

O-rings for Divers

By [Akimbo](#)

Special thanks to the Scubaboard Moderators that helped me with this thread and [XS Scuba](#) for their technical assistance.

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Introduction

Question:

I'm a recreational diver. Why should I care about O-rings?

Answer:

For starters, an O-ring failure could empty your SCUBA tank in about a minute.

Equipment Failure Test Results			
Test Conducted	Depth (ffw)	Time to Drain 3000 to 0 (seconds)	Cuft drained in 15 seconds
High Pressure Hose Failure	0 ffw	1320 seconds (22 min)	0.90 cuft
	99 ffw	1320 seconds (same)	
	232 ffw	1320 seconds (same)	
Low Pressure Hose Failure	0 ffw.	83 seconds	14.45 cuft
	99 ffw.	81 seconds	
	232 ffw.	82 seconds	
Failed Burst Disk	0 ffw	72 seconds	16.66 cuft
	99 ffw	74 seconds	
	232 ffw	74 seconds	
Free Flow Second Stage	0 ffw	255 seconds	4.7 cuft
	99 ffw	155 seconds	7.74 cuft
	232 ffw	91 seconds	13.18 cuft

Figure 1. This table appeared in *Life Ending Seconds, 3000 to Zero in 72 Seconds*, *Advanced Diver Magazine* by Curt Bowen.
(Table Reprinted by permission)

Don't worry. Catastrophic O-ring failures are extremely rare, as long as you know what you're doing.

However, O-ring leaks aren't unusual at all, and can prematurely abort your dive or detract from an expensive vacation. Fortunately, understanding them is easy and will dramatically reduce failures. Many O-rings can be safely replaced in the field with minimal skill and are part of most Save-a-Dive kits.



Figure 2. You can repair most leaks with some spare O-rings, a removal tool kit, a wrench or two, and some lubricant.

What is an O-ring?

O-rings are "resilient" toroids (doughnuts) made from a variety of materials and are primarily used for liquid and gas tight pressure seals.



Figure 3. Literally billions of O-rings are made every year. They come in an enormous variety of materials, sizes, colors, and shapes.

Where are O-rings Used?

Most divers are wearing about 50 O-Rings. Here are a few of the diving-related products that depend on them:

- Cylinder valves
- Regulators
- SPGs (Submersible Pressure Gauges)
- Dive Computers
- BCDs
- Underwater lights and camera housings
- High Pressure Compressors, Nitrox mixing systems, etc.
- Machinery and fittings on boats
- Commercial diving equipment – like almost everything we use

O-ring Types

O-ring applications are divided into two broad categories; Static and Dynamic. There are so many creative applications that some can be seen as hybrids. Static simply means that the sealing surfaces are not moving under pressure while dynamic do. For example:

Static

- Scuba cylinder to valve seals
- Scuba valve to first stage seals, DIN and Yoke
- Hose connections on first stage Scuba regulators
- The lens seal on metal-body SPGs
- Port and door seals on underwater camera housings
- Door and port seals on decompression chambers



Figure 4. The first O-ring that divers learn to use is usually the stage regulator connection to the cylinder valve. This image is of a DIN connector.



Figure 5. The first O-ring that divers learn to service is often the hose to first stage regulator connections.



Figure 6. O-ring grooves don't have to be round. This image of is an underwater camera housing. This is classified as a static pressure-seating face seal O-ring.



Figure 7. Pressure-seated O-rings like this one don't require robust clamping mechanisms because the pressure does the work. The four small spring-loaded latches are all it takes to compress the O-ring enough to make the initial seal.



Figure 8. This PLB (Personal Locator Beacon) housing has threaded caps at both ends with static piston seal O-rings. You can see the compression of the O-rings through the clear plastic tube.

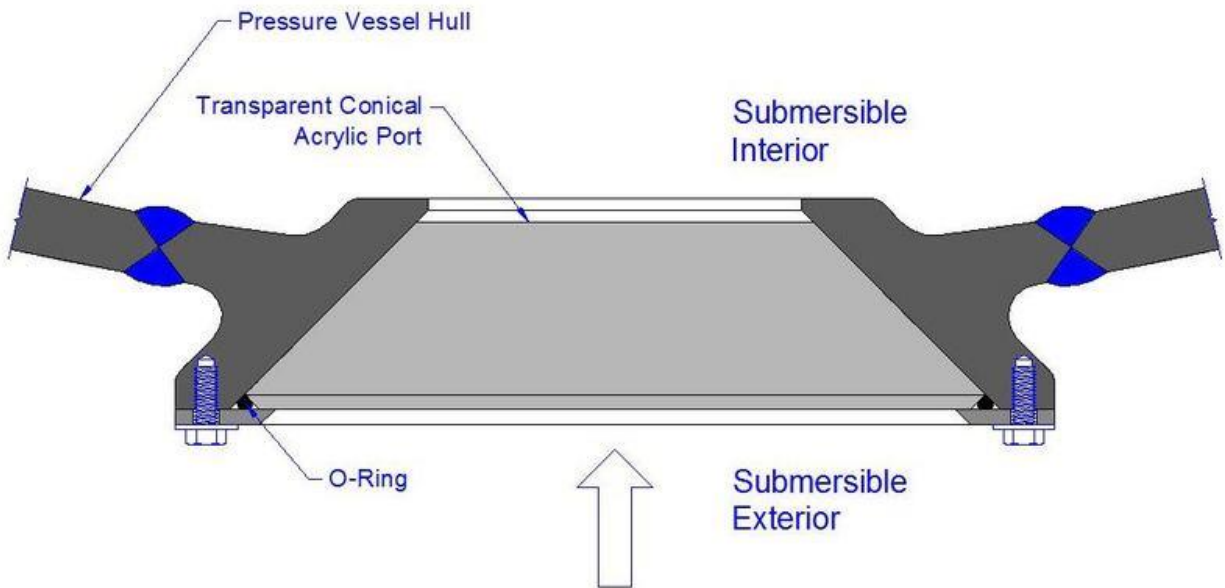


Figure 9. Sectional view of a conical Acrylic pressure-seating viewport for a deep submersible rated for 1,000 M or 3,281' working depth.

