Fluidic and Microfluidic Pumps, Micropumps, Compressors, Fans and Blowers

an Overview

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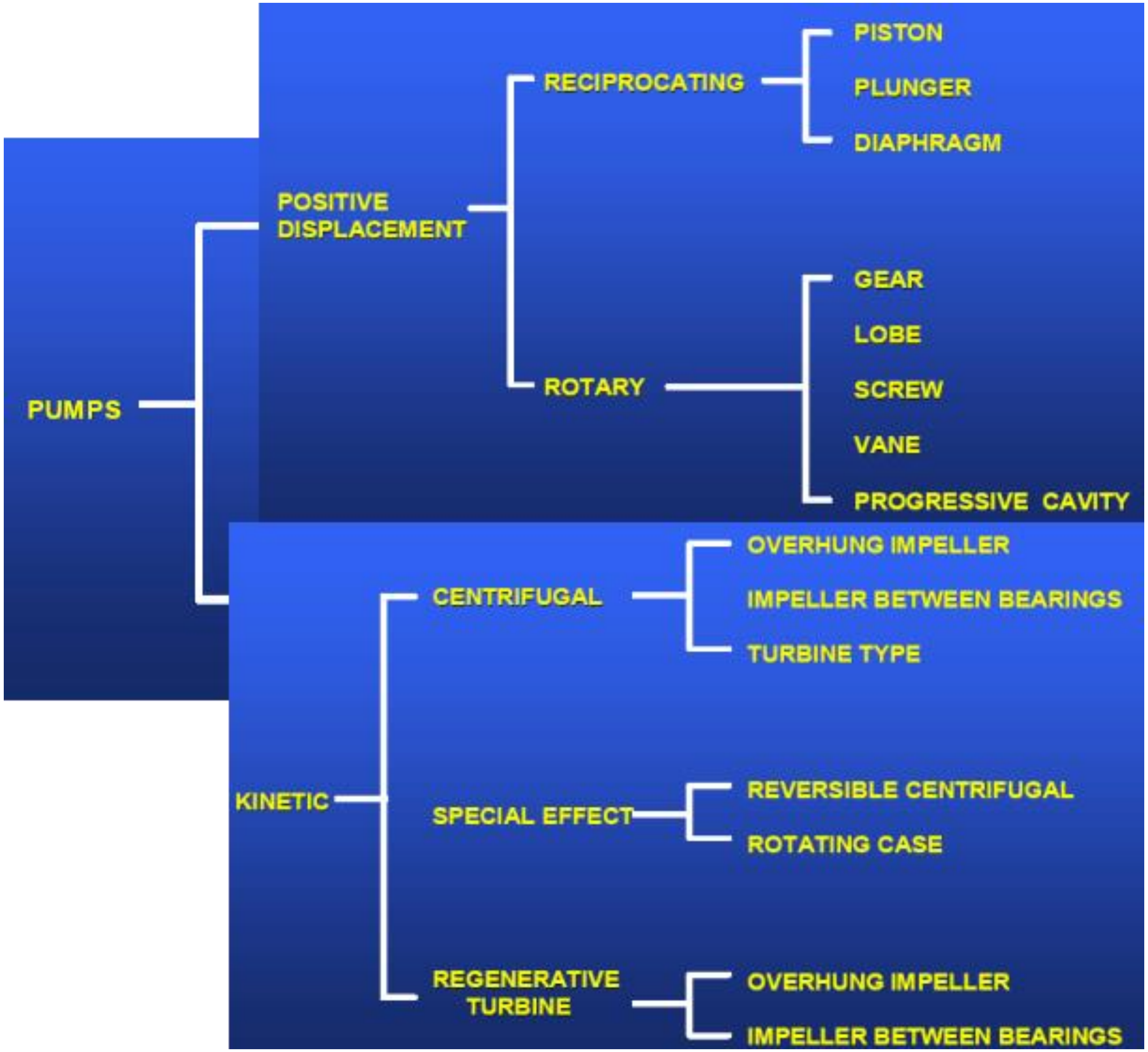
Pumps, Fans, Compressors and Blowers Increase Fluid Energy

1. Velocity – Kinetic Energy
   a) Fans
   b) Propulsion Propellers

2. Pressure – Internal Energy – Enthalpy - Heat
   a) Pumps
   b) Compressors

2. Velocity and Pressure – Some of Both
   a) Pumps
   b) Blowers

Types of Pumps, Fans, Compressors and Blowers



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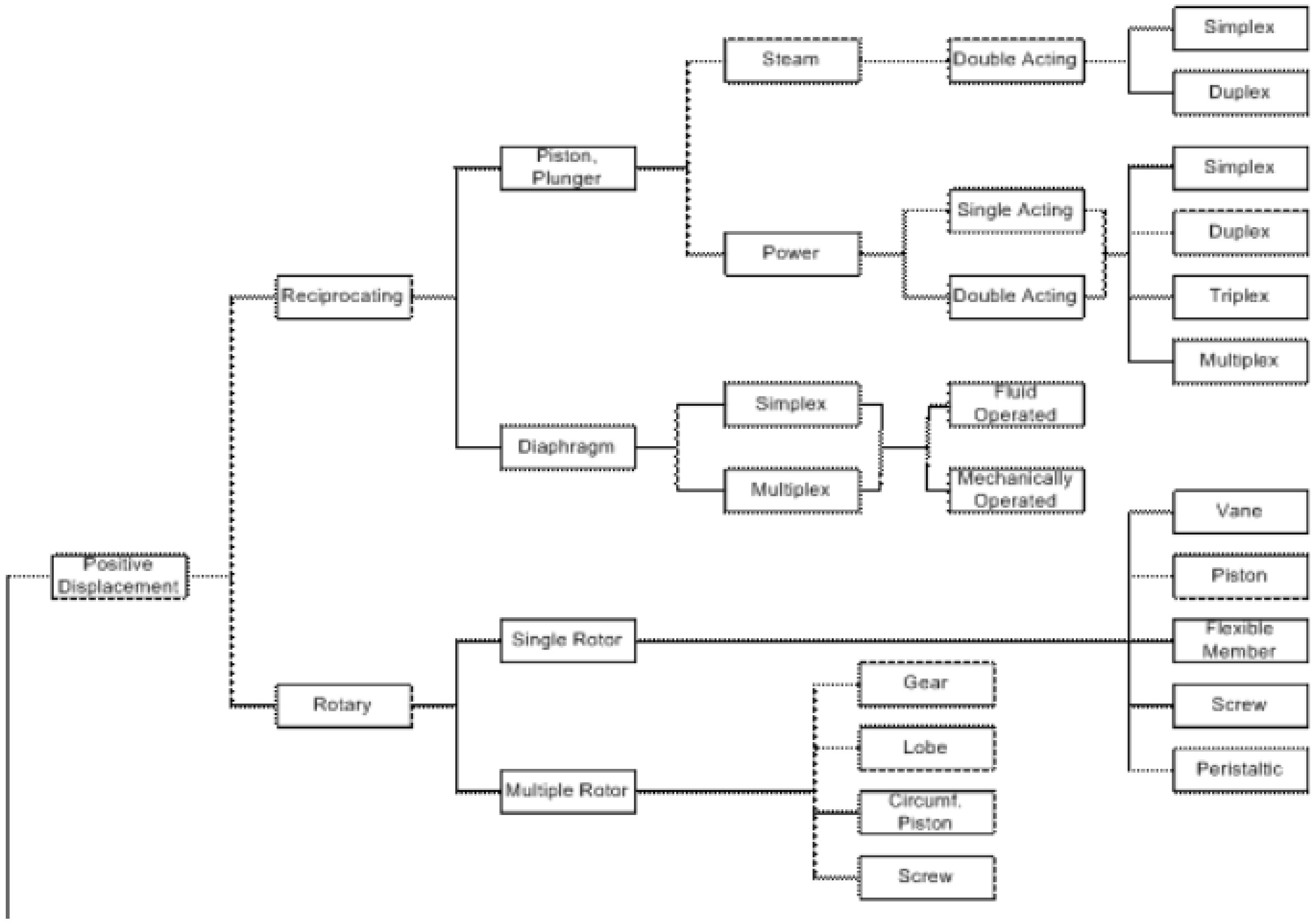

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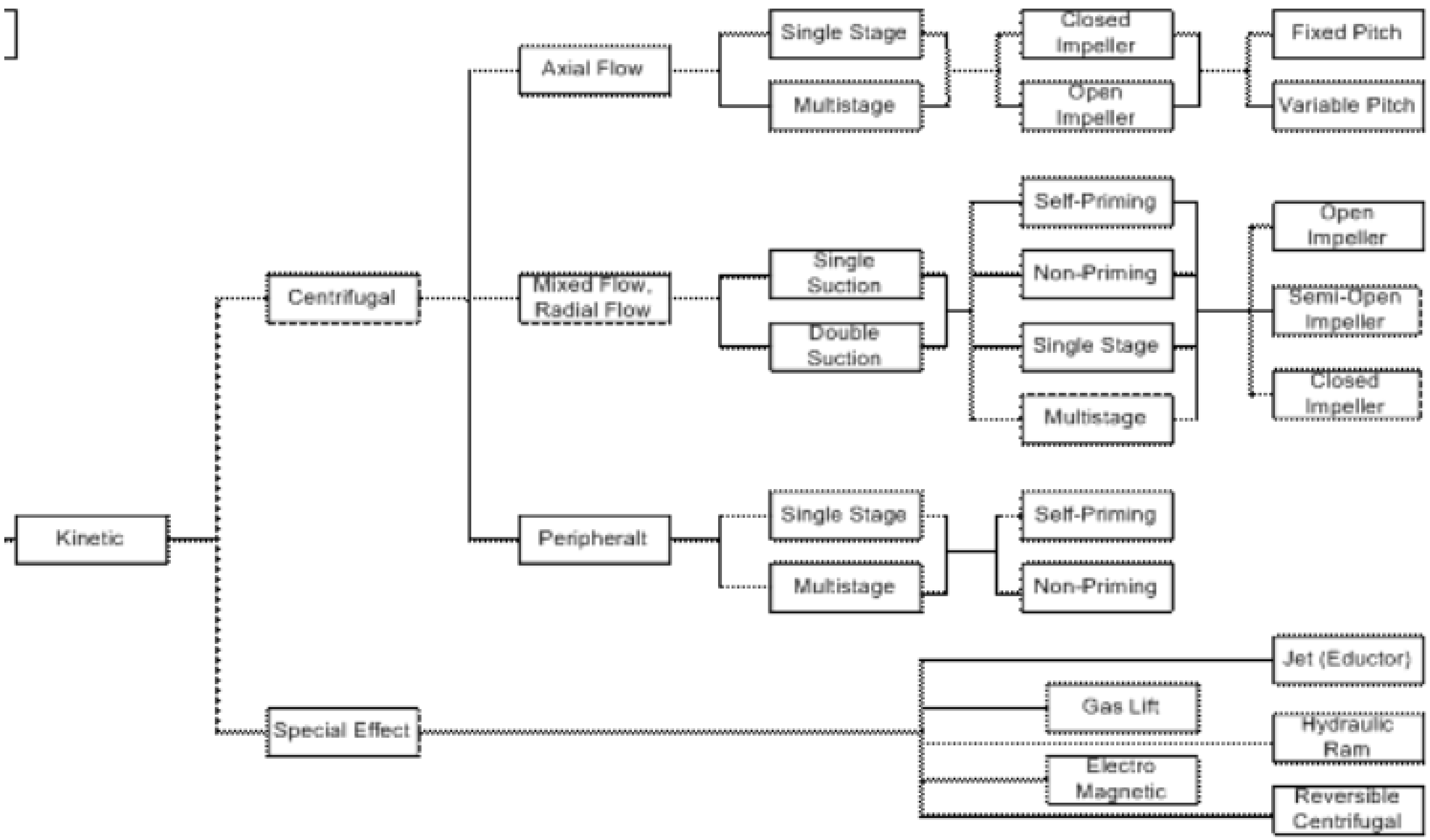
Types of Pumps, Fans, Compressors and Blowers



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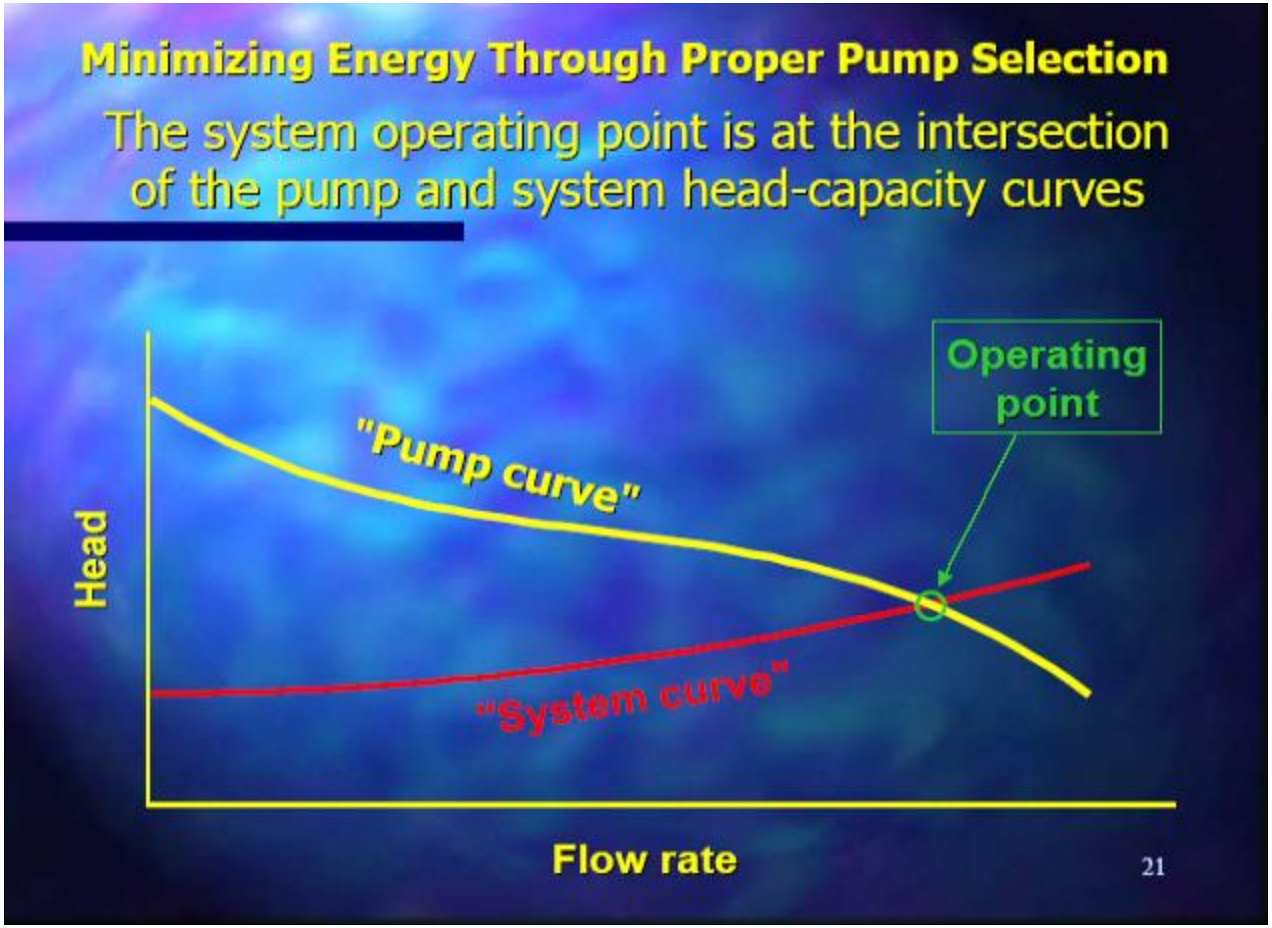
Pump Performance Trade offs

Parameter	Centrifugal Pumps	Reciprocating Pumps	Rotary Pumps
Optimum Flow and Pressure Applications	**Medium/High Capacity, Low/Medium Pressure**	**Low Capacity, High Pressure**	**Low/Medium Capacity, Low/Medium Pressure**
Maximum Flow Rate	**100,000+ GPM**	**10,000+ GPM**	**10,000+ GPM**
Low Flow Rate Capability	**No**	**Yes**	**Yes**
Maximum Pressure	**6,000+ PSI**	**100,000+ PSI**	**4,000+ PSI**
Requires Relief Valve	**No**	**Yes**	**Yes**
Smooth or Pulsating Flow	**Smooth**	**Pulsating**	**Smooth**
Variable or Constant Flow	**Variable**	**Constant**	**Constant**
Self-priming	**No**	**Yes**	**Yes**
Space Considerations	**Requires Less Space**	**Requires More Space**	**Requires Less Space**
Costs	**Lower Initial Lower Maintenance Higher Power**	**Higher Initial Higher Maintenance Lower Power**	**Lower Initial Lower Maintenance Lower Power**
Fluid Handling	**Suitable for a wide range including clean, clear, non-abrasive fluids to fluids with abrasive, high-solid content. Not suitable for high viscosity fluids Lower tolerance for entrained gases**	**Suitable for clean, clear, non-abrasive fluids. Specially-fitted pumps suitable for abrasive-slurry service. Suitable for high viscosity fluids Higher tolerance for entrained gases**	**Requires clean, clear, non-abrasive fluid due to close tolerances Optimum performance with high viscosity fluids Higher tolerance for entrained gases**

