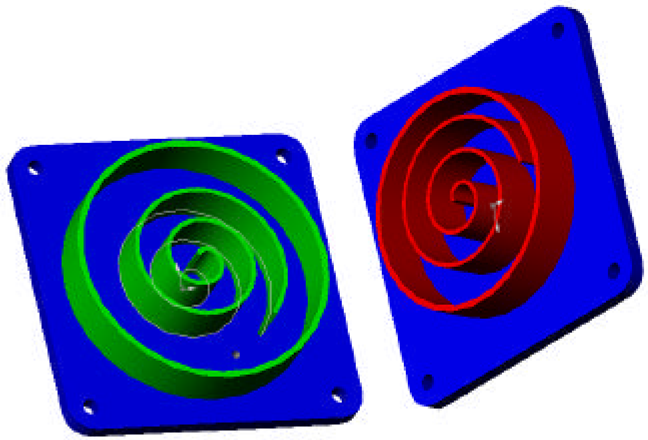
MESO SCALE SCROLL PUMP



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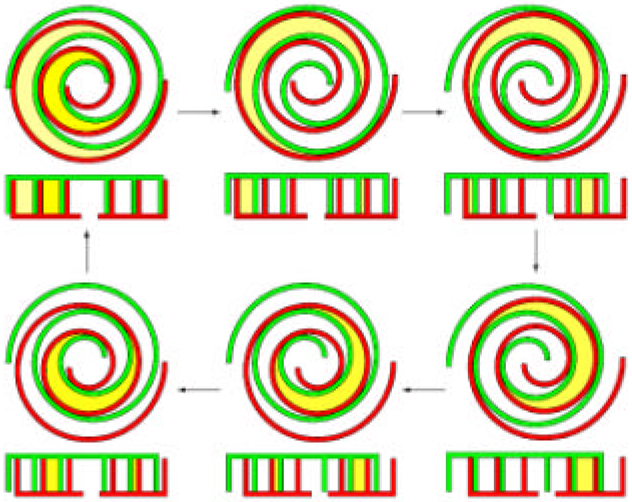
2nd NASA/JPL Minature
Vacuum Pumps Workshop

Overview

- Introduction
- Advantages and Disadvantages
- Scroll Pump Basics
- Predicted Performance
- Experimental Setup
- Conclusions

Introduction

- Invented in 1905 by Leon Creux
- Works by compressing and moving pockets of gas along the fixed scroll
- Oil free pump



Potential Advantages

- Simple concept
- Easily staged
- Only need a few stages to get desired pressure ratio

Potential Disadvantages

- Wears quickly
- Moving parts
- Tolerances need to be very small

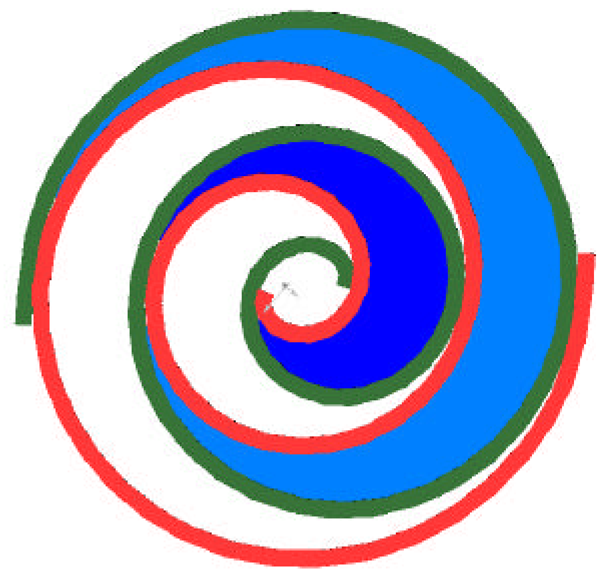
Physical Properties

- Volume of the trapped gas.

