March 7, 1967 E. M. SHUGARMAN 3,307,597

FIRST STAGE PRESSURE REGULATORS MOUNTED WITHIN AIR CYLINDER PLUG

Filed Sept. 16, 1964 3 Sheets-Sheet 1

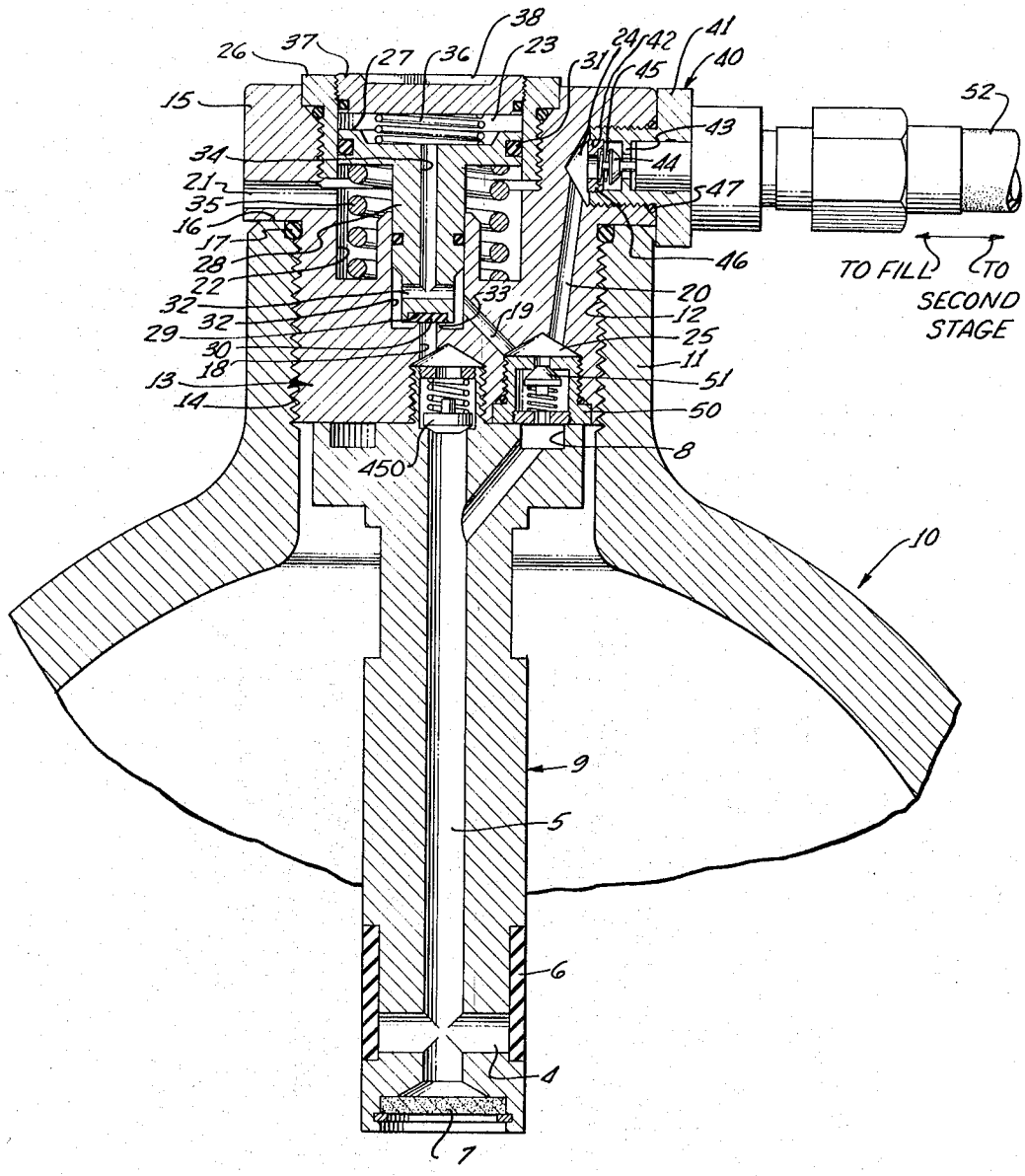


FIG. 1.