Fluidic System Pressure vs. Flow Curve

Determines the type of Pump Needed

Typical Pump Operating Curves



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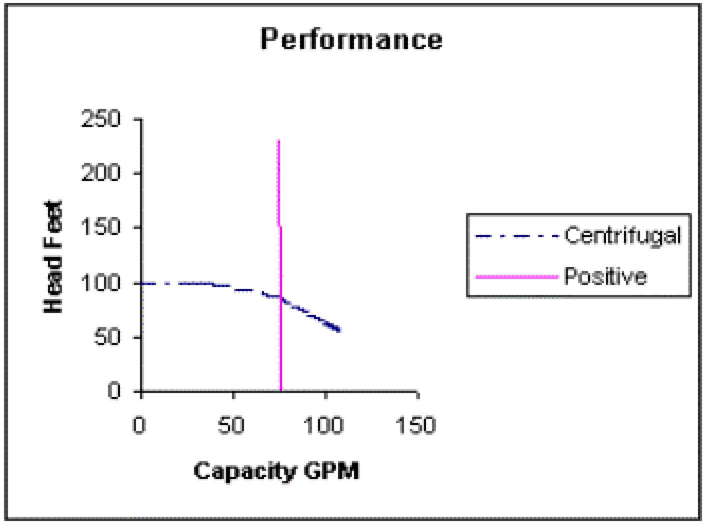
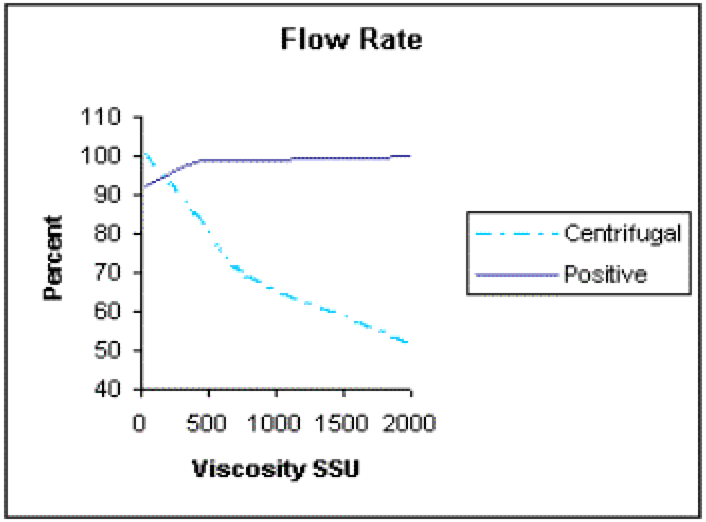
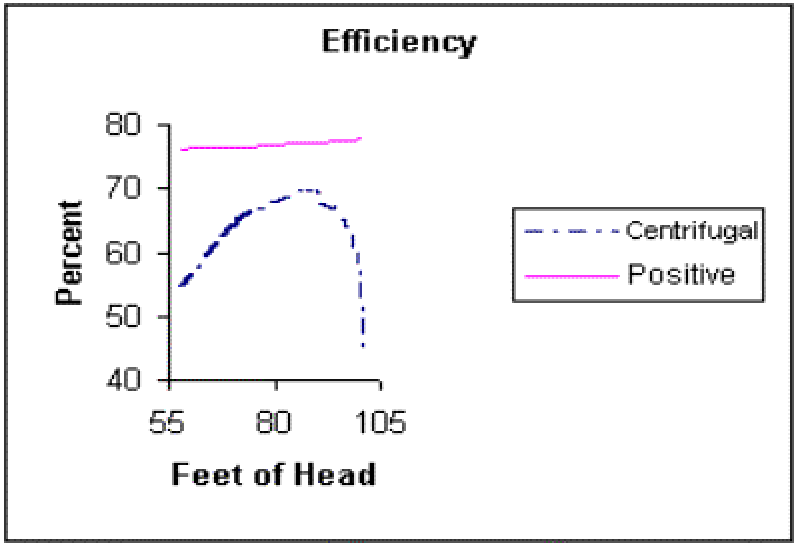
Typical Pump Operating Curves







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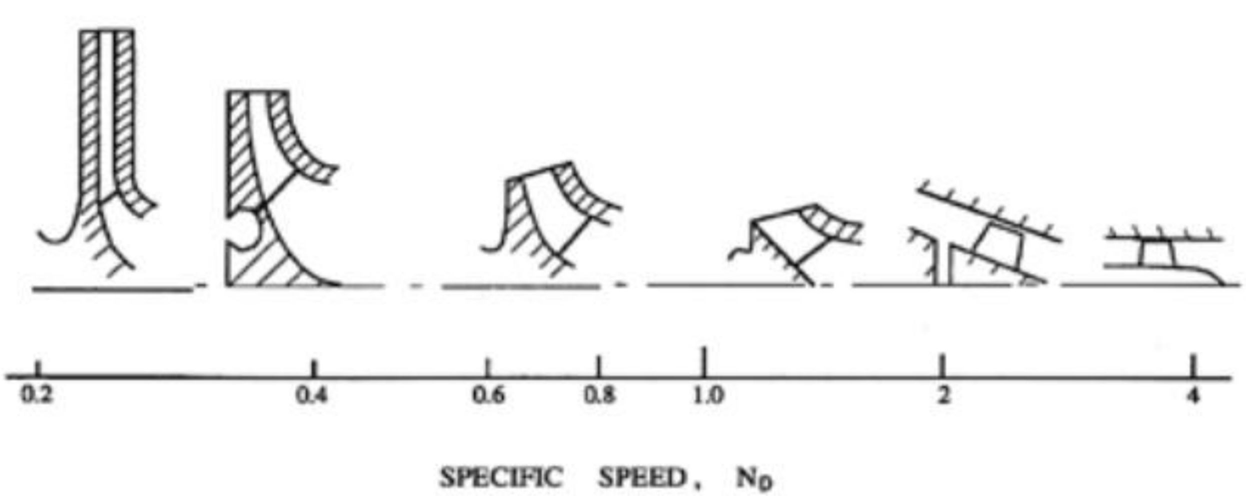
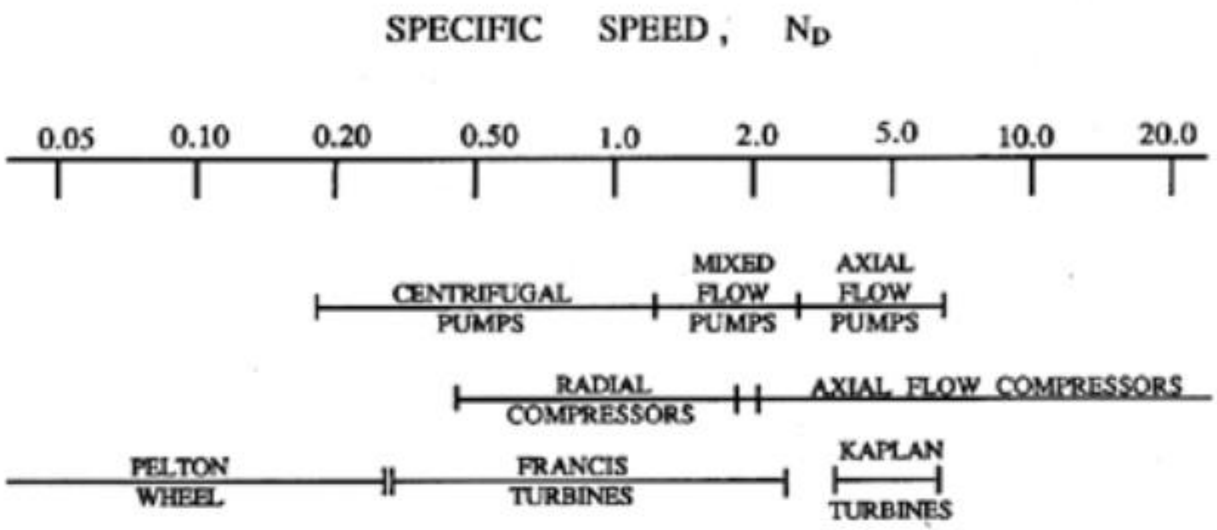
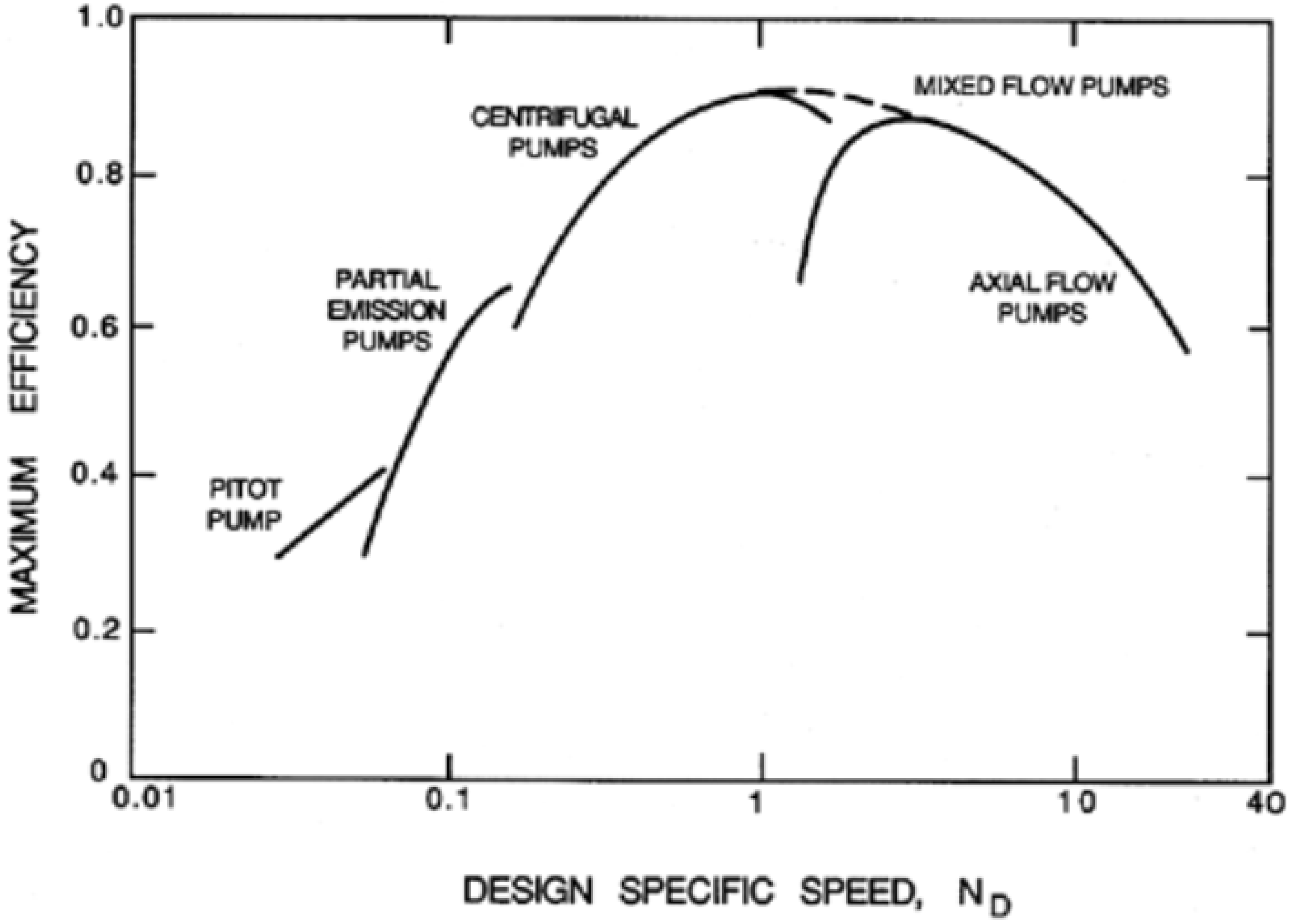
Fan and Blower Geometries





Pump Type Efficiencies



Some General Pump Theory

BERNOULLI'S THEOREM

- The Bernoulli equation is a special statement of the **general energy equation**
- Work added to the system is referred to as pump head (h_P)
- Losses from the system are referred to as head loss (h_L)
- Pressure (lbf/in^2) is a form of work
- Strictly Mechanical Energy so we get the equation:

$$\mathbf{P_1 + PE_1 + KE_1 + WK = PE_2 + KE_2 + WK_{FRIC} + P_2}$$

BERNOULLI'S Equation

$$Z_1 + (P_1/\gamma) + (V_1^2/2g) = Z_2 + (P_2/\gamma) + (V_2^2/2g) + h_P - h_L$$

Z : Elevation (ft)

P : Pressure (lb/ft^2)

γ : Density (lb/ft^3)

V : Velocity (ft/sec)

g : acceleration (32.2 ft/sec^2)

Hp: pump head (ft)

H_L: Head Loss (ft)

$= f(L/D)(V^2/2Zg)$

where

f : friction factor

L: Length

D: Diameter

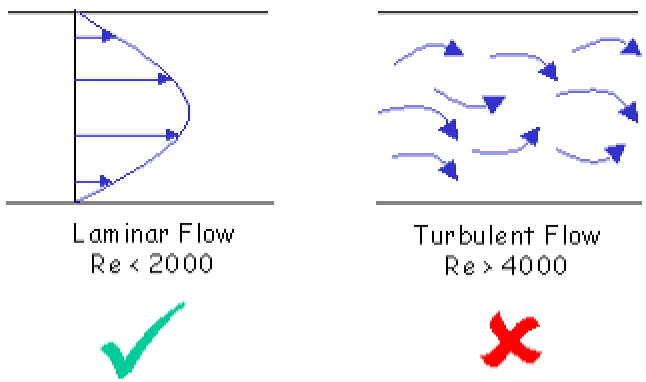
Fluidic Design Equations – Bernoulli Again

$$Z_1 + \frac{p_1}{\rho g} + \frac{V_1^2}{2g} + h_p - h_f = Z_2 + \frac{p_2}{\rho g} + \frac{V_2^2}{2g}$$

$$\dot{W} = p_2 Q$$

$$Z_1 + \frac{p_1}{\rho g} + \frac{V_1^2}{2g} + h_p - h_m - h_f = Z_2 + \frac{p_2}{\rho g} + \frac{V_2^2}{2g}$$

$$h_p = \textit{Pumphead gain} = \frac{\dot{W}_p}{\rho g Q}$$



$$h_m = \textit{Motor head loss} = \frac{\dot{W}_m}{\rho g Q}$$

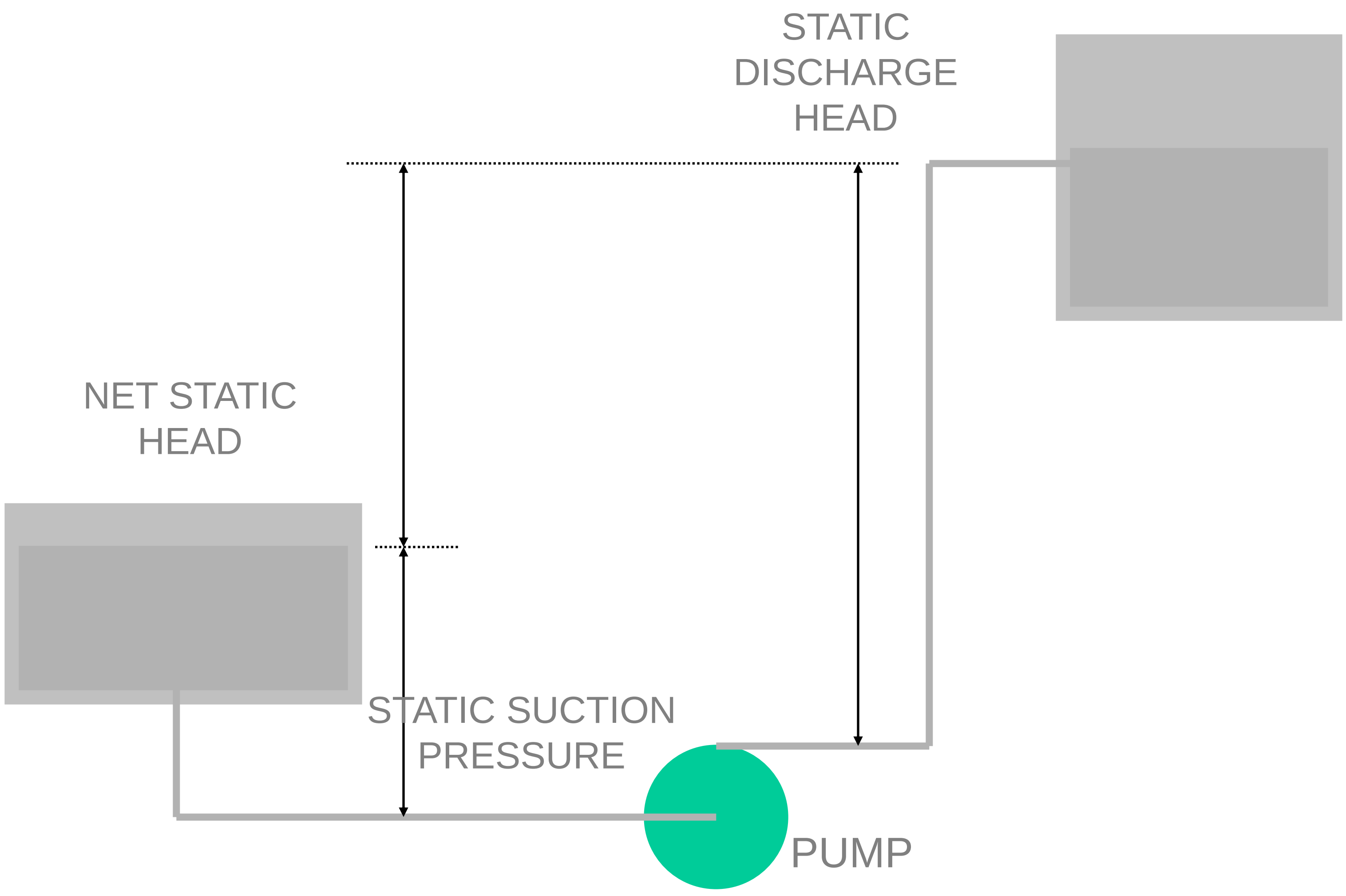
$$h_f = \textit{Frictional losses} = f \frac{L}{d} \frac{V^2}{2g}$$

$$f = \textit{Friction Factor} = \frac{64}{\mathrm{Re}} \quad \textbf{for laminar flow}$$

THE CONCEPT OF "HEAD"

- The vertical difference between 2 levels of liquid
  - Use FT to measure the pressure exerted by a body of liquid in term of weight
- Head α Pressure α Energy
- Velocity Head
  - The distance a liquid would have to fall for a given V
  - $H_v = V_1^2/2g$
- Friction Head
  - $H_l = f(L/D)(V^2/2Zg)$ where
    - f : friction factor
    - L: Length
    - D: Diameter

