technical matters

Edited by Brian Keegan

A collection of claasic regs: Scubapro MK25 and X650, Mares V32 and Abyss, Legend LX ACD, Apeks ATX100, Beuchat VX200 , Aqualung Titan LX Supreme, Poseidon Xstream.

How to choose a regulator

After my very first pool session, I was hooked. Every thought I had circled around diving and dive equipment. I could not wait for my next session. The instructor was a God, and what he said must be true. I was an easy target! By the end of the class, I walked out of there with an Open Water dive certificate and a great deal on a dive package.

Or so I thought... Living in Sweden, in the Northern part of the world, the weather is not always at its best behavior and definitely not warm most of the year. I mean, the Polar circle cuts through my home country for crying out loud! A month later, I had my first free flowing experience, and let me tell you, was I glad we practiced that in class! Escorted by bubbles from a lively mouth piece, I made it to the surface. My mind was racing. What can I do to avoid this in the future?

Well, the almighty instructor said that with a different breathing and handling technique, I could avoid these incidents in the future, and he was right; there are things you can do to avoid freezing regulators, but they are not bullet proof. Trying not to reveal my age, it was back when only a few regulators were made to withstand arctic temperatures. Poseidon was one of them and still going strong. Most regulators were made for diving environments like the Mediterranean Sea, which even during winter provides a different water temperature than the cold lakes and the Baltic Sea up north provide us Viking-spirited divers.

Today, you will find a number of high-quality cold water environmentally sealed regulators on the market. Most of them meet the European standard (EN250) for cold water—a standard you can use when choosing your weapon of arms.

Text by Millis and Brian Keegan

"What kind of diving will you be doing, and in which environment are you going to dive?"

First, ask yourself

What kind of diver are you?

There are different kinds of regulators. While the basic function is to provide you with air, you will find that there are different regulators for different kind of activities. We will go through what you need, step by step. The first thing you need to decide is what kind of diving you will be doing and in what environment you are going to dive. This is perhaps the most important piece of your dive equipment and nothing to be rushed into.

What kind if diver are you?

What environment are you going to dive? Identifying your needs will help you choose the right regulator for your activities.

Are you a Warm Water Diver?

A warm water diver is someone who dives only in warmer water temperatures who does not require extreme measures to be safe and comfortable while diving. According to the EU norm cold water diving begins when the temperature of the water is equal to or drops below 6°C (50° F).

Then choose:

While it never hurts to buy the best equipment you can, under those circumstances where there is no risk, at any time, that your regulator will freeze while breathing—it is not necessary to buy a top-of-the-line regulator.

Or a Cold Water Diver?

When diving in cold water, it's vitally important that you use regulators designed for cold water. You will be looking for both a first stage that limits formation of ice, as well as second stage that doesn't freeze in an open or closed position when the warm moisture in the diver's breath touches the cold regulator.

Then choose:

This should go without saying—use regulators designed for cold water diving! Look for regulators that meet the EN250 standard for cold water performance. Cold water regulators are either environmentally sealed or use something called a 'heat sink' . A heat sink uses the cold water to 'warm' the first stage, which limits the formation of ice. By default, cold

Heat sink:
Many piston regulators utilize some heavy metal parts, like the spring or part of the body to transfer warmth from the water to help keep the water around the piston from freezing.

Can I use a cold water regulator in warm water?
Yes. A regulator designed for cold water is by necessity a top performance regulator that can handle the most extreme conditions. Any good quality regulator from a reputable dealer will provide you with air in a safe way, when diving in warm water.

200bar (2900psi) **or 300?** (4350psi)
SCUBA tanks come in a variety of pressure ratings from around 200 to 300 bar. Different pressures are common is different countries.

water regulators are high performance regulators.

Are you considering Nitrox?

A recreational nitrox diver is a diver that uses nitrox during a dive for a safer dive, by using the air tables. When diving with the gas mix nitrox, there are certain things to consider. You will dive with a higher content of oxygen in your tank, which is a flammable gas, and you need to adjust your equipment for this.

Then choose:

First, make sure you are trained for nitrox diving. Dealing with nitrox means dealing with a risk of explosion, albeit small. Your dive equipment needs to be grease free. Because mistakes can be made in mixing the O_2 and air to get the appropriate mixture, each tank needs to be analyzed for O_2.

DIN or Yoke? Which is better?

DIN connectors are rated at 200 and 300 bar / 3000 and 4500 psi (ISO12029-2) and yolk connectors are rated at 230 bar/ 3450 psi (ISO 12209-1). Also DIN connectors provide a sturdier connection, drop a SCUBA package on the first stage and it can come dislodged from the valve.

Which brand?

Sorry, but here is no straightforward answer. There are a lot of great regulators on the market and an almost bewildering variety. Look for well reputable makers, narrow down the choices and concentrate on them. Do your research and don't be afraid to ask questions when you shop around.

Most new high performance regulators are either nitrox-compatible or ready for nitrox use, with a DIN or yoke first stage.

Ask your local dealer

At this stage, you should now be concentrating on details like comfort and airflow. If the sales person tries to baffle you with technical phrases and fancy words, call him/her on it and have them explain. That is what they are there for, and one good reason to spend your money in a dive shop instead of shopping online.

Don't be cheap

To think cheap can be costly. There are sometimes huge price differences on dive equipment in different parts of the world, and although you might be tempted to save money while traveling, don't do it unless you have done your research before the trip. If you do buy a regulator made overseas, stick to an international brand, or you could be in for an expensive surprise when it is time for service. Sure, your regulator was a find, but if your new find is not sold in your country, it is quite possible that you wont be able to find a service technician trained for that brand in your neck of the woods. On top of that, if you do find someone, the parts might have to travel overseas as well. You do the math. Make sure you know what brands sells in your country, and if the warranty is valid in your home country, before going on a shopping spree. ■

A few points to check

Does the second stage feel comfortable? Is the mouth piece a good fit for you? Bear in mind the mouthpiece can be changed. Consider the dental ones

Is the second stage heavy, does it "drag" in the corner of your mouth. Details like that can get real old real quick, believe me.

Do you want to be able to adjust your second stage air flow? If you do do, can You handle the adjustment easily, with and without gloves?

Will you travel with your equipment? Include weight and size in your requirement for a good regulator.

Does the regulator come with a warranty? And if so what is covered. Can your regulator be serviced regularly?

Can you handle the adjustment easily, with and without gloves?

If the second stage feels like dragging, perhaps try one with a different hose configuration.

How does it work?

and what differentiates regulator from another?

