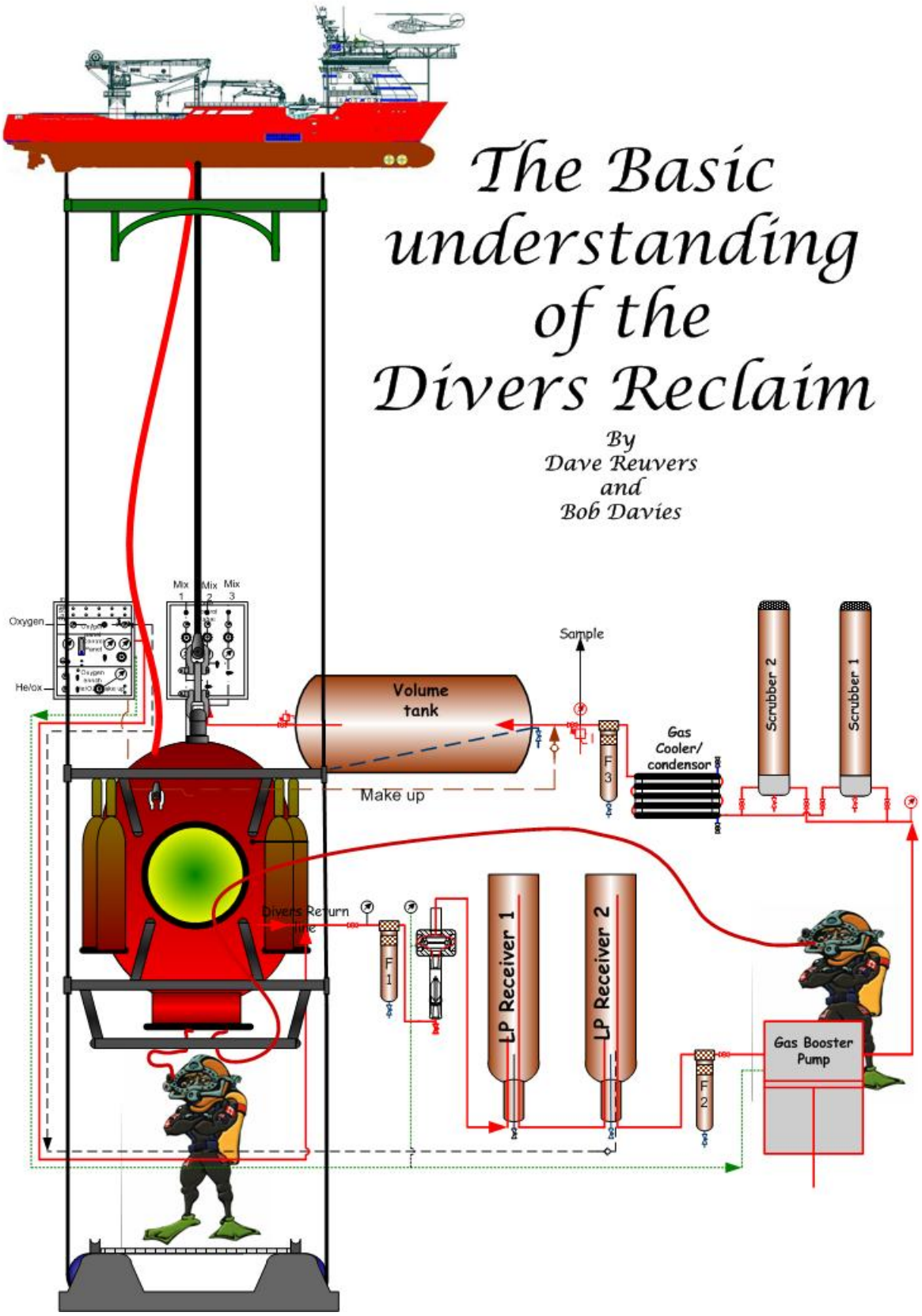


The Basic understanding of the Divers Reclaim

By
Dave Reuvers
and
Bob Davies

Reclaim Basic Set Up

The purpose of this document is to simplify the set up and understand the Gas Services reclaim system functions. The Gas Services Reclaim Manual is to be used for reference, maintenance, and servicing.

The principle of the Gas Reclaim System is to re-circulate the gas supply to the diver's. This will save on gas consumption to the diver's bell breathing supply by up to 90% on average. Helium is an expensive gas and can be difficult to purchase and supply to offshore vessels. The exhaled gas from the diver needs to have the C02 removed as well as impurities. Metabolic make up of oxygen at the correct amount to replace what the diver consumes during a dive.

The reclaim system comprises of the following main components:

1. Gas Booster Pump.
2. Gas Volume Tank or multiple Tanks.
3. Reclaim Control Panel.
4. Dive Control Panel.
5. Bell control panel.
6. Bell, including diver excursion hose, helmet, BPR and Water Trap.
7. Bell Umbilical Exhaust Hose.
8. Re-Processing unit consisting of Low Pressure (LP) CO2 Removal scrubber Towers, Filters. Receivers, and BPR

Operation:

Initial Setup, Charging and Gas Recirculation

NOTE: THE OXYGEN ON THE RECLAIM PANEL SHOULD BE CLOSED.

1. Initial gas charging for the reclaim system is done via the Reclaim Control Panel. Gas is supplied at the correct Oxygen Percentage to the panel for the bell working depth. The Makeup Valve should be opened and Makeup Regulator set to the desired setting (refer to chart), gas will then flow through Reclaim Control Panel to the Volume Tank and commence charging the supply pressure (volume tank) of the reclaim system.