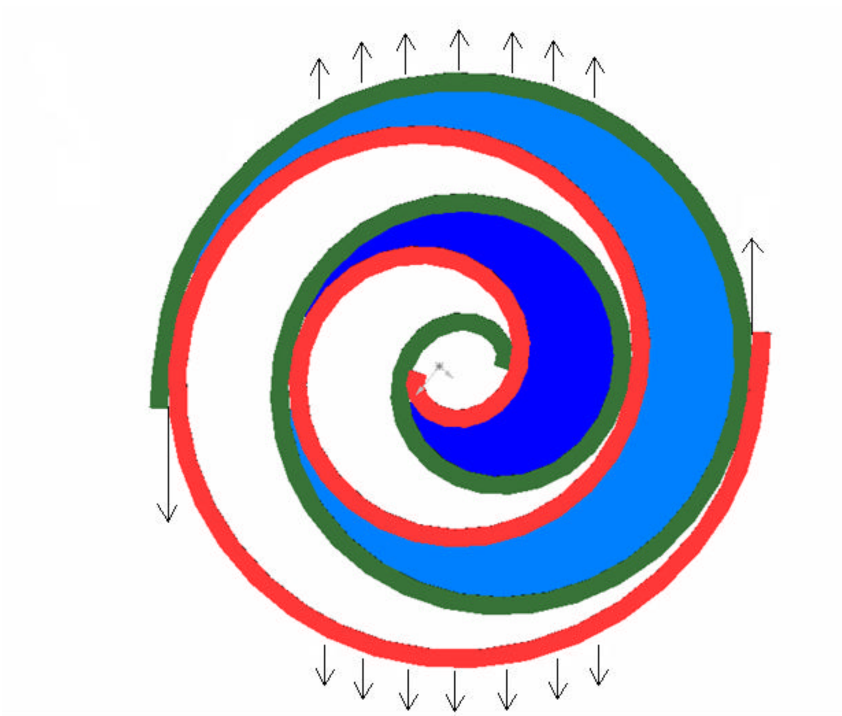
$$V\ ?\ \frac{1}{2} ? ? r^{2}\ ?\ r ? s(?\ ?\ 2?)\ ?\ s(?) ? ? H$$

- Arc length

$$s(?)\ ?\ \int_{0}^{?} ?(u)\,du$$



Leakage



- Top and Bottom Leak

$$C_{LTB} ? ? A_{SC} \sqrt{\frac{kT}{2?m}}$$

- End Leak

$$C_{LE} ? A_{E} \sqrt{\frac{kT}{2?m}}$$

- Total Leak

$$C_{L} ? 2(C_{LTB} ? C_{LE})$$

Governing Equations

Pumping Speed

$$S_p ? 2 f_D V_{TI} ? ?\frac{n(?)}{n_I} ? 1? C_L$$

$$\frac{n(?)}{n_I} ? P(?) ? \frac{P_G(2?) ? \frac{C_L ?\frac{n_E}{n_I} ? 1?}{2 f_D V_T(2?)} ? 1}{2 ? \frac{C_L}{f_D V_T(2?)}}$$

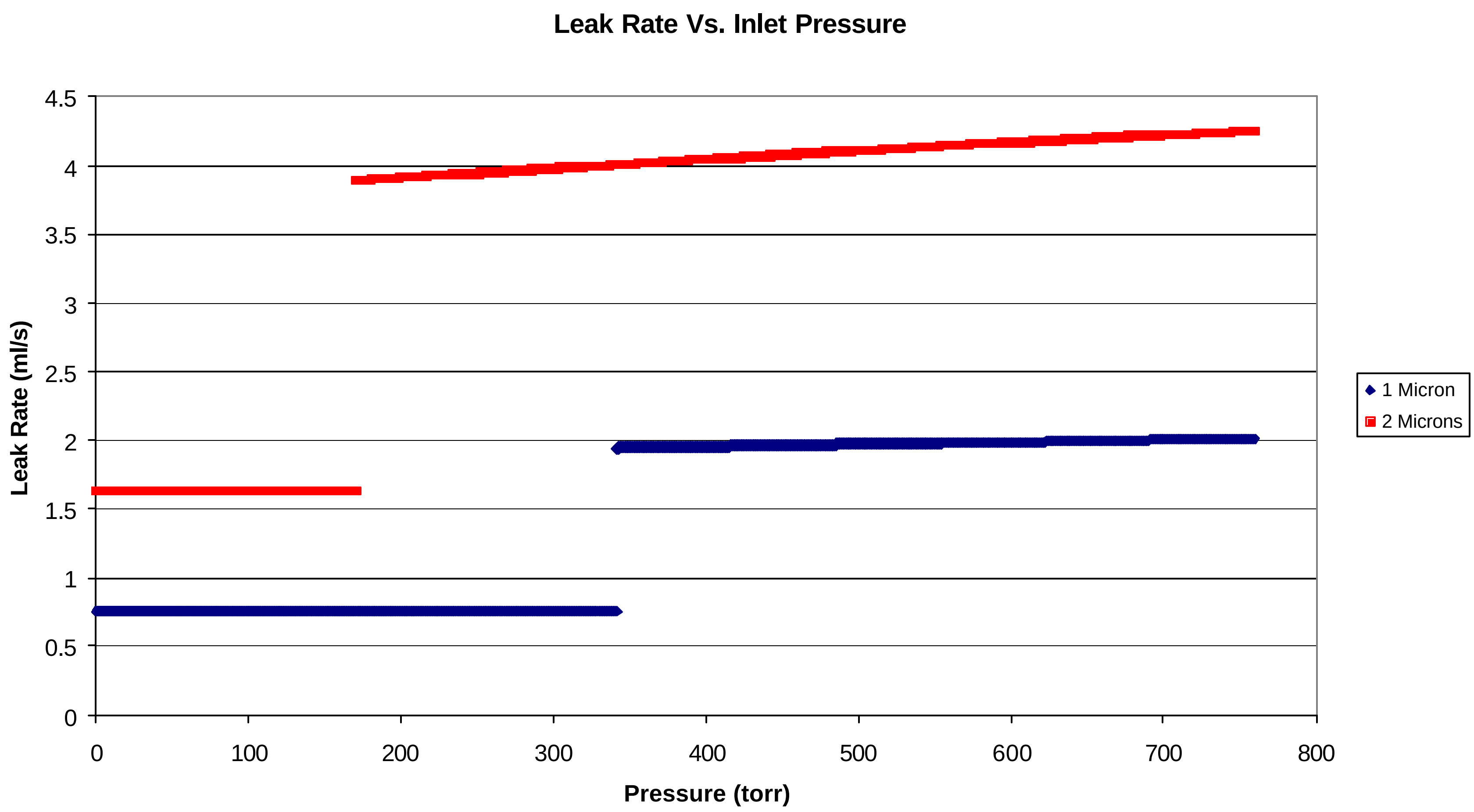
$$S_{p\max} ? 2 f_D V_{TI} ? ?\frac{P_G(2?) ? \frac{C_L}{f_D V_T(2?)} ? 1}{2 ? \frac{C_L}{f_D V_T(2?)}} ? 1? C_L$$

Maximum Pumping Speed

$$?\frac{n_E}{n_I} ? 1?$$

Maximum Pressure Ratio $?S_p ? 0?$

$$P_{E\max} ? ??\frac{2 f_D V_{TI}}{C_L} ? 1??2 ? \frac{C_L}{2 f_D V_T(2?)}?? P_G(2?) ? 1?\frac{2 f_D V_T(2?)}{C_L} ? 1$$

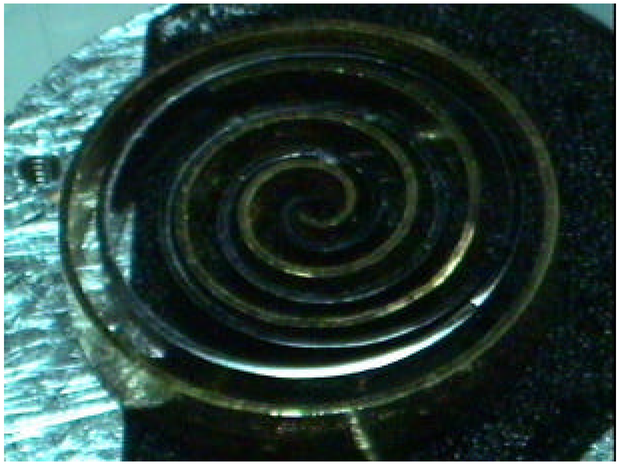


Leak Rate Vs. Inlet Pressure
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
100
200
300
400
500
600
700
800
Leak Rate (ml/s)
Pressure (torr)
1 Micron
2 Microns