Similar ports are used for decompression chambers. The O-Ring only functions at very shallow depths, enough for the pressure to create a metal to plastic seal.

Dynamic

- Cylinder valve stems
- Hose connections on second stage Scuba regulators and swivels
- Hose to SPGs and dive computer connections
- Button and rotary controls on underwater camera and light housings
- Power inflator quick disconnects on BCs (sort of a hybrid but they are allowed to rotate)
- Hydraulic and pneumatic pistons including counterbalance pistons on hatch-back cars



Figure 10. Hose connector to the second stage regulator is a dynamic seal. Look closely and you can see the brown O-ring in the groove under the lock nut.



Figure 11. The standard HP (High Pressure) hose connection that was originally designed for SPGs are also used for AI (Air Integrated) dive computer adapters and wireless transmitters for AI wrist-mounted computers.

Note the different style "spools" with a separate O-ring for the hose and the mating device.

How do O-Rings Work?

O-Rings are much different than gaskets. They are designed to move in their groove, or more properly "gland", and require very little force to achieve the initial seal.

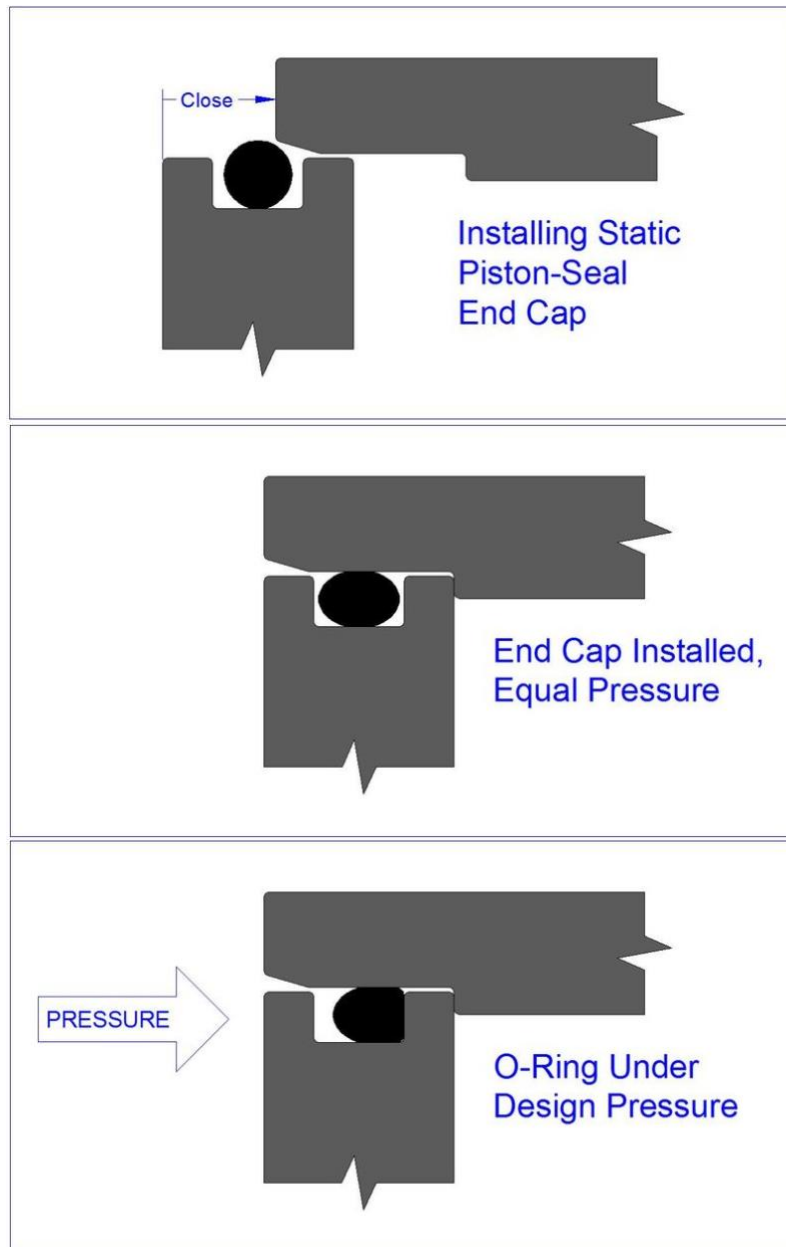


Figure 12. O-Rings are designed to move and deform in the groove, which is why proper lubrication is advised. Unlike gaskets, very little initial compression force is required for a positive seal.

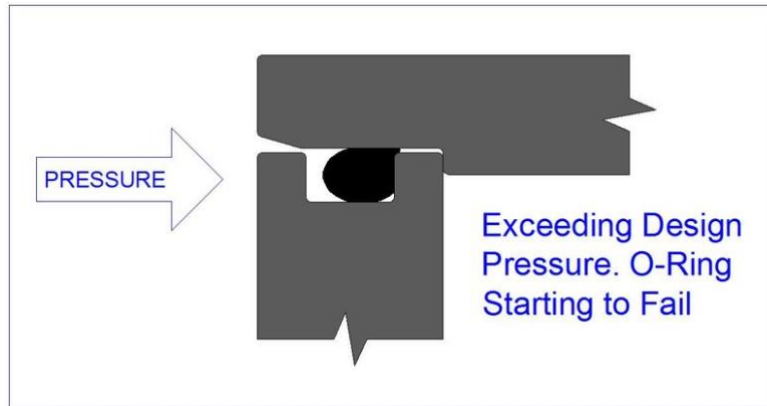


Figure 13. O-Rings will extrude and fail catastrophically when design pressure is exceeded beyond the safety margin, or the wrong O-Ring is used. That is why using the proper size, material, durometer, and lubricant is important.