2. Referring to the Gas Reclaim Panel Setup Chart now set the desired BPR Regulator setting.

3. Once some volume accumulates within the Volume Tank, the Cross Over valve on the Reclaim Panel should be opened to allow gas from the supply pressure side to charge the low pressure side of the system. This charges the exhaust hose in the bell umbilical and should always be done prior to bell being launched. Once the Gas Pressure reaches the BPR setting, gas will pass through the BPR and charge the Receivers. Care must be taken to not allow too much pressure to accumulate in the exhaust hose when opening the cross over valve. It is suggested to maintain it slightly above the BPR setting while re-circulating the gas (see below).

4. The valves on the LP Receivers, Scrubbers and other valves in line for the return and delivery of Reclaim Gas should all be opened. Not the Dive Control Panel Diver Supply Valve, this should be isolated until diving operations commence

5. The Gas Pump is now ready for starting.

6. Start the Gas Pump. On start up the pump will firstly:

   a. Charge itself with gas from the Volume Tanks. This is done with a solenoid valve which by-passes the outlet check valve and dumps gas into the Gas Booster system

   b. The Gas is first dumped into the high side then the BPR loader controlled re-circulation regulator allows a regulated amount to cross over into the LP side of the Gas Pump.

   c. A 2nd solenoid valve allows regulated gas to close the unloaders, allowing the cylinders to start pumping gas pressure, and also open the supply valve to the Gas Pump giving supply from the Receivers.

   d. Slowly the gas pump will increase pressure until no more gas is available to be pumped. The amount of gas is regulated by the total volume in the system

7. To test run the Reclaim for gas sampling, the Crossover Valve on the Gas Reclaim Panel can be left partially opened. This allows for circulation of the gas from the Volume tanks, through the Reclaim Control Panel, into the Divers Exhaust Hose; pass the BPR, into the Receiver Tanks and Filters, then to the Gas Pump for pressure boosting back to the Volume Tanks. Care must be taken to not over charge the system with excess volume.

When running the reclaim in Re-cycle, shut the Makeup Gas Valve, this will prevent over charging the system volume. Always observe the Diver Exhaust Hose and Diver Supply Pressure Gauges on the Reclaim Control Panel when re-cycling the gas.

Diving Operations

Once the above has been completed the Reclaim is ready for use. Dive and bell checks should be as per normal procedures.

Dive Control Panel Setup

1. Open Supply from Reclaim to Diver

2. Open supply to Diver from Mix Gas Supply

3. Set Mixed Gas on line Supply Regulator to be I bar below Reclaim Supply Pressure (volume tank). This will act as an automatic supply should reclaim supply be lost.

4. Ensure that Bellman has set the Onboard Gas supply to the diver slightly lower to that of the Mix Supply on the Dive Control Panel. This will be the emergency onboard Supply should surface supplies be lost.

5. Bellman to set up the reclaim in the bell as per procedures listed on the Gas Services Bell Card.

Once the diver has dropped below the bell, the diver needs to close the Diverter Valve and open the Return Valve on the side of the Helmet.
This should now give reclaim. Once the diver is on Reclaim, the Oxygen metabolic make up supply on the Reclaim Control panel should now be set up following the guidelines on the chart. This will give a metered amount of oxygen to mix with the returned gas to replenish the oxygen the diver consumed. This is an automated system which shuts down should there be no flow of exhaust gas back from the diver an indicator light goes from green (Flow) to amber (No Flow).

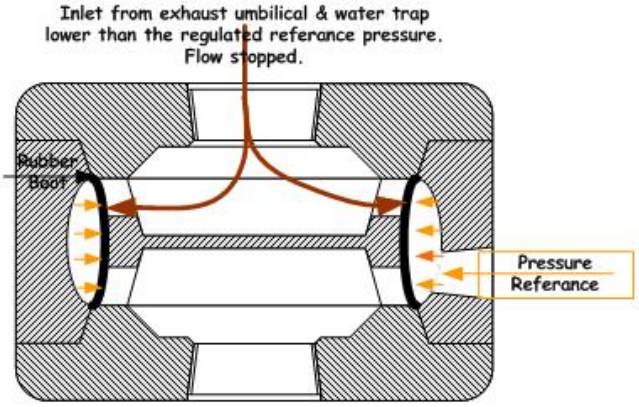
How the Reclaim Functions

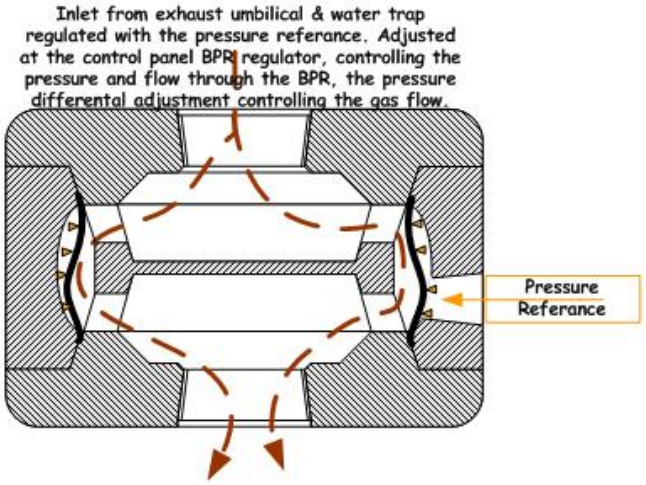
Gas supply to the diver's helmet is as per normal procedures. The helmet itself has some differences in the gas delivery side. Parts are not interchangeable between standard helmets and reclaim helmets.