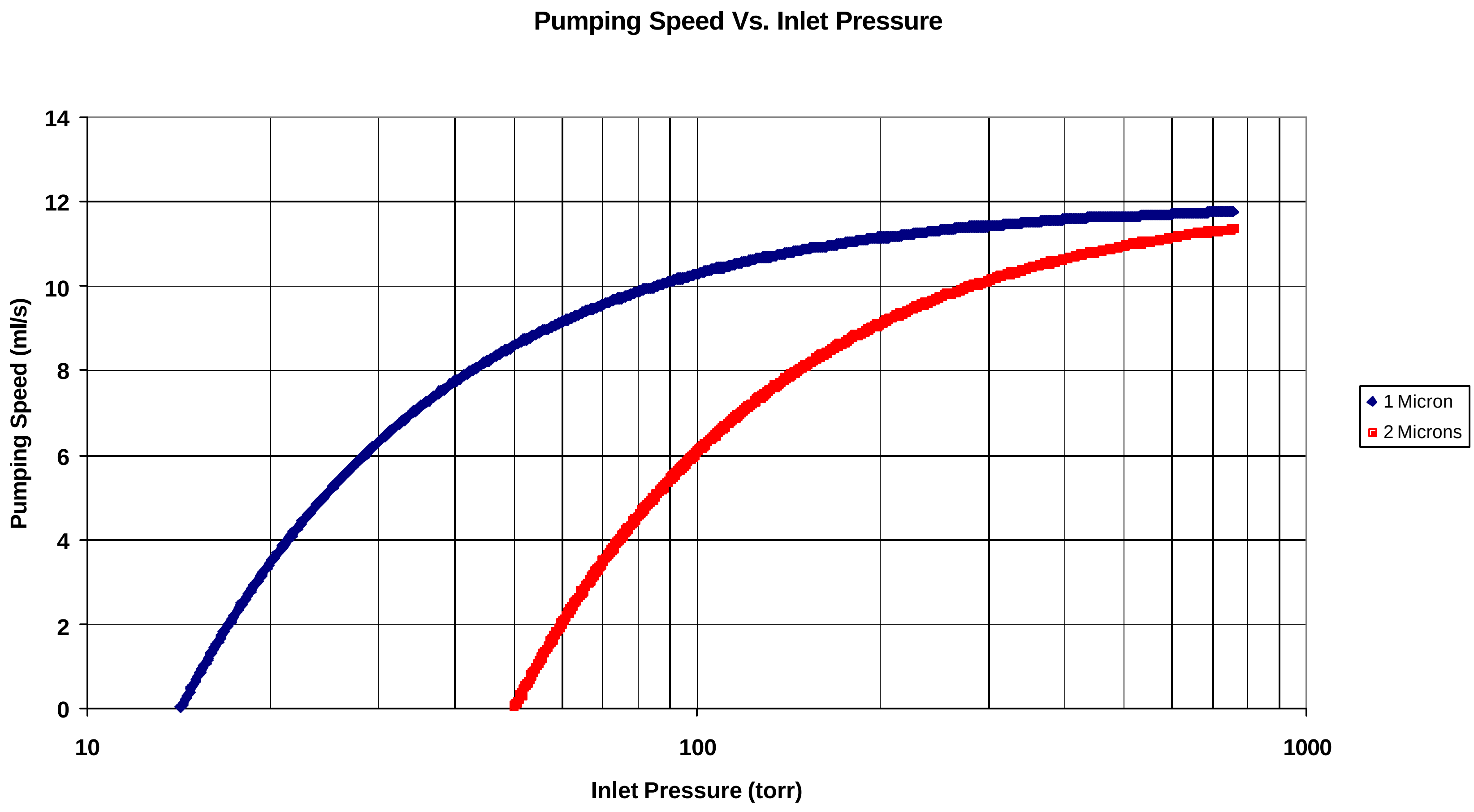
Scroll Pump

- One Stage (~6mm Radius)
- 2.5 Turns
- Operating at 100 cycles per second

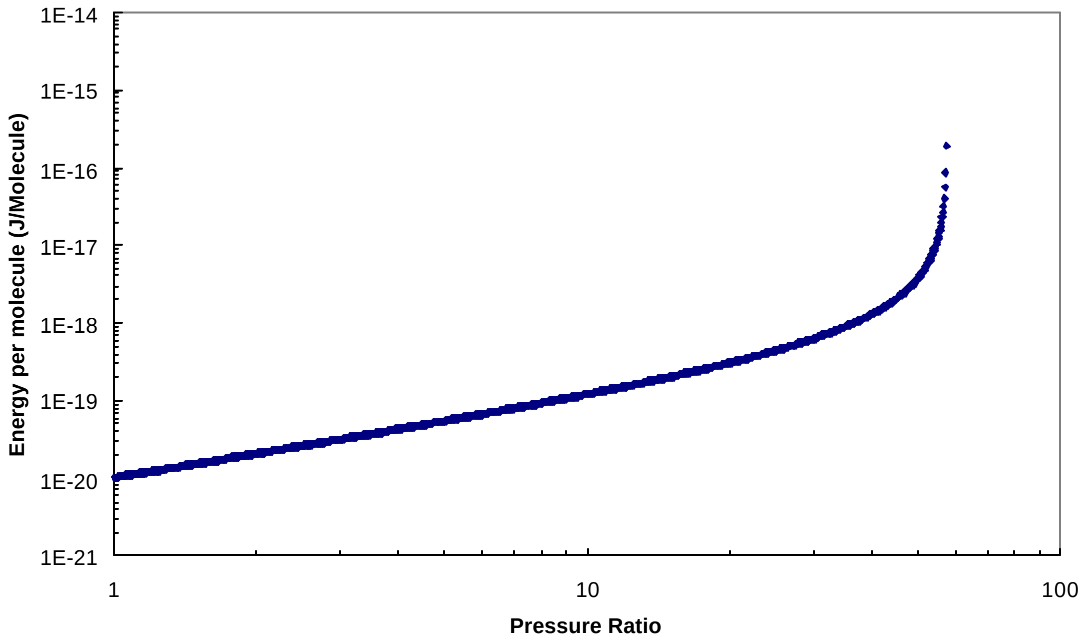
- **Estimated Performance**
- Maximum pumping speed 11.75 ml/s
- Ultimate Pressure ~14 torr