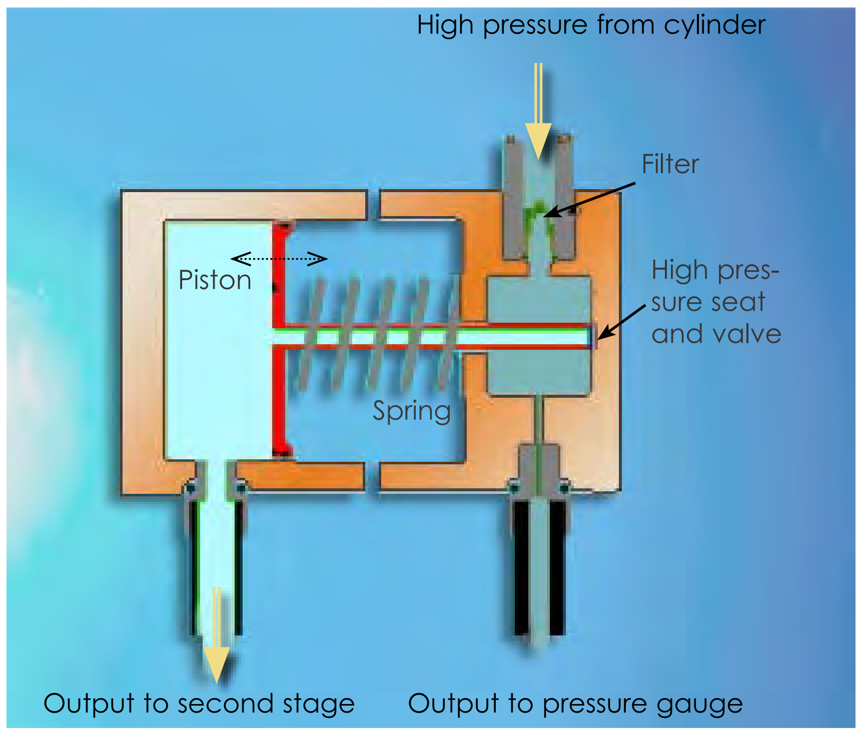
First stages can process very large volumes of air. At 200 Bar some can process much more air in one minute than most scuba tanks hold. So how does the regulator transform that high pressure air to a steady supply of ambient pressure air when you need it?

It's a two step process and your regulator has two parts or stages to do the job. The part you attach to your tank valve is called the first stage. It's job is to supply air at a fixed pressure above the ambient pressure. The second stage uses this to supply you with breathable air on demand.

There are two main types of first stages, the piston and diaphragm.

The balanced piston first stage

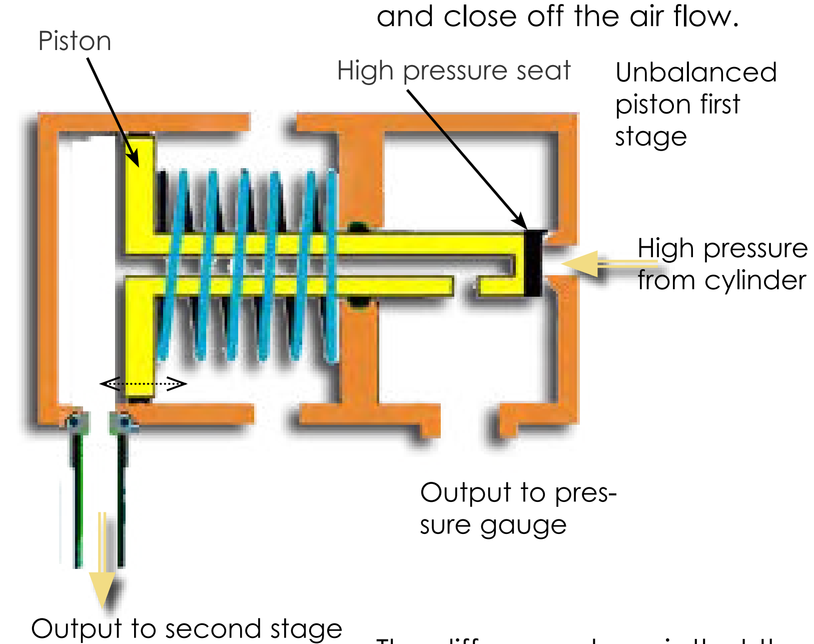
The piston first stage has a piston that has a sharp knife edge that seals against a high pressure seat. A spring and the ambient pressure push one way against the piston and try to move the knife edge of the piston away from the high pressure seat and let high pressure air flow through the piston to the intermediate pressure side and down the hose to the second stage. When the pressure on the intermediate side gets high enough, its force against the other side of the piston overcomes the combination of the spring and ambient pressure, and the pistons slides so that the knife edge once again seals against the high pressure seat and cuts off the air flow.



Balanced piston first stage

The unbalanced piston first stage

In an unbalanced piston first stage, the high pressure seat is mounted in the end of the piston shaft and seals against the knife edged orifice through which the high pressure air flows. As you see in the diagram—just like in the case of the balanced piston—the spring and ambient pressure act to move the piston and open the flow of air and the intermediate pressure acts to move the piston the other way and close off the air flow.



Piston-type first stages are simpler to make than the diaphragm type. They provide higher performance when breathed at depth. They need more careful maintenance because some of the internal moving parts are exposed to water and contaminants in the water

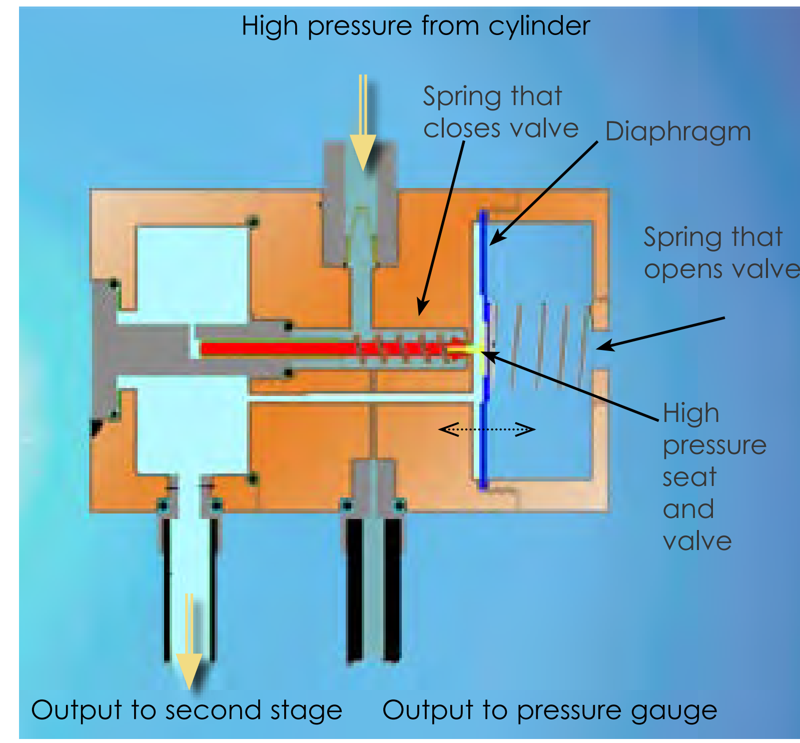
The difference here is that the high pressure air is pressing against the high pressure seat and is helping the spring and ambient pressure to move the piston and open the flow of air. The problem is that this force varies as the tank pressure changes. As the tank pressure drops during the course of the dive, it takes less and less intermediate pressure to close off the air flow. This is what makes it unbalanced. Since the second stage is built to work with one specific intermediate pressure, as the intermediate pressure drops in the regulator, it gets harder to breathe.

The diaphragm first stage

The diaphragm first stage has a flexible diaphragm that separates the internal parts from the surrounding water.

On the water side, the water pressure and a spring provide a force to help open the valve.