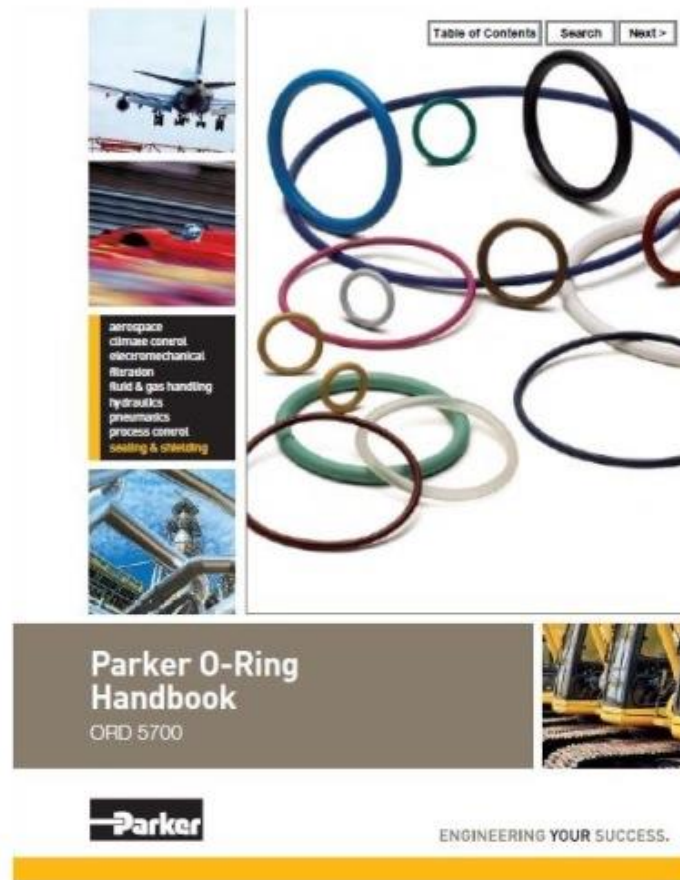


Figure 14. The Parker O-Ring Handbook has been my faithful companion for almost 50 years.

The latest edition of the [Parker O-Ring Handbook](#) has 292 pages and is a free download. The handbook's first paragraph is not an exaggeration:

Since its initial release in 1957, the Parker O-Ring Handbook has become a fixture on the reference shelves of engineers worldwide. This book contains extensive information about the properties of basic sealing elastomers, as well as examples of typical o-ring applications, fundamentals of static and dynamic seal design and o-ring failure modes. It also provides an overview of international sizes and standards, and compatibility data for fluids, gases and solids.

O-Ring Materials, Lubrication, and Maintenance

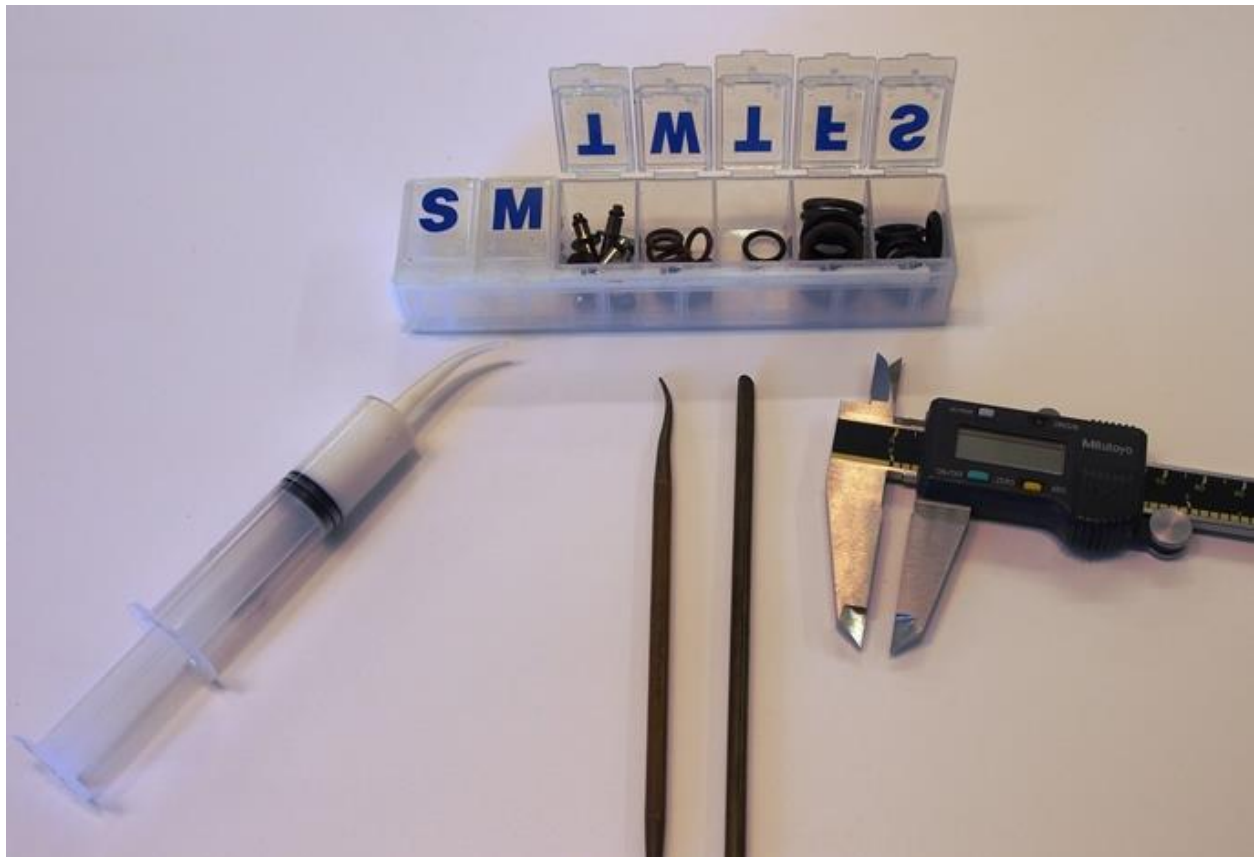


Figure 15. Most well-equipped "Save-a-Dive" kits include spare O-rings, lubricant, and removal tools.