Pumping Performance

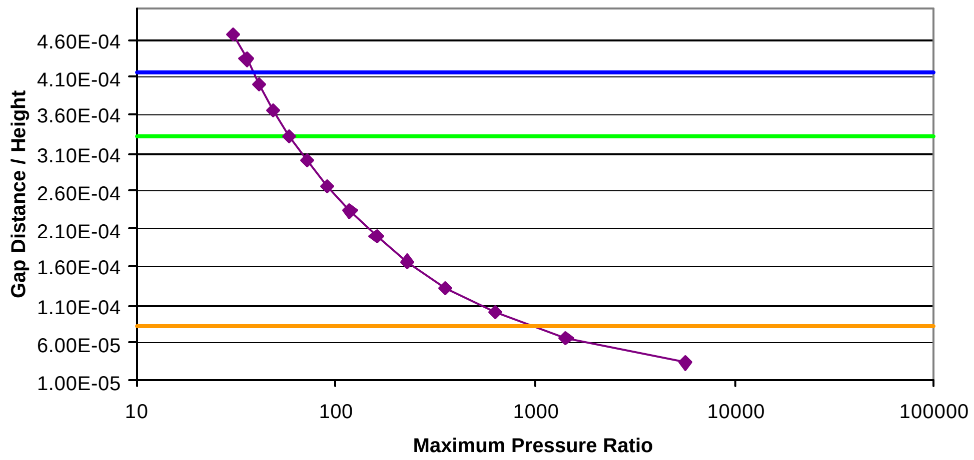


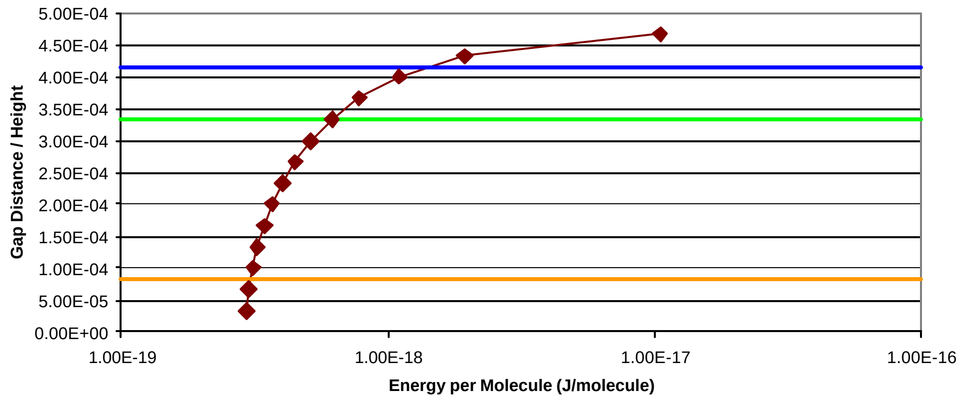
Power Requirements



- Sapphire base and nickel scrolls. ? $_k$? 0.15
- One Stage at 100 Hz and 1 Micron gap
- Operating power 2-3 Watts

- Importance of characteristic gap size
- Small decrease in gap distance results in a large change in pressure ratio and energy per molecule
- Large gap distances equals poor performance
- Orange line is one quarter micron gap distance
- Green line is one micron gap distance
- Blue line is one and a quarter micron gap distance