When you breathe and the intermediate pressure drops, the spring and water pressure flex the diaphragm in and lift a poppet. Depending on the model of the regulator, the poppet has either the knife edge or the high pressure seat. The air flows until the intermediate pressure and a small spring on the same side win the battle and reseat the poppet.

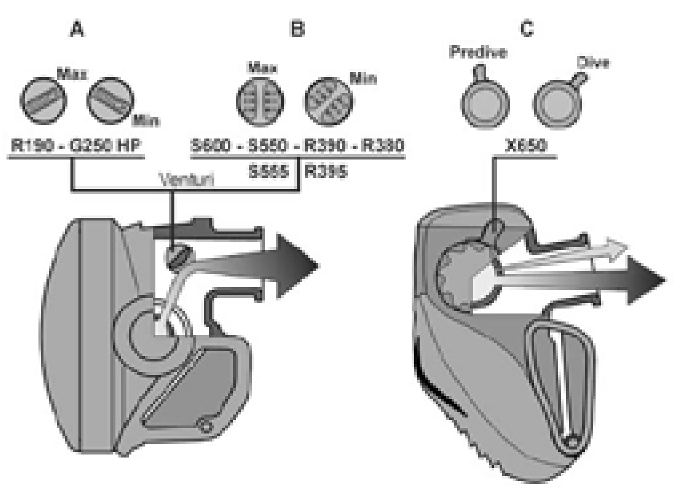


Diaphragm-type first stages are more complex and have more components than the piston type. They are more responsive; they provide gas when the diver uses little inhalation effort

Ports!
There are high pressure ports for pressure gauges and low pressure ports for most everything else. In some older regulators the ports were the same size. Don't put a low pressure hose in a high pressure port!

The Second Stage

The second stage's job is to take the intermediate pressure air that comes from the first stage and deliver it to you at ambient pressure when you demand it. There are a variety of basic designs of second stages. In the most common design, when you inhale, the drop in pressure inside the second stage draws in a large, flexible diaphragm. The diaphragm depresses a lever that acts to move a low pressure seat away from a knife edge and allow air to flow. When you stop inhaling, the air flow allows the diaphragm to return to its original position, and a spring presses the low pressure seat against the knife edge around the inlet orifice. When you exhale, an exhaust valve allows the exhaled air to flow out.



Air on demand

Even though there are other variations of basic second stage designs, one of the characteristics that all modern designs share is that they have demand valves that only deliver air on demand instead of a constant flow of air. Most, called downstream valves, are designed to free flow if supplied with excessively high pressure air. That might not sound so good but considering that the alternative is that the valve slams shut and will not open it's not so bad. Some models, from Poseidon for instance, are upstream valves. Their diaphragm activates a very sensitive pilot valve. The airflow from this pilot valve opens the main valve. At the end of the breath the pilot valve is closed by a very small spring and the closing of that valve causes the main valve to close and stop the air flow. They can provide extremely easy breathing but can't handle very high supply pressure. The hoses that come with these second stages have a built in over-pressure relief valve. It is very important that they always be used with the correct type of hose.

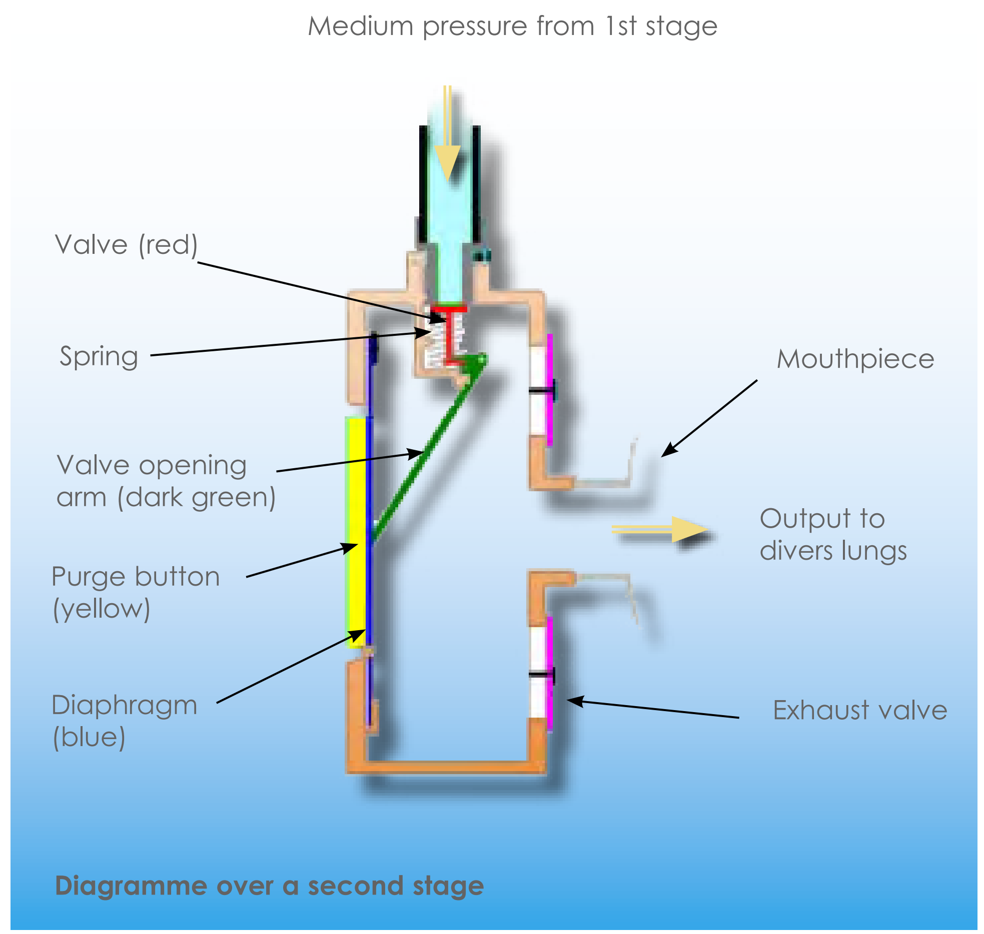
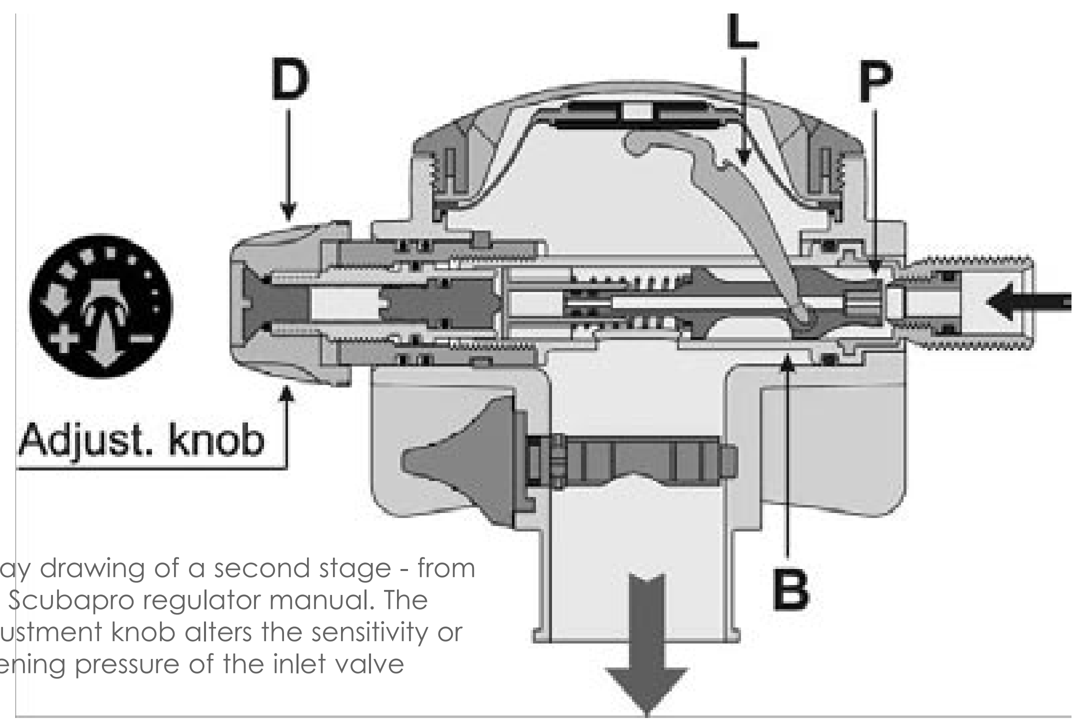