O-Ring Installation

This is an expansive subject but here are a few guidelines:

- Avoid reusing small inexpensive O-Rings. Carefully inspect for deformities and flaws if you do.
- Take great care to only use compatible lubricants (more later)
- Fastidiously clean all mating surfaces and the O-ring itself

- Only use compatible degreasers and solvents
- Avoid materials that shed fibers or lint. Foam makeup applicators are preferred over cotton tipped swabs. Clean metal, rubber, silicone, or high-pressure laminate work surfaces are preferred over fabrics.
- Protect O-rings that pass over threads that can cause minute cuts and abrasions

Protecting O-rings when sliding over threads has been an industry "best practice" for decades, but is rarely discussed in recreational Scuba diving.



Figure 16. Shrink tubing makes excellent thread protectors for installing O-rings on SAE J1926 straight thread boss connections used on first stage regulators.

(Ideally use a heat gun to shrink the tubing or carefully clean soot off the tubing when heated with an open flame.)



Figure 17. O-rings can be protected from thread damage on Scuba cylinder valves with adhesive-free Flagging Tape.

Useful tools include:

- O-Ring removal tool kits and soft plastic O-ring picks (guitar picks or equal)
- Air cans or air nozzle from a clean/breathing air source
- Compatible degreasers
- Lubricant applicators. Sprays should be avoided. Plastic syringes are excellent
- Optical magnifiers and loops

SAFETY WARNING

Always verify that manufacturers rate their lubricants and products for HP (High Pressure) Oxygen Service before using. Specifications and standards may change. Standards for Oxygen Cleaning also vary wildly so proceed with caution.

Material

Nearly all O-rings were molded Neoprene when I was a kid but the variety is mind boggling now. The most common materials that divers will encounter include:

- Buna-N or Nitrile, hydrocarbon based synthetic rubber
- EPDM (Ethylene Propylene Diene Monomer)
- [Viton](#) fluorocarbon elastomer (FKM), 40%-100% Oxygen compatible. pronounced: vi (like vise) ton (like futon)
- Polyurethane, often for O2 service
- Silicone, popular on underwater camera housings

Lubrication

O-ring lubricants in diving applications should be used sparingly. Typically just a thin film is fine, just enough to make it shiny. You will see a lot of videos showing grease being heavily smeared on O-rings and glands for hydraulic and pneumatic applications. That is valid because great globs of grease in the system just adds to the lubricated media. This is not the case for breathing gas applications or in instruments like underwater camera housing and computers. It doesn't matter how high the quality of the lubricant is, you don't want it in your lungs or on the camera lens.

The first consideration for choosing a lubricant must be compatibility with the medium and the O-ring material. You will see a lot of Silicone-based "Food Grade" grease being used and it is fine for most applications but NOT for all. The most frequently recommended lubricants for Scuba gear O-rings are:

For Air Service Only:

- [Dow Corning Molykote 111](#) (previously Dow Corning Silicone 111)

For Nitrox and Oxygen Service:

- [Engineered Custom Lubricants](#)
 - [ChristoLube MCG 111](#) and [ChristoLube MCG 129](#)
- [Aerospace Lubricants](#)
 - [Tribolube 71](#)

Quite a few other suitable brands and formulations are available.

Caution:

Camera housing manufacturers use a variety of O-ring materials and are very particular about the lubricants they recommend and warrant. Use lubricants that they do not specify or brand at your own risk.

Oxygen Compatibility and Cleaning

The catastrophic Apollo fire on 2 February 1967 prompted Oxygen safety research that dramatically expand our understanding. Unfortunately it was too late for two divers that perished in a chamber fire at the [US Navy Experimental Diving Unit](#) on 16 February 1965.

Several government and private agencies publish standards for cleaning and material compatibility for high pressure Oxygen systems. Here are a few commonly used in North America:

- [ASTM G93](#), "Standard Practice for Cleaning Methods and Cleanliness Levels for Material and Equipment Used in Oxygen-Enriched Environments"
- CGA G-4.1, "Cleaning Equipment for Oxygen Service"
- MSS (Manufacturers Standardization Society), MSS SP-138-2009, "Quality Standard for Oxygen Cleaning of Valves & Fittings."

Oxygen cleaning is typically performed on recreational Scuba equipment rated for 40-100% Oxygen service. Many military and commercial diving organizations will routinely O2 clean all of their systems for safety and to improve reliability.

Oxygen Cleaning in the Real World

Oxygen clean means a lot of different things depending on your context. A Scuba regulator and cylinder manufacturers might use a standard like those above while individual divers use a variety of DIY methods. Larger commercial diving companies will sub-contract O2 cleaning services or have their own portable and onboard clean rooms with:

- Positive-pressure Class 100,000 certifications or better
- Vapor degreasers
- Ultra-sonic cleaners
- Cleaning fluid purification and pumping systems for long tubing runs, cylinders, and hoses.
- UV inspection lights



This article might help provide some perspective: [Oxygen Clean - Is a Myth](#), by Bart Bjorkman (excerpt from Advanced Diver Magazine issue 10). Divers interested in performing their own oxygen cleaning are encouraged to investigate the [Oxygen Hacker's Companion](#) by Vance Harlow published by [Airspeed Press](#).

