**Oversizing parts by 1%**

When we first received parts from ProtoLabs (the initial order of 100 units) we found that all the dimensions were ~1% smaller than intended. This is likely an artifact of the manufacturing process: MJF involves heating and cooling, and it makes sense that the thermal expansion/contraction of parts renders them smaller than expected. To account for this, we submitted a 1% oversize version of the part for future manufacturing. The result of this decision will be that future parts come out with the correct dimensions, which is important for ensuring compatibility with hospital connectors (22 mm tubing, etc.)

**Reconfiguring tubing**

During testing of the initial prototype, we discovered that the water indicator for flow was not fully responsive for low flow rates (40-50 L/min). Through various other tests, we deduced that this was due to two factors: 1) the compressibility of air, and 2) the mass of the water column. The former feature refers to the fact that over long distances or high pressures, air is compressible and behaves like a spring. Our flow meter, which relies on a pressure difference between the throat and the tubing to move the water column, can be seen as exerting a force on the water with the air acting as a medium. When the tubing is too long, that force must be transmitted a very long distance, and, instead of moving the water column, the force is wasted in compressing the air. When the force is high enough (flows greater than 50 L/m), the energy being wasted on the air isn't noticeable, and thus the water column moves seemingly like normal.

The second problem has to do with the high mass of the water column. At low flow rates, and thus low force exertion, the water column is too massive to move. Additionally, the high inertia associated with high mass means that the water column doesn't respond in time to measure low forces. Both this problem and the problem of air compressibility are solved through a reconfiguration of the tubing. By shortening the tubing pathway between the two pressure taps (the barbs), the effects of air compressibility are greatly attenuated. The shorter tubing also means that less water is required to fill the meter to the zero mark, meaning that the water in the tubes has less mass, and therefore less inertia. The original design called for 15 mL of water, whereas the new design calls for only 5 mL. Both of these properties allow the water level meter to respond quicker and more precisely for low flow rates, without affecting the meter's performance at high flow rates. The revised tubing configuration is shown on the following pages.