Pressure Head



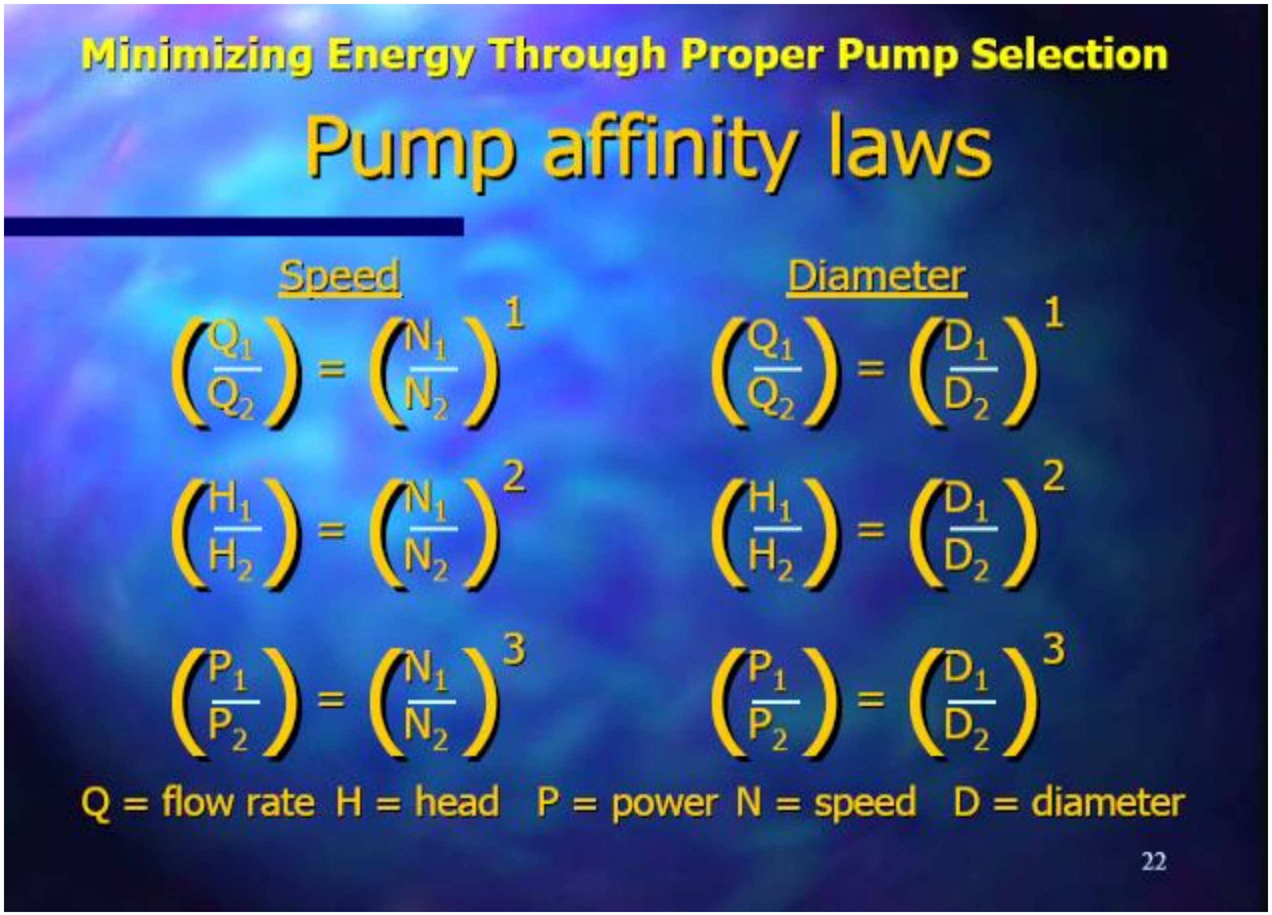
Velocity Head

- Head required to impart velocity to a liquid
- Equivalent to the vertical distance through which the liquid would have to fall to acquire the same velocity
- Equal to $V^2 / 2g$

Friction Head

- The force or pressure required to overcome friction is obtained at the expense of the static pressure head
- Unlike velocity head, friction head cannot be "recovered" or reconverted to static pressure head
- Thermal energy is usually wasted, therefore resulting in a head loss from the system

Centrifugal Pump Scaling "Laws"



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More Pump “Laws”

Apply to centrifugal (non-positive displacement) pumps only

$$\dot{V} \propto N$$
$$H_p \propto N^2$$
$$\dot{W} \propto N^3$$

$\dot{V}$ = volumetric flow rate

N = speed of rotation

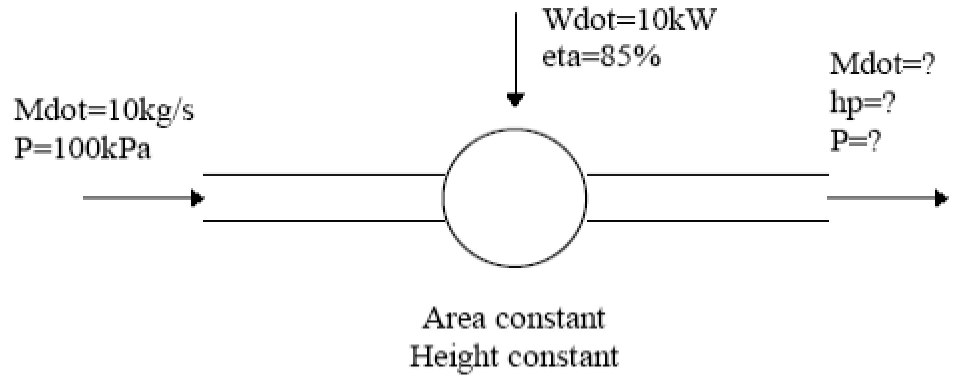
H_p = pump head

$\dot{W}$ = power required (prime mover)

Pump Design Equation – Bernoulli Again

So let's work some typical pump and turbine problems.

Here's the simplest setup: Consider a water pump:



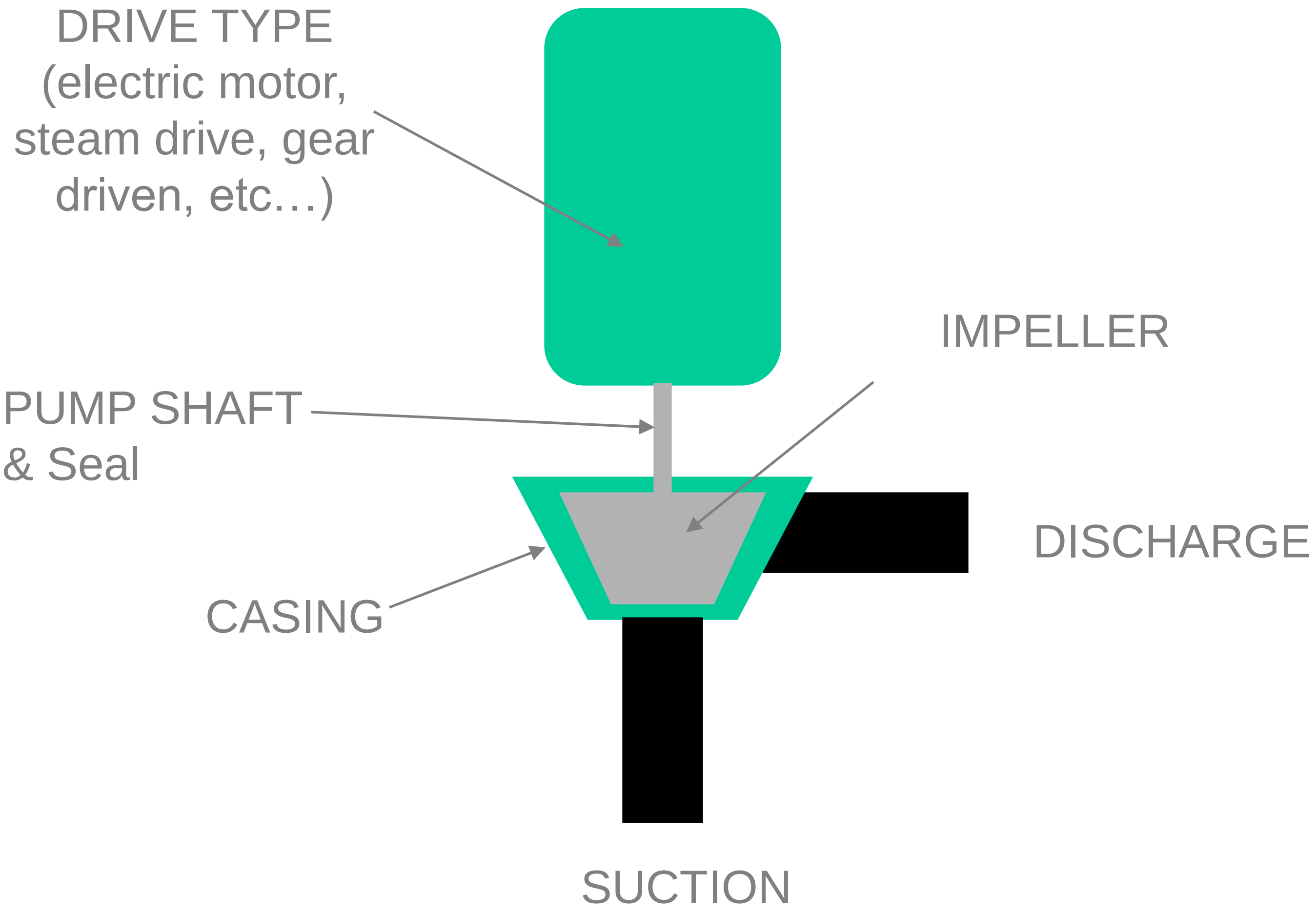
This is a PUMP. (We're adding work)

So here's Bernoulli's equation for a pump:

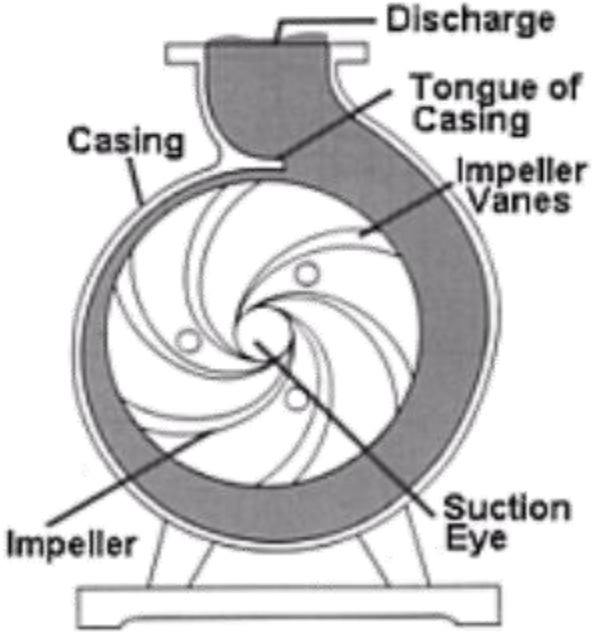
$$\frac{V_1^2}{2g} + \frac{P_1}{\rho g} + z_1 + h_p = \frac{V_2^2}{2g} + \frac{P_2}{\rho g} + z_2$$

Anatomy of Several Pump Types

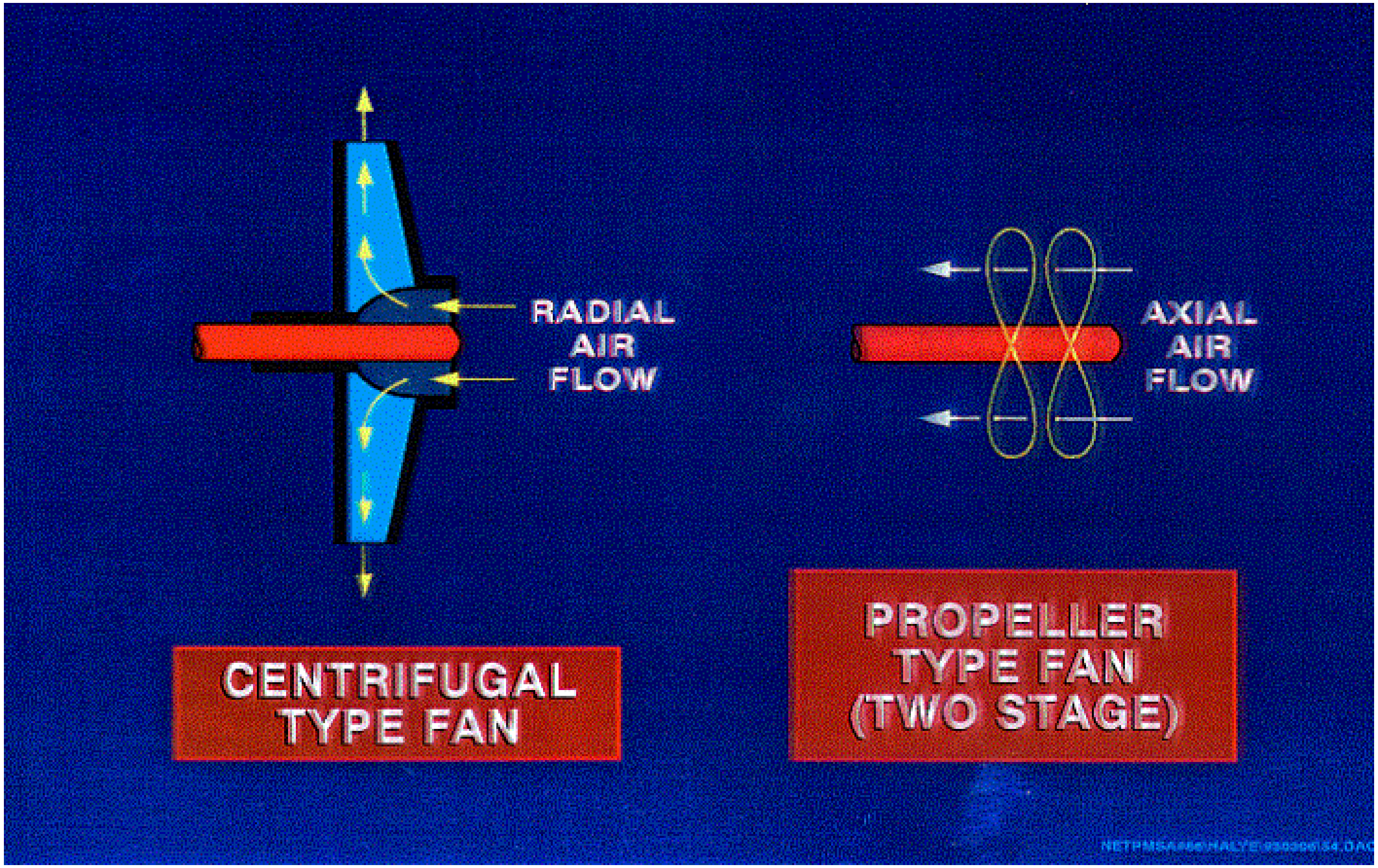
Centrifugal and Fan Pump Elements



Centrifugal Pump Elements



Centrifugal and Fan Pump Elements



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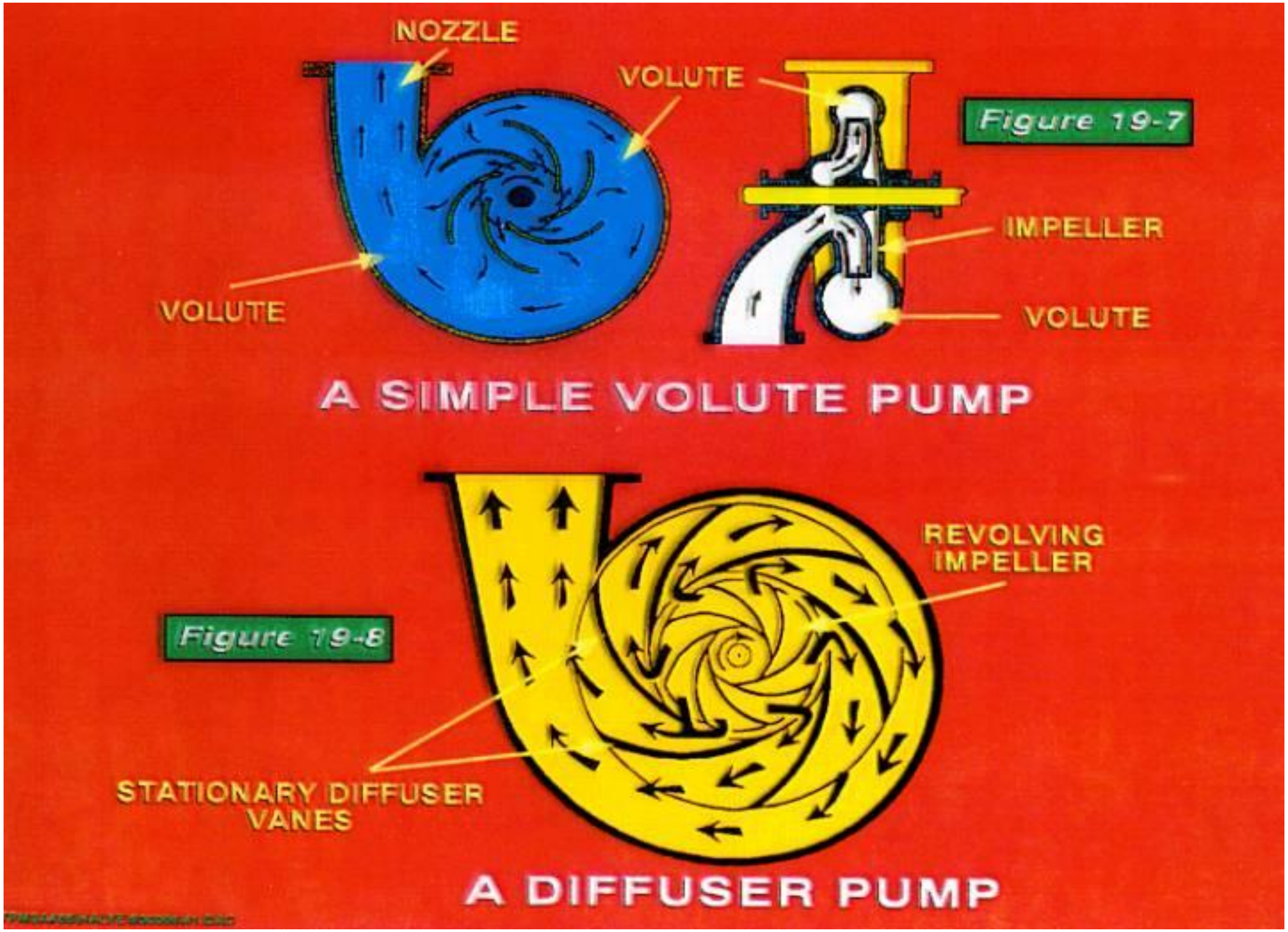
Centrifugal and Fan Pump Elements



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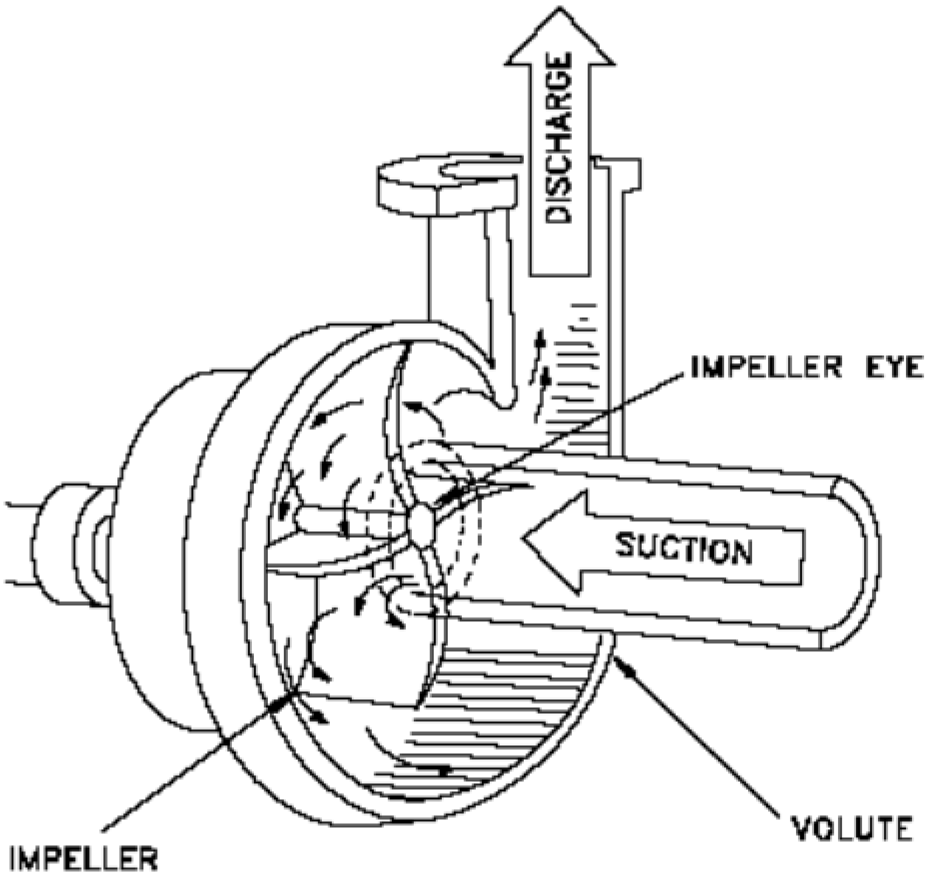
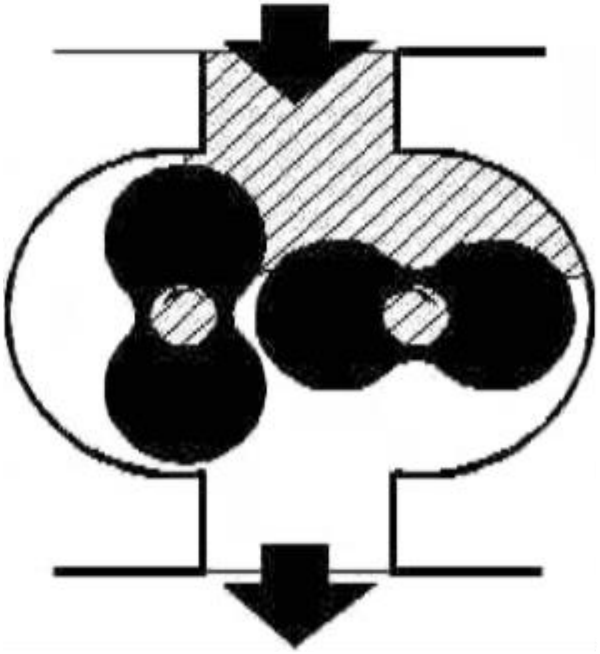
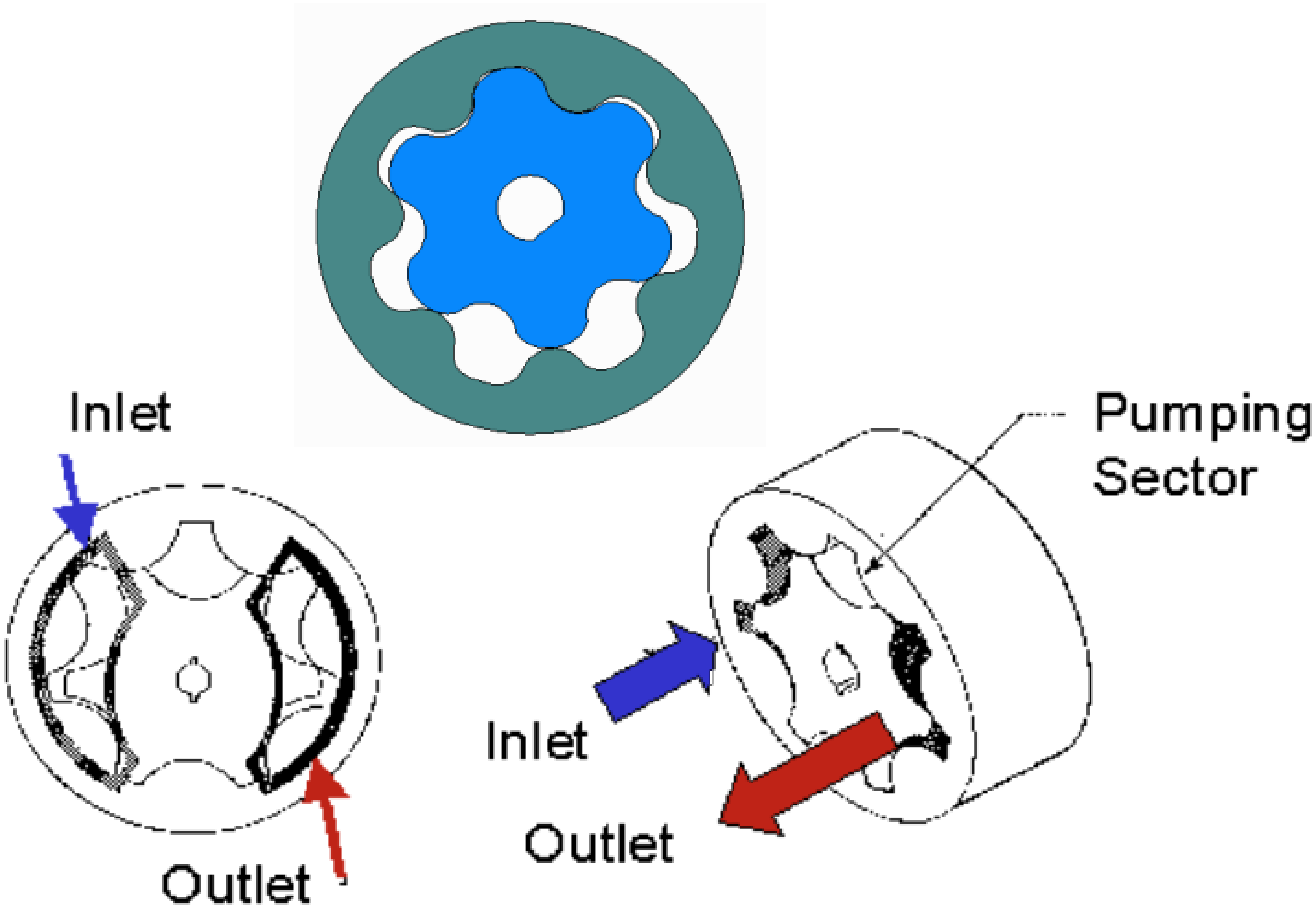
Centrifugal Pump Elements



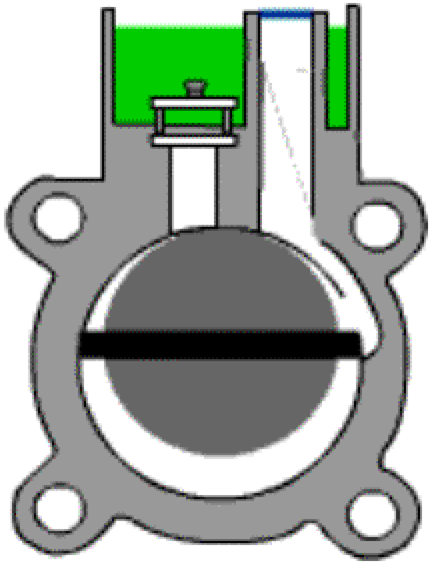
“Roots” Blower

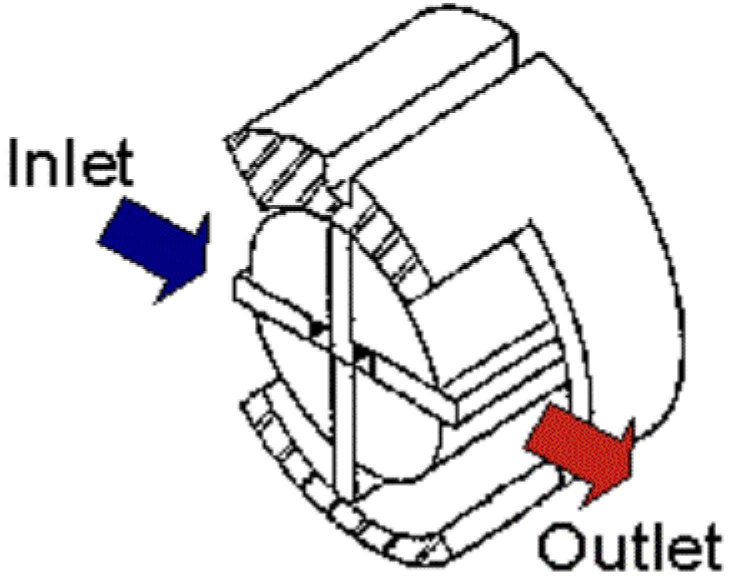


Gerotor Pump



Vane Pump



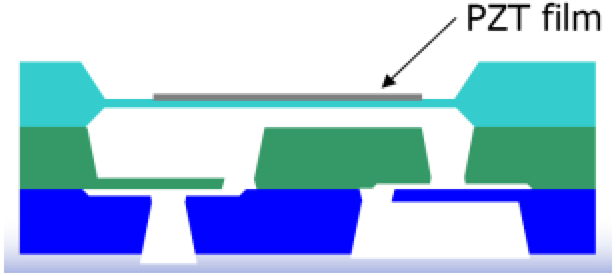


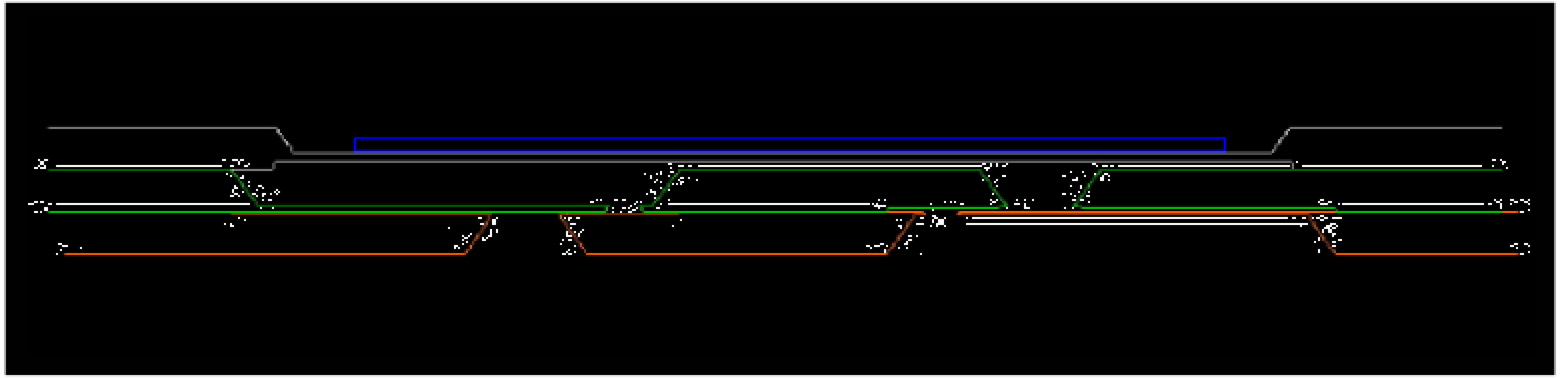
Small Silicon Micro-Compressor Design Concept

Microcompressor

◆ **Membrane Actuator with PZT Film**

- 1st wafer: A membrane with PZT film
  - Membrane: 12mm x 12mm, 100μm thick
- 2nd & 3rd wafer: Check valves and ports
- Wafers are aligned and bonded (Silicon Fusion bonding)





MEMS Magnetically Actuated Micropump

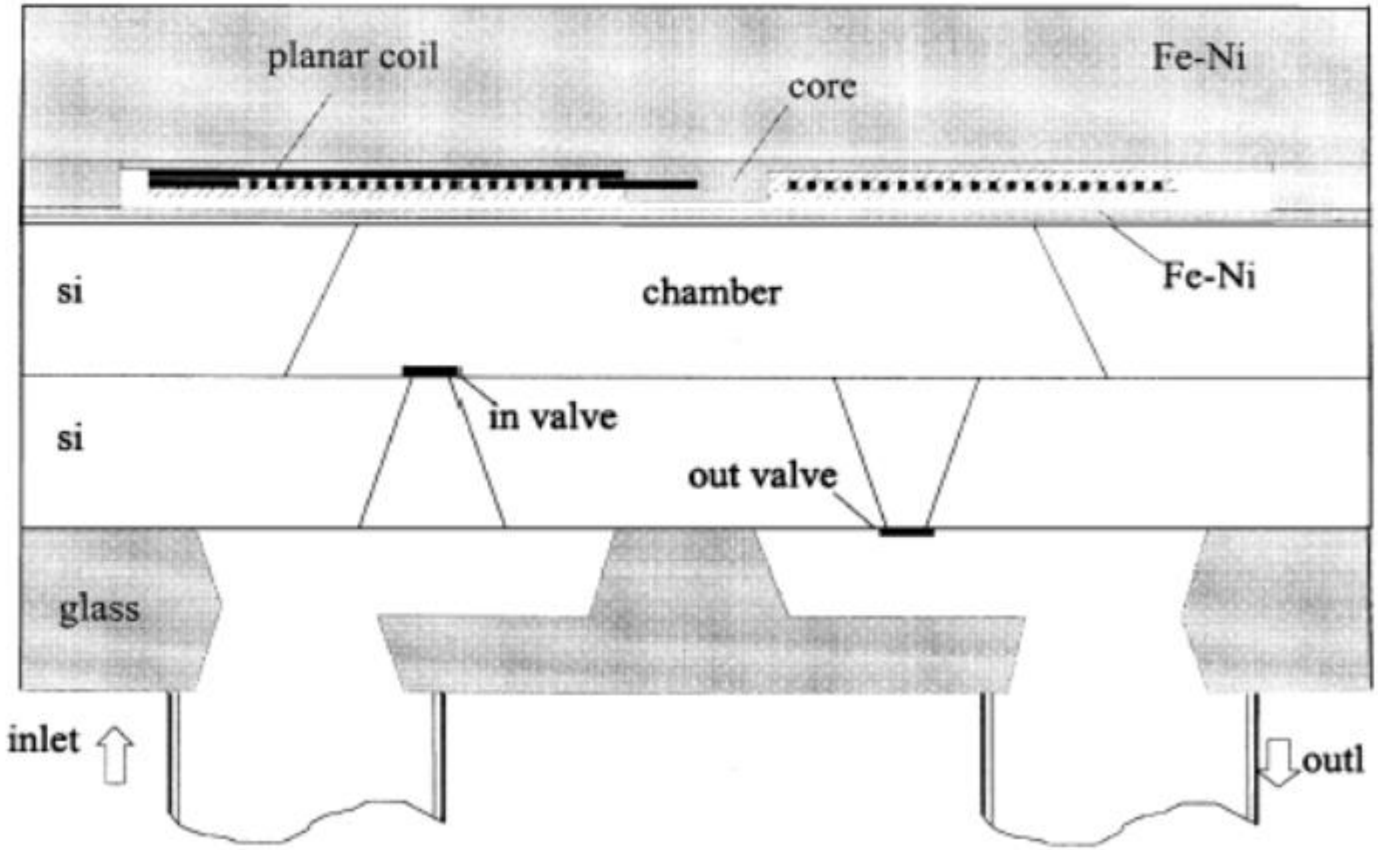


Fig. 1. Structure diagram of four-layer micropump.

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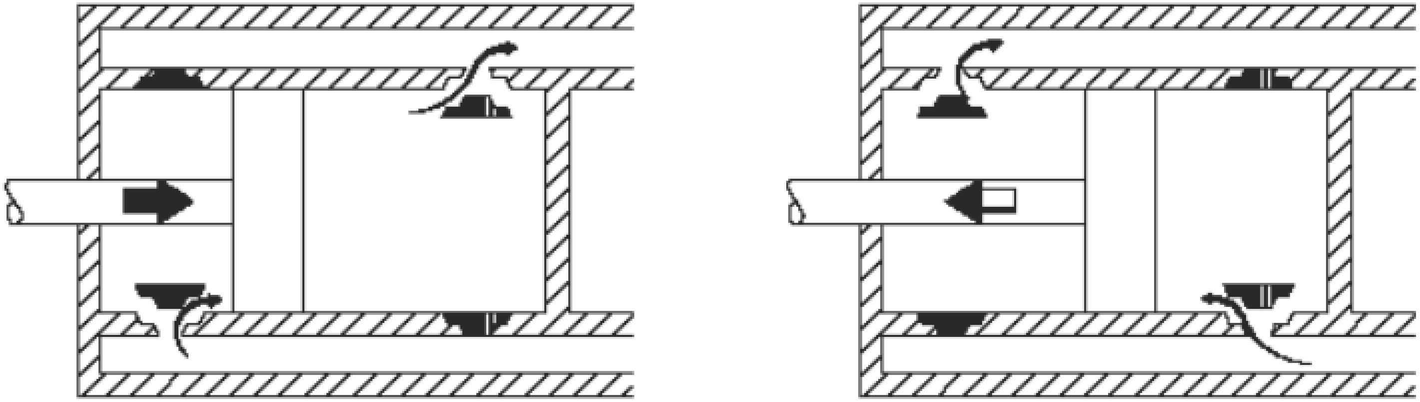
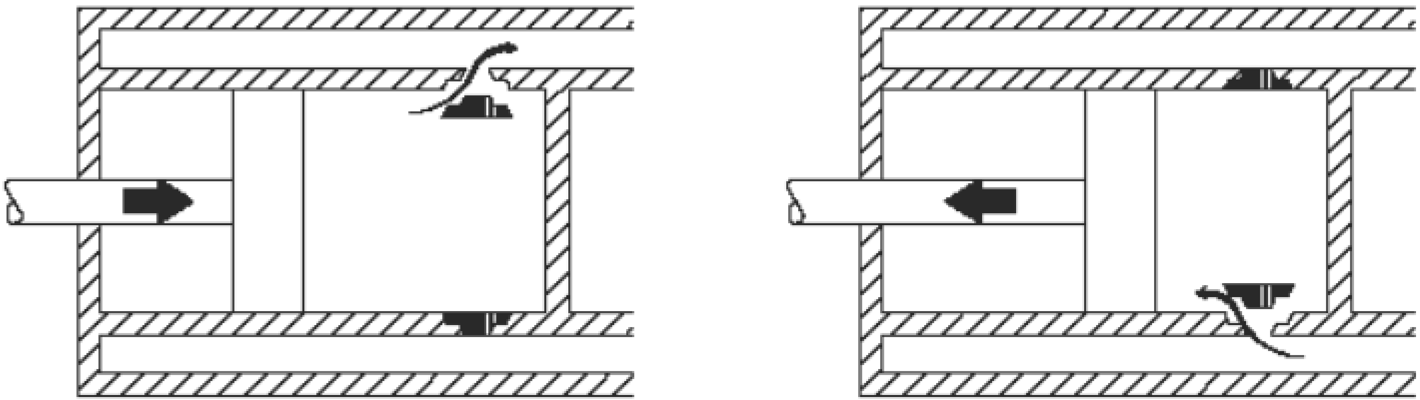
Single and double Acting Piston Pumps



