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Medical Design
ENGINEER'S SOURCE FOR CONTRACT MANUFACTURING

A custom retrofit may be the best way to place an orifice and filter into medical equipment.

Filling the Holes on Placing Orifices and Filters

Paul Baillio
Vice President
Bird Precision
Waltham, Mass.

In the rush to get new designs to production, engineers often sacrifice uniformity of design, ergonomics, and accuracy because they *perceive* limited choices. This perception is fueled by fitting manufacturers that offer few filters or fixed orifices for their connectors. Choices are even fewer for fixed orifice-and-filter combinations.

Most medical-device companies standardize on one fitting manufacturer. So although a company catalog offers page after page of products, it's probably lacking options for filters and fixed orifices. So you must find an additional filter, or fixed orifice, or both, and somehow sandwich them into the design. This usually adds two extra fittings and neither matches the catalog fittings in the rest of the device.

A solution

A custom retrofit solves the problem of extra fittings. It's a short step outside the box but pays huge dividends. It works like this: you choose the best fitting or connector. The orifice manufacturer then bores it a bit larger and press fits the orfice, filter, or both into the fitting where the design dictates. The fitting is now compact and aesthetically pleasing because everything matches. This also trims the number of components which usually saves money and simplifies procurement.

Orifices and filters are available to fit most standard fittings. Chances are, a selected fitting can be machined for a retrofit. Cartridges that hold a filter and orifice are usually plastic, brass, and stainless. Typical fitting choices for medical applications include push-to-connect designs, luers, and tube connectors, but most any fitting or connector can be a candidate. It's also possible to install orifices and filters directly into manifolds.

Most medical-equipment designers opt for fixed orifices rather than adjustable needle valves, and for good reasons. For one, the equipment's calibrated flow settings cannot be tweaked after it leaves the factory. Recalibration requires expensive service calls. In oxygen applications, no one wants to risk patients receiving uncalibrated flows because an unauthorized person changed the setting.

Fixed orifices come in a variety of materials. Ruby and sapphire versions work best for medical applications because these single-crystal materials are almost chemically inert. Sapphire and ruby are somewhat unique in that they have zero porosity, do not outgas, and are nonthrombogenic. In addition, they are manmade and economical.

These materials are used in a wide range of medical applications from oxygen and anesthesiology gasses, valves, wire feed thrus, brain-shunt valves, and precision dispensing tips. Because sapphire and ruby do not oxidize, they have no flash point, making them well suited for use with oxygen. The materials also have five times the abrasion resistance of carbides, so orifice edges do not wear even at high pressures and temperatures.

Commercially available cartridges and fittings such as these from Bird Precision, hold orifices and filters for medical equipment and come in brass, stainless steel, plastic, and titanium.

The orifices are also sharp edged and maintain their coefficients of discharge, C_v values. A worst case tolerance on dimensions is +0.0002 –0.0000 in. All holes are polished to better than 2μin. surface finish and are very round. Even the throat length is closely held. This controls variables that might alter flow. Ruby and sapphire orifices are laser pierced then wire lapped into nearly perfect holes. The faces are further lapped for the required sharp edge and surface finishes. Production is economical because

Flow resistance for stainless steel wire mesh filters

Ave. micron rating	Six Sigma wire mesh	Wire size (in.)	Est. scfm/in.^{2}
5	325×2300	0.0014 ×0.001	7.8
10	165×1400	0.0016 × 0.0026	11.0
25	80×700	0.004 × 0.003	14
43	325×325	0.0014 × 0.0014	17

The brief chart covers air-flow tests at 75°F and 1 psi differential.

When the gas isn't air

To find flow rates for gases other than air, use:

$Q_{gas} = Q_{air}/\sqrt{S_{g\,gas}}$

Where Q_{gas} = gas flow rate, sccm (standard cubic cm/min); Q_{air} = air flow through the selected orifice, sccm; and $S_{g\,gas}$ = specific gravity of the other gas.

For example, find the flow of fluorine through a 0.0016-in. orifice at a pressure of 20 psi.