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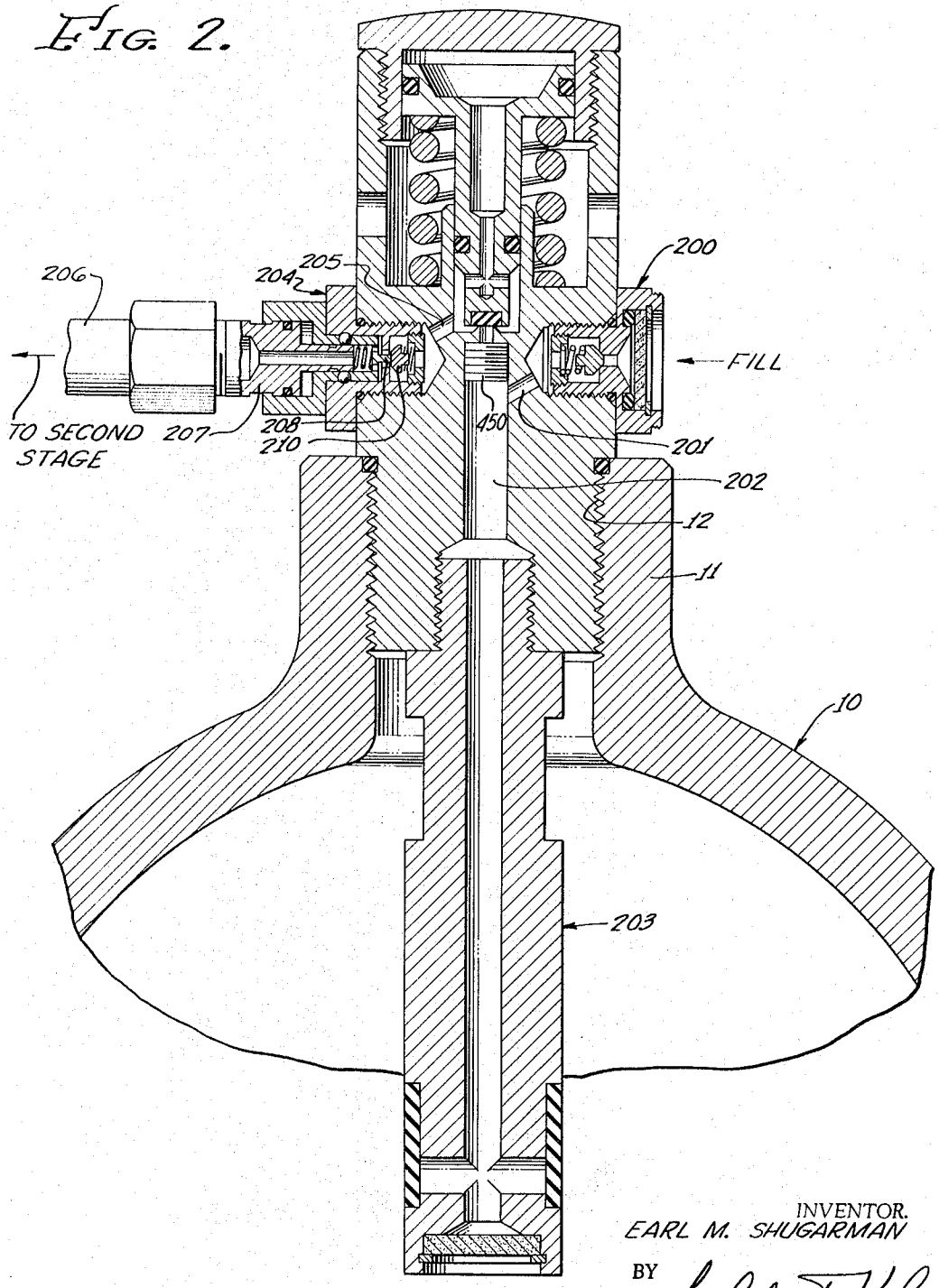
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FIRST STAGE PRESSURE REGULATORS MOUNTED WITHIN AIR CYLINDER PLUG

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FIG. 2.



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FIG. 3.

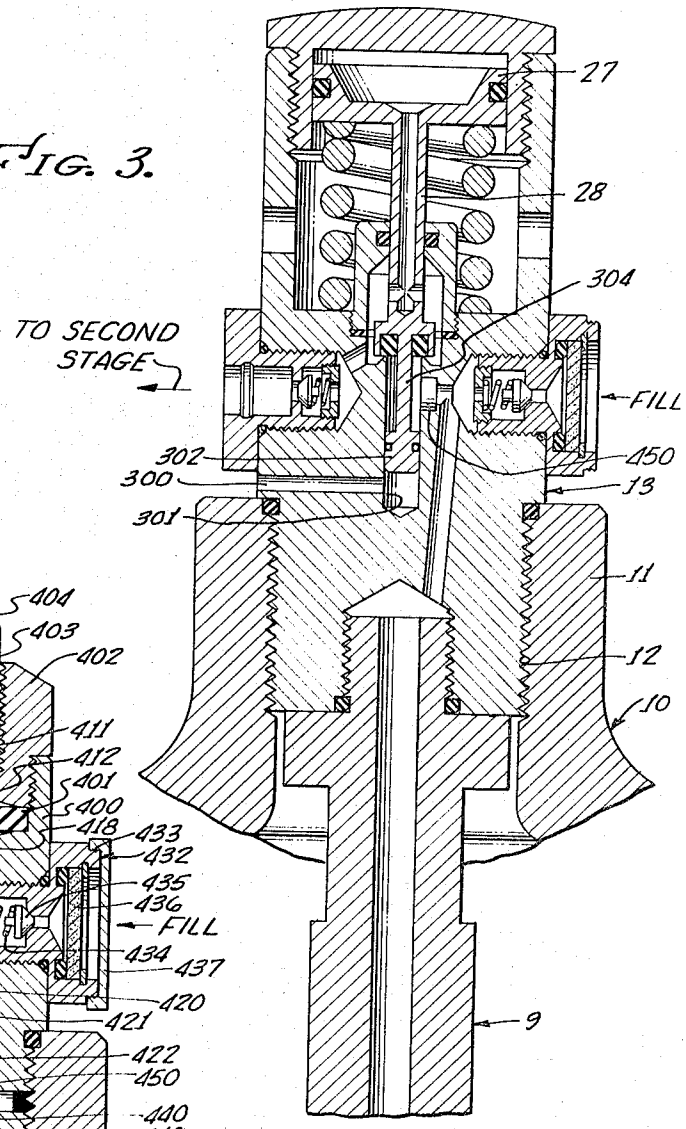
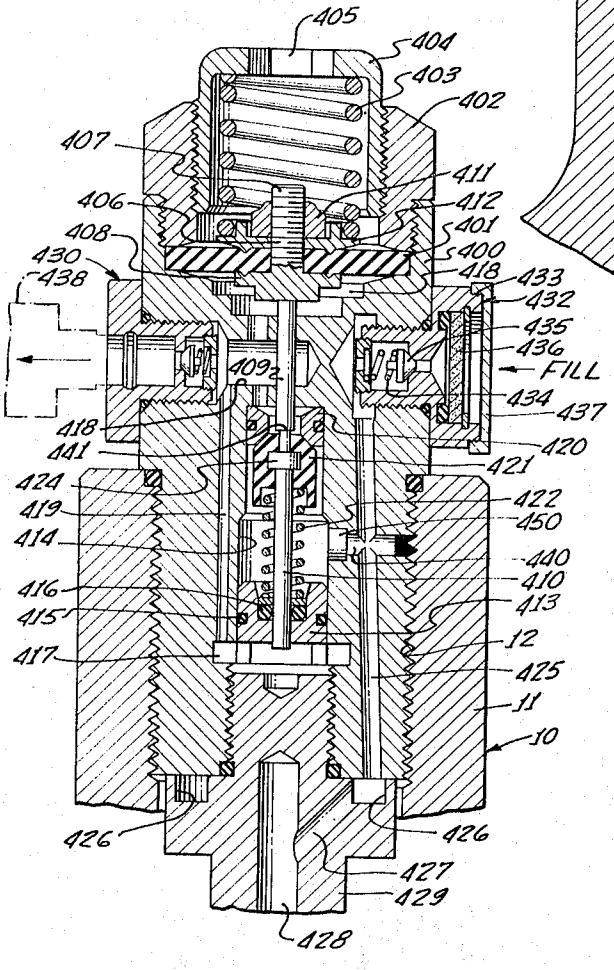


FIG. 4.



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FIRST STAGE PRESSURE REGULATORS MOUNTED WITHIN AIR CYLINDER PLUG

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7 Claims. (Cl. 141—18)

This invention relates to pressure regulators for self-contained underwater breathing apparatus.

It is an object of this invention to provide a regulator of a very compact miniaturized dimension which is mounted completely within the plug and for closing off an air cylinder which furnishes compressed air to the regulator.