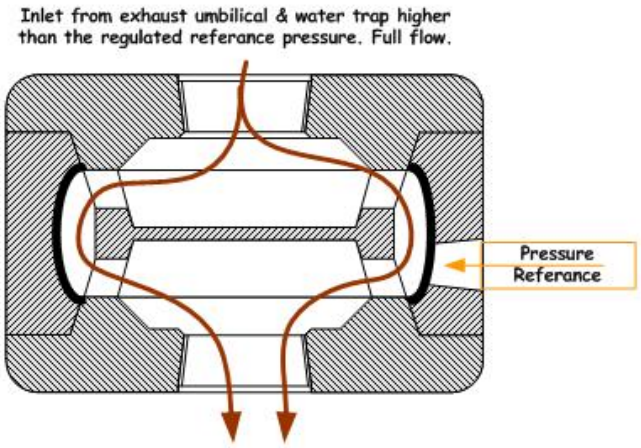
The Gas recovery works on the simple principle of an air lift, meaning the gas wants to rise to the surface. However! For example with a diver working at 60 m of sea water, there is to great a difference between the surface pressure and the diver. So this ascent rate of the diver exhaust gas must be slowed down.
This slowing of the gas being recovered is achieved by a Back Pressure Regulator (BPR). There is one mounted inside the bell, then another top side before the Reclaim Receiver Tanks.
The BPR achieves this by maintaining a set amount of "Back Pressure" before the regulator and allowing any increases in the pressure from the divers exhaust to pass through to the outlet side.

Drawings showing the BPR

How the BPR works — Bob Davies







Reclaim Basic Set Up

The above drawings show the operation of the BPR. This is a simple device with no moving parts.

The reference pressure is the pressure needed to close the BPR Rubber Boot. This is set by the BPR regulator either on the Panel in the Bell for the Bell BPR, or the BPR Loader on the Gas Services Reclaim Panel in Dive Control.

1st diagram. The suction port has a negative pressure; this is created by the intake of the Gas Pump.
This negative pressure combined with the reference pressure is what closes the flow off through the BPR.

2nd diagram. When the diver exhales, pressure increases in the diver exhaust hose. This increase overcomes the reference pressure and opens the rubber boot; gas is allowed to then pass through the BPR to the Suction side.

3rd diagram. The more the diver exhales, the more the Rubber Boot will open allowing Exhaled Gas to pass through the BPR to the Suction side.

The BPR on the surface is to maintain a minimum gas pressure within the Diver Exhaust Hose inside the bell umbilical. The BPR inside the bell is to do the same for the Diver Exhaust Hose in the Diver's Excursion Umbilical.

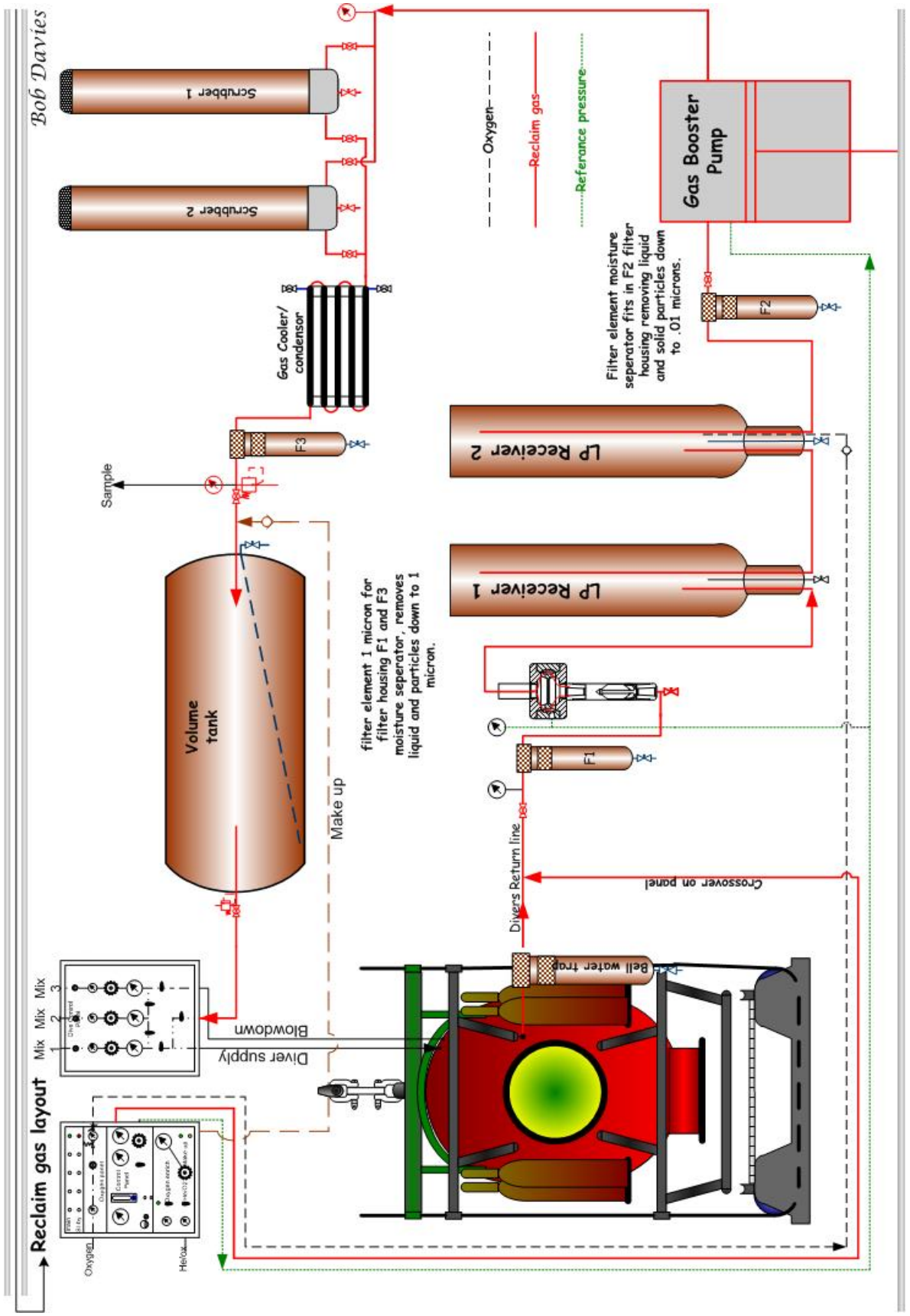
The bell BPR maintains, for a 60 m sea water dive, about +/- 1 bar difference between the Diver's ambient Pressure and the Excursion Umbilical Exhaust Hose pressure.