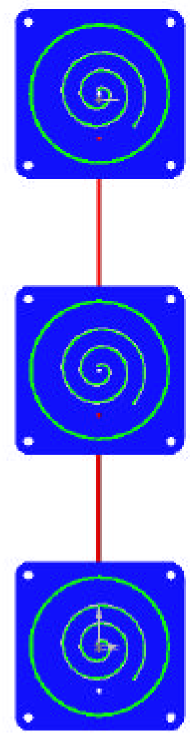
Staging

- Conservation equations

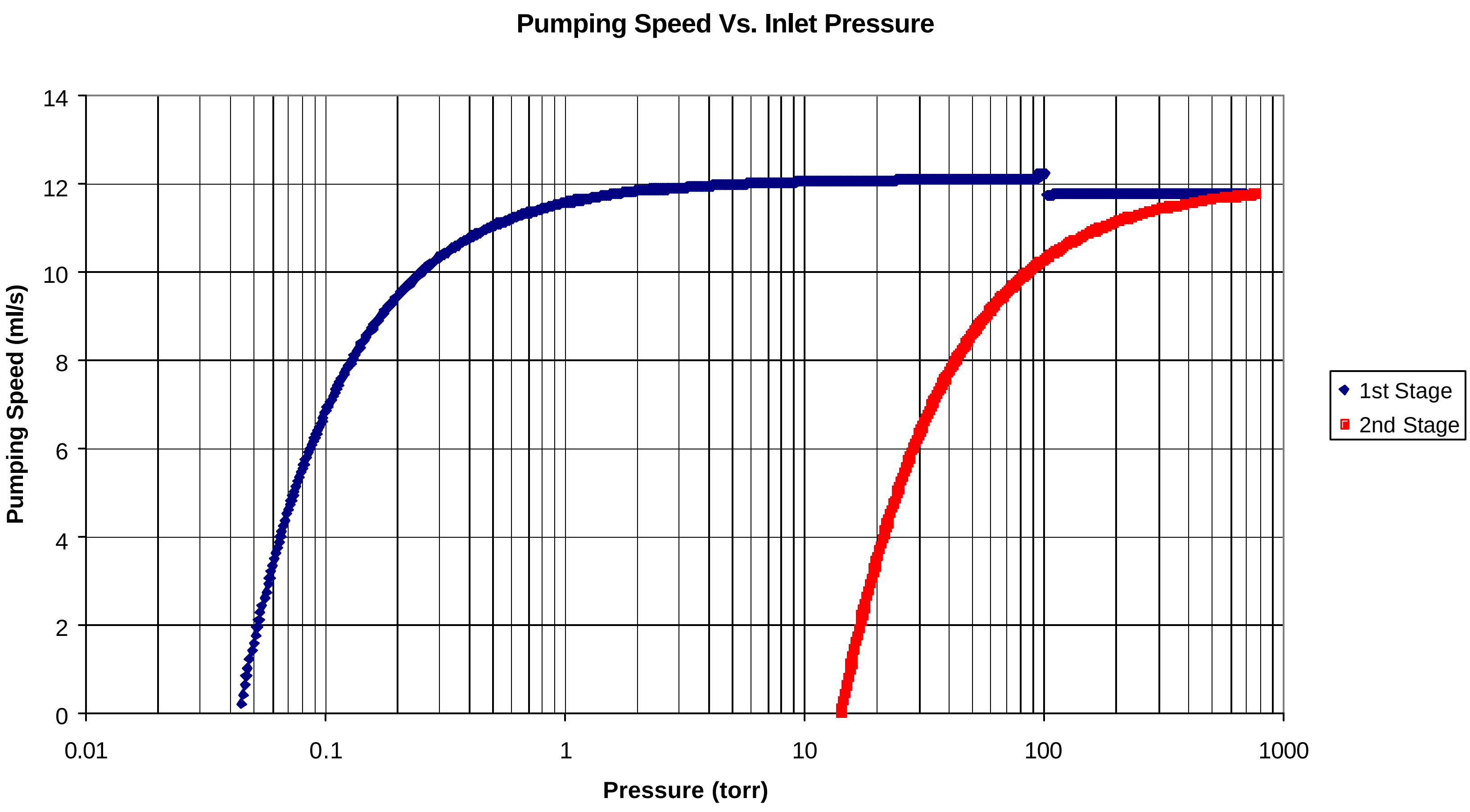
$$n_I S_{p1} \; ? \; n_{1?2} S_{p2}$$

$$n_{1?2} S_{p2} \; ? \; n_{2?3} S_{p3}$$

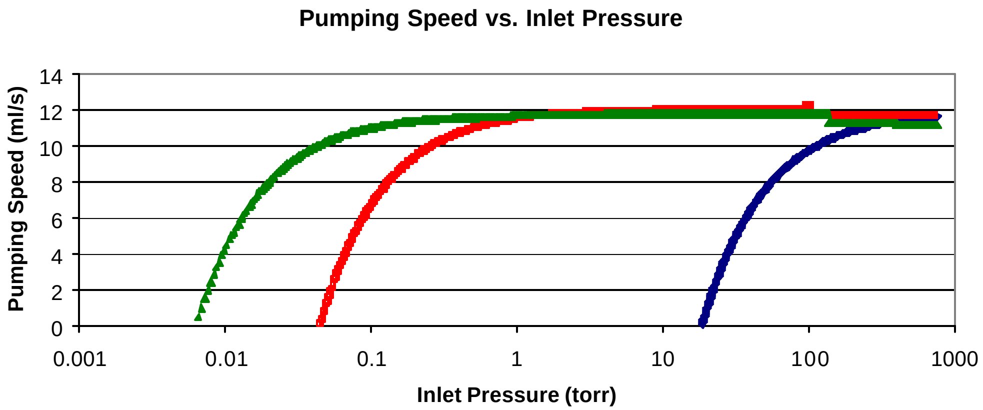
- Provides greater overall pressure ratio