Diagramme over a second stage



X-Ray drawing of a second stage - from the Scubapro regulator manual. The adjustment knob alters the sensitivity or opening pressure of the inlet valve

Balanced or unbalanced

Second stages can be balanced or unbalanced. In balanced second stages, air flows through the part that holds the low pressure seat into a chamber at the other end. This helps counteract the force of the air pushing the low pressure seat away from the knife edge. The reduction of this force allows the use of a weaker spring to close off the airflow. The effect of this for you is that the weaker spring reduces the amount of force needed to start the air flowing.

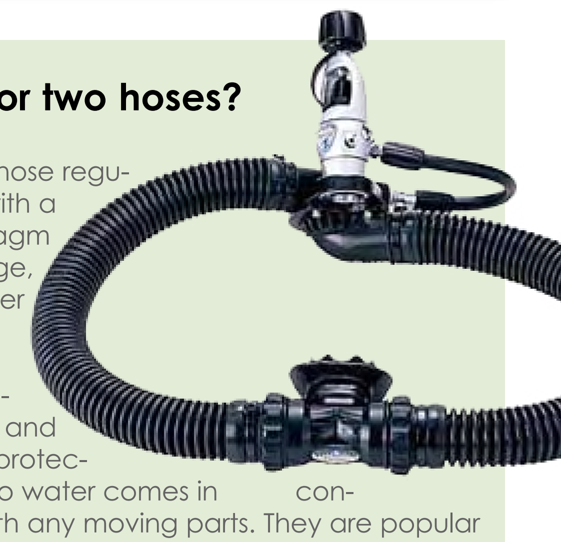
Many second stages now come with external adjustments. Scubapro was the first to provide an adjustment knob for the spring tension that closes the second stage. This can be used at times, such as when entering the water, to increase the breathing effort when entering the water or swimming in a head down position. It can also be used to help stop some types of minor free flow that may develop between servicing.

Some second stages also have a small knob that adjusts a vane or other device that effects the characteristics of the air flow inside the body. In these models the air flow is designed to hold the diaphragm drawn in until the diver stops inhaling. With this Venturi or Vacuum assist effect, once air flow is initiated it takes little or even less than no effort to continue to inhale. This is handy when

Venturi Effect

All the manufacturers that use it have their own cleaver name for it, but the principle is the same. With this venturi or vacuum assist effect, once air flow is initiated, it takes little or even less than no effort to continue the inhalation. The way this is accomplished is that the air flow is designed to hold the diaphragm drawn in until the diver stops inhaling.

One or two hoses?



A twin hose regulator, with a diaphragm first stage, can offer complete environmental and freeze protection—no water comes in contact with any moving parts. They are popular with some photographers, biologists, etc., because the exhaust bubbles are behind your head rather than in front.

Regulators

you are breathing but can cause the regulator to free flow when it's in the water and out of your mouth. The adjustment allows you, for example, to stop that effect and help prevent free flows when you are at the surface and not using the regulator. Before a dive I often tune mine to the point just before the regulator free flows after the purge valve is pressed. During the dive if I feel that the breathing effort is too high I adjust it to full venturi effect. But that's just my personal preference, you should experiment and find the settings that suit you best.

Service

Regulators should be serviced once a year or about every 100 dives which ever comes first. The limit on the number of dives covers excessive wear and the time limit covers aging of the soft parts. Over the course of time the soft parts deteriorate and take a set over time.

It's easy to damage a regulator during service and special tools and instruments are needed to properly work on, assemble and adjust a regulator so service should only be performed by a trained technician who has access to the latest from the manufacturer.

During service the soft parts of the regulator are changed, like the o-rings and pressure seats. Also the knife edges, diaphragm, exhaust valves, mouthpieces, etc are inspected and replaced as necessary. If there's any corrosion or buildup of salt, lime a s o, on the metal parts they can be cleaned in an ultrasonic cleaner. Both stages will be properly lubricated during service, reassembled and the intermediate pressure (IP) and breathing resistance will be checked.

The regulator should also be checked for leaks. Hoses can develop leaks, especially the high pressure hose that connects the pressure gauge. If you look carefully at that hose you can see a line of small perforations. These are pin holes through the rubber outer layer of hose. The inner layers contain the pressure and the holes allow you to see when the inside of the hose has developed a leak. In the old days before the perforations the outer layer would swell up like a balloon. Another common place for a leak to develop is at the end of the hose where the pressure gauge is mounted. There is a little adapter with two small o-rings that goes in between the hose and the gauge and these o-rings, which are exposed to the outside environment don't last forever.

Regulators should be serviced once a year or about every 100 dives which ever comes first

Except for the parts covered by the warranty that must be returned to the manufacturer, all the old parts should be returned to you so you can see what you paid for.

Warranty

In the US the warranty usually covers defects and the parts needed for standard maintenance. Most manufacturers will require as terms of the warranty that the regulator be serviced once a year by an authorized dealer using only parts supplied by the manufacturer. As we mentioned before regulators are life support equipment so regular, qualified maintenance is important for your diving comfort and safety. The service replacement parts are also an important part of the warranty. Over the course of the regulators lifetime the cost of the replacement parts can easily add up to more than the original cost of the regulator. The warranty can differ from country to country, keep that in mind when you buy. Will the warranty be as good as it would be if I bought it at home? Will I be able to get authorized service and replacement parts?