The Top Side BPR does the same thing by creating the difference between the Bell BPR pressure and the Top Side Unit pressure. Again this for a 60 m sea water dive giving a difference of about + /- 1 bar.

The bell BPR maintains, for a 60 m sea water dive, about +/- 1 bar difference between the Diver's ambient Pressure and the Excursion Umbilical Exhaust Hose pressure.

The Top Side BP does the same thing by creating the difference between the Bell BPR pressure and the Top Side Unit pressure. Again this for a 60 m sea water dive giving a difference of about + /- 1 bar.

Reclaim Basic Set Up



GAS BOOSTER PUMP OPERATION

The flow of the gas through the Reclaim Gas Booster is:

1. Inlet supply from the LP Receivers.
2. Pass the Supply Control Valve.
3. 1st stage cylinder.
4. Interstage gas cooler.
5. 2nd stage cylinder.
6. 2nd stage gas cooler.
7. 2nd stage moisture trap.
8. Gas Pump Outlet via check valve.

Additional components on the Reclaim Gas Booster.

1. 1st Stage bypass valve.
2. Control solonoids.
3. Supply control valve Actuater.
4. Gas charging system.
5. UnLoaders/Moisure dumps.
6. Gas cylinder void gas venting (seal problem if over venting).
7. Dome loaded recirculating by-pass regulator.

The main functions of the Gas Booster is straight forward, it is a two stage gas pump. The pump is a ratio of what is put in to what is pumped out. When deep diving over 150 MSW, the 1St stage cylinder is not required and just the 2nd stage. This is the reason for the By-pass valve; it simply cuts out the 1st stage cylinder.

Reference drawing on the page 8. The sequence for start up is:

- Solenoid *"A"* opens and charges the system with the same breathing gas to be pumped, this is drawn from the Volume Tanks

- The gas accumulates in the gas pump high pressure side, and then the Recirculation by-pass Regulator allows the gas to pass through into the inlet side at a regulated pressure.

- The regulated pressure for the **Recirculation by-pass Regulator**, is the BPR Loader Pressure setting – I bar (less 1 bar), this is to ensure a minimum gas volume intake to the gas pump at all times

- Solenoid ***"B"*** opens and allows regulated (10 bar) gas to close the loaders and open the Intake Valve. This valve can be seen actuating by observing the indicator dial, there are white dots for this to reference.

- Now the pump is ready to pump gas.

Other controls

- Oil pressure cut out, low oil pressure will shut the Gas Pump Down

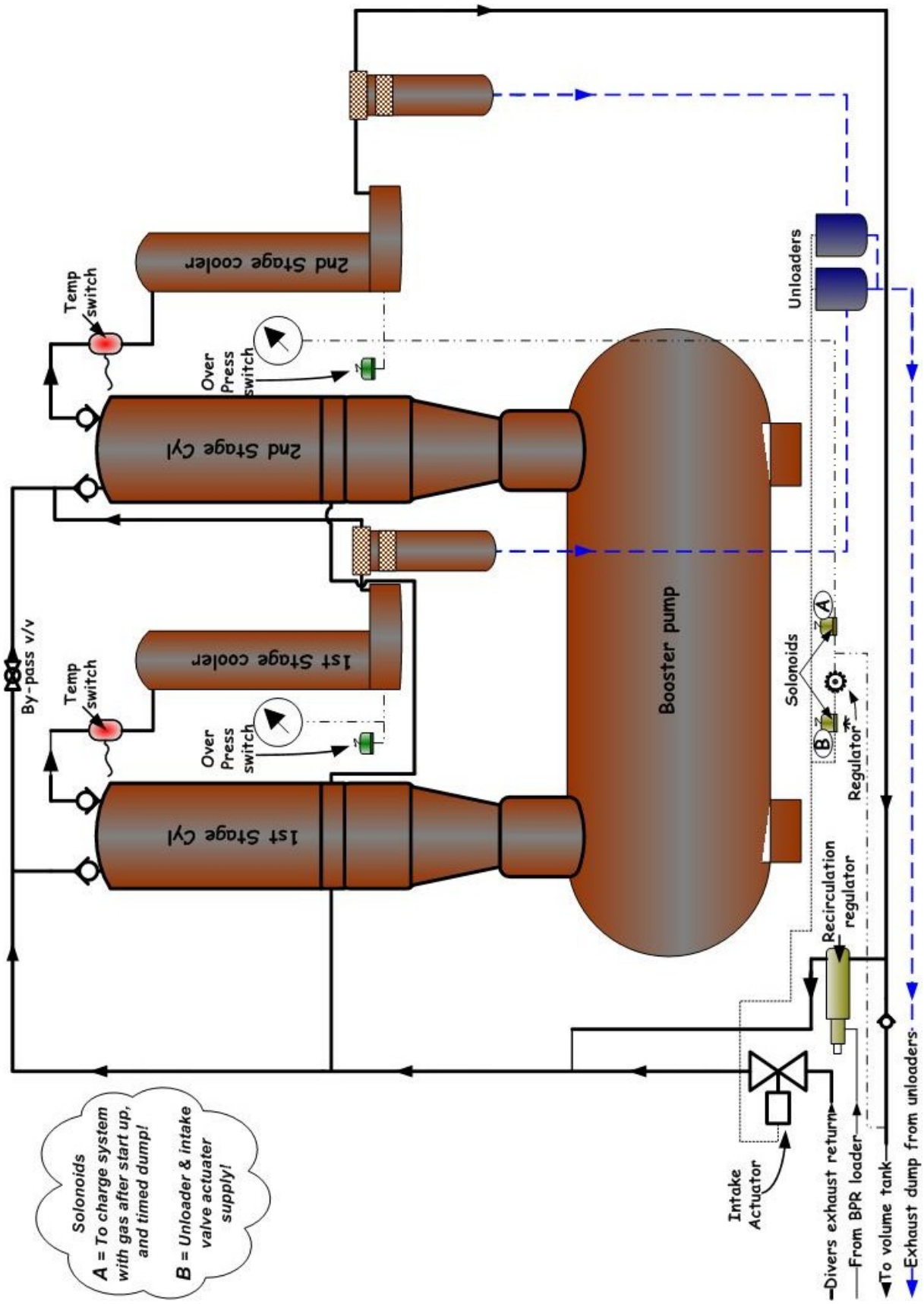
- High Gas temperature cut outs (1 for each stage); this is measured at the inlet to each stage gas cooler. Shuts down for over temp.