DOUBLE ACTING



SINGLE ACTING

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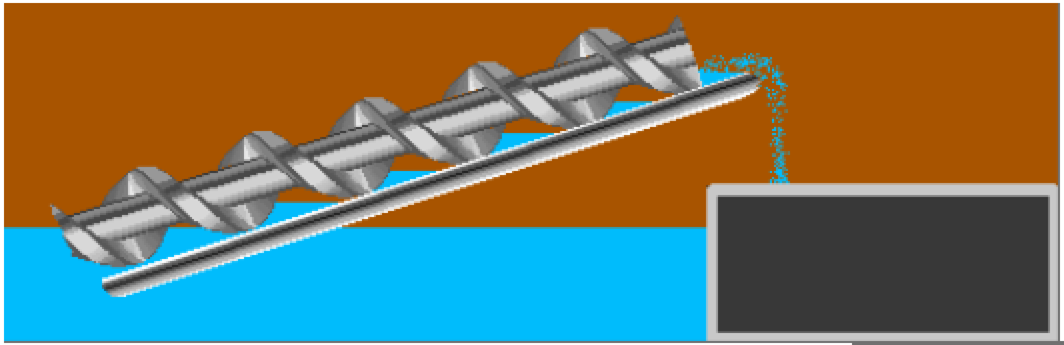
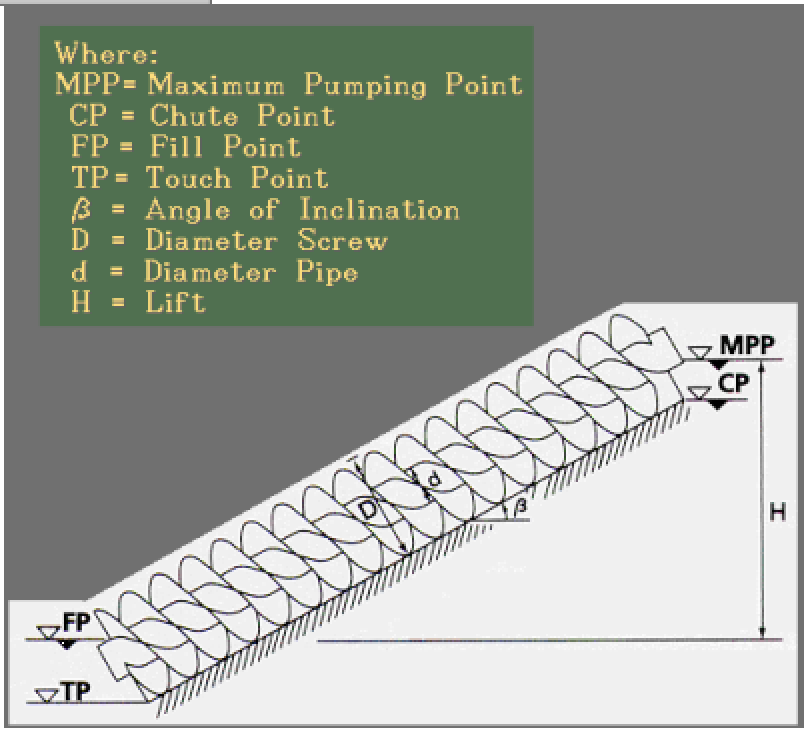
Archimedes Screw Pump





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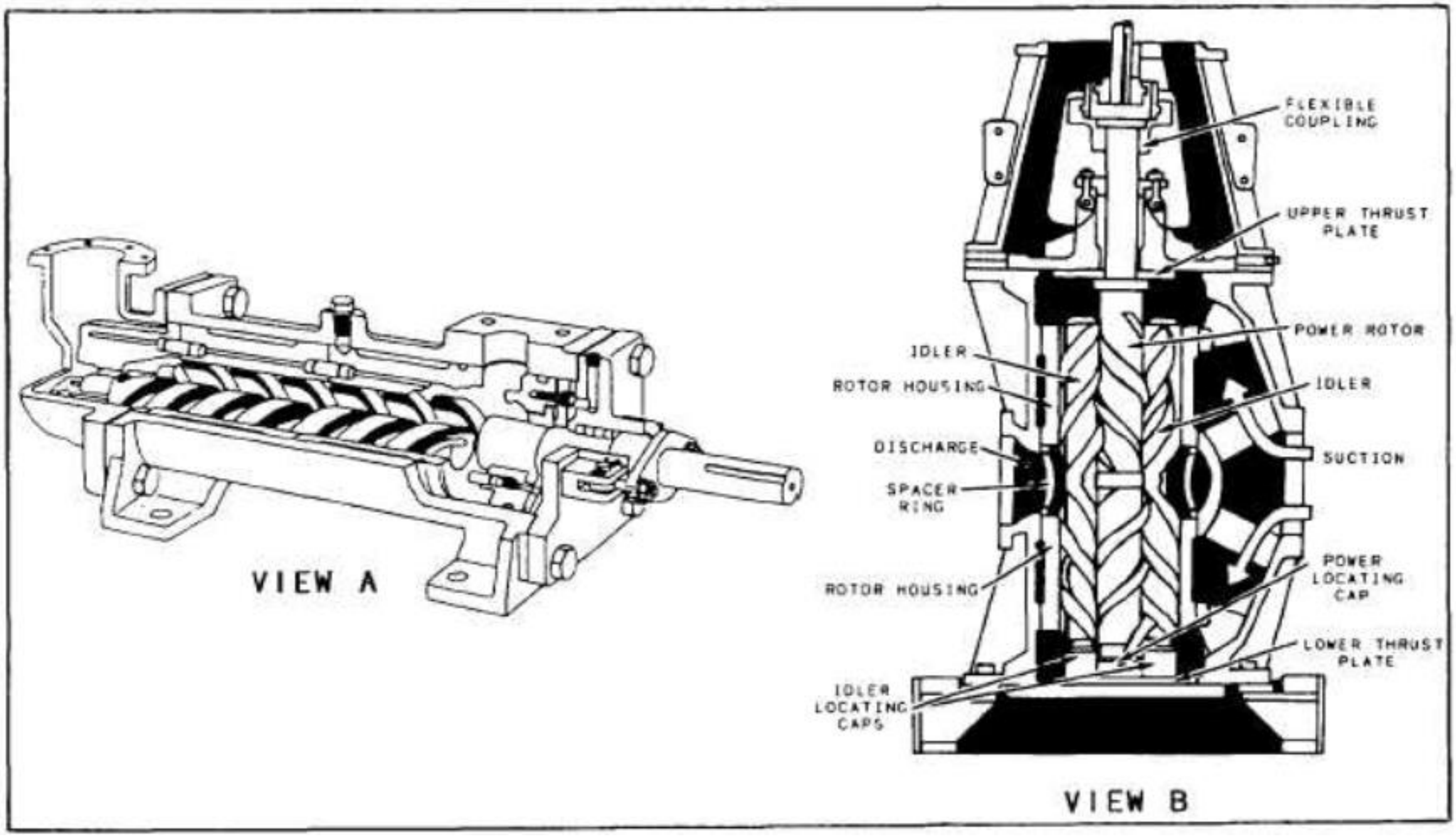
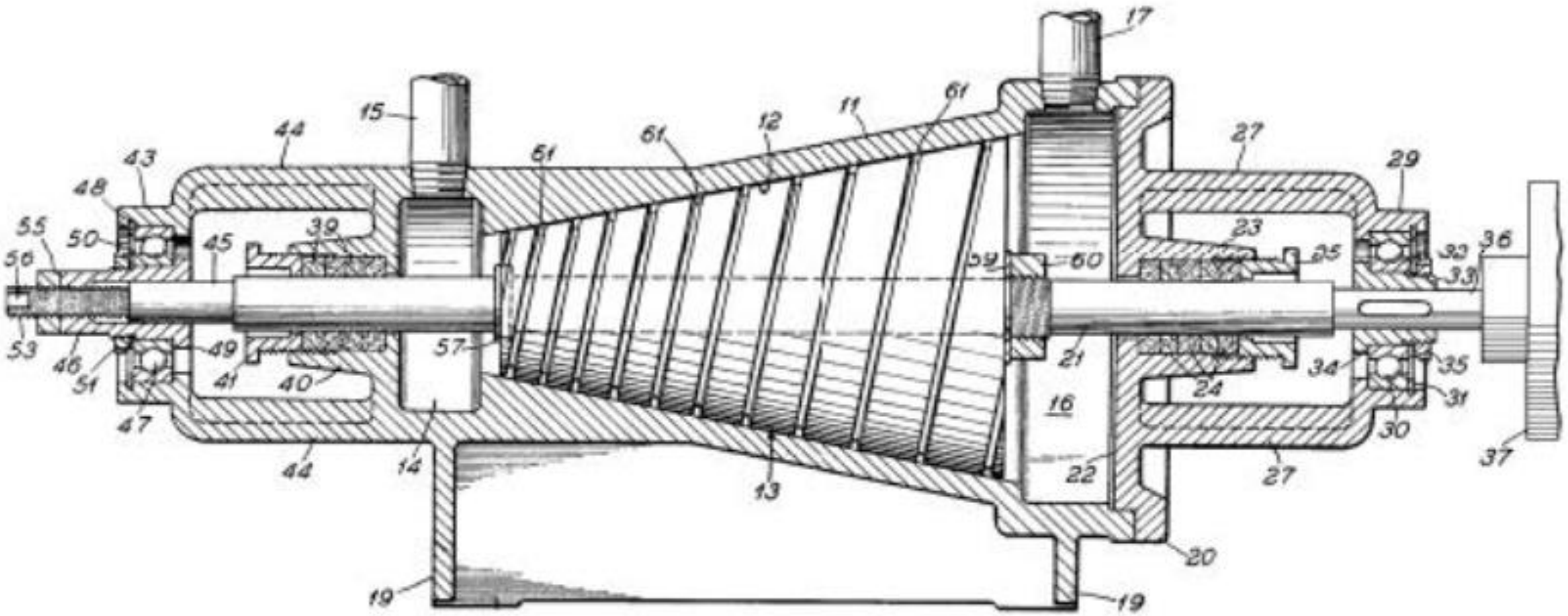
Multiple Screw Pump



Conical Drag Pump



- Truncated Conical Drag Pump -

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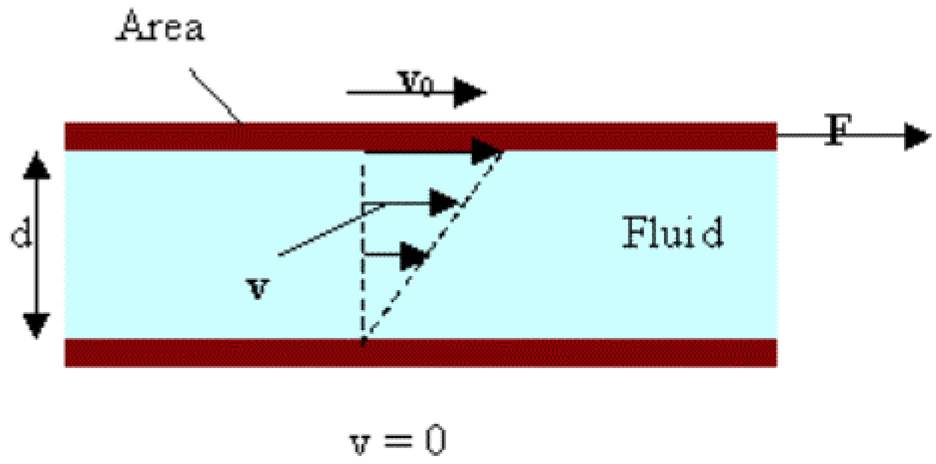
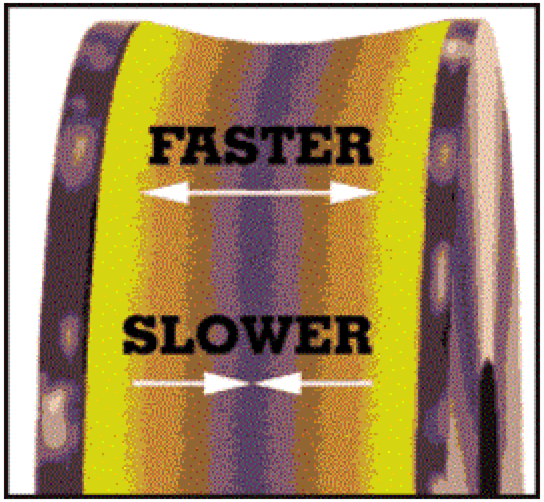
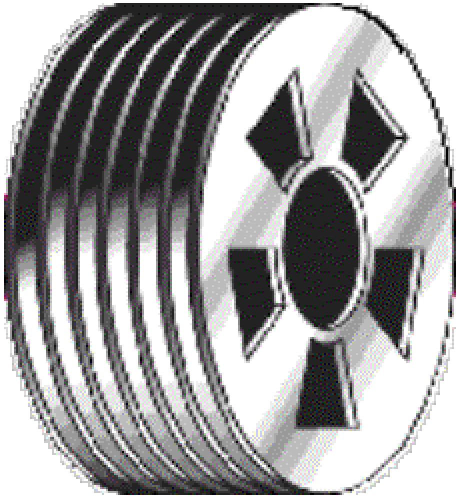
Tesla "Drag" Pump







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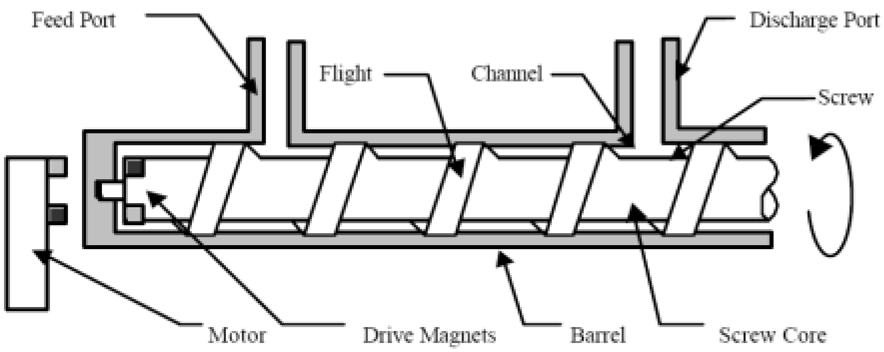
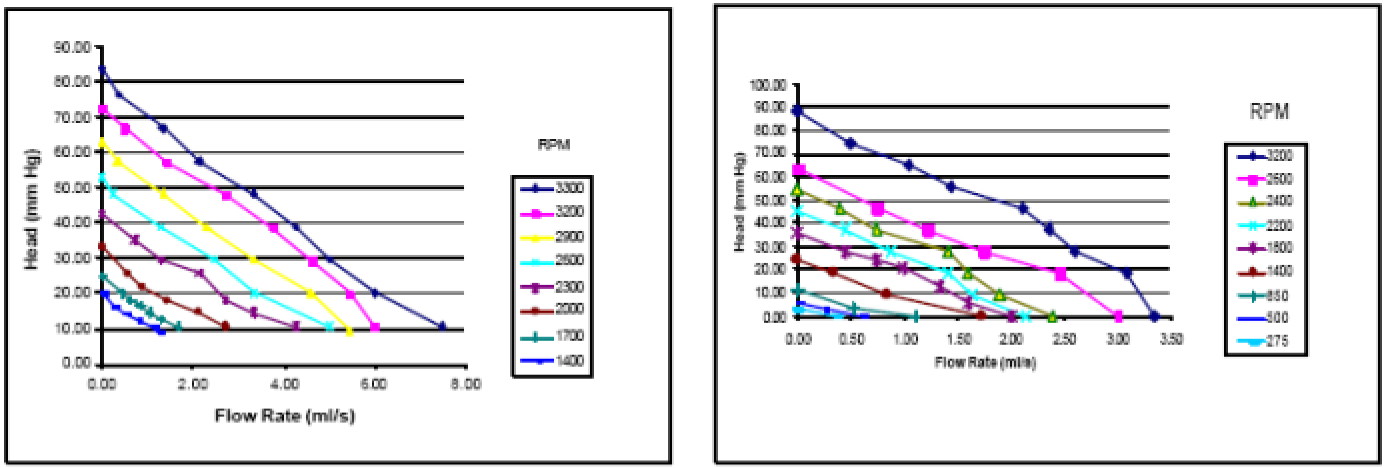
Drag or Pos. Displacement "Screw" Pump





(a) (b)

Figure 2. Flow rate – pressure head characteristics.
(a) $\phi = 6^{\circ}$ (b) $\phi = 12^{\circ}$

Small Spiral “Viscous Drag” Pump

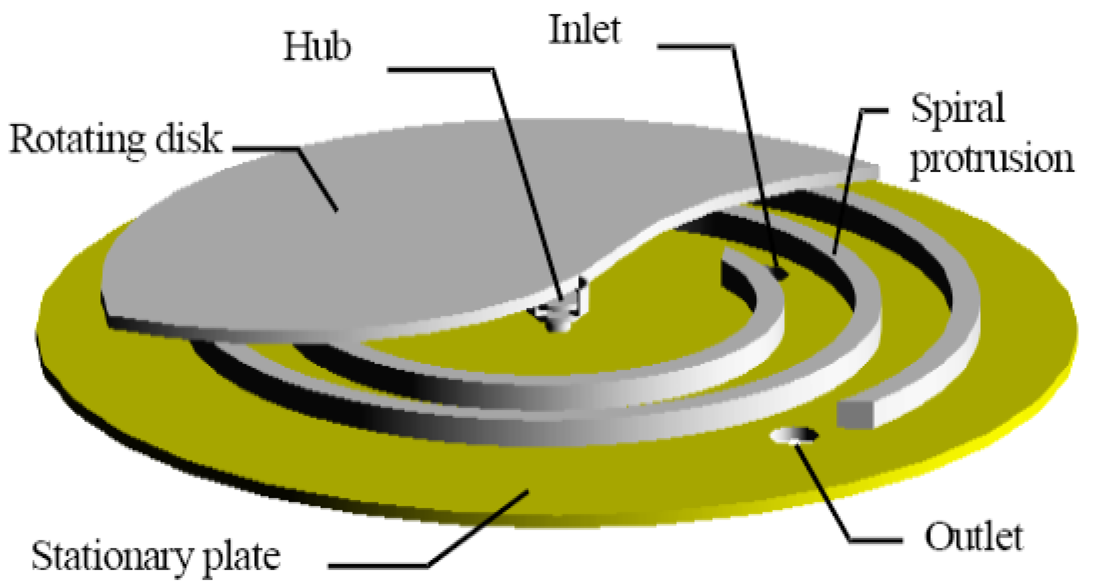


FIG. 1. A schematic illustration of the spiral pump concept

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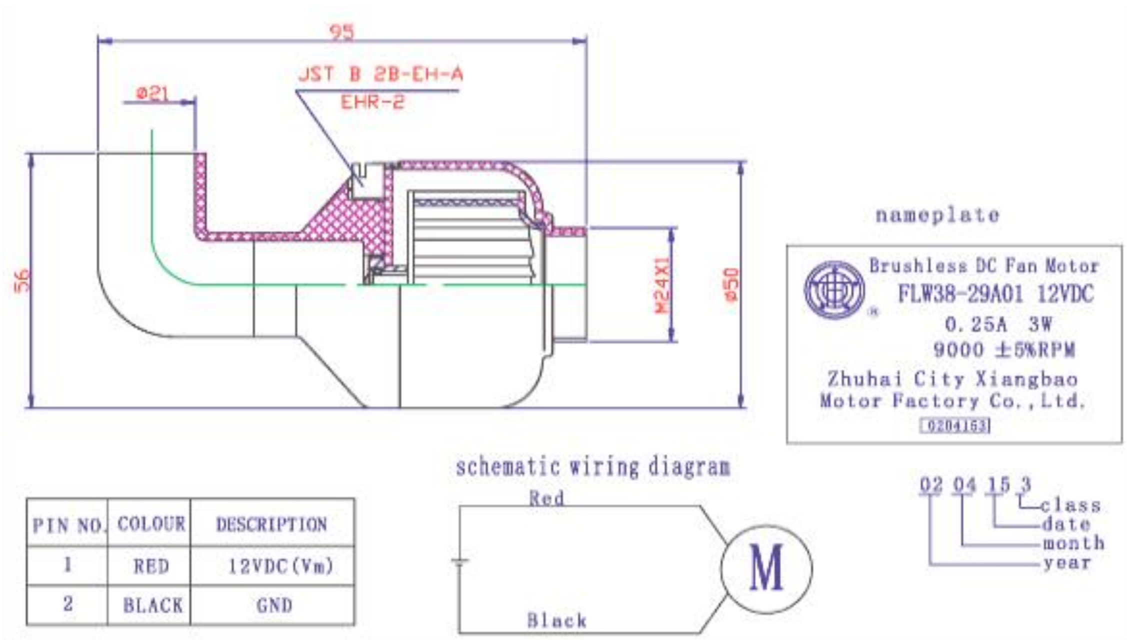
Examples of Small Commercially Available and "Academic Research" Pumps