O-Rings Buying Guide

The easiest way to purchase O-rings is in pre-packaged rebuild or soft-goods kits. That relieves you having to determine the correct size, material, and Durometer required. However, it is also the most expensive method by a significant margin. Divers that want to buy from industrial O-ring suppliers may find the following information useful.

Measurements

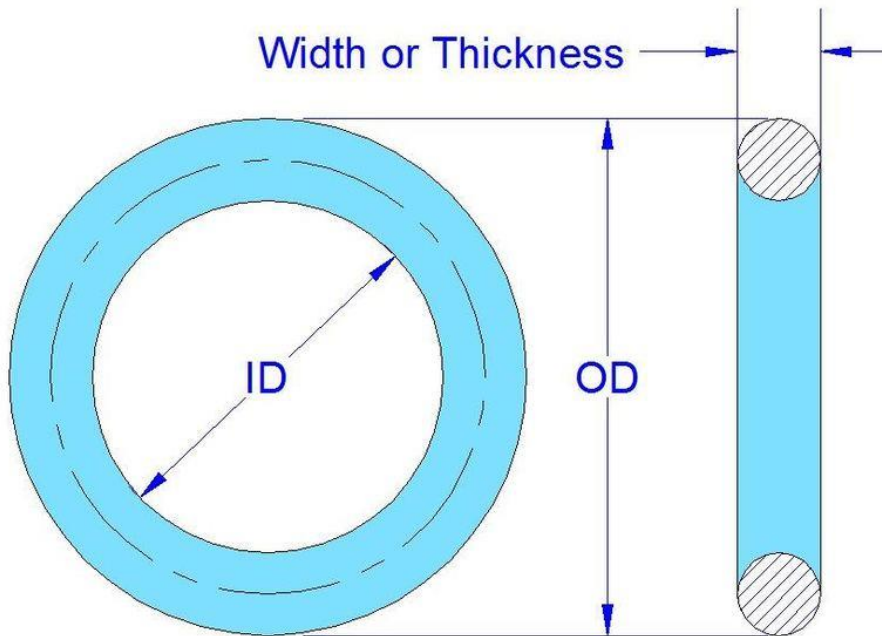


Figure 18. Most O-Ring suppliers measure them by the ID (Inside Diameter) and the Width or Thickness (cross-sectional diameter).



Figure 19. The vast majority of O-ring cross sections are round, but not all. For example, the Quad or X-Rings.

As a rule, round cross sections are assumed unless otherwise specified. The Width or Thickness can be measured with calipers or O-ring gauges.



Figure 20. Parker O-ring sizing cone and tape gauge.

Material

You can specify the material you want or most suppliers can help you determine the proper replacement material from a sample. Don't be fooled into thinking that color is a reliable indicator. It is not.

[Metal O-Rings](#) are available for ultra-high pressures and/or purity, high temperatures, and for corrosive materials. They are seldom used in diving applications. Materials commonly used in diving applications are listed in Post #3.

Durometer

Durometer is the O-Ring material's hardness, or resistance to indentation. Albert Ferdinand Shore developed the [Shore Hardness Scale](#) and instrument in the 1920s. "Durometer" is used in the O-Ring industry for the value and the instrument that measures Shore hardness of resilient materials.

Most industrial O-ring suppliers have instruments to check material Durometer and will test samples for you at the counter. Gauges are available for under \$100 but are rarely required. Most O-rings used in diving applications are 70 to 90 Durometer but selecting the correct one can be critical.

Making Custom O-rings

It is rare that custom O-rings are needed in the recreational Scuba industry, but commercial and military divers frequently encounter them. Larger O-rings required for chamber hatches,

viewports, and mating trunks are seldom available and quantities are too small to justify such large tooling for custom production runs.

Extruded O-ring stock is available in large cross-sectional widths and a variety of materials. Formulations of [Cyanoacrylate](#) (like Superglue) adhesives are sold specifically for splicing O-ring stock.

Pro Tips

Bonding machinery is available for more critical O-ring splicing applications.

Commercial divers and chamber technicians will often see full and half dovetail O-ring glands (grooves) in:

- Chamber and utility lock doors and hatches
- Bell and chamber mating flanges
- Chamber to chamber bolt flanges
- Hydraulic and pneumatic flanges and end bells

Changing O-rings can be tricky. This video might help

I'm embarrassed to admit how many times I started pressing an O-ring in a chamber door's half-dovetail groove from one point, worked my way around, and ended up with more O-ring than groove. Naturally all the old hands were watching the "new guy" demonstrate that I deserved that title.

O-Ring History

Sweden issued a patent to J. O. Lundberg in 1896 and Niels Christensen filed a patent in the US in 1937. The O-ring patent was appropriated by the US government during World War II which dramatically accelerated its adoption, especially in the aircraft and hydraulics industries.

Personal Sidebar

I grew up around O-Rings so never gave them much thought. My dad had a water-well drilling and pump business and I played in his shop before I was old enough to push a broom. This was the mid-1950s and very much the "post war" period. I'm sitting on the shop floor playing one day while listening to dad talking to buddies about these new O-Rings, which I thought were just rubber bands that didn't shoot very well. One guy was a flight mechanic on

aircraft carriers in the Pacific and went on and on about how great they were. I had forgotten about this until writing this but it illustrates that O-Rings were largely unknown to the general public until after the vets came home.

Maybe it's just my impatient nature, but I always wondered: What the heck took so long? After all, the O-Ring concept is pretty obvious when viewed through a modern prism.

Enabling Technologies

The answer is complicated, but largely boils down to advances in material and machine tool technologies. The wide-spread requirement for pressure-tight seals began with the Industrial Revolution in the mid-1700s, especially with the advent of the steam engine.

Although O-Rings don't require high tolerances or finishes by today's standards, they would have been difficult to achieve at production levels before the automotive revolution of the 1920-30s. Prior to that, sealing systems had to be much more forgiving. Early gaskets, seals, and packing were made from leather or various recipes including plant fibers, tree pitch, graphite, lard, and soft metals like lead and copper.

Machine tool precision is an interesting chicken and egg problem. You need precision machine tools to make them. The key to this evolution is the skill and time of the craftsman combined with the best (most expensive) materials and processes. Those produce machinery that can more cost-effectively reproduce quality parts... and then the cycle repeats. Metallurgical sciences are also critical participants since they produce harder, more stable, stronger, and more temperature resistant metals.

DIY O-Rings for Divers

This post is a collection of information for divers that want to custom build something using O-rings. A few examples include:

- Housings to keep the contents dry underwater
- High pressure manifolds for cascade and mixing systems
- Special HP Scuba cylinder manifolds
- Custom switch block for FFMs (Full Face Masks)
- Decompression chambers, submersibles, DPV (Diver Propulsion Vehicle) housings, etc.
- A housing to keep car keys dry during a dive

Underwater Housings

Building your own camera housings was the "big thing" when I started diving. These techniques are still used for specialized instrument housings in the scientific and commercial diving segments and are useful to inventive recreational divers.

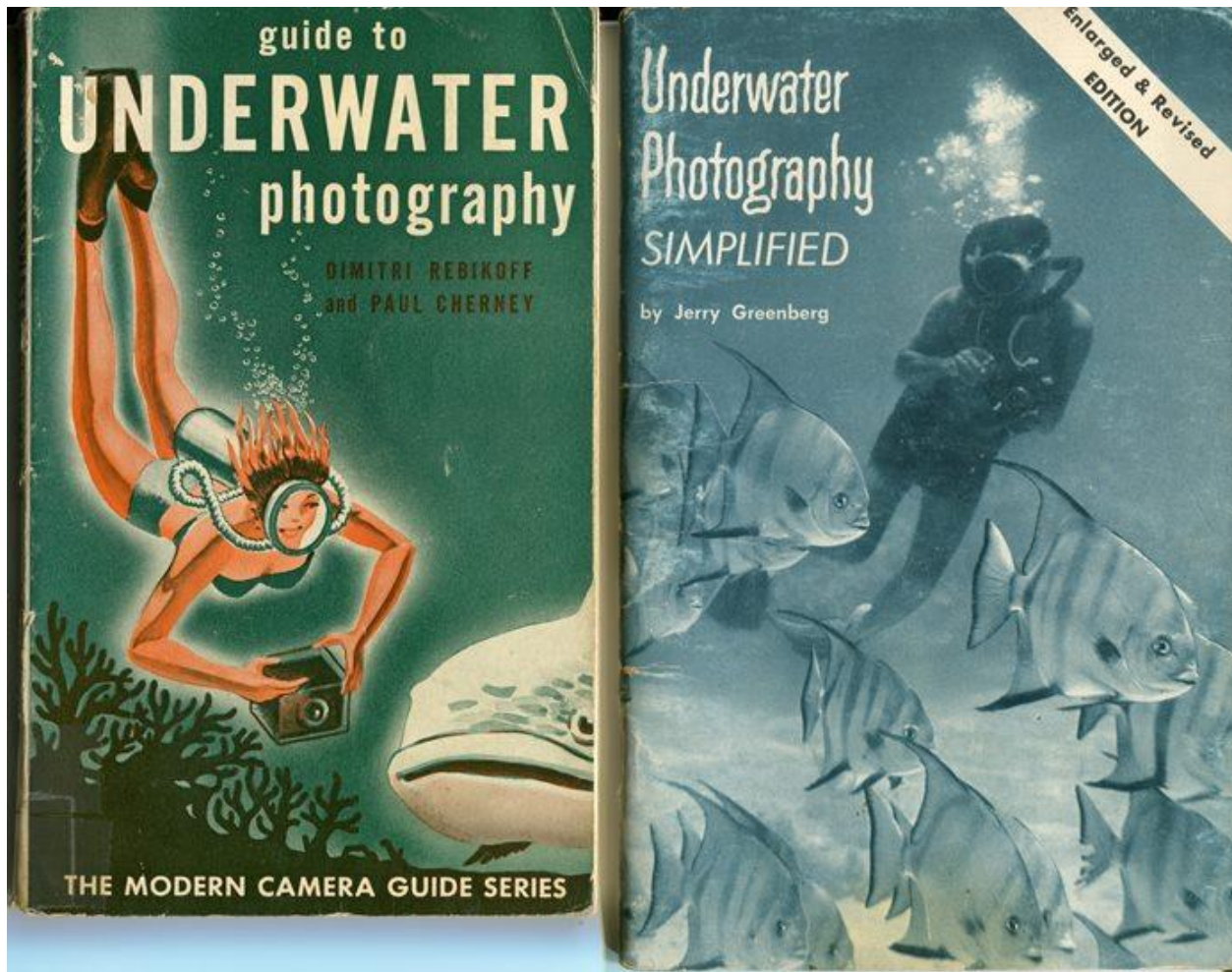


Figure 21. Here are some underwater photography books from my youth. They were as much about making housings as photographic technique.

CUSTOM CAMERA HOUSINGS FOR ANY CAMERA



- Camera housings start at \$59.00.
- Housings are constructed from 1/2" optical grade plexiglass.

- Double o-ring control glands.
- Stainless steel controls.
- Gear driven.
- Tested to 150 feet.

Send self-addressed stamped envelope for free illustrated brochure.

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584 4th St. San Francisco, Calif.

CAMERA HOUSING MANUAL

Easy to follow, step by step instructions to build a housing for ANY CAMERA.

