Engineering World Health: Aspirator

C. Flanagan, J. Lundell, A. Rieves, M. Socie

Client: Robert Malkin, PhD[1] Advisor: Willis Tompkins, Ph.D[2]

[1]Duke University, Engineering World Health [2]University of Wisconsin-Madison, Department of Biomedical Engineering

Problem Statement

Challenge

- ❖Hospitals in developing world do not have functional suction apparatuses
- ❖Issue is the inability to maintain/power equipment

Project Goals

- ❖Design a suction device to perform intrasurgically
  - ·Low maintenance
  - ·Low cost
  - ·Built entirely from locally available materials

Aspirators in Clinical Settings

- ❖Remove bodily fluids
- ❖Critical in operating rooms and clinical care
- ❖Compact, powerful
  - ·87 KPa (gauge) at 26 L/min[1]
- ❖Expensive (>$300)
- ❖Require a technician to repair

Previous Semester

Design Features

- ❖Motor: car heater fan + 12 VDC car battery
- ❖Suction: piston-based
  - ·Radial to linear motion conversion
  - ·One-way valves define flow direction

Performance

- ❖10 KPa (gauge) suction
- ❖1.5 L/min water flow rate
- ❖$52.74

Figure 1. *Fall 2007 EWH Aspirator prototype.*

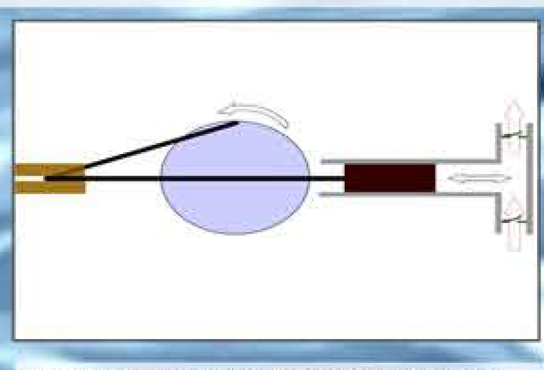

Figure 2. *Fall 2007 EWH Aspirator prototype operation mechanism.*

Design Constraints[1,7]

- ❖60 KPa (gauge) vacuum
- ❖ >10 L/min suction of air
- ❖Total cost <$100 USD
- ❖Receive power from 12 VDC battery
- ❖Entirely buildable from locally available materials
  - ·Simple assembly
- ❖Minimal, simple maintenance
- ❖Autoclavable suction tip & collection vessel
- ❖Compatible with manual backup

Abstract

Most developing world hospitals do not possess operating suction machines; yet, they are required for many procedures. The main problems are the lack of available parts, the cost of a replacement unit, and dependence on consistent electricity. We designed an aspirator that uses a water jet eductor, constructed with low cost, locally available materials, that produces suction when connected to a garden hose and water line. We achieved maximum vacuum pressure of 58 KPa (gauge) and pulled maximums of 20 lpm of air or 3.2 lpm of water.

Competing Products

Figure 3. *Commercial water jet eductors*[2]

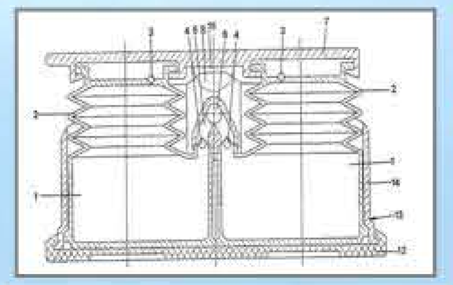

Figure 4. This design makes use of a bellows design to create suction[3]. *(U. S. Patent No. 5,934,888)*

Figure 5. *Commercial medical aspirator*[4]

Patient Safety

- ❖ Materials are sterilization compatible
- ❖ Eductor shut-off valve
- ❖ Back-flow prevention valve
- ❖ Fenestrated, autoclavable suction tip

Final Design

Figure 6: *Final image of eductor design*

Mechanism

- ❖ Water jet creates pressure differential
- ❖ Air drawn in through port evacuates collection vessel
- ❖ Fluid drawn in at suction tip to fill collection vessel