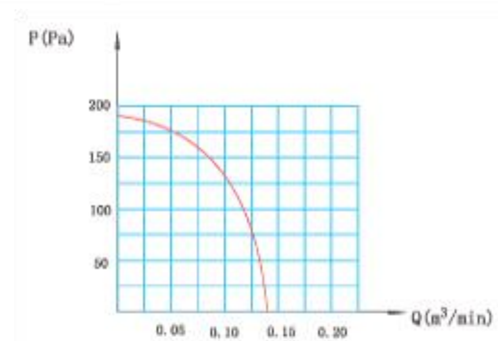
Fans and Blowers

Typical "Micro-Blower"

香港祥达电器有限公司
HONG KONG CHEUNG TAT ELECTRICAL CO.,LTD

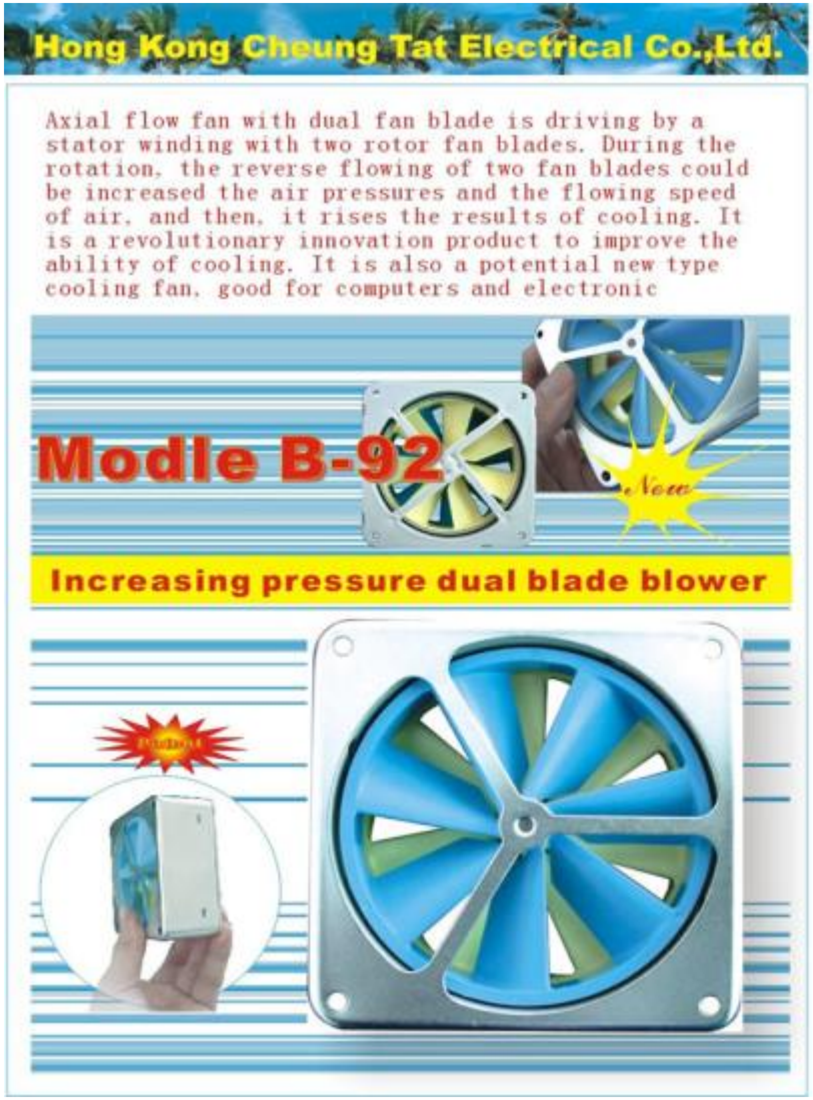
FLW 38-29A01





Model No.	Rated Voltage (V)	Rated Current (A)	Rated Speed (rpm)	Max Static Pressure (Pa)	Max. Airflow (m³/min)	Life (hr.)	Insulation Class
FLW38-29A01	**12**	**0.25**	**9000**	**180**	**0.135**	**20000**	**B**

Typical Double Fan Blower



Typical Fan based "Micro-Blower"

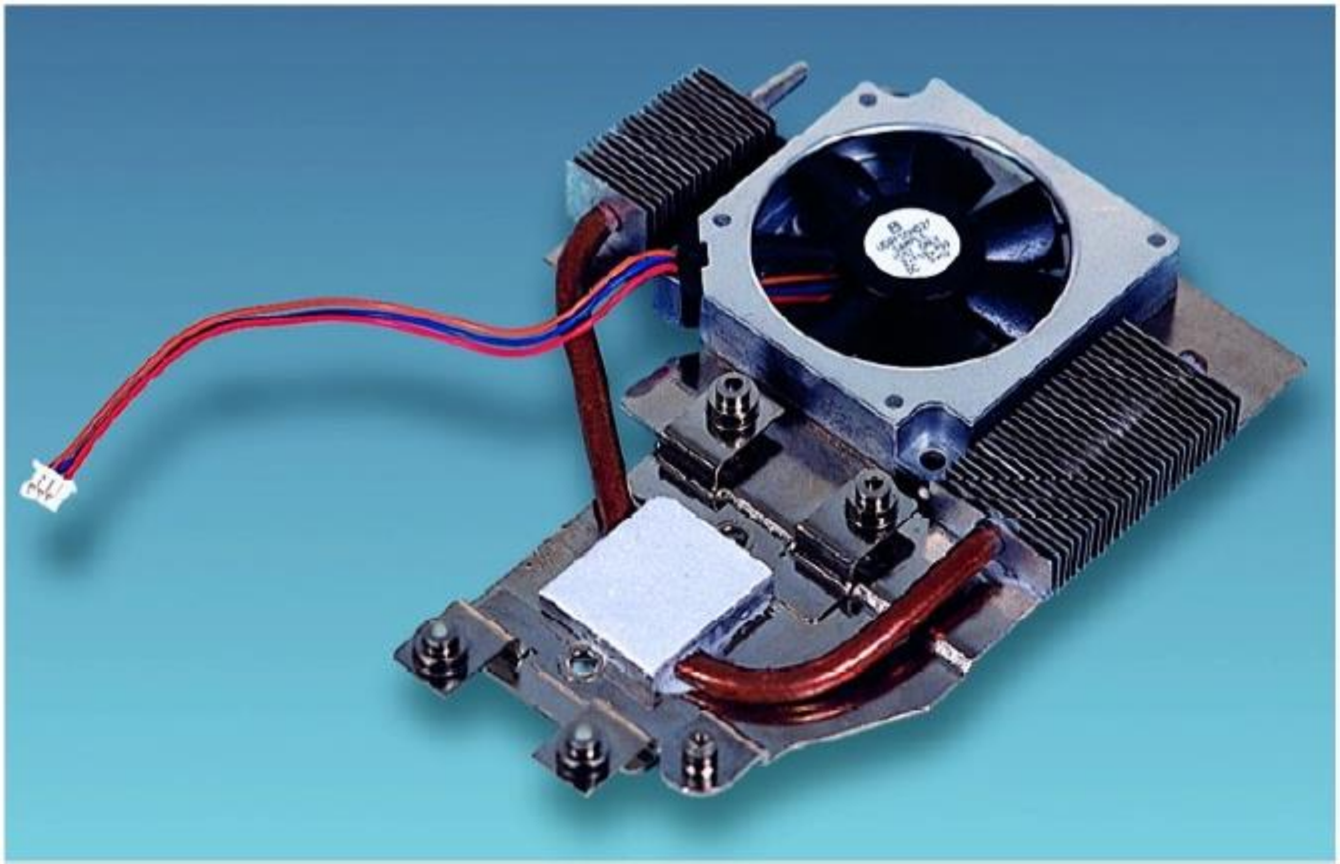


Figure 1: Micro blower-heat sink system for portable computer.

Small Sunon Blower

50x50x15 mm

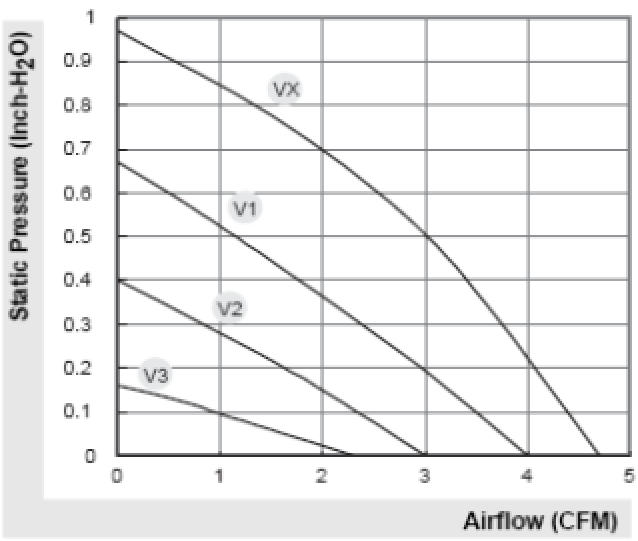
SUNON

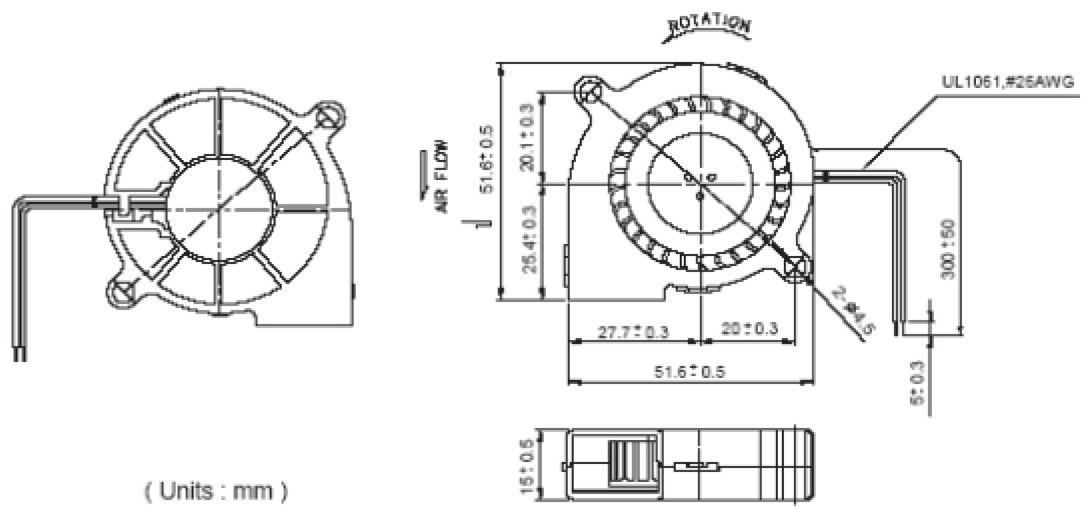
MagLev Green Motor Blower

2.3~4.7 CFM

Model	P/N	Bearing (● VAPO, ⚙ 2BALL)	Rating Voltage (VDC)	Power Current (AMP)	Power Consumption (WATTS)	Speed (RPM)	Air Flow (CFM)	Static Pressure (Inch-H_2O)	Noise (dBA)	Weight (g)
GB1205PHVX-8AY	GN	●	12	0.18	2.2	6000	4.7	0.97	42.2	30
GB1205PHV1-8AY	GN	●	12	0.11	1.3	5000	4.0	0.67	39.8	30
GB1205PHV2-8AY	GN	●	12	0.06	0.7	4000	3.0	0.40	33.4	30
GB1205PHV3-8AY	GN	●	12	0.04	0.5	3000	2.3	0.16	27.0	30

Small Sunon Blower - Continued





High Volume - Low Pressure - Centrifugal Blower

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Micro-Vacuum Products

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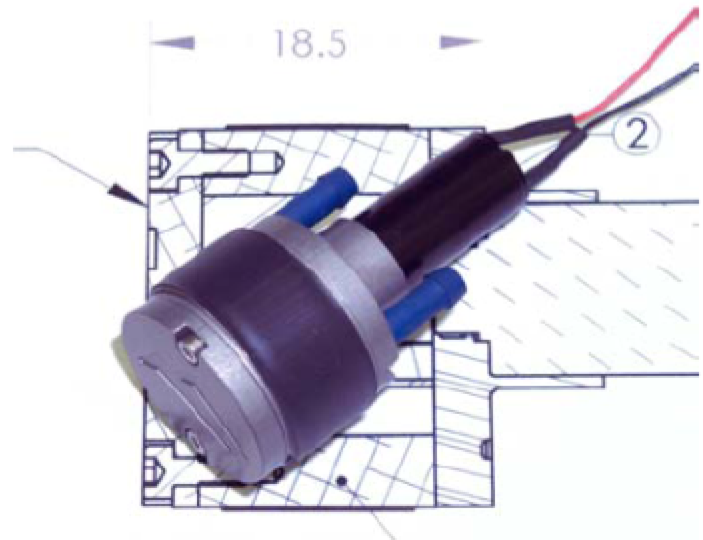
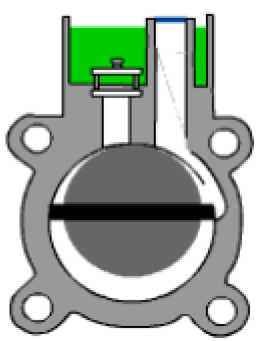
Small Blower – Mesoscopics, Inc.

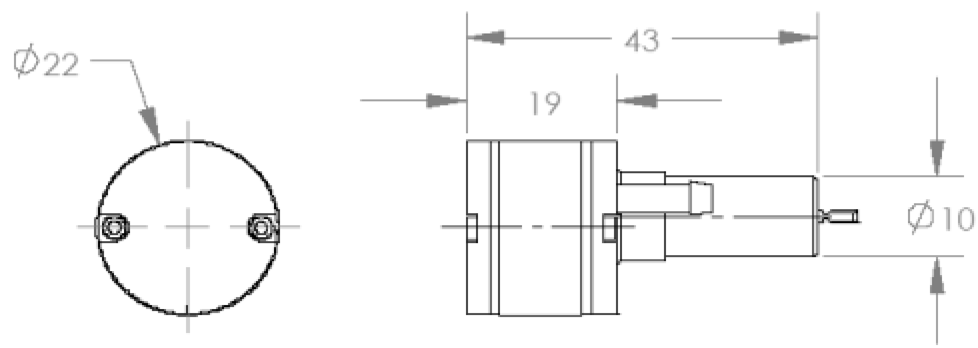
VB-10 Mesoscale Vane Blower

The VB-10 is the most compact member of the VB-series rotary vane blower family, and is ideal for portable applications where minimum size and weight are required. The VB-10 can support open flow rates up to 5 l/min and shutoff pressures of over 0.5 psi, all in a package that weighs only 28 grams and requires less than 1.5 watts of input power. VB-10 blowers use high-precision, long-life vanes to provide steady flow output with minimal pulsation and very low noise. Brushed DC motors provide simple flow rate control by varying motor voltage.

Wetted components are PPS (polyphenylene sulfide), graphite and anodized aluminum. The VB-series blowers are scalable for different pressure-flow ranges. Contact Mesoscopic Devices to discuss your specific application.







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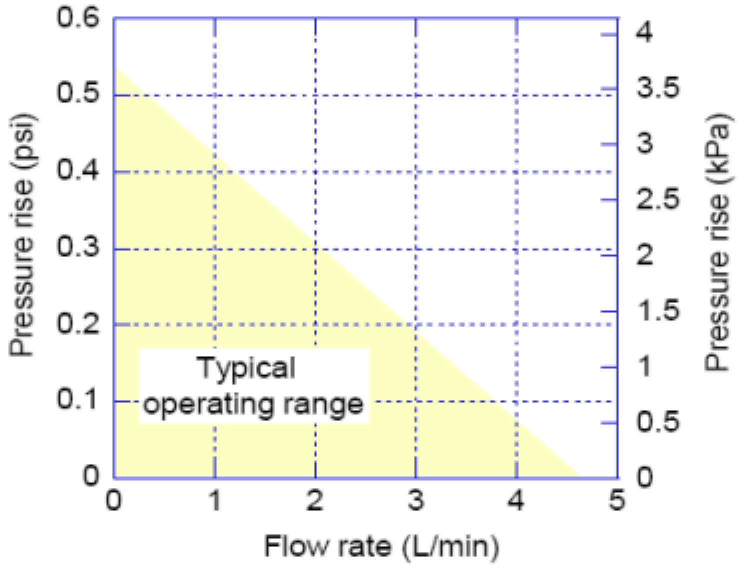
Small Blower – Mesoscopics, Inc.

