Electromagnetic Valve for Bodily Fluid Drainage

The intention underlying the electromagnetic valve concept was to utilize magnetism to raise and lower a metal plunger inside rubber tubing, as shown in Figure 1. The necessary components for this design included a metal plunger with a rounded, cupped end piece that could seal off a section of latex tubing, a circular electromagnetic cuff that could fit around the tubing, and a power source, preferably the 24 Volt power supply found on most electric wheelchairs.

When the electromagnet was off, the weight of the plunger and the fluid would be enough force to pull the plunger down (Figure 1), creating a tight seal between it and the flexible rubber tubing and preventing any fluid from leaking out. This ensured that the valve would be in a normally closed position, and that accidental leakage was prevented even if the power supply failed. When the fluid needed to be drained, the electromagnet could be activated, creating an electric field that would attract the metal plunger, pull it up (Figure 2), and let the fluid drain around it and out the bottom of the tubing. This would allow a bodily fluids bag to be emptied at the user's convenience, anywhere a floor drain is available.

There were many intriguing benefits for this design concept. It was intended to work with the leg bag and tubing components Mr. Egan already used. Cleaning would be minimal, since the cuff was completely outside the tubing, and would probably need little maintenance, the tubing was changed bi-weekly, and the metal plunger could be soaked in some sort of non-corrosive cleanser every time the tubing was changed. It met all of the customer design requirements. Most importantly, it appeared to be a new way of applying electromagnetism that had never been attempted before.

However, mathematically trying to calculate the magnetic force required to pull the magnet up proved that the idea probably was not very feasible. The forces acting on the plunger are its own weight, the weight of the fluid, and the force of friction along the sides of the tubing to create a tight seal. The magnetic force Fm would have to overcome all these forces.

$$(1)\ F_m > m_{plunger}g + m_{fluid}g + F_{friction}$$

Since the frictional force would have to be very large to ensure a leak-proof seal, the magnetic force required to overcome it would also need to be very large. And, the cup of the plunger would rub against the tubing all the way it was pulled up, never letting the fluid escape through. This meant that some sort of necked, funnel-like tubing would need to be used so that when the plunger was pulled to the up position, the tubing diameter would be larger and the cup of the plunger would not touch the tubing sides. However, this meant that Mr. Egan would have to use a different type of tubing. Although it was still feasible to find a new kind of tubing, it was difficult to determine the magnetic force the electromagnet would be required to produce. Since the friction coefficient for the tubing was unknown, the frictional force could not be mathematically determined. However, if we had actually built a prototype, we could have determined the conditions necessary for the prototype to work, and then derived the magnetic force using the following equations:

$$(2)\ F_m = is \times B$$
$$(3)\ F_m = B \times qV$$
$$(4)\ B = u_0 ni$$

where Fm is the magnetic force, *i* is the current supplied to the magnetic solenoid, s would be the distance between the plunger and magnet, B is the magnetic field strength, q is the constant value for the charge on an electron (1.6 x 10-19eV), V is the voltage supplied to the magnetic solenoid, u_0 is the permittivity of free space (4*pi*1x10-7), and n is the number of turns in the wire used to make the solenoid. Thus, the required strength of the electromagnet could be varied by changing the distance s between the plunger and magnet or changing the number of turns in the solenoid.

A prototype was never built because two additional problems became apparent with the design. First, the same magnetic field that pulled the plunger up would attract ions present in the urine, either eventually causing the tubing to clog up near the electromagnet or coating the plunger, making an even stronger magnetic force necessary. Secondly, the cap of the plunger would have to be perfectly round to create a tight seal; otherwise, if even a tiny nick were present on the side that met with the tubing, fluid would be able to leak through.

Figure 1:

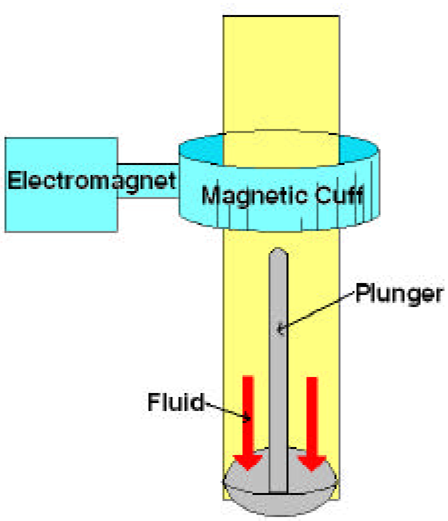

Figure 2: