CEJN-style Offboard Gas Supply Quick-Disconnect Subsystem for Closed-Circuit Rebreathers

Edit 03.2011

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Key terms
CEJN, flow coefficient (cV), LP, HP, diluent, hypoxic, normoxic, hyperoxic, closed-circuit rebreather (CCR)

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Introduction

With a growing population of rebreather divers, subsystem level components are in need of being standardized to enable cross-unit compatibility within a dive team. One such area, of critical importance, is cross-compatibility of offboard gas distribution systems. All members of a dive team should be able to share or utilize any other members' offboard gas supply for bailout/gas sharing purposes.

During the course of diving's evolution, a variety of quick disconnect fittings have been adopted. The one that is most familiar is the 'standard' BC nipple used on your inflator mechanism. Many manufacturers have developed proprietary inflator nipples, only to confuse the consumers and create a mish-mash of nipples and corresponding coupling/hoses on workbenches and on dive gear. Likewise, in commercial diving, a number of higher flow quick-disconnect (Q/D) fittings and couplings are used, though these are not frequently used in recreational diving.

When customizing your rebreather system, the need for a BOV, offboard gasses, and diving as a team will surface sooner than later, and the question of which fitting to use, and how to configure these into your unit, ends up being a tantalizing and overwhelming task given the lack of an industry-wide accepted best practice or consensus amongst equipment manufacturers.

So, where to start?

As of this writing, there are several camps, each with its own advantages and disadvantages. AP Diving sells a proprietary system. DeltaP/VR uses a QC6 style fitting, many Meg folks use a standard BC inflator, KISS folks use an Omniswivel version, the Cis-Mk5P uses a hydraulic coupling assembly, and so on. While the goal of this paper is not to criticize any of these methods, here we present an argument for a highly versatile and best compromise of features in one particular subsystem design that incorporates a number of features ideally suited for rebreather diving. Here, we will discuss components and subsystem design and assembly for offboard gas systems incorporating 'CEJN' and compatible quick-disconnect components.

About CEJN Component Parts

Some background; CEJN (pronounced 'sane') is a manufacturer of various hose coupling systems for fluid and gas applications. They made their first appearance in diving with that 'other' fitting found on drysuit inflator valves. Both Poseidon Unisuits and Viking drysuits have incorporated this type of nipple fitting for several decades of product development. If you dive one of these suits, your first thought was probably "ugh, how annoying-this fitting doesn't work with any of my normal inflator hoses!". Having become a long lived industry standard, today, several drysuit manufacturers use this type of nipple, and compatible parts have been incorporated into BC inflation mechanisms and Q/D assemblies for breathing gas supplies. For example, Apex uses this style fitting on their BC's. Ocean Reef, the manufacturer of fullface masks, sells a Q/D assembly for their masks featuring true CEJN parts.

Now, a look at the CEJN catalog will be overwhelming. Several of their fittings are listed as suitable for breathing gasses, however these are geared towards SCBA units or other hazmat supplied air systems. **CEJN Series 220 and 221** are what is used for diving applications. Components in Series 220 and 221 are interchangeable, and likewise are compatible with those used in diving from Poseidon, Viking, Apex, and Ocean Reef. One should note however, that Series 220 nipples are steel. Series 221 are stainless and brass, thus best suited for in-water applications. Both 220 and 221 Series female couplings are constructed of non-corrosive materials and suited for in-water use.

Why use CEJN style fittings & assemblies?

The original, and very simple advantage, stemming from Series 221 use on drysuits, is the ease of connecting and disconnecting the fittings, even while under pressure, and with heavy gloves on.

Figure 1: female CEJN 221 fitting.

The knurled collar on the Series 221 female coupling makes use very simple (figure 1). These female couplings are self-checking, just like a standard inflator hose, allowing them to be disconnected underwater without gas loss.

The next consideration, and perhaps most important if designing a system from scratch, is providing ample gas flow to any second stages demand systems; a BOV or ADV in this case. Standard BC inflators are not designed to supply breathable volumes of gas, and thus are not suitable for offboard gas addition to second stages. True CEJN 220/221 fittings, or those from Ocean Reef, are specifically designed to provide sufficient gas flow to a second stage (figure 2).

This is much less critical if only feeding your rig. However, if your BOV is fed from a manifold, there should be no restrictive fittings in line from the gas source; this includes non-return valves (see note on flow coefficients). By using high flow fittings throughout, there is no confusion, and an offboard whip can be plugged into the rig, or directly to your BOV without concern.