It is an additional object of this invention to provide the regulator of the above type which includes a first check valve connected in series with the input-output duct which is opened by means of a push rod provided in the connector mounted at the end of a hose which is used for connecting the regulator to the second stage or to the compressor when it is necessary to fill the cylinder with compressed air, the regulator also including a second check valve in series with the input duct and in shunt with the regulator, the second check valve being in closed position when the regulator is in operation and in open position only when the air cylinder is being filled with compressed air by the compressor.

Another object of this invention is to provide a regulator of the above type in which the regulator is made adjustable for adjusting the reduced pressure produced by the regulator on the output side.

It is an additional object of this invention to provide scuba apparatus of the above type in which the first stage regulator and the two check valves are mounted in the plug used for connecting the scuba apparatus to the neck of the air cylinder, the check valves also acting as shut-off valves in the scuba system.

Referring to the drawings,

FIGURE 1 illustrates the vertical section of the air cylinder and of the piston-type regulator and two check valves mounted within the cylinder plug;

FIGURE 2 is the vertical section of the piston-type regulator mounted within the plug and two check valves mounted on two opposite sides of the projecting portion of the plug;

FIGURE 3 is a vertical section of the piston-type regulator and two check valves mounted within the air cylinder plug with the regulator being provided with a balancing feature;

FIGURE 4 is a vertical section of the diaphragm type regulator mounted within the cylinder plug with two check valves being mounted on two opposite sides of the plug.

Referring to FIGURE 1, the air cylinder **10** is provided with a neck **11** having an internal thread **12**. A plug **13** is mounted in neck **12** by means of a thread **14**. The cylinder is also provided with a dip tube **9** with a recess **8**, a sintered metal filter **7**, a by-pass valve **6**, and a duct **5**. Air is supplied to the system from cylinder **10** through filter **7** and duct **5**, and cylinder **10** is filled with air through duct **5** and by-pass valve **6** which is a rubber band stretched over a cross-duct **4**. A dip tube of this type is disclosed in William F. Summerfield's patent application United States Serial Number 206,703, filed July 2, 1962, "Dip Tube for Gas-Filled Cylinder," now United States Patent No. 3,148,965, granted September 15, 1964. Plug **13** is provided with an enlarged head **15** which engages a circular wall **16** of neck **11**. An O ring **17** is used to make an air-tight connection between the plug **13** and neck **11**. Plug **13** is provided with ducts **18**, **19**, **20** and **21** and chambers **22**, **23**, **24**, **25** and **32**. Chamber **22** is

connected to an ambient medium by means of duct **21** permitting the regulator to compensate for any changes in water pressure as the dive gets deeper or shallower. A first fixed plug **26** closes off the upper portion of chamber **22** and it also acts as a guide or a cylinder for a piston **27** which actuates the valve of the regulator with the aid of a push-rod **28** provided with a seat **29** for a washer **30** mounted within the seat **29**. Piston **27** and push rod **28** are provided with O rings **39** and **31** to seal off chamber **32** from chamber **22** with O ring **39** and chamber **22** from chamber **23**. Duct **18** terminates in a valve seat **33** normally engaged and closed off by washer **30**. Chamber **32** is connected to chamber **23** by ducts **33** and **34** within push rod **28** and piston **27**. In this manner chamber **23** is filled with air at the pressure produced by the pressure regulator. Piston **27** is subjected to a balanced pressure produced by springs **35** and **36**, spring **36** being used for the sole purpose for adjusting the balanced pressure produced by the two springs on the piston. Spring **36** is held in place by means of a second adjustable plug **37** having a key recess **38** which is used for adjusting the pressure exerted on the piston **27** by spring **36** and in this manner, the reduced pressure produced by the regulator on the downstream side which includes chamber **32**, ducts **19** and **20**, and chambers **24** and **25**. Chamber **24** is provided with a one-way check valve assembly **40** having a housing **41**, a threaded duct **42**, a valve seat **43**, a valve **44**, a spring **45**, and an adjustable cap **46**, which is used for adjusting the pressure of spring **45** on valve **44**. An O ring **47** is used to seal housing **41** within and to plug **13**. An identical check valve **50** having the same elements as valve **40**, is mounted in chamber **25**. In this case, valve **51** normally is closed because of high and full air pressure exerted on valve **51** by the compressed air within cylinder **10**. It is opened when the check valve **40** is connected to the air compressor, or a source of high pressure air, used for filling the cylinder. Air then flows into the cylinder through the two check valves **40** and **50** and duct **5**. The regulator valve is now closed because of high pressure in chamber **23** which also presses on piston **27** and keeps valves **30–33** closed.