Theory

- ❖ Venturi principle[5]
- ❖ Continuity equation

$$\frac{v^2}{2} + gh + \frac{p}{\rho} = constant$$

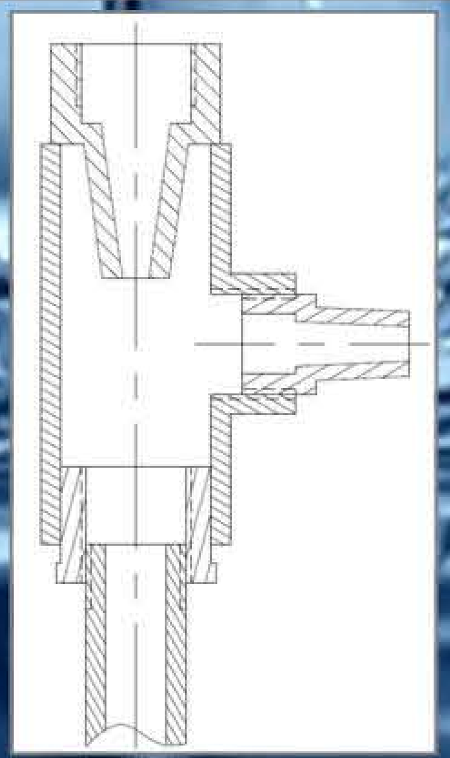

Figure 7: *Cross-sectional view of eductor*

Features

- ❖ PVC constructed eductor
- ❖ Brass fittings
- ❖ Modified polypropylene pipette tips
- ❖ Nalgene collection vessel
- ❖ Flexible tubing
- ❖ Garden hose

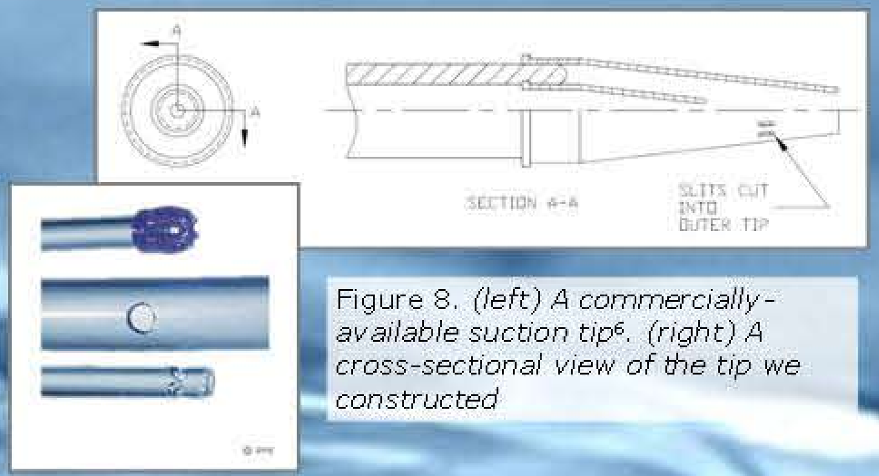

Figure 8. *(left) A commercially-available suction tip*[6]*. (right) A cross-sectional view of the tip we constructed*

Advantages

- ❖ Efficient energy transfer
- ❖ Pressure requirements
- ❖ Flexible material selection
- ❖ No pump necessary

Disadvantages

- ❖ Bulky OR integration
- ❖ Some assembly required
- ❖Requires reliable water line access

Testing

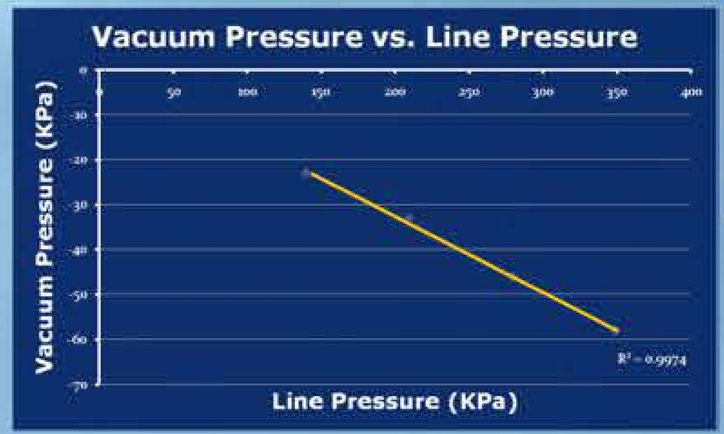

Figure 9. *Vacuum Pressure vs. Line Pressure. This graph shows the vacuum pressure (KPa) produced by the prototype as a function of the line pressure (KPa) powering it.*