*****NOTE: Any and all fittings used in a gas supply system should have flow coefficients (cV) suitable for supplying a breathable flow of gas to second stages. Creating restrictive flow paths leading to second stages will cause inadequate gas supply, especially during arduous breathing cycles associated with bailing out under stress. This could escalate the breathing pattern, and increase the chance of a hypercapnic event.*****

The CEJN website describes their Series 221 nipples and couplings are listed in their 'breathing air' section, and are described as follows:

Figure 2: CEJN line. (www.cejn.com)

"Requiring only one hand for operation, Series 221 are suitable for a variety of fluid applications, such as water inlet and return for injection molding lines. Series 221 features valved couplings and valveless nipples. Other sealing materials, such as Viton® and EPDM, are available on request. Straight-through couplings are also available on request."

The following technical data is also provided:

Technical data

Nominal flow diameter:	5.0 mm (3/16")
Air flow:	580 l/min (20.5 CFM)
Max. working pressure:	35 bar (510 PSI)
Min. burst pressure:	140 bar (2030 PSI)
Temperature range:	-30°C to +100°C (-22°F to +212°F)
Material coupling:	Chrome-plated brass
Material nipple:	Chrome-plated brass
Material seal:	NBR

One should note, however, that the above technical data is true for CEJN 221/220 Series parts only. While Ocean Reef and Apex produce CEJN-style fittings that are fully compatible with true CEJN parts, their internal bore diameter is slightly different. In these cases, the parts are suitable for breathing gas, per Ocean Reef and Apeks specifications when used with their respective hardware.

A final advantage to CEJN style fittings, is that they can be used throughout your rig including offboard whips, at manual add valves, and for BC/suit inflation. This consistency used throughout the rebreather gas distribution configuration makes it possible to access any gas supplies at any point in your equipment – which eliminates confusion and anxiety in addressing any number of failure modes. This also allows for full bypass of the rig itself to directly feed the BOV in a full boom scenario.

Figure 3: Ocean Reef (left) and CEJN 221 (right) nipples with large bores suitable for supplying breathing gas.

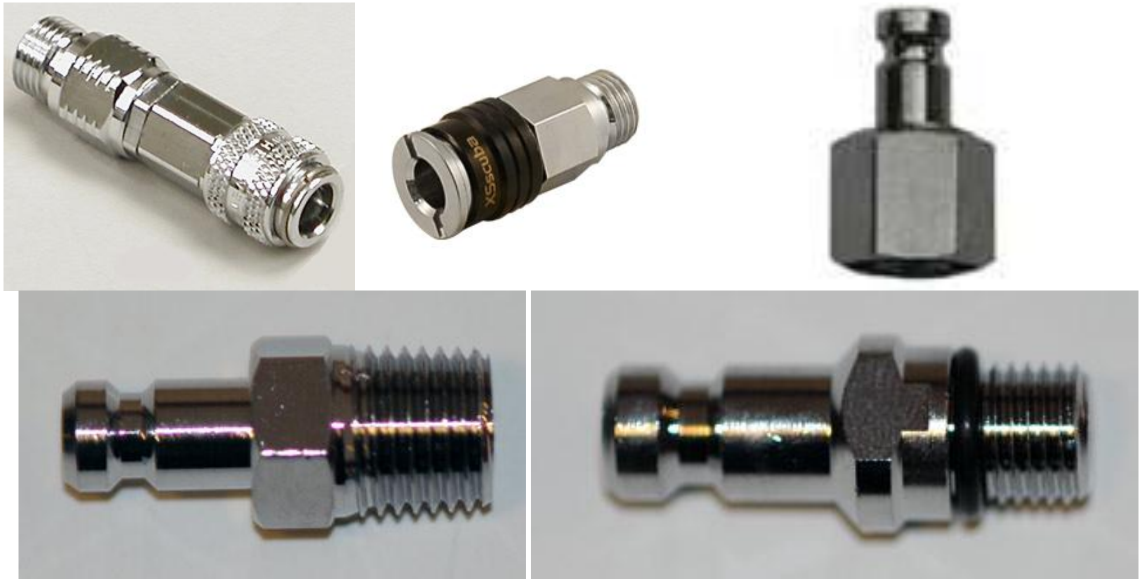

Figure 4: The variety of CEJN compatible adapters available to divers. From top left: Apeks female adapter, XS Scuba female adapter, Ocean Reef male to 2nd stage adapter, Apeks male 1/4 NPT adapter, Viking/Poseidon nipple to 3/8-24UNF (not suitable for breathing). Images sources: GMC Scuba website, and Northeast Scuba Supply website.