- High Gas Pressure cuts outs (1 for each stage), mounted next to the loaders. Shuts gas pump down on high pressure.

- Un-Loaders, these are valves which close and load allowing the cylinders to pump gas and pressure to increase. These are plumbed into the underside of each stage after cooler. This circuit doubles as an auto dump for any moisture the after coolers condense. A timer regularly allows the control solenoid to de-energise, the control circuit gas. This then allows the Un-loaders to open and gas in the after coolers to vent its accumulated moisture. The solenoid also closes the inlet valve to the gas pump. Then the Solenoid energises and sends gas back to the loaders and inlet valve to allow the gas pump to pump gas again.

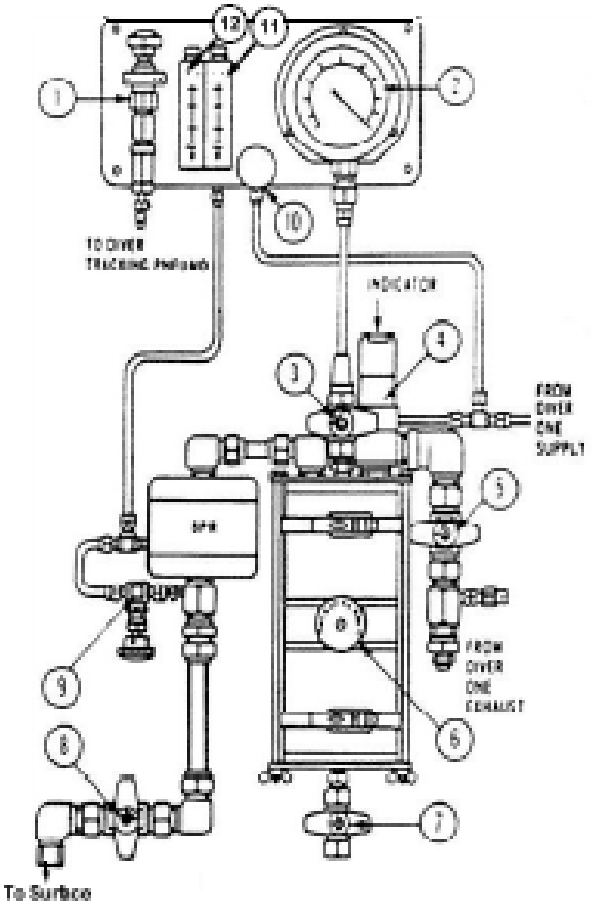
Beneath the gas cylinders is a chamber which must be vented with the same gas which is being pumped, this is achieved by the intake gas supply being "T" into these chambers. This prevents contamination of diver's gas.

Reclaim Basic Set Up



Bell Internal Reclaim Panel and equipment

The drawing is shown for one diver. Although with two divers it would mean two take offs from valve 1 BPR loader valve to two tracking pneumos.
Also two lines to the water trap with valves 5 & 13 and two Saeco valves 4 & 4a. Set up is basicly the same.