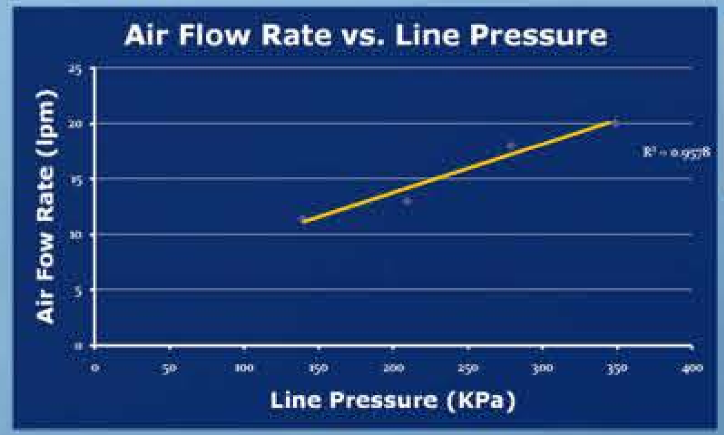

Figure 10 *Air Flow Rate vs. Line Pressure. This graph shows the rate that the prototype aspirates air (lpm) as a function of the line pressure (KPa) powering it.*

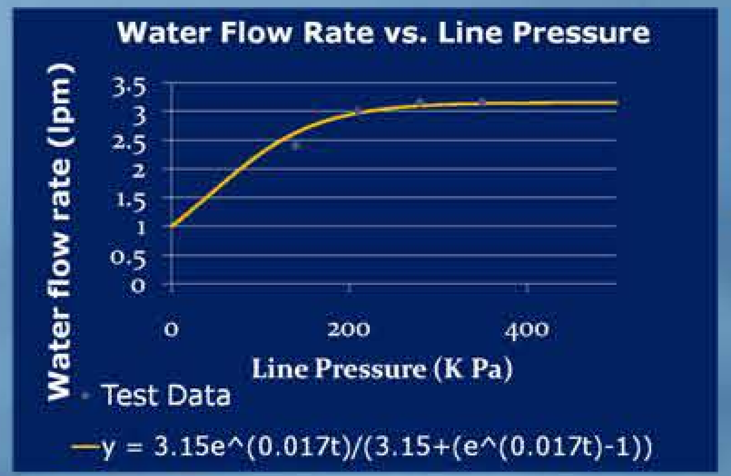

Figure 11. *Water Flow Rate vs. Line Pressure. This graph shows the rate that the prototype aspirates water (lpm) as a function of the line pressure (KPa) powering it.*

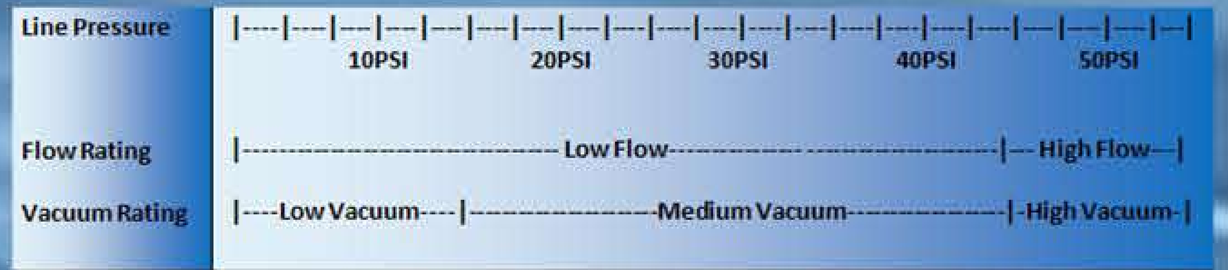

Figure 9. *Aspirator classification. Classifications based on ISO standards for medical suction devices.*[7]

Future Work

- ❖ Optimize water recycling
- ❖ Submit to EWH
- ❖ Clinical testing

References

1. "Engineering World Health." (2008). Online. http://www.ewh.org
2. "Eductors" (2008) Online. http://www.millerplastics.com
3. Marka et al. (1999). U.S. Patent No. 5,934,888. Washington, D.C.: U.S. Patent and Trademark Office.
4. "Portable vacuum aspirator." (2008). Online. http://outlet.med1online.com
5. "Venturi Effect." (2008). Online. http://en.wikipedia.org/wiki/Venturi_effect
6. "Argyle Yankauer Suction Machine Tip." (2008). Online. http://www.specialty-medical.com/suction-machines.html
7. ISO 10079-1:1999. Medical suction equipment – Part 1: Electrically powered suction equipment. Safety requirements.

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