Specifications	
Size	Ø22x43 mm (Ø0.87x1.69 in)
Volume	9.4 cm^3 (0.6 in^3)
Mass	28 g (1 oz)
Ports	Barbed fittings for 1/8" ID tubing
Voltage	3-12 V DC
Power	1.5 W max.
Pressure Rise	> 0.5 psi @ shutoff
Flow Rate	5 SLPM open flow rate



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Examples of Small Commercially Available

and

“Academic Research” Pumps

Water Pumps

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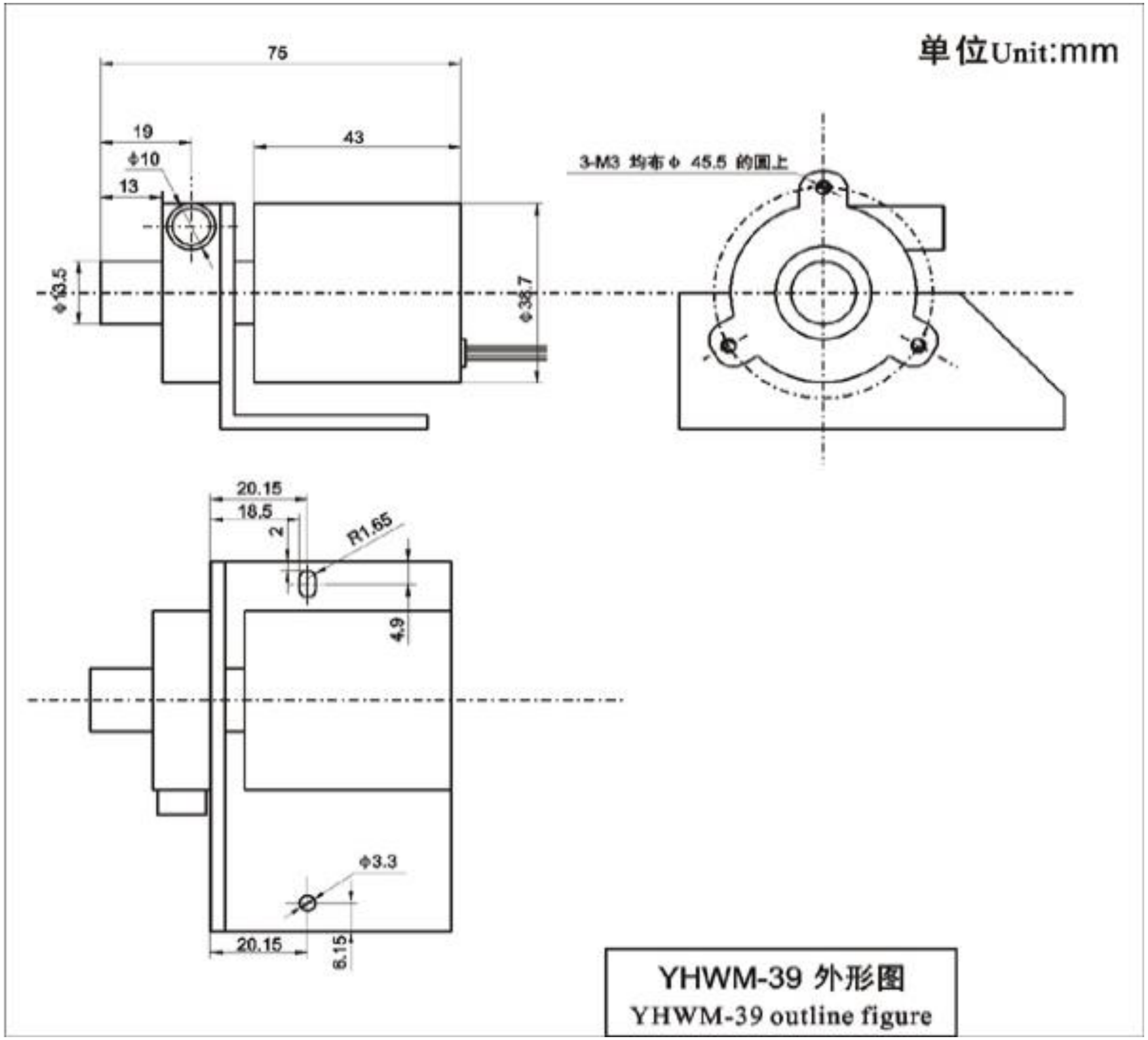
Typical Small Water Pump



Small Diaphragm Water Pump

▲ LIQUID PUMPS

Tiny package

Designed for high-efficiency, continuous-duty pumping of low-viscosity liquids, SMF 4 Series miniature diaphragm pumps are widely used in fuel cells and HVAC applications. They are used in medical, laboratory, and industrial settings. The pumps are 3.35 inches in length and weigh 6.4 oz. They have a top-rated fluid flow of up to 270 ml/min, a maximum height of 472 inches H2O, and a maximum suction height of 276 inches H2O. Both 12 and 24V dc motors are available, as well as 115 and 230V ac motors.

Rietschle Thomas

http://rbi.ims.ca/4394-586

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Small Centrifugal Water Pump

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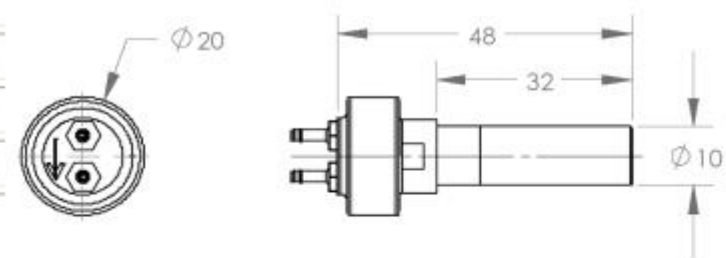
Gerotor Liquid Pump – Mesoscopics, Inc.

GP-series Mesoscale Gerotor Pumps

Mesoscopic Devices' GP-series gerotor pumps were developed under Army Research office funding to provide compact fuel pumps for portable combustion power sources. This rapidly expanding family of pumps is ideal for use in portable equipment, and provides very high flow rates in a tiny package. The GP-10 pump is smaller than a person's thumb, and the GP-16, with over 300 ml/min of flow rate, is only slightly larger.

These compact pumps use mesoscale internal gear elements to provide pulsation-free flow at pressures of up to 2 bar. They are ideally suited to miniature fuel cells, and can provide long life with gasoline, JP-8, kerosene, or water/methanol mixtures. Compared to diaphragm pumps, the GP-series pumps offer more flow in a smaller, lighter, lower power package. The GP-series pumps are currently available in the GP-10 size, optimized for flow rates under 100 ml/min, and the GP-16 size, optimized for flow rates under 300 ml/min. These pumps can be customized for specific applications through choice of motors, encoders, and wetted materials. Click on the pump names in the table below to access detailed PDF data sheets on the pumps.

Parameter	GP-10	GP-16
maximum flow	100 ml/min	300 ml/min
max. pressure	1 bar (15 psi)	2 bar
mass	22 g	50 g
power draw (max..)	1.5 W	3.2 W



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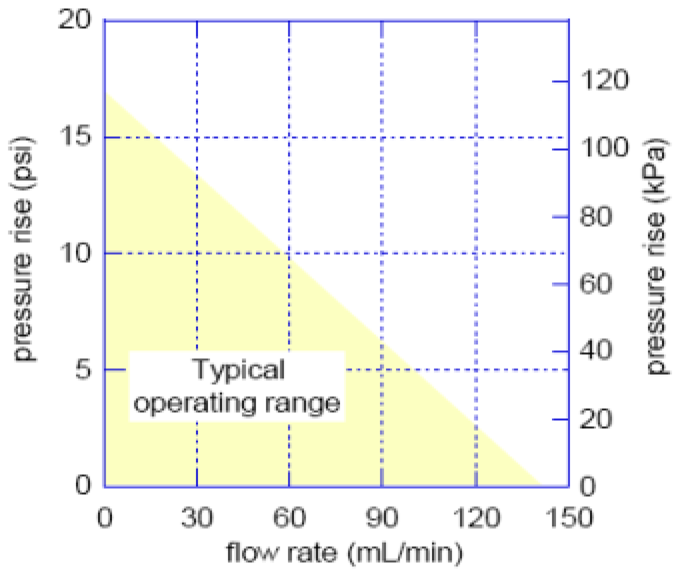
Gerotor Liquid Pump – Mesoscopics, Inc.

Specifications	
Size	Ø20x 48 mm (Ø0.79x1.89 in)
Volume	6.6 cm^3 (0.4 in^3)
Mass	25 g (0.90 oz)
Ports	Barbed fittings for 1/16 inch or 1/8 inch ID tubing
Voltage	3-12 V DC
Power	1.5 W max.
Pressure Rise	15 psi @ shutoff
Flow Rate	140 ml/min open flow rate



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Implantable Artificial Heart Pump - Medtronic

Examples of Small Commercially Available and “Academic Research” Pumps

Exotic Turbine and Tesla Pumps

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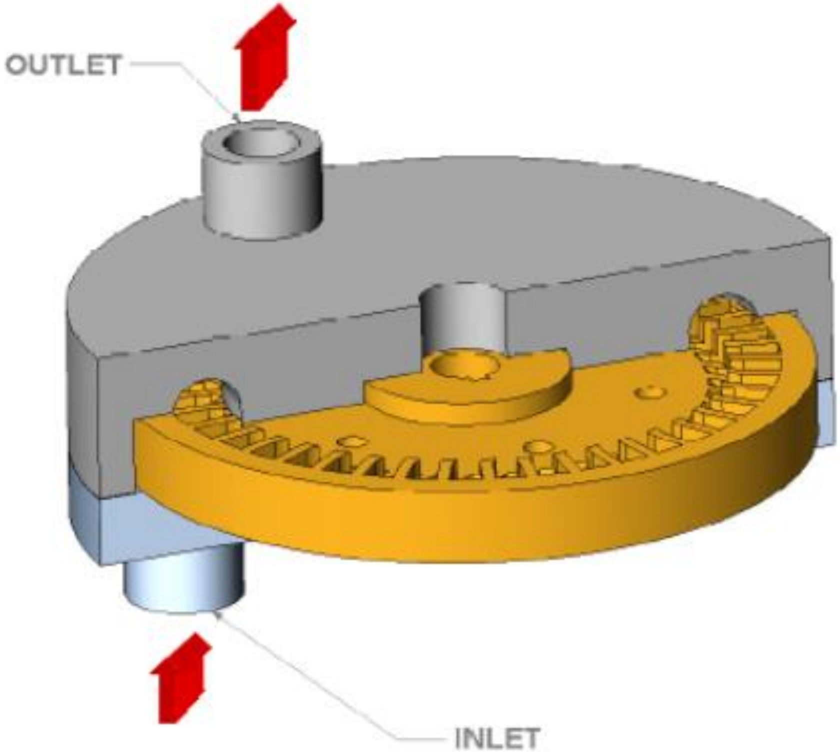
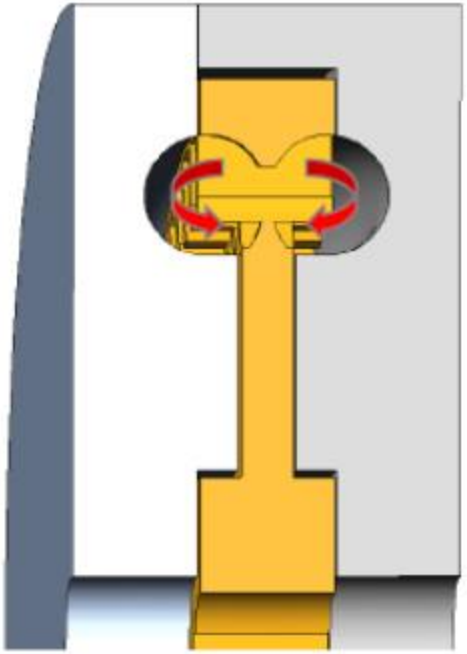
Micro-Compressor





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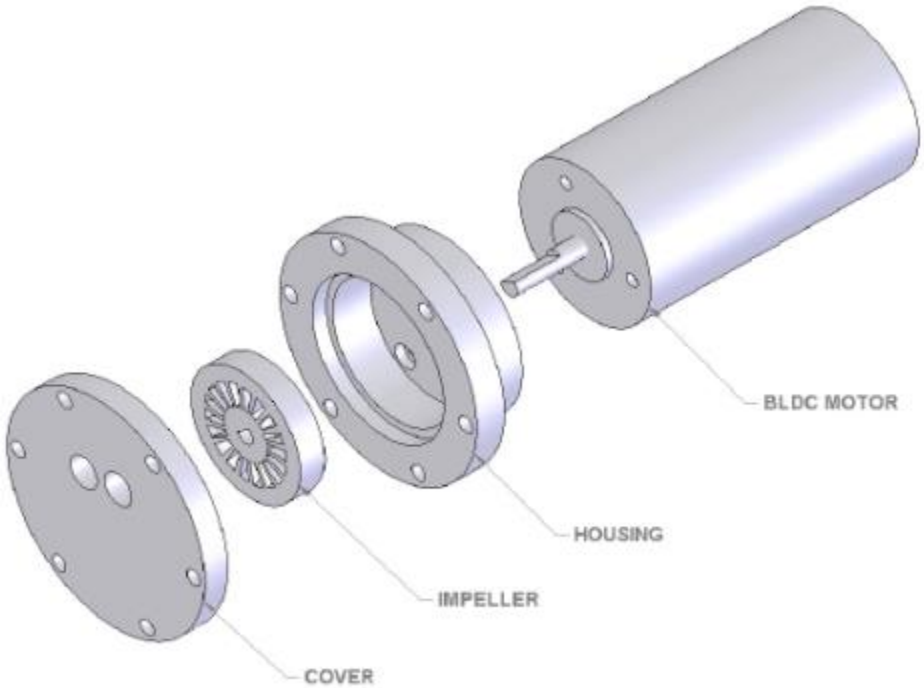
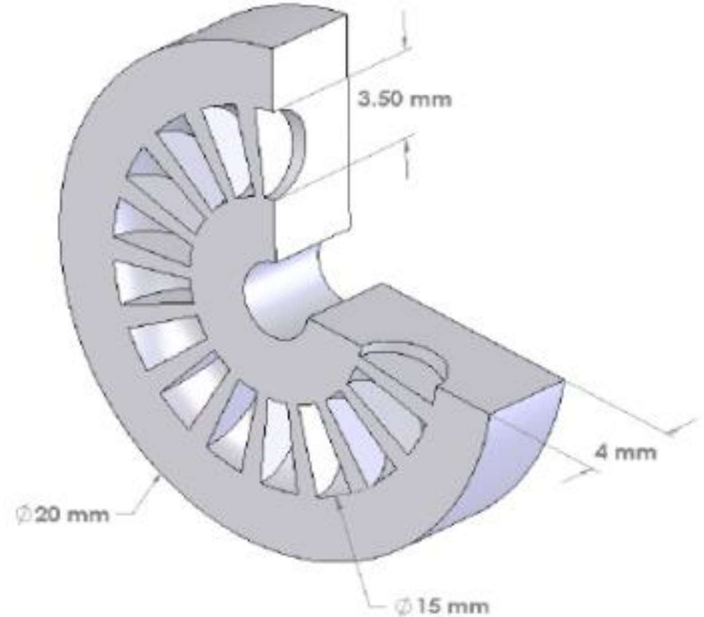
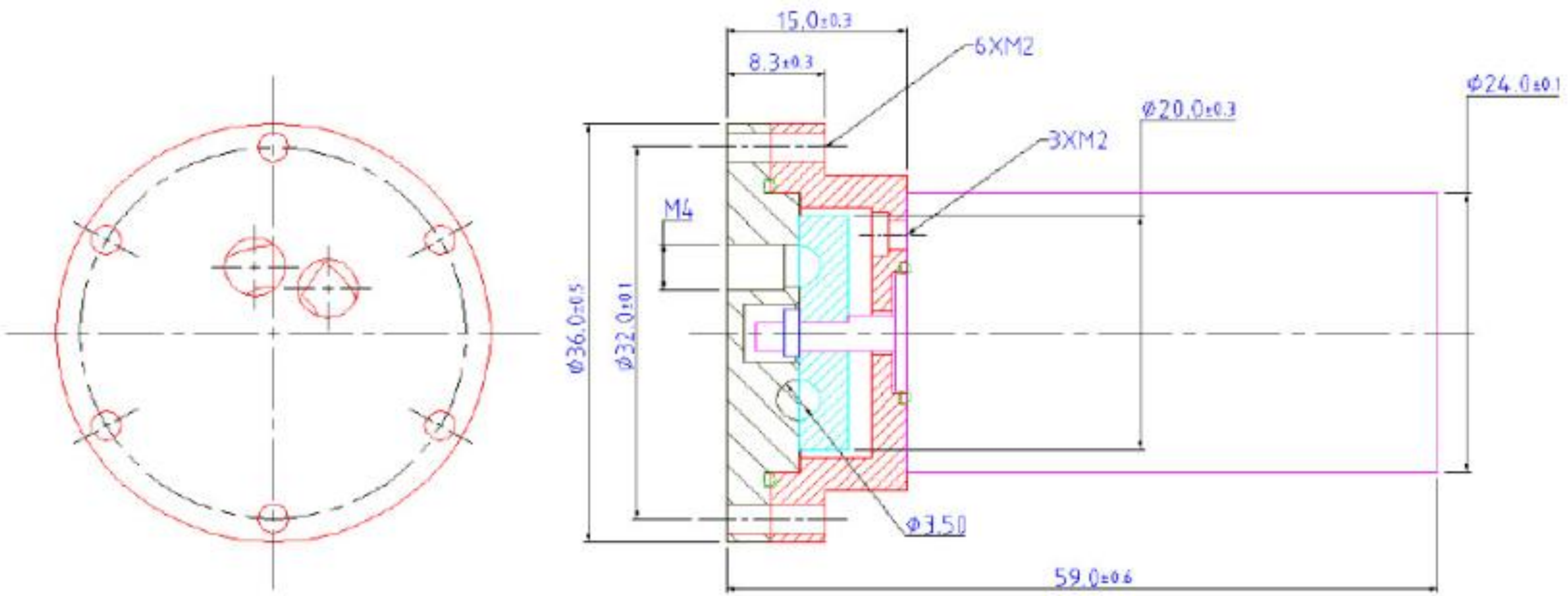
Micro-Compressor - Continued