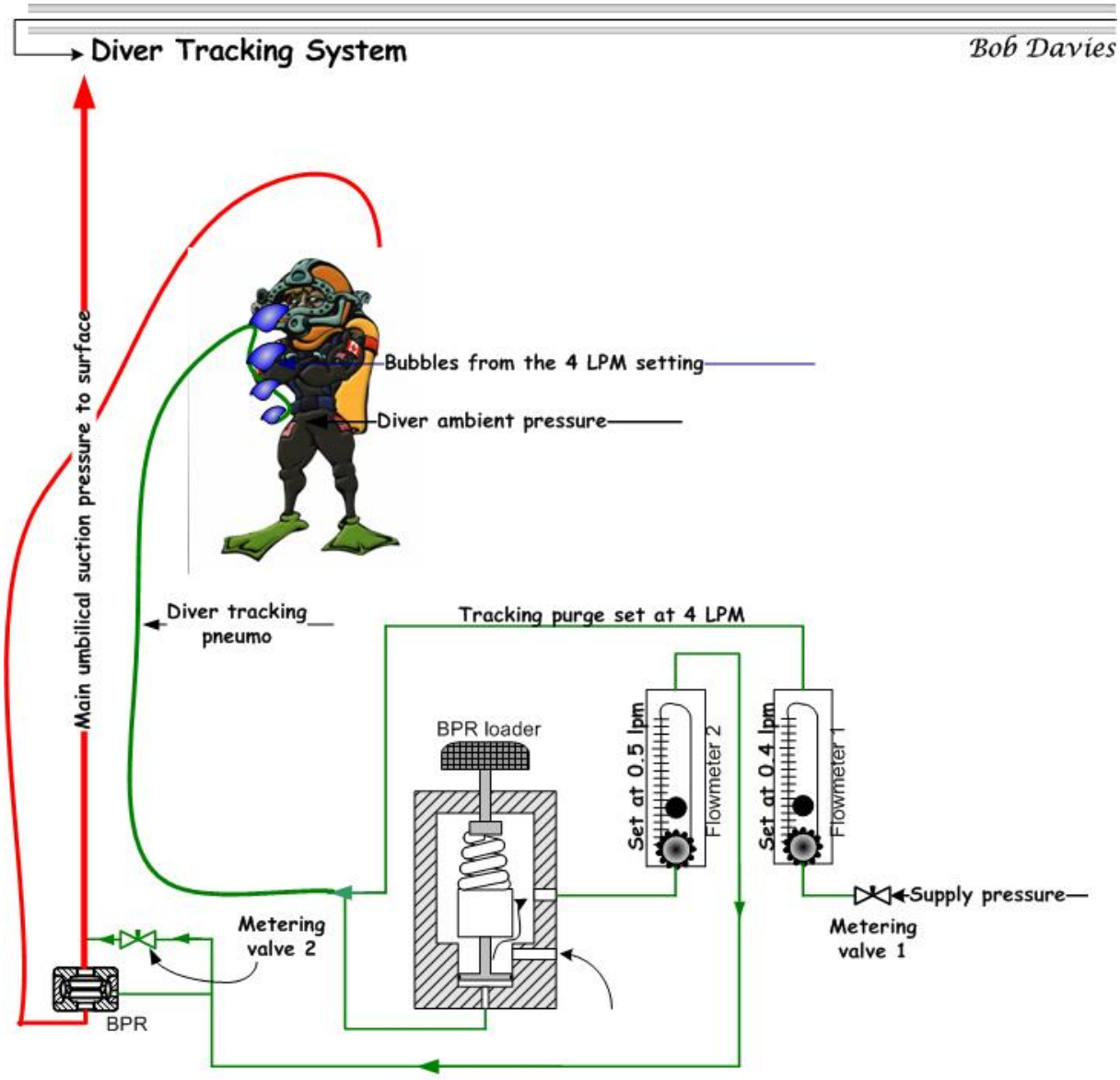
1. BPR loader valve supplies regulated pressure to the BPR reference port.
2. Pressure gauge.
3. Bell scrubbing valve.
4. SAECO valve.
5. Umbilical exhaust isolation valve.
6. Water trap.
7. Water Trap drain valve.
8. Exhaust return Hull isolation valve.
9. Metering valve.
10. Metering Valve #2 BPR bleed valve tracking system.
11. Flow meter.
12. Flow meter.

Operation

The BPR Loader *(1)* senses and regulates Bell ambient pressure; this regulated pressure is adjusted with the top adjusting knob.
The regulated gas then flows through the Flow Meter (12) (at the desired flow rate) to the BPR reference port and via the Metering Valve *(9)* to the exhaust hose.
This sets the reference pressure for the Bell BPR, which in turn determines the pressure in the exhaust hose for the diver excursion umbilical and bell water trap.

Diver tracking system

Tracking pneumo tends not to be used! The system was more used with the Helinaut valve system on the divers reclaim helmet.
The helmet system more widely used today is the ultra jewel 601 reclaim helmet. The Ultra jewel 601 is by far a better valve for breathing and exhaling. In order to obtain minimum breathing resistance was the purpose of the tracking pneumo to maintain the pressure in the return umbilical approximately 1-2 bar below diver ambient. Thus as the dive moves above or below the bell, It is desirable to adjust the BPR loading accordingly. This is achieved automatically by means of the diver tracking system. The system is shown schematically in the diagram below. The loader which controls the set pressure for the BPR, as suction is drawn is first applied to the system, gas will be drawn from the BPR loader line, reducing the pressure until it reaches the set pressure of the loader when it will lift, allowing gas to flow to prevent further depressurization. In this way, a fixed reference pressure is available for the BPR.