Maintenance

When you are in the water check for air leaks. Be a good buddy and look for leaks in your buddies gear, it's easier for you to see them. Check for the kind of leaks around the hoses we mentioned in the service section. After each dive you should rinse off the regulator especially after diving in salt water. The best way to do this is to soak the regulator in water, preferably warm water. Leave it attached to the tank with the air turned on. This keeps water from getting in where it shouldn't be. If you can't soak it, disconnect it from the tank, dry the first stage dust cap and secure it in place. It's ok to dry the dust cap with air from the tank but be careful not to blow any water into the inlet of the first stage. If the dust cap is supposed to have an o-ring make sure it is in place. Then you can use a hose to rinse with. If you do it this way be sure not to press the purge button, which would allow water to enter the hose. Be careful when you rinse the second stage, don't blast water at it, as it can displace or damage the delicate diaphragms. After rinsing, allow to dry thoroughly. You can give it a shake and pour water out of the second stage or wipe the outside with a cloth to help it along. It is best not to store the regulator by hanging it or curling the hoses too tightly. This stresses the hoses and can cause them to fail prematurely. One thing you can do to help the hoses is to have hose protectors put on them. These are plastic sleeves that are placed up at the first stage end of the hoses to distribute the stress of bending the hoses. The sleeves should be constructed so that they drain water and don't promote corrosion.

Between servicing you can check out the mouthpiece, check to see that the bite blocks are not partially bitten off. Check for cracks and splitting, especially at the end of the part of the second stage body that the mouthpiece is mounted on. They are prone to splitting right where the tube like section they are mounted on ends. ■

Some cool Accessories

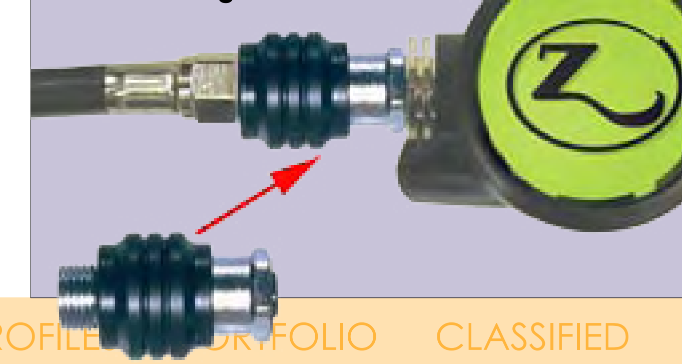
"Remove before Dive" Dust cap with extra o-ring from German Divedelight protects your precious reg when not in use. **www.divedelight.de** **(NB: Site in German)**

Hoseprotectors

Swivel for second stage hose - eases the pull on the jaw. This one found at **www.zeagle.com**

Suffering from jaw fatigue? Try a different mouthpiece. This one from Seacure uses your own dental impression. **www.seacure1.com**

The Isolator Valve is used to shut off the air supply in any situation where 2nd stage isolation is desired.t **www.zeagle.com**



Text: Millis Keegan
Images: Peter Symes

How to avoid free flows and the zen of being a cold water diver

All regulators will perform differently in cold water compared to warmer water temperatures. If you dive in cold water, chances are you will experience a free flow sooner or later. It is not a matter of if, it is a matter of when. No regulator, no matter how well manufactured and full with fancy features it is, can safeguard you completely

Since you are a diver, you should already know that gases heat up during compression, (i.e. while filling a tank), and that they cool during expansion which is what happens you breathe them from a scuba tank. This cooling may affects the regulator in various ways, When air from a cylinder undergoes a drop in pressure, which happens when air passes through the first stage, the pressure is typically reduced to 11 Bar (the interstage pressure) before it enters the second stage. In each stage of the regulator, the air temperature keeps dropping, and droplets inside the mechanism may form ice crystals, which in turn can cause a malfunction such as a free flow.

When water temperature reaches 5°C and colder, a regulator is at risk of freezing. The first stage freezes in an open position, which causes a free flow of air. It is designed to do so, as a failsafe feature, since the option would be blown hoses, which is an experience we could do without while diving. The rapid airflow in turn can cause the second stage to freeze While not being in a pleasant situation, one can still breathe from a free flowing regulator ...until it runs out of air.

Cold water divers may also choose to dive with two independent scuba regulators for extra safety.

Precautions

It is important that the air in your tank is dry. Usually vapor will be trapped by the compressor,

Then make sure that your tank valve orifice is dry before attaching your first stage to avoid moist being drawn into the inside.

Cold water divers may also choose to dive with two independent scuba regulators for extra safety.

Prevention

The key to avoiding free-flowing incidents is prevention. While the use of a cold water regulator is the first step of prevention, the second step is to minimize the demand on it. Use these simple precautions and you are way on your way to become a true cold water diver.

Take every opportunity to practice in safe conditions, simulating a situation by pressing the purge button. This way you will find what works for you.

Breathe only under water

In winter, the air will often be colder than the water so avoid breathing from the 2nd stage out of the water when the air temperature is low.

A cool 1st stage can, however, be warmed by the surrounding water. Therefore keep the 2nd stage under water until it is time to dive. Put the mouthpiece in as you submerge and take your first breath with it under water. If you for any reason need to stick your head above the water again before the dive, remove your mouthpiece in water and keep it submerged.

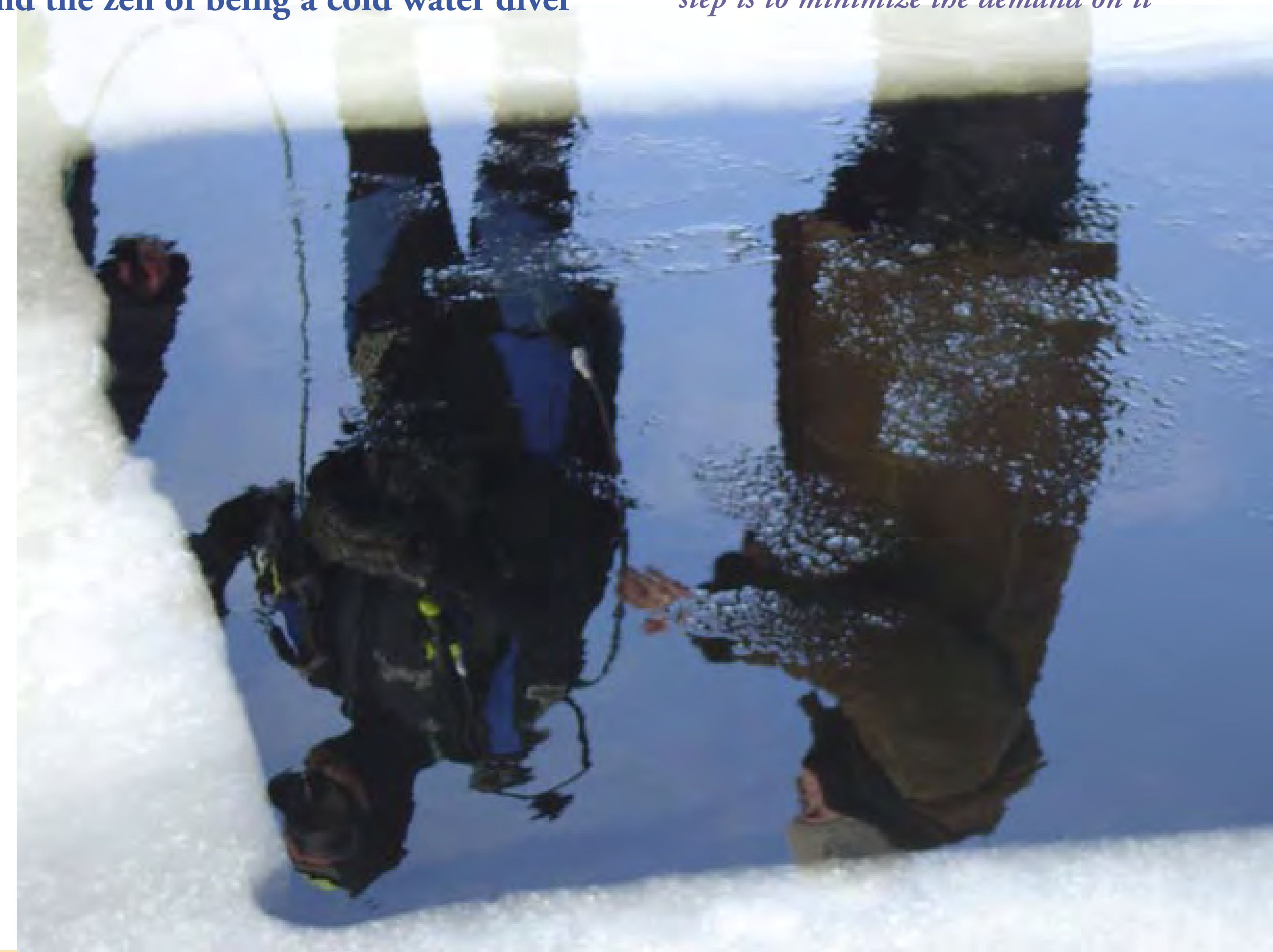
Inflate your BC slowly, preferably while you exhale, to reduce the stress of the first stage.