When the regulator supplies air to the second stage regulator through an outgoing hose **52**, air flows through ducts **18**, **19** and **20**, periodically opened valve **30–33**, chambers **32** and **24** and check valve **40**. When pressure on the downstream side of the regulator valve **30–33** drops because of the withdrawal of air by the second stage connected to hose **52**, spring **35** opens the valve and admits air into chambers **32**, **23**, **24** and ducts **19** and **20** which causes valve **30–33** to close at that pressure which is capable of overcoming the pressure of spring **35** and the pressure of ambient water on the ambient side of piston **27**. In this manner the regulator valve is compensated for ambient water pressure and will increase the air pressure in chamber **32** with the increase in the ambient pressure of water and vice versa.

FIGURE 2 discloses the second version of the regulator which is similar to the regulator disclosed in FIGURE 1 except that the check valve **50** of FIGURE 1 now is externally mounted at **200**. This check valve is used for filling the cylinder **10** with compressed air through ducts **201** and **202** and the dip tube **203**. The second check valve **204** and a duct **205** are used for supplying air to the second stage through the hose **52** as in FIGURE 1. The second check valve is connected to a hose **206** provided at its end with a connector **207** having a push rod **208** which opens the check valve **210** when connector **207** is connected to the check valve **204**.

The construction and operation of the regulator illus-

trated in FIGURE 2 otherwise is identical to that illustrated in FIGURE 1.

FIGURE 3 illustrates still another version of the regulator, similar to that illustrated in FIGURE 2 except that a pressure of ambient water is now introduced through a duct 300 to compensate the regulator valve more fully for changes in the ambient pressure. For this purpose, the plug 13 is provided with a cylinder 301 and a piston 302 forming a sliding fit within cylinder 301. Piston 302 is an integral part of a rod 304 which, in turn, is a part of the rod 28 and piston 27. The diameter of the piston 302 is made substantially equal to the diameter of rod 28 to obtain a complete balance.

The operation of the regulator in FIGURE 3 otherwise is similar to the operation of the regulator in FIGURES 2 and 1.

FIGURE 4 illustrates mounting of a diaphragm type of regulator within the air cylinder plug. Plug 400 is provided with a diaphragm 401 held in place by a hollow nut 402, a spring 403, a hollow cap 404 provided with a hexagonal opening 405 for adjusting the pressure of the spring on diaphragm 401, a push rod 406 having a threaded end 407, an integral flange 408, and the cylindrical push rod portion 409 which pushes on a rod 410 provided with a flange 424 and a poppet valve 421 molded around the upper end of a rod 410 and a flange 424. Rod 406 is fastened to the diaphragm 401 by means of the threaded end 407, a nut 411 or washer 412 and the flange 408. The poppet valve 421 and rod 410 are guided by a ring 413 inserted in a cylindrical chamber 414. The ring is provided with two O rings 415 and 416 to seal off the lower chamber 417 from chamber 414. Chamber 417 is connected to a low pressure chamber 418 by a duct 419. The regulator valve includes a reversible seat 420 and the poppet valve 421 molded around rod 410 and its flange 424. A spring 422 surrounds rod 410 and counteracts the pressure of spring 403. Spring 422 normally keeps the valve closed and seated against seat 420. The valve becomes open when diaphragm 401 pushes down rod 409 and rod 410 which opens the poppet valve 421. Two check valves 530 and 432 are mounted on two sides of plug 400, the check valve 430 being used for connecting the low pressure chamber 418 to the second stage in the manner illustrated in FIGURE 2 at 204, 206, 207 and 208, while the check valve 432 is used for filling the cylinder 10 with compressed air. A duct 425 connects the check valve 432 with a circular recess 426 and ducts 427 and 428 in a dip tube 429, the lower end of which is illustrated in FIGURE 2.

The operation of the regulator illustrated in FIGURE 4 is as follows: Cylinder 10 is filled with compressed air through the check valve 432, ducts 425, 426, 427 and 428. When the high pressure hose is disconnected from the threaded end 433 of the check valve 432, spring 434 closes the poppet valve 435 and it is also kept closed by full air pressure in cylinder 10. The check valve 432 is provided with a sintered metal air filter 436 and a cap 437 which is used for closing the check valve 432 after the high pressure hose is disconnected. A low pressure hose 438 is connected to the check valve 430 which keeps this check valve open. When pressure in chamber 418 is low, diaphragm 401 pushes rod 409 down which opens valve 421. Air under pressure flows through the dip tube 429, ducts 428, 427, 417, 440, chamber 414, through the open valve to chamber 418 and hose 438 to the second stage. Duct 419 conveys low pressure to chamber 417 and balances the pressure exerted on the upper end of rod 410 by the air in the low pressure chamber 418. It should be noted here that 409 and rod 410 are two separate elements although they may appear as a single piece in FIGURE 4. The cross-line at the junction point 441 indicates where the two rods meet each other, rod 409 pushing on rod 410 when diaphragm 401 is depressed inwardly by spring 403 and ambient pressure of water.

