient means to position said valve face against said seat.

5. The fail-safe system, as recited in claim **4**, wherein said switching means of said regulator includes:

an interconnected circuit between the activation and deactivation sections for transmitting an electrical signal to said control means corresponding to an operational signal from an operator to said regulator.

6. The fail-safe system, as recited in claim **5**, wherein said control means further includes:

override means secured to said plunger for permitting manual movement of said valve face away from said seat causing said shaft to engage said notch and thereby allow fluid to flow from the inlet port to the outlet port in said build-up circuit.

7. The fail-safe system, as recited in claim **6**, wherein said control means further includes:

release means secured to said shaft for permitting manual disengagement of said shaft with said notch to allow the valve face of the plunger to seat and prevent fluid flow in said build-up circuit through said chamber.

8. The fail-safe system, as recited in claim **7**, wherein the electrical circuits for the first and second solenoid includes:

plug-in means for connecting the regulator with the control means having a lock pin which snaps into a slot to assure proper alignment of the circuits and the corresponding solenoids.

9. The fail-safe system, as recited in claim **8**, wherein said supply circuit includes:

connector means for opening a check valve upon joining said supply circuit with said build-up circuit to permit said gas to freely flow to the regulator.

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