If you have a second stage with a breathing resistance adjustment, set the adjuster to minimum when not in use.

If you dive with a redundant air supply, switch to that and then shut off the tank valve a few minutes and then turn it slowly back on.

Do not use your buddys air supply for this exercise, since the extra demand on his regulator can cause his equipment to freeze as well.

While the use of a cold water regulator is the first step of prevention, the second step is to minimize the demand on it



Rehashing your basic training

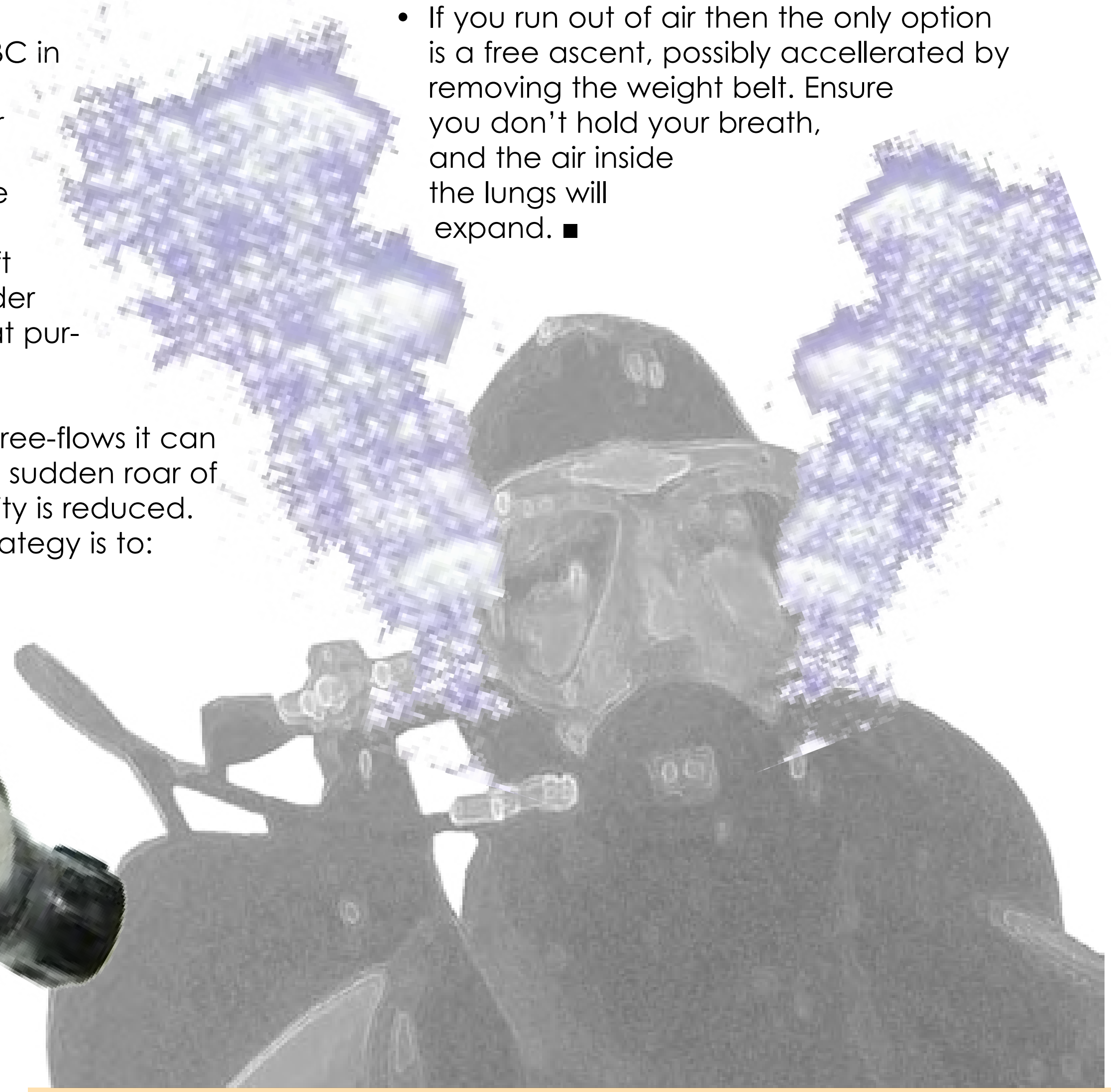
Breathing from a Free Flowing Regulator

What to do:
Hold the regulator second stage loosely in your mouth, allowing excess air to escape. If possible angle your head slightly to avoid bubbles in front of your eyes.