Simplified design Details of all controls. Only \$1.00

72 Fact Filled pages, 60 illustrations

Plus* A complete line of moderately priced parts and material-over 40 items listed.



With the manual as a guide, order your kit by mail.

For example, Dive-Rite will precision cut, machine groove and supply the 'O' ring for all sizes of plexiglas tubing—only \$3.00 plus cost of tubing.



DIVE RITE

BOX 14444, LONG BEACH, CALIFORNIA

Figure 22. These are typical "back page" advertisements in Skin Diver Magazine in the mid-1960s.

The DIY material of choice was Plexiglas because it could be worked with common woodworking tools, was affordable, and came in sheets, tubes, and rods. You could purchase O-ring control glands for 1/4" stainless steel shafts from companies like Dive Rite in the ad above and a few garage machinists in my area made them.

The big problem was making the seal on the back where the camera went in. You could have a machinist cut an O-ring groove on a piece of Plexiglas tubing but cutting any shape groove other than round was a very expensive proposition. Some anonymous diver came up with this really simple trick.

- Cut a piece of 1/4" thick Plexiglas sheet to a close inside slip-fit of the housing opening
- Glue (chemically weld) it centered on the housing door/hatch/back, which was typically 1/2" thick
- Stretch a 1/8" width (cross section) O-ring around the 1/4" thick backing
- Clamp it down enough to make a seal, which was pretty easy to see through the clear Plexiglas
- Clamping force was often accomplished with 1/4-20 UNC brass studs with wing nuts or stainless steel spring loaded latches. The [Neilsen latches](#) are still used today on a lot of commercial Aluminum camera housings.

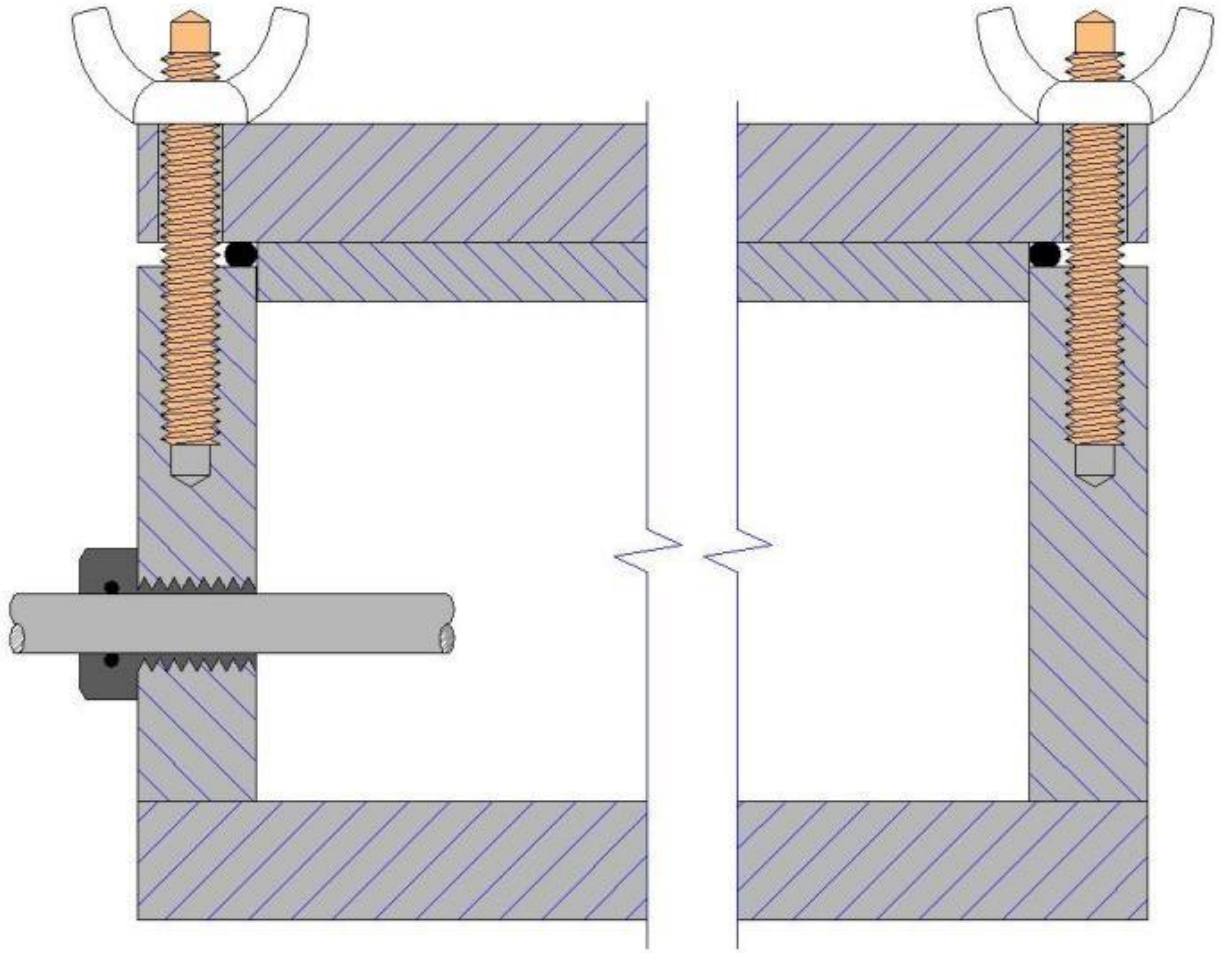


Figure 23. Cross section of a DIY Plexiglas O-ring sealed housing with a gland for a control shaft.

You can also cobble together small housing using PVC plumbing fittings from your local hardware store.



Figure 24. Just ask for slip-socket PVC O-ring sealed union.