As illustrated in all figures, an additional check valve 450 is interposed at the downstream end of the dip tube 9 and it is adjusted to a pressure in the order of ten or twenty pounds. This check valve is used for preventing water from entering the air cylinder after the air has been discharged from the cylinder. Without such check valve, the fully discharged air cylinders at times create suction and become flooded with water if under such conditions, their necks become immersed in water. The check valve 450 interposed at the upper end of the dip tube prevents such flooding of the air cylinders.

What is claimed as new is:

1. In an underwater breathing apparatus including an air cylinder having an aperture at one end for supplying air to said apparatus, the combination comprising:
   - a plug mounted in the aperture of said cylinder and having a plurality of ducts located therein and an aperture extending through a side portion thereof,
   - a pressure regulator mounted within the plug and controlling the flow of air from the cylinder, said regulator being exposed through the plug aperture to an ambient medium to regulate the pressure of the air in accordance with the pressure of the medium,
   - a first check valve mounted within a first duct leading from the cylinder to the regulator said duct permitting a flow of air from the cylinder to the regulator and said regulator permitting a controlled flow of air to a second duct, and
   - a second check valve being positioned at the outlet of the second duct within the plug and being normally closed to a flow of air to a third duct which leads into the cylinder due to the cylinder pressure on said valve, said valve normally permitting the air to flow to a fourth duct leading to the breathing apparatus, and permitting the air to flow into said cylinder through the third duct during a filling operation when the first check valve becomes closed to a reverse flow of air.

2. An underwater breathing apparatus according to claim 1 wherein:
   - the plug includes a dip tube mounted thereto, said tube having the first duct extending axially therealong into the cylinder and the third duct intersecting the first duct at an intermediate point shunting the first check valve, said dip tube having a filter mounted at the lower end thereof and a by-pass valve for avoiding the filter during a filling operation.

3. An underwater breathing apparatus according to claim 1 wherein:
   - the plug includes a plurality of threaded chambers, and the first and second check valves are mounted in threaded engagement within respective first and second chambers.

4. An underwater breathing apparatus in accordance with claim 1 wherein:
   - the plug includes a threaded aperture at the outlet of the fourth duct and
   - a check valve and hose assembly is mounted to the threaded aperture to feed the air in either predetermined direction.

5. An underwater breathing apparatus according to claim 1 wherein:
   - the pressure regulator comprises a piston-type regulator having spring means for adjusting the pressure delivered by the regulator on the downstream side of the regulator.

6. An underwater breathing apparatus in accordance with claim 1 wherein:
   - the pressure regulator comprises a balanced diaphragm type regulator.

7. In a pressure regulating system for a gas, the combination comprising:
   - a tank having an outlet portion and a pressurized cham-

ber therein to supply the gas in controlled quantities,

a plug mounted in the outlet portion of the tank and having an aperture extending through a wall portion to an ambient medium and a plurality of ducts located therein,

a regulator mounted to the plug and including a valve portion slidably mounted within the plug, said valve portion having an enlarged head and an elongated body portion having an aperture extending axially therethrough to permit the gas to flow therethrough and exert pressure on the upper portion of the head, a plug mounted to the regulator opposite the head, first spring means mounted between the upper portion of the head and the regulator plug and second spring means mounted about the elongated body portion to normally contact the lower portion of the head and urge the valve in a direction opposite the first spring means in conjunction with an ambient medium surrounding said second spring means through the aperture in the plug,

a first supply circuit for the gas comprising a first check valve at the outlet portion of the tank, the regulator and a second check valve located at the outlet of the

circuit, the respective circuit portions being connected in series by said ducts, and

a second circuit for the gas comprising a third check valve and a duct leading to the tank chamber and shunting the first check valve, said third check valve being normally closed to an outflow of gas from the tank through said duct but becoming open during a tank recharging operation when the first check valve at the outlet of the tank becomes closed to a reverse flow of air.

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