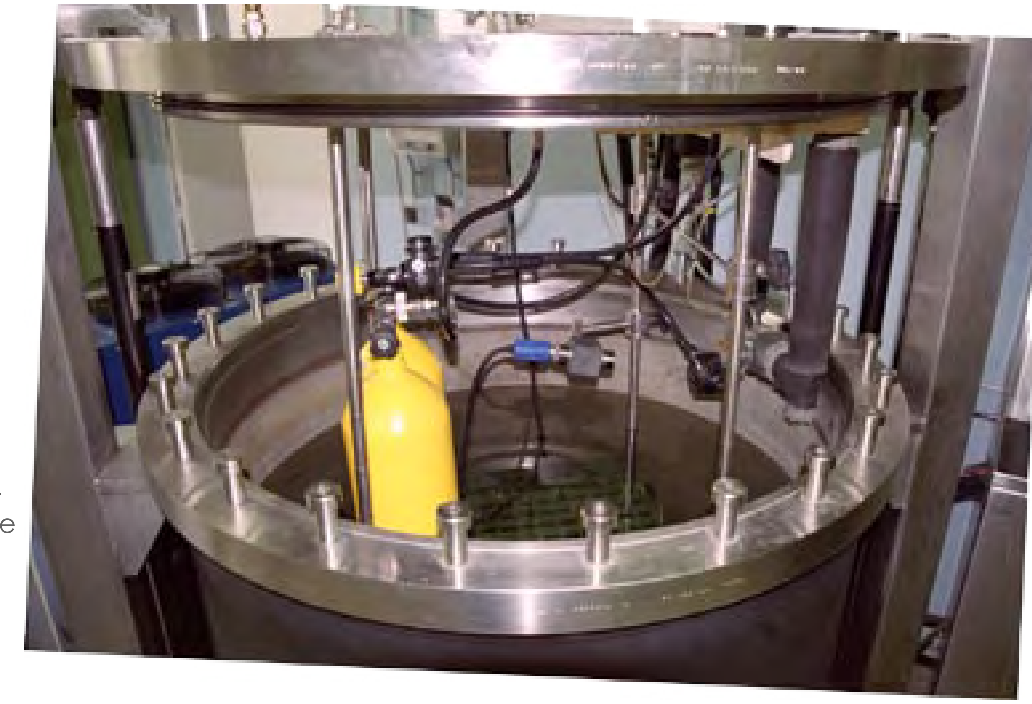
No-nos
- Avoid taking a "test" breath from your regulator in temperatures near freezing. The moisture in the atmosphere and your breath can easily cause icing in the second stage.
- Avoid pressing the purge button.
- Avoid heavy breathing
- Avoid adding air to your BC in small bursts
- Avoid using your regulator for secondary use. While filling up a safety sausage use your exhaust valve, and if you need to fill a lift bag in cold water, consider using a spare tank for that purpose.

When a regulator suddenly free-flows it can be very startling as there is a sudden roar of bubbles and visibility is reduced. The main strategy is to:

- **Remain calm: Stop - Think - Act**
  If you are confident in breathing from a free flowing regulator do so, but check and prepare alternate sources just in case.
- If an alternate air supply is preferred and available switch to it.
- Head for the surface.
- If a buddy is available, or you can reach the cylinder valve, switch off the cylinder and slowly switch it back on.
- If you run out of air then the only option is a free ascent, possibly accellerated by removing the weight belt. Ensure you don't hold your breath, and the air inside the lungs will expand. ■



How to understand the
Breathing Diagram
Why is it an important tool?



The regulator is connected to an air supply and placed in a hyperbaric chamber. The chamber is filled with water and pressurized to the test depth

Let's make one thing clear, it is not an important tool for you while choosing a regulator, but it is an important tool for a manufacturer while designing a regulator. What you, as a recreational diver should look for when shopping for a regulator is whether it passed the US Navy tests, and/or EN250 standards.

Text by Brian Keegan

ANSTI

Those tests are done on a system called The ANSTI Demand Regulator Test Station. The system scientifically evaluates a regulators performance, simulating human breathing. It is designed to measure the dynamic performance of SCUBA demand regulators to 80 metres at the maximum ventilation requirements of EN250. The ANSTI can identify if a regulator passes or fails a test criteria.

During the testing, the ANSTI system takes continuous readings, a work of breathing diagram is generated by a breathing machine simulating a human breath. It shows how much effort it takes to complete a breathing cycle under different circumstances, like diving at different depths, and in different temperatures. The effort is referred to as the Work of Breathing (WOB).

The machine also supplies pressure, simulating the air pressure in a tank to create a realistic diving situation. The regulators are tested at several different breathing rates. When the regulators are tested, the ANSTI measures the inhalation and exhalation in liters per minute (RMV*) times the size of the breath (Tidal Volume).

Example: At an RMV of 37.5, a diver's lungs are filled with 2.5 liters of air on every inhalation and forcing the same amount out on every exhalation. The RMV at 15 breaths per minute would be 18.75 liters per minute during inhalation and 18.75 liters per minute during exhalation, which equals total air moved through the lungs—37.5 liters in one minute.

An average breathing rate during a stress-free dive is generally between 25-31 RMV. The initial testing begins at 37.5 RMV—a number chosen because it best represents a regulator's performance during a dive made by an average fit diver. A higher work rate—standards used both by the US Navy and the European EN250 while evaluating a regulator's performance—is used during the second test, which is done at 62.5 RMV.

RMV: RESPIRATORY MINUTE VOLUME IS THE VOLUME OF AIR WHICH CAN BE INHALED (INHALED MINUTE VOLUME) OR EXHALED (EXHALED MINUTE VOLUME) FROM A PERSON'S LUNGS IN ONE MINUTE

Reading a breathing diagram

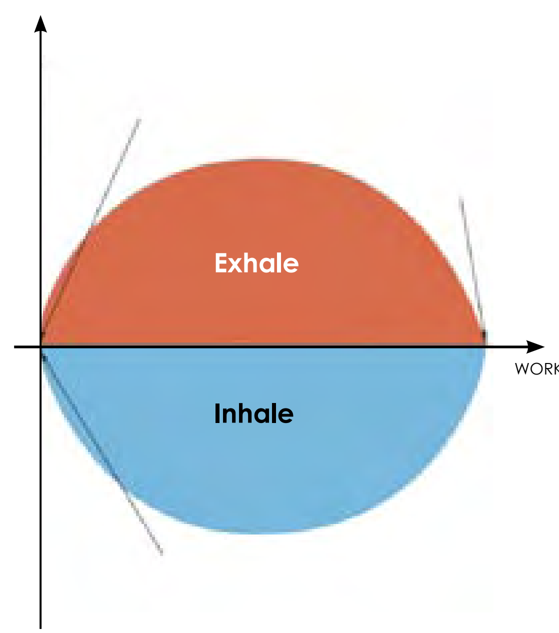
Lets look at a work of breathing diagram. If we start on the left side, the curve above the horizontal axis represents the exhalation. The area under that curve (S1) is the effort required to exhale a breath. Then, the inhalation curve runs from right to left with the area above that curve representing the effort required to inhale the breath.