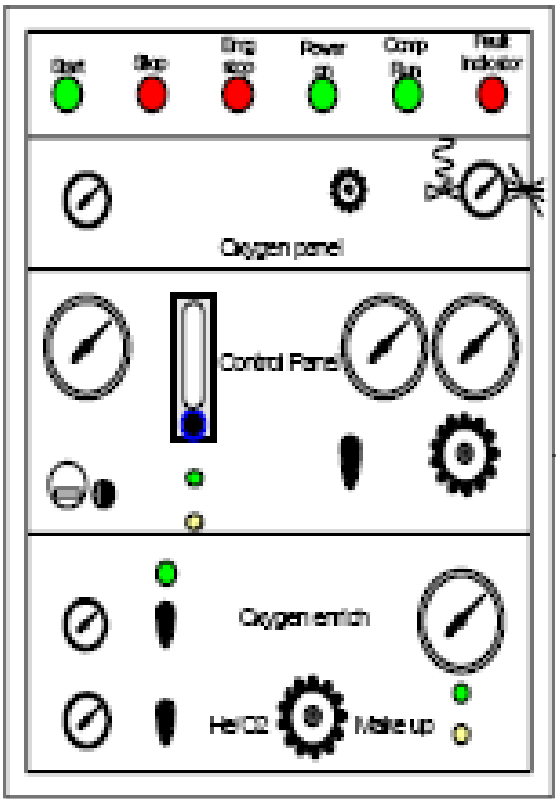
Controls the set pressure of the BPR. As suction is applied to the system gas will be drawn from the BPR loader line reducing the pressure till the pressure reaches the set pressure of the loader. It will then lift allowing gas to flow, preventing depressurisation. Allowing a fixed referance pressure for the BPR.
As the diver moves on a upward or downward excursion the change in pressure in the tracking pneumo will activate the piston in the BPR loader this pressure will change the set pressure of the loader and compensate for various working depths.
So the BPR loader maintains a constant difference in the pressure between diver ambient and the BPR loader referance pressure.
It will adjust the exhaust pressure automatic to compensate for changes in Divers depth.

Water Trap

Reclaim Basic Set Up

With normal operation the water trap is at a negative pressure. Water that may be recovered with the divers exhaust gas is captured in the water trap. This water flows down to the lower half of the twin canisters. Once water is showing in the water trap, the equalisation valve *(6)* should be pulled out. This closes the top section of, vents the lower section to bell atmosphere pressure. Now the lower water trap will be equalised to the bell and the drain valve *(7)* can be opened to drain the fluid out. Once drained, close valve *(7)* and push closed *(6)* to continue normal water separation. Valve *(3)* is to allow the bell to be scrubbed with the Reclaim System. The valve will allow higher ambient bell pressure to enter the water trap and be drawn through the BPR to the top side Reprocessing Reclaim System.
Once this valve is opened, the bell will start to lose pressure (or start ascending from depth). It is important that gas is replaced into the bell from the diver supply, thus maintaining depth. This simulates the diver's normal breathing but is for the bell. The purpose is for emergency scrubbing of the bell should there be a problem with internal scrubbers.

Gas Services Reclaim Control Panel



The control panel is divided into 4 parts, from the top they are:

1. Booster Panel
2. Oxygen Panel
3. Control Panel
4. Makeup Panel

The **Booster Panel** is where the on/off switches and indicator lights are mounted.
The **Oxygen Panel** *is* for oxygen control. It is injected into the reclaim system via 2 methods; both are situated inside the Panel. They are:

Method 1

The automated injection for 02 replenishment which the diver consumes. No injection takes place unless

there is gas flowing via the divers exhaust hose. A flow switch senses flow and allows the injection. The 02 is injected via an orifice which is mounted behind the panel, this restricts the flow to metabolic make up.

Method 2

Makeup Oxygen is for rapid injection of 02, this is to be used for mixture enrichment only. **Extreme care** must be taken when using this that the oxygen is mixing with the return exhaust gas. Typically this 02 injection is used in conjunction with the "Cross Connect" feature for recirculating the gas in the reclaim.

OXYGEN MAKE UP SHOULD NOT BE USED IF DIVERS ON RECLAIM AS THERE IS A POSSIBILITY TO CAUSE AN OXYGEN SLUG OR HIGH CONCENTRATION IN THE VOLUME TANK.

Control Panel.

Shows from left to right, Divers supply pressure, sample flow meter, divers exhaust hose pressure, BPR Loader regulator pressure. Below from the left are, an 02 alarm flow indicators for the 02 injection, the cross connect valve and BPR Loader regulator.

Makeup Panel

02 pressure gauge (from 02 Panel Regulator), 02 enrichment needle valve (see above), below is the 02 vent valve, makeup regulated supply gauge. Make up gas supply pressure from quads, makeup gas regulator and makeup gas flow indicator lights.

Makeup gas is from the Mix Gas supply, it is regulated on this panel and is injected into the Volume tanks, where it mixes with the stored gas as it circulates with the flow from the gas transfer pump. This make up regulated pressure is to maintain the minimum desired pressure in the volume tank. As gas in lost, it is made up for with this system.

Common Faults and Helpful Hints

Oxygen % keeps dropping in the reclaim, have to use 02 make up:

- Check the Oxygen Regulator setting against the reference chart.
- Check the restriction orifice is not blocked, this is mounted behind the oxygen panel after the regulator. It looks like a ¼" npt nipple. If blocked, clean with oxygen friendly products and replace.
- Check the O2 injection at the LP receiver if restricted. The check valve mounted at the base of the receiver can block or be partially blocked.

Water level in bell is rising when reclaim operating:

Possible causes are Reclaim is drawing the bell ambient gas in through the diver's exhaust system. Check the following:

- Water trap valves closed
- Water trap plunger is pushed in
- All fittings, tubes and hoses are secure
- Inward relieving PRV's are not sticky, there are 2 of these for a one Diver set up, these being:
  - On the top of the water trap to protect the water trap from high pressure differentials
  - On the fitting where the diver excursion exhaust hose connects, this is to protect the diver exhaust hose from to great a pressure differential, two diver set up has a 2nd of these prv's
- Water trap Seals, plunger and body
- Diver 2 hat in the bell exhaust v/v open.

Diver's exhaust hose pressure keeps rising, diver struggles to exhale. Surplus gas is being dumped from receivers:

- Check the water trap, see above
- Check operation of Gas Pump, look for pressure differentials on the low pressure gauges after the BPR, possible filter blockage
- Check all valves are open on the supply and return side
- Check that the diver's gas supply is from the reclaim supply and not from an alternative.
- Bell Emergency Onboard Gas not set correctly, gas is being drawn from

this supply. This alternative gas source will accumulate in the system.