A Note on Flow Coefficients

Normally the coefficient of flow (cV) means nothing to divers, and frankly it should not be a concern. However as CCR-divers start to make custom hoses, adding inline shutoffs, pivoting adaptors, quick-connects, and non-return-valves – flow resistance can greatly reduce gas flow, producing an undesirable, or even unbreathable, supply of gas to the diver.

For discussion, a starting point in understanding adequate flow is needed. CEJN 221 Series parts have a flow rate of 580 l/min at surface pressure (1 ATA). This equates to 50 liters/min at 100msw, and is the frame of reference used here. Another variable is considering pressure drop across the fitting itself, or other restrictive component. Pressure drop across CEJN 221 Series fittings is listed at 0.5 bar.

The most widely used characteristics of valves and various adapters in the industry is the flow coefficient, or cV-value (coefficient of volume). The cV value is defined as the number of gallons of water per minute that can flow through an orifice with a pressure-difference of one psi. You can also use these values to calculate the flow of gasses. Swagelock has produced an online calculator for this purpose which can be found here:

http://www.swagelok.com/tools/CV_Calculator.aspx

When using the above values for CEJN 221 Series products, where:

Pressure_1 P1 = 6.0 bar (max rated inlet P for CEJN
Pressure_2 P2 = 5.5 bar (P with reduction)
Temperature = 4 C
Media = Air

Flow = 580 l/min

The calculated cV is 0.81.

So as a rule of thumb, very crudely, components with a cV higher than 0.8 will give a flow better than a CEJN-coupling.

Running multiple fittings and components in line will result in multiple pressure drops. For example, addition of one non-return valve (cV = 1.2 for the component part), or check valve, used commonly with the CEJN male nipple to prevent gas loss through this assembly would calculate as follows (again per Swagelock calculator):

Off-board CEJN (cV = 0.81) will drop from 6.5 bar to 6.0 bar
NRV (cV = 1.2) will drop from 6.0 bar to 5.75 bar

Further, addition of a Q/D at the BOV:

BOV CEJN (assume cV=0.81) will drop further from 5.75 bar to 5.25 bar

Knowing the cV values of your components would allow for a rough estimate of the resulting pressure-drop. The lower the pressure drop through these various fittings and components, the better. The objective should be to supply your second stages (BOV, ADV) with an inlet P suitable for their proper operation, and hence sufficient gas flow for breathing.

In short, the fewer restrictions in line with critical components, such as a BOV, the better. If a number of restrictions are in place, flow should be checked on a flow bench, or other suitable life support testing environment. Again, it is possible to have adequate flow at the surface, but dangerously high resistance due to low flow at depth, which could result in exacerbated carbon dioxide problems.

Geez…I'm confused already! What goes where, and why?

Here, very basic subassemblies for male whips, both diluent and oxygen, mating with your rig, and female whips from your offboard cylinders will be broken down and discussed. Numerous variations are commercially available and numerous others have been custom configured by end-users. In the end, it is up to the end user to make an educated decision on design of the best suited offboard gas distribution system for his/her particular diving needs. The concepts presented below are basic guidelines and considerations for design and integration of this hardware into a rebreather.

Male subassembly – Diluent side

In general, the male diluent whip assembly should consist of a CEJN-style nipple with a high cV, a ball/isolator valve, and a check valve/non-return valve - only permitting flow into this hose (figure 3). This assembly prevents the onboard gas supply from escaping the whip, and keeps water out of the system when not plugged in. The ball/isolator also makes it necessary for the diver to make a conscious effort to switch to/from an offboard gas (described below), which is necessary to avoid a diluent mix-up during the dive. This male assembly is affixed to a LP hose and installed at either the diluent first stage LP port of the onboard gas supply, in which case the diluent first stage serves as your diluent manifold – OR - to the diluent manifold in the unit. In either case, the system is plumbed such that all devices (BOV, ADV, manual add valve, etc) on the rig are fed by the same diluent gas, either onboard or offboard.

Figure 5: Sample diluent Q/D subassembly.