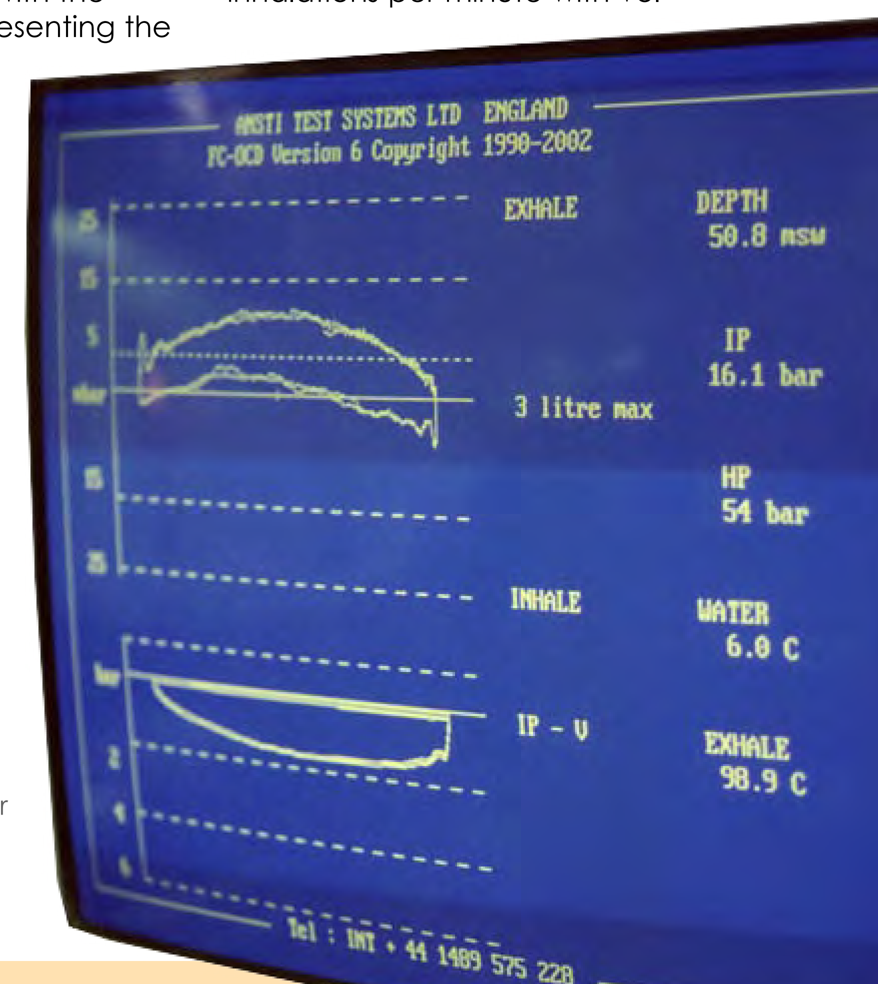
Thus, the total work of breathing is represented by the sum of the two areas

European standard EN 250 demands, that total work of breathing from a regulator on depth in 50 meters at intensity of breathing in 62.5 liters per minute and cylinder pressure in 50 Bar does not exceed 3 J/l.

This is done by the machine making 25 inhalations per minute with vol-

Ansti Test Systems Ltd specialises in the design and manufacture of test facilities for performance measurement of underwater breathing apparatus. The facilities are turnkey packages, which utilise computerised data acquisition techniques to display in real time the dynamic performance of the breathing apparatus under test.
www.ansti.com





The display of the ANSTI machine shows the results of a breathing test in the form of a Breathing Diagram. The diagram give researchers and designers an idea of how a regulator performs during a breathing cycle.

tech talk

ume of 2,5 liters of air per inhalation. This is considered representative of a diver performing hard physical work. The regulator is supplied with air at 100 bars.

The inhalation phase is the part of the breath that really differentiates regulators these days. Along with the total work of breathing effort, we can get a better idea of how this relates to the way it feels to breath on a particular regulator. Lets look at Fig 2.

Phase one

We see the beginning of the breath in phase one. When the diver starts to breath in and sucks air out of the second stage, the diaphragm is drawn in and eventually opens the second stage valve and starts the air flowing. This is commonly referred to as the cracking effort, and we see this as an initial spike in the curve. Too much cracking effort doesn't feel natural, you have to really work hard and all of a sudden – woosh, lots of air.

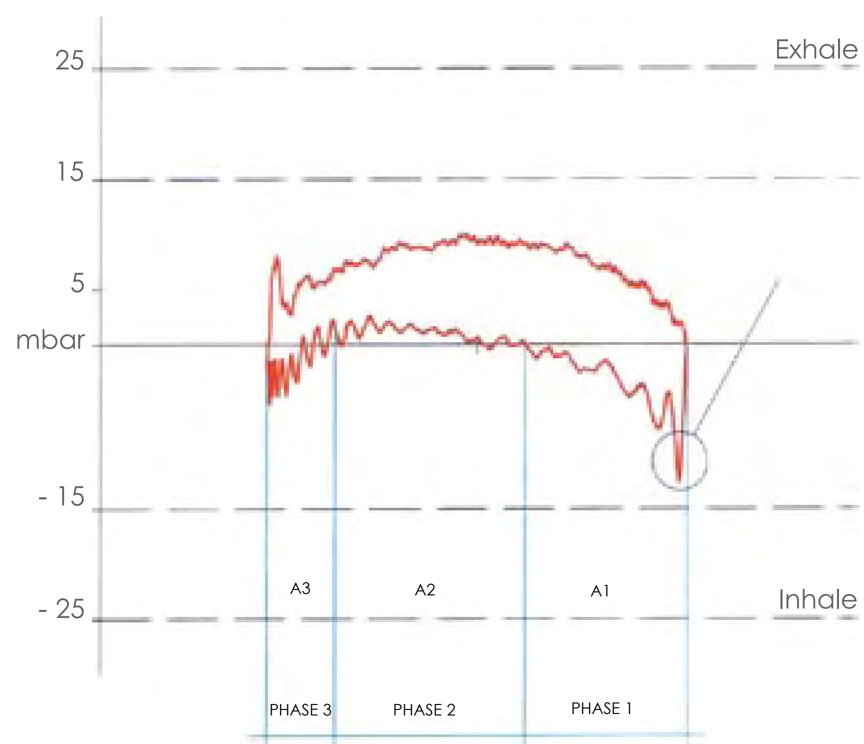
Phase two

Now that the air is flowing, the breathing resistance drops. The air is coming from the hose and the intermediate pressure area in the first stage. If the second stage has a venturi assist feature, the air flow holds the valve open, and the flow of air can actually exceed the demand. If this is excessive, you feel like you are being force-fed air. Not having to work is nice, but the regulator designers don't want you to feel like you're being inflated like a balloon. As we near the end of phase two, the intermediate pressure is dropping to the point where the first stage will open and start to replenish the available air with air from the tank.

Phase three

The first stage is opening now. If it is poorly designed and waits too long to open or can't supply air fast enough, we would see an increase in WOB effort here. Note: With modern regulator design that is no longer a common problem.

This WOB graph, shows phase 1, phase 2 and phase 3 as mentioned in the text.



Conclusion

In conclusion, don't get too hung up on the numbers. On the one hand, lower WOB is better, but on the other hand, the quality of your breathing experience is also greatly influenced by how natural each part of the breathing cycle and the cycle as a whole feels.

Add to that, that even if the ANSTI machine is very sensitive and can measure differences down to 0.1 J/l, you can't. A human being is only able to feel a difference in the effort down to about 0.5 J/l. ■

The inhalation phase is the part of the breath that really differentiates regulators these days

Common standards

Here are three standards that regulators are judged by:

U.S. Navy Class B
Depth of 40 m with a supply pressure of 100 bars, 25 2.5 liter breaths per minute with WOB less than 1.4 joules per liter.

U.S. Navy Class A
Same criteria as Class B except at depth of 60 m.

European Standard EN250
Depth of 50 m with a supply pressure of 50 bars, 25 2.5 liter breaths per minute with WOB less than 3.0 joules per liter

Tidbit

The most powerful breathing machines is found in the possession of Aqualung. It can simulate a dive down to 100 meters in water temperature down to 0 degrees