Diver's have poor reclaim, 0 to -5 negative pressure on bell gauge, all looks good top side. Divers exhaust pressure is the same as BPR loader setting on the control panel when view from Control panel, the gas pump responds well with gas dumped into the bell umbilical exhaust hose via the cross connect:

- Check the Control Consol BPR loader setting is the correct value by the chart
- Have the bellman check the reclaim settings on the bell panel
- Clean the Jewel 601 regulator (helmet exhaust regulator) could have debris within, more so if working in mud etc
- Diver excursion umbilical exhaust hose could be partly flooded. Remove from both ends and insert pig and blow through.
- Water could be lying in the main umbilical loop, disconect both ends and push a pig through using the panel regulator pigs can be purchased from the umbilical manufacture.
- Diver excursion umbilical exhaust hose in not secure on the helmet, check and secure.

It is possible for the sake of completing the work the diver is doing to make a simple adjustment to the BPR loader setting on the Reclaim Control Panel. Adjust the BPR loader to a lower setting, take it down a small amount and check with bellman for the new negative pressure. This is a quick fix only, to great of an adjustment is not recommended. The Helmet should be checked when possible.

Diver exhaust hose pressure is rising, diver supply is dropping:

- A Valve is closed
- Check operation of gas pump
- Check for flow restrictions across reclaim filters and/or scrubber towers.

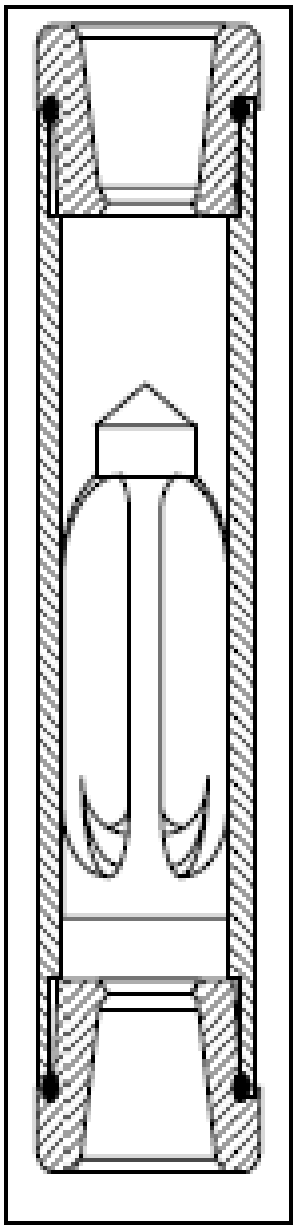
Water trap constantly filling with water:

- Bell Check what the diver is doing, may be flooding the helmet for cleaning.
- Check gas hose connections on helmet.

Constant water being found in exhaust hose water trap on reprocessing unit:

- Check connections of Exhaust hose on out side of bell, snoop for leaks when bell on surface. At depth, hose is at a negative pressure relevant to the ambient water, this water can flood the hose if there is a lose connection

No flow back from diver exhaust:



- It is possible if an excessive amount of water has flooded the exhaust hose that a safety float valve has closed. Shown here on the left, the float will rise with any fluid in the cylinder. The gas flow is from the bottom to the top; the float normally sits on the bottom and is not affected by gas flow. There are 2 of these floats, these are:
  1. on the top side unit after the water trap, below the BPR
  2. on the outside of the bell before the water trap

Note:
This 2nd float valve listed on the outside of the bell is used as a check valve, if there is a failure of the bell internal equipment, it is possible for the higher ambient water pressure outside to flood the bell, this check valve prevents this from occurring.

Gas Booster shuts down from fault, 1st or 2nd stage light showing:

- Check for cooling water and oil levels, check sea water supply to

cooling heat exchanger

- Check gas settings on reclaim; ensure they are at the recommended settings by the chart. *When diving shallow the pump is actually working the hardest as the ratio of gas in and out is at its greatest. It is important to maintain the pump at the recommended settings for the depth of the diver.*
- Ensure all valves are open

Unfortunately the set up doesn't indicate a difference between high gas temperature and high gas pressure with the warning lights. Usually a simply trouble shooting gives the answer of which it is. One thing to keep in mind for older units, the springs in the temp alarms become brittle and don't respond as well or over compensate, this can give inaccurate results and trigger false high temp alarms.

This is easy to adjust, there are tell tale guides for approximate temperature settings on the temp switches themselves, check the setting and condition of the unit. Ensure power is of for this.

Makeup regulators on panel constantly leaks gas out from behind adjustment knob:

- Gas is leaking past the main valve seat, accumulating on the regulated side and being vented from its own internal vent. The regulator will need the main valve and seat serviced, and the inline filter serviced.

Makeup gas regulator check valve is constantly creaking, flow lamp is showing:
Reclaim system is losing gas somewhere:

- check all drain valves are secure
- Check Pneumo supply is not left open
- Check divers gas usage, free flow
- Check divers neck dam sealing

Reprocessing unit has white crusty debris in the control circuit regulator and the solenoids:
This is from moist gas being used to charge the system on start ups and timed auto dumps.

- Check that the scrubber towers are being serviced correctly
- Check the filters on the scrubber towers

A helpful hint here is to relocate the charging gas line to the same place at the top of the filter beyond the scrubber where the sample is taken from. Tee into the fitting there before the sample regulator and supply the gas pump circuits from here, be sure to block of the original take of point just after the check valve on the outlet of the gas pump unit. This will ensure that the gas pump is receiving clean moisture free gas.