Male subassembly – Oxygen side

In general, the male oxygen whip assembly should consist of a CEJN-style nipple, and a check valve/non-return valve - only permitting flow into this hose (figure 4). This assembly prevents the onboard gas supply from escaping the whip, and keeps water out of the system when not plugged in. No ball/isolator is used, as there is no risk of using the 'wrong' gas. It's all oxygen. This male assembly is affixed to a LP hose and installed at either the diluent first stage LP port of the onboard oxygen supply, in which case the oxygen first stage serves as your oxygen manifold – OR - to the oxygen manifold in the unit if there is one. In either case, the system is plumbed such that all devices (solenoid, orifice, needle manual add valve, etc) on the rig are fed by the same oxygen supply, either onboard or offboard.

Figure 6: Oxygen Q/D subassembly.

Female subassembly

There are a number of compatible CEJN-style female hose fittings. Hoses with this coupling can be attached directly to an offboard gas supply's 1st stage, as they are self-checking valves. CEJN Series 220 females are seawater safe, as are CEJN 221 females. Drysuit hoses from Poseidon/Viking are also suitable whips, as is the whip provided in an Ocean Reef Q/D kit. A female assembly is also produced by the company Hansen, which is sold as the female counterpart to the Apex CEJN-style fittings (see Figure 4). Each of these mentioned female fittings are cross-compatible with all of the above mentioned male fittings. If making custom whips, it is useful to color code the hoses. Blue is for diluent, green is for oxygen. An alternative to colored hoses, is simply wrapping a band of colored electrical tape on a standard black hose (figure 7).

Figure 7: An array of cross-compatible male and female subassemblies.

Making a gas switch

Should you plan on making a gas switch, it is recommended to make the male to female connection prior to the dive. This will prevent any water from entering your hoses and contaminating critical orifices (oxygen side consideration only). Should you make a wet connection, slight water will intrude through the male side. This is not detrimental, however care should be taken to clean any critical orifices as they will have been exposed to seawater.

To make a gas switch, turn 'on' the offboard supply, turn 'off' the current onboard supply. In the case of diluent, switch the ball/isolator valve 'on'. Diluent flush if this is a diluent switch. Done. To switch back to onboard, reverse the process; turn 'on' the onboard gas, turn 'off' the ball valve, turn 'off' the offboard gas (for good measure, though not necessary). Flush if necessary. DONE.

Turn on offboard → turn off onboard → open isolator → flush

Keep in mind, that with no isolator on the oxygen side whip, the unit will draw from the regulator with the higher intermediate pressure if both onboard and offboard cylinders are turned on. The only means to isolate your oxygen supply is by turning either cylinder on/off.

Likewise, and this is a critical note; if making a diluent side gas switch, be sure to turn the gas not being used 'off'. Otherwise, should the ball valve/isolator be open, the gas with the higher intermediate pressure will be feeding the rig. This may, or may not, be the desired gas. All systems should be designed such that intentional checks and balances are made during the gas switch process.

The Bottom Line – What is most important

Nothing will provide more knowledge and experience than spending time with your rebreather unit. Understanding gas flow pathways is critical in making any rig modifications. Beyond the components however, these fundamental considerations need to be evaluated and incorporated into the subsystem design:

•Ensure that all fittings in-line with gas supplies that feed a BOV or second stage provide sufficient gas flows for the device.

•When planning to incorporate multiple diluent gasses, all auxiliary functions must being served by the gas that is turned 'on', to avoid any confusion as to what is feeding each auxillary item. Always utilize a diluent gas that is suitable for breathing in open-circuit mode at any given depth. Should a hypoxic diluent be utilized, one should be certain that the BOV is always fed by a gas that is breathable at depth.

•Standardize your rig by utilizing cross compatible components at all points where you might want to connect an offboard whip, or may require access to a redundant gas supply.

•By utilizing a high flow CEJN male fitting at the BOV, you can easily bypass your rig and plug offboard whips directly to the BOV. This is particularly useful is you need to access offboard O2 for decompression.

•Ensure that all members of your team are using the same configuration, and most importantly, compatible components!

Figure 8: BOV, backup 2nd stage, and MAV, all using CEJN compatible male nipples.

Additional Information
For information on suppliers, and recommendations on assemblies and configuration, please contact the author at explore@oceanopportunity.com.

References & Credits

The author extends his thanks to the many members of the Rebreatherworld.com forum, for sharing ideas and tips related to this topic.

Additional information on this topic can be found in the presentation entitled 'Offboard gas selection for CCRs including configuration, design, & assembly of related hardware' by Dave Sutton. This was presented at the 2010 Northeast Rebreather & Advanced Diving Technology Workshop on January 23rd, 2010 at the University of Rhode Island's Bay Campus. The presentation can be viewed online at http://www.youtube.com/watch?v=2QfkAmR3Dr0.