$Q_{fluorine}$ = 32 sccm/$\sqrt{1.31}$
= 27.9 sccm

Specific gravity of some gasses

Air	1.00
Argon	1.379
Chlorine	2.470
Ether	2.550
Fluorine	1.310
Helium	0.138
Oxygen	1.105
Steam	0.620

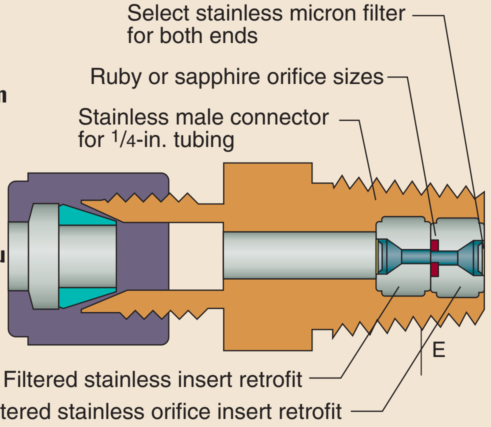
Flow estimates for dry air (sccm)

	Orifice size (in.)		
Pressure (psi)	0.0008	0.0016	0.0030
5	2.66	13.0	48.0
10	4.5	20.0	75.0
20	7.75	32.0	109.0
40	12.5	52.0	180.0
80	24.5	96.0	313.0

Examples of a precision retrofit

In most cases, custom retrofits are done by precision boring connectors and fittings so a filter-and-orifice cartridge fits inside. For example, Swagelok stainless fittings for 0.25-in. tube come with a 0.190-in. E-dimension thru hole. The hole is precision bored out to 0.204-in. dia. so it accepts a press-fitted filter-orifice cartridge. Likewise, a Swagelock tube fitting for 0.125-in. tube is likely to have an E opening of 0.09 in. This is bored out to accept a 0.112-in. dia. cartridge. In some cases, such as in Swagelok face-seal glands, an orifice is installed directly into the fitting without a cartridge.

The drawing from Swagelok, one manufacturer of many that makes 1/4-in. fittings, shows the E dimension or thru diameter for an interior section.



thousands are produced in each batch. Machined metal orifices, on the other hand, have burrs and out-of-round holes from drill wobble.

How to size

Sizing an orifice and filter into a design primarily needs three characteristics:

Δp, differential pressure across the orifice.
Q, expected flow rate at Δp.
S_g, specific gravity of the gas
and a direction of flow.

An orifice can be selected with this information using estimated flow guides. Orifices off-the-shelf range from 0.0004 to 0.081 in., depending on fitting choice.

A common design flaw, however, specifies an orifice material that can wear or oxidize over time. It's not hard to see that the longer an orifice wears, the further out of calibration it becomes. High pressure and high-oxidation applications exacerbate this wear. What's more, small orifices go out of calibration faster than large ones because small changes account for a larger percentages of the hole's total area.

Filters can be inserted forward and aft of the orifice if needed. Most designs need only protect the upstream side of the orifice. However, when a design needs orifices in the micron range, filters are usually crucial. Stainless, wire-mesh filters are most widely used. They have more open area and are less likely to clog. One manufacturer of oxygen analysis equipment uses a 0.005-in. ruby orifice with upstream and downstream filters to ensure the orifice remains unhindered by debris.

For special situations, porous plastic materials, plastic mesh, stainless, and bronze sintered materials are also possible filter choices depending on application. Stainless-steel mesh filters are available in micron filtration levels of 5, 25, 43, 75, and 150. (The resistance chart in an accompanying table tells more about these figures.)

It is important to pay attention to filter-restriction rates as well. All filters exhibit some restriction depending on wire size and micron level. One way to reach the expected flow is to use slightly larger orifices. After selecting an orifice and filter, it is necessary to establish where the two devices will be placed. It's usually in the throat or thru diameter of the fitting. Knowing this diameter helps select the correct filtered orifice insert.

For example, the Swagelok catalog shows that a 1/4-in. tubing fitting has an "E" dimension (a thru-diameter hole) of 0.19 in. Thus, from a table of standard orifices, select one with 0.200 diameter filtered orifice inserts. Inserts are designed for this opening in a variety of materials. ■