Regenerative type impeller

Micro-Compressor - Continued



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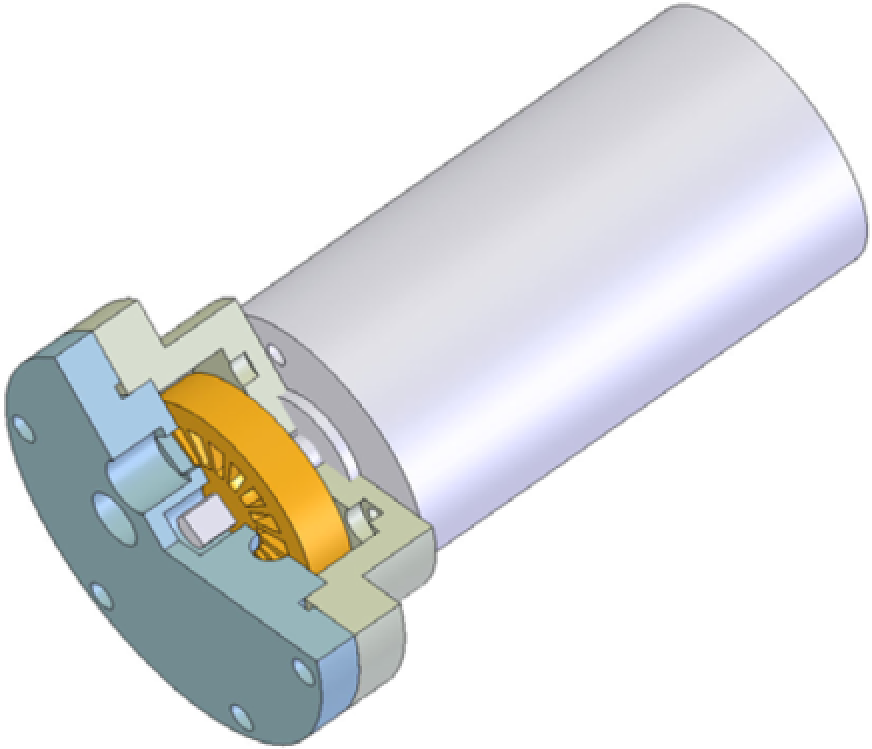
Micro-Compressor - Continued



Performance
0.26 bar
5.5×10^{-4} kg/s
38,000 rpm
2 W

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Micro-Turbine

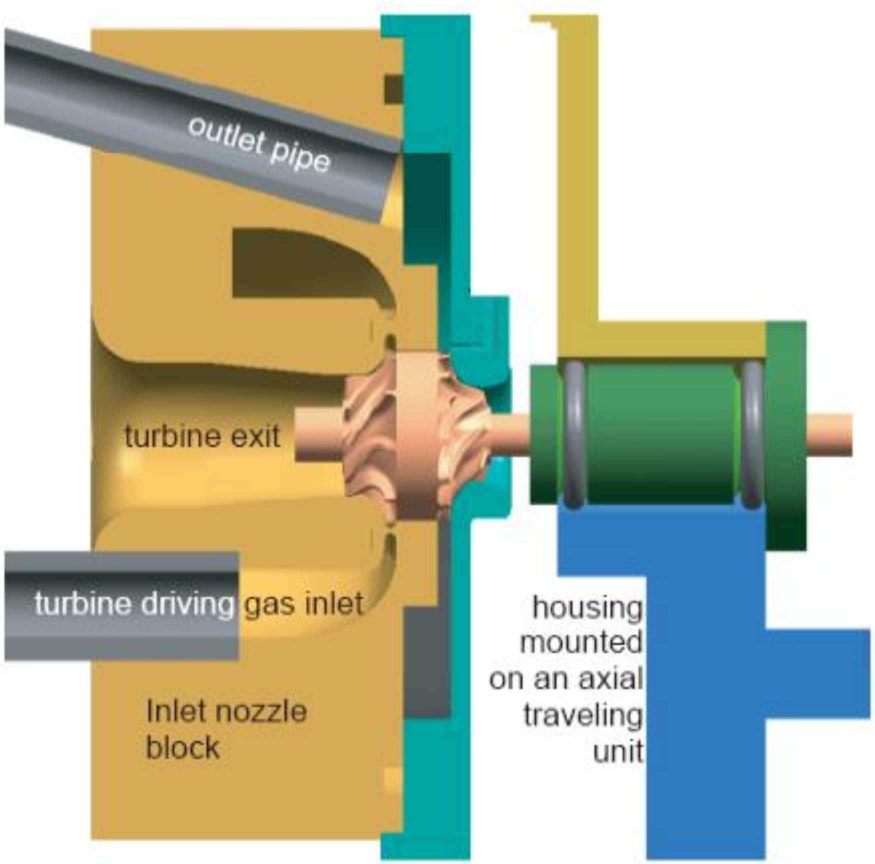

Figure 4. Cross section of inlet nozzle block, rotor group, bearings and mounting unit

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Micro-Turbine

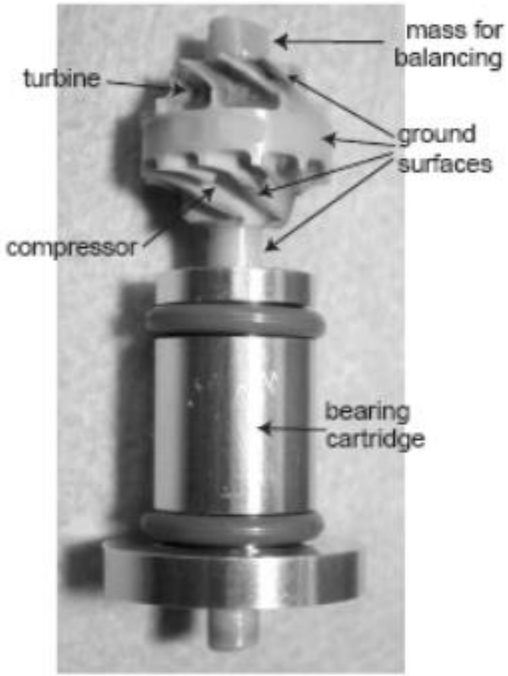

Figure 5. Rotor group mounted on ball bearings.

surfaces such as turbine and compressor blade-shroud-contour profiles, the outer tip diameter and the shaft of the rotor were ground to fine tolerances. The ground rotor was mounted on two bearings (hidden inside the cartridge) as shown in Figure 5. The rotor blades are much thicker compared to their span compared to those on larger rotors. No noticeable sagging of blades during sintering was observed.

The finite element analysis of the rotor at 800,000 rpm predicted that the maximum stress of 290 MPa will occur at the root of the compressor blade near the exducer. In this study, the life

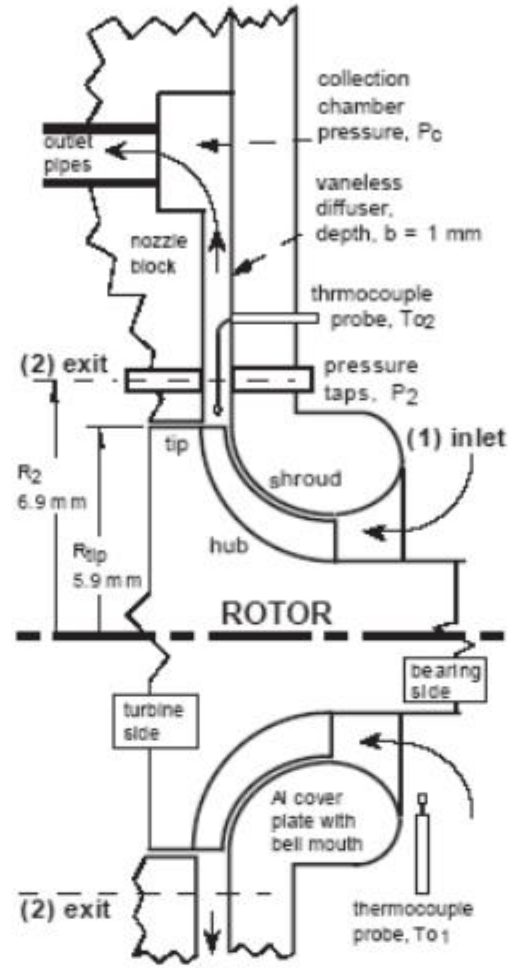

Figure 6. Compressor rotor in test rig showing measurement stations and instruments

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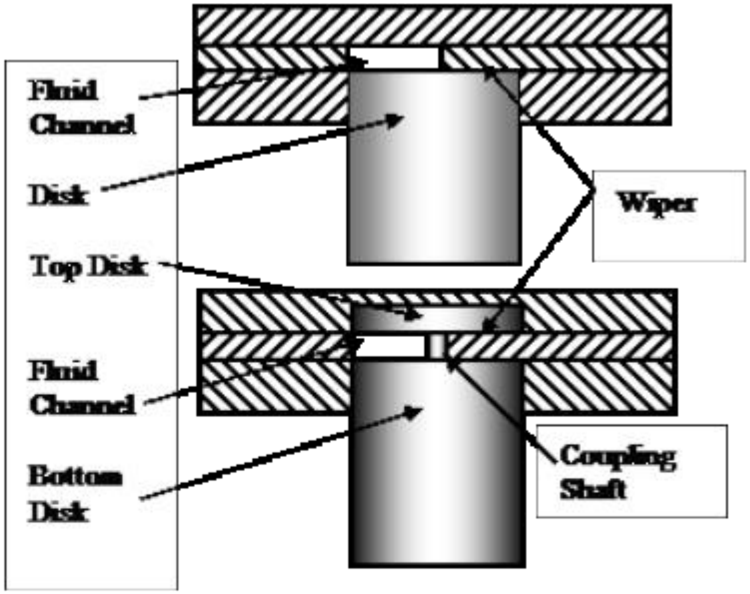
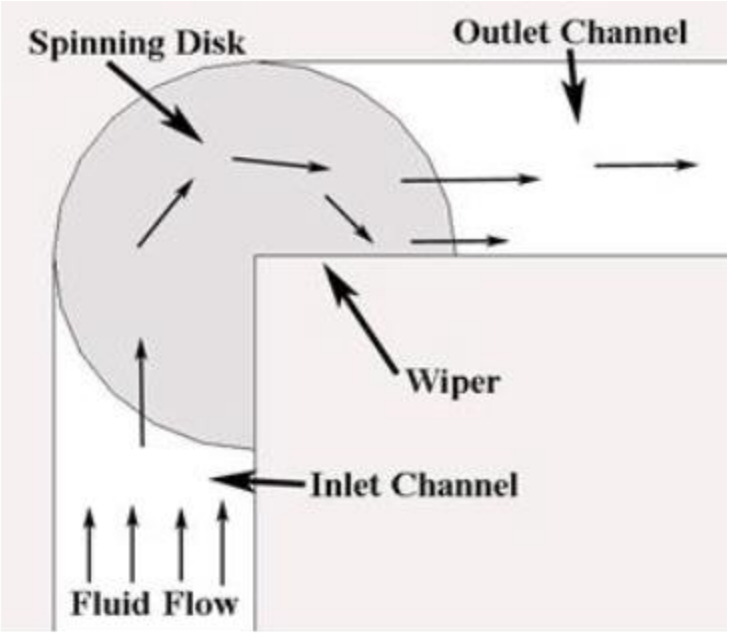
Small Rotary "Tesla" Drag Style Pump





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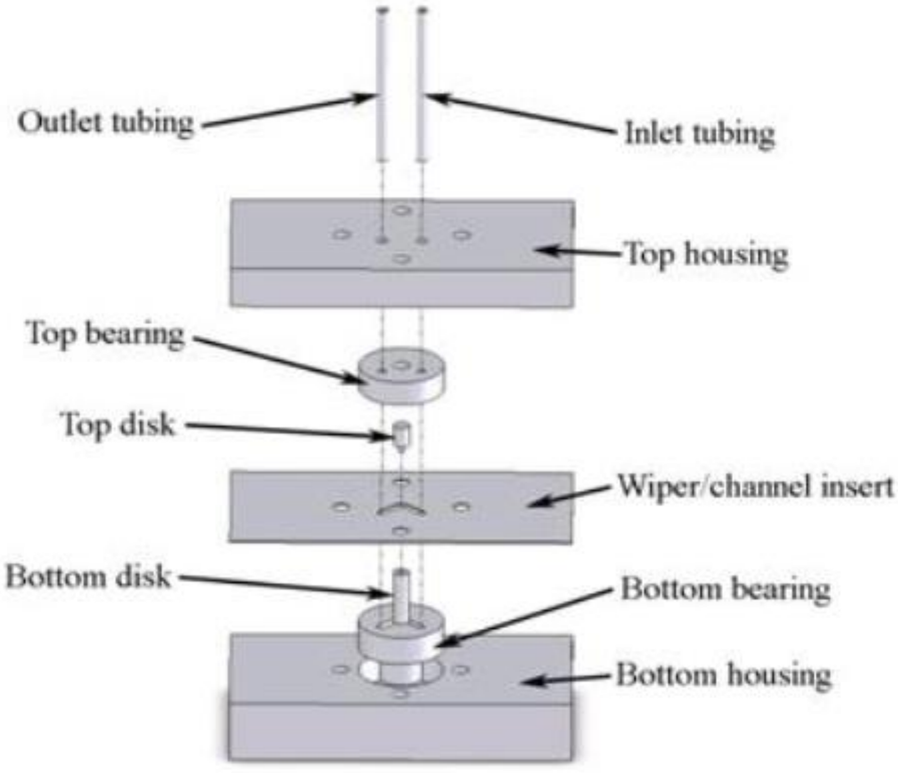
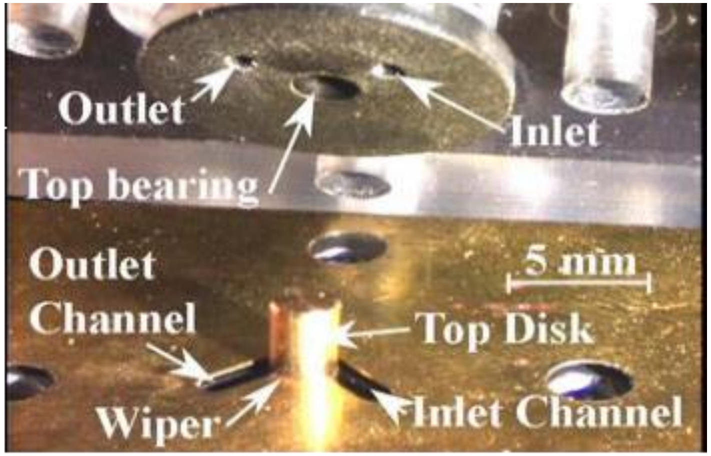
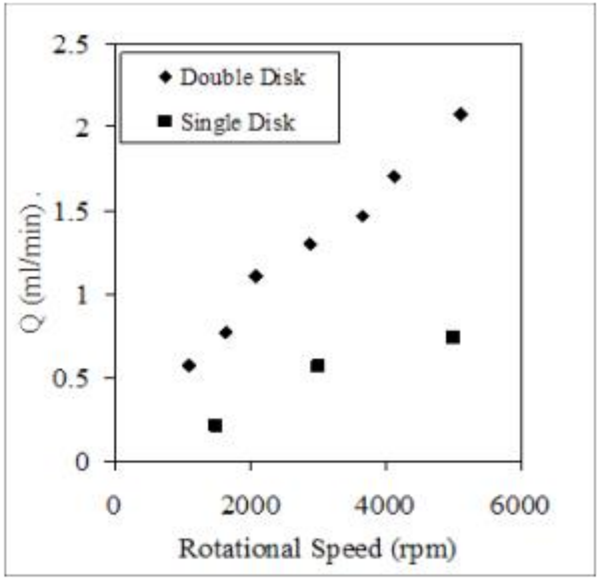
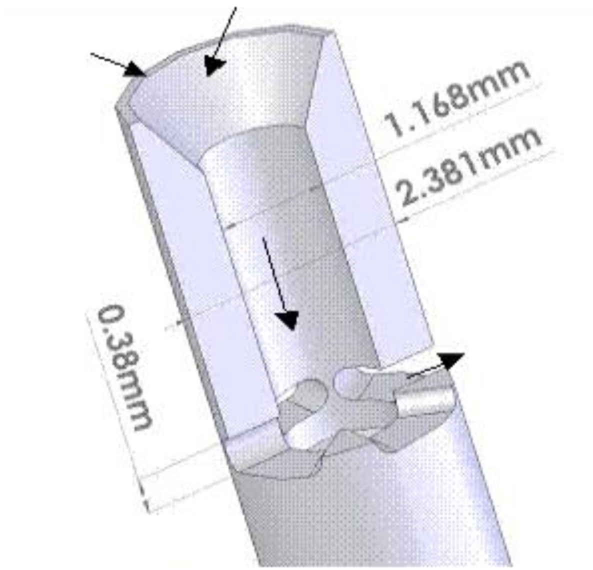
Small Centrifugal Pump

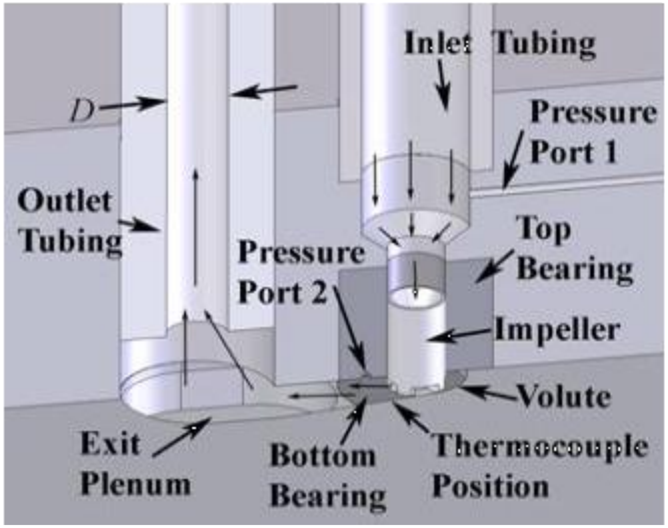


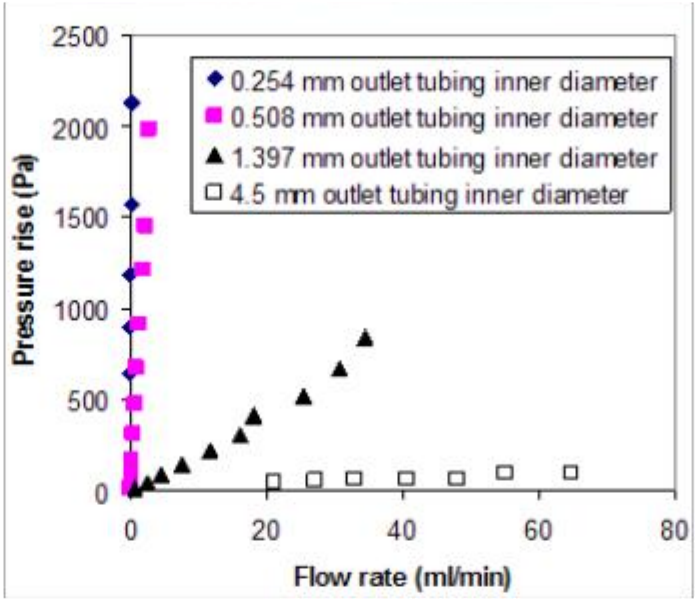




“Shaft” Style Centrifugal Pump







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Examples of Small Commercially Available and “Academic Research” Pumps

Small Piezo, Magnetic and Crank Actuated Diaphragm Pumps

Magnetic Micropump - Shinano Kenshi Co., ltd.

Description	**Micro pump**
Pumping method	**Electro magnetic driving, piston pump**
Rated pressure	**6kPa**
Rated flow	**400ml/min.**
Rated voltage	**12V DC**
Life	**44,000 hours min.**

Magnetic Diaphragm Actuator for a Micro Pump