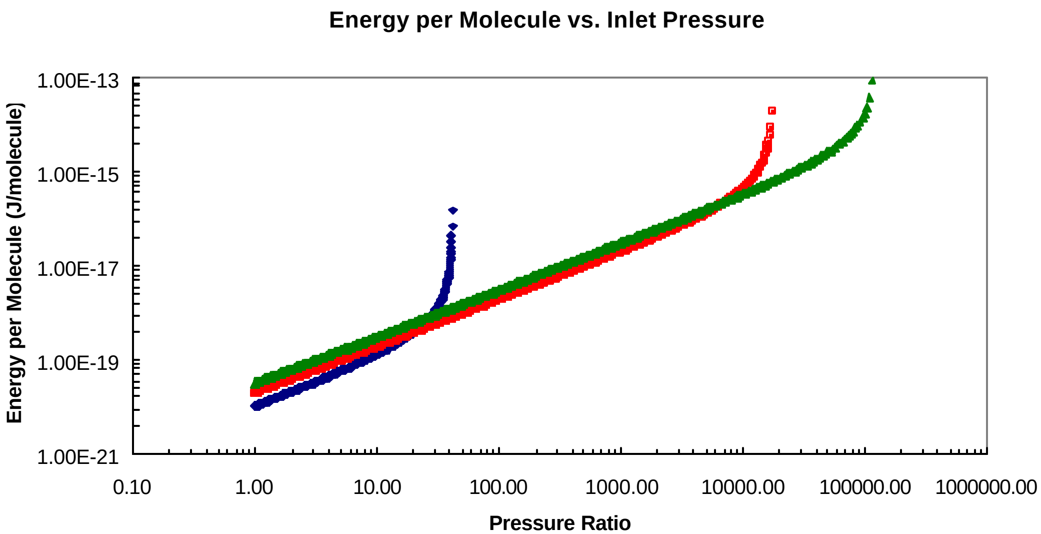


2 Stages


Pumping Speed Vs. Inlet Pressure
Pumping Speed (ml/s)
14
12
10
8
6
4
2
0
0.01
0.1
1
10
100
1000
Pressure (torr)
1st Stage
2nd Stage

- Blue: 1 Stage
- Red: 2 Stages
- Green: 3 Stages
- Very large pressure difference between 1 and 2 stages.
- 10 millitorr is the pumping limit for a scroll pump
- 3 stages is the ideal design

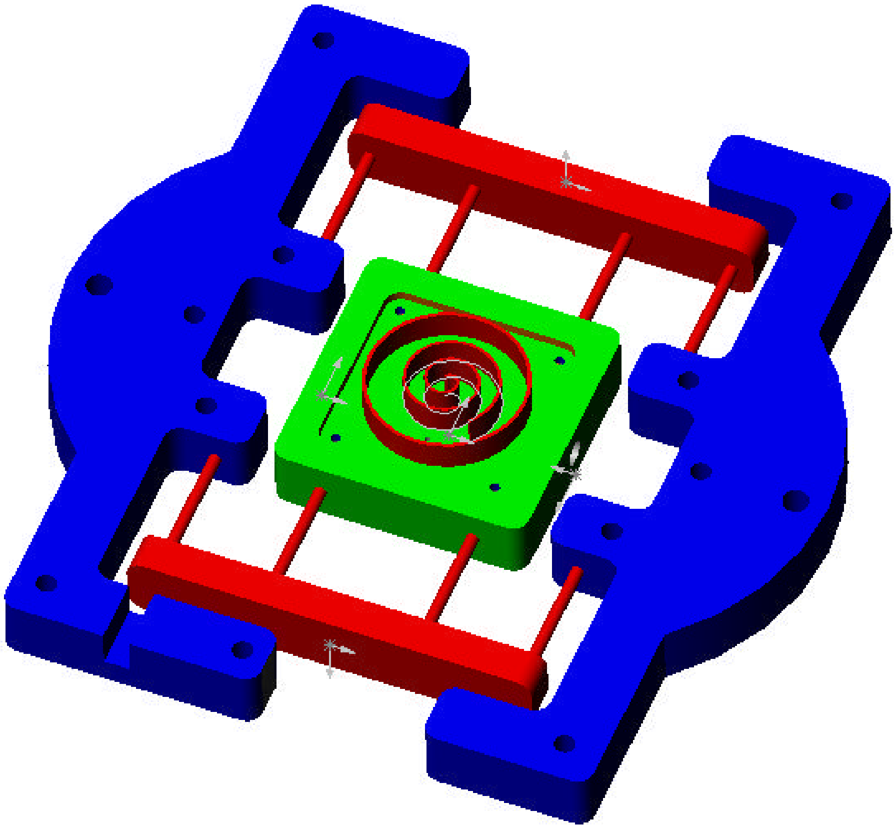




Stage Comparison

# of stages	1 stage	2 stages	3 stages
Energy efficiency (J/molecule)	6.74e-17	9.53e-15	3.86e-14
Volume efficiency (m^3/#/s)	1.39e-24	9.77e-23	2.65e-22
Ultimate pressure (torr)	14.85	0.044	0.007
Operating power (W)	2.5	4.8	7.2

Experimental Setup



What Next?

- Compare computer code with a large scale scroll pump
- Compare results with experimental pumping performance
- Design a compact scroll pump driver
- Test multiple scrolls (staging)