Warning: PVC Should NOT be used for internal pressure gas systems

The reason PVC should not be used for pressurized gas is the failure mode, not the pressure rating. PVC will shatter on impact and little bits of plastic become projectiles like Shrapnel. An accidental bump can ruin your life, subject you to legal liability and the wrath of government bureaucrats, and give your local emergency room unnecessary practice.

Fluids don't compress (for all practical purposes) so PVC is safe for liquid service because the pressure drops instantly when there is a failure.



Figure 25. Old underwater light housings can be a handy starting point for inventive divers.

High Pressure Gas Systems

You can make a lot of useful high pressure gas systems out of commercially available fitting, tubing, and pipe... which is probably a subject for future threads like this one. However, there are times when space constraints, ergonomics, and the added number of potential leaks makes it worth the trouble to use a manifold.

Custom Gas Manifolds

A common problem when installing everything from garage compressor systems through saturation diving systems is the need to join several inlets and outlets together. Connections may use rigid tubing and hoses and some of those connections may also require valves. Most custom manifolds are made from Brass or Aluminum because they are easy to machine and reasonably compatible around salt water environments; though Aluminum should be anodized in most cases.

Flat or hexagonal bars are usually the most convenient starting points. Local machine shops drill the stock and install:

- Female NPT ports using a standard tap
- SAE straight thread O-ring sealed ports using SAE J1926 port cutting tools (SAE ports are best for Aluminum so the anodizing won't be scarred).
- ISO 6149-1 Metric Straight Thread O-ring cutting tools
- Brazed (Brass) or welded (Stainless Steel) fitting tail-pieces

Note: Hose connections on Scuba first stages are industry standard SAE J1926 O-ring sealed straight thread ports. The HP port is designated -4 or 1/4" and has a 7/16-20 UNF thread. The LP or IP ports have a 3/8-24 UNF thread are designated as -3 or 3/16".

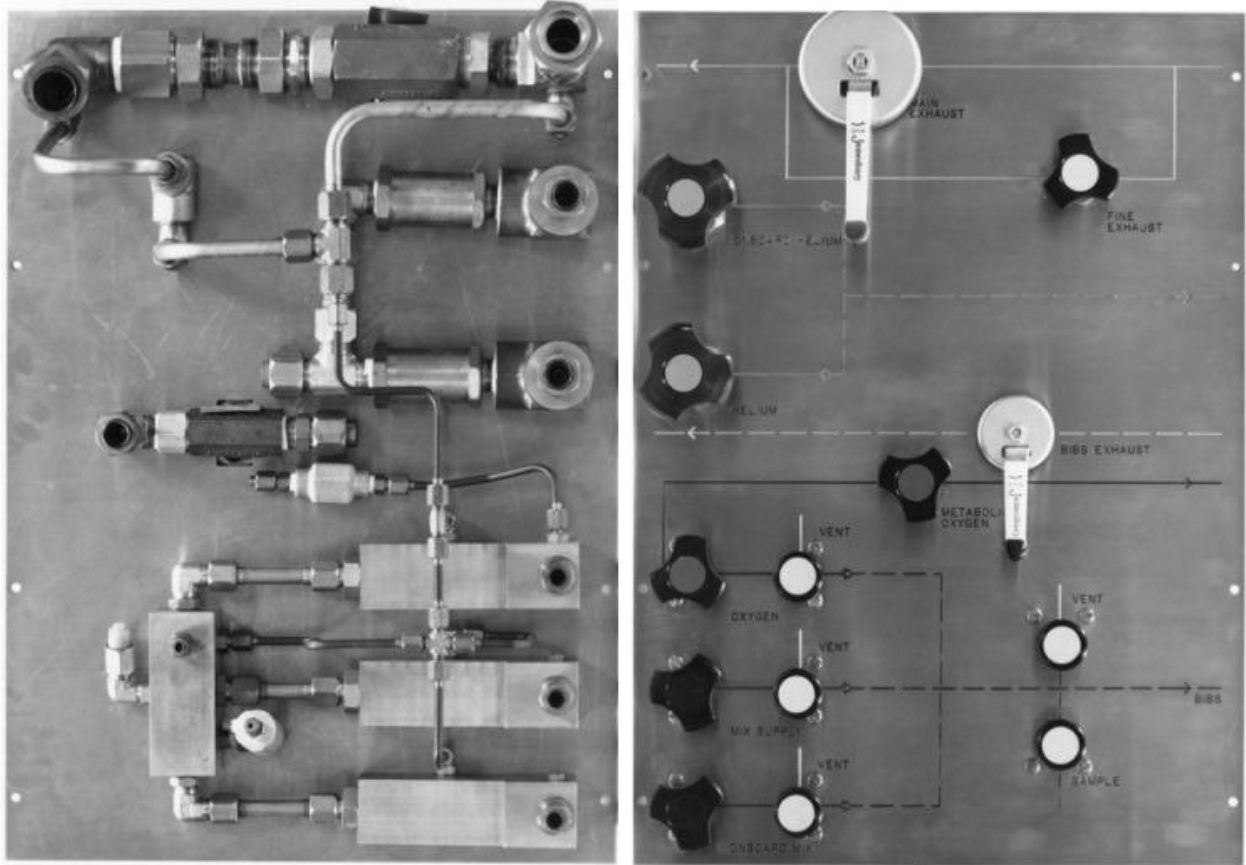


Figure 26. Back and front images of a chamber gas control panel for a saturation diving system.

Note the four manifolds that include check valve cartridges, valve cartridges, and internal connections. Dozens of fittings, tubes, and potential leaks are eliminated.

Custom Scuba Cylinder Manifolds

There are a lot of ways that specialized manifolds can be made using off-the-shelf cylinder valves and industrial tube fittings. Here is just one example:



Figure 27. Custom doubles manifold for bail-out bottles for surface supplied diving.



Figure 28. This manifold uses Stainless Steel DIN plugs and CPV Mark 8 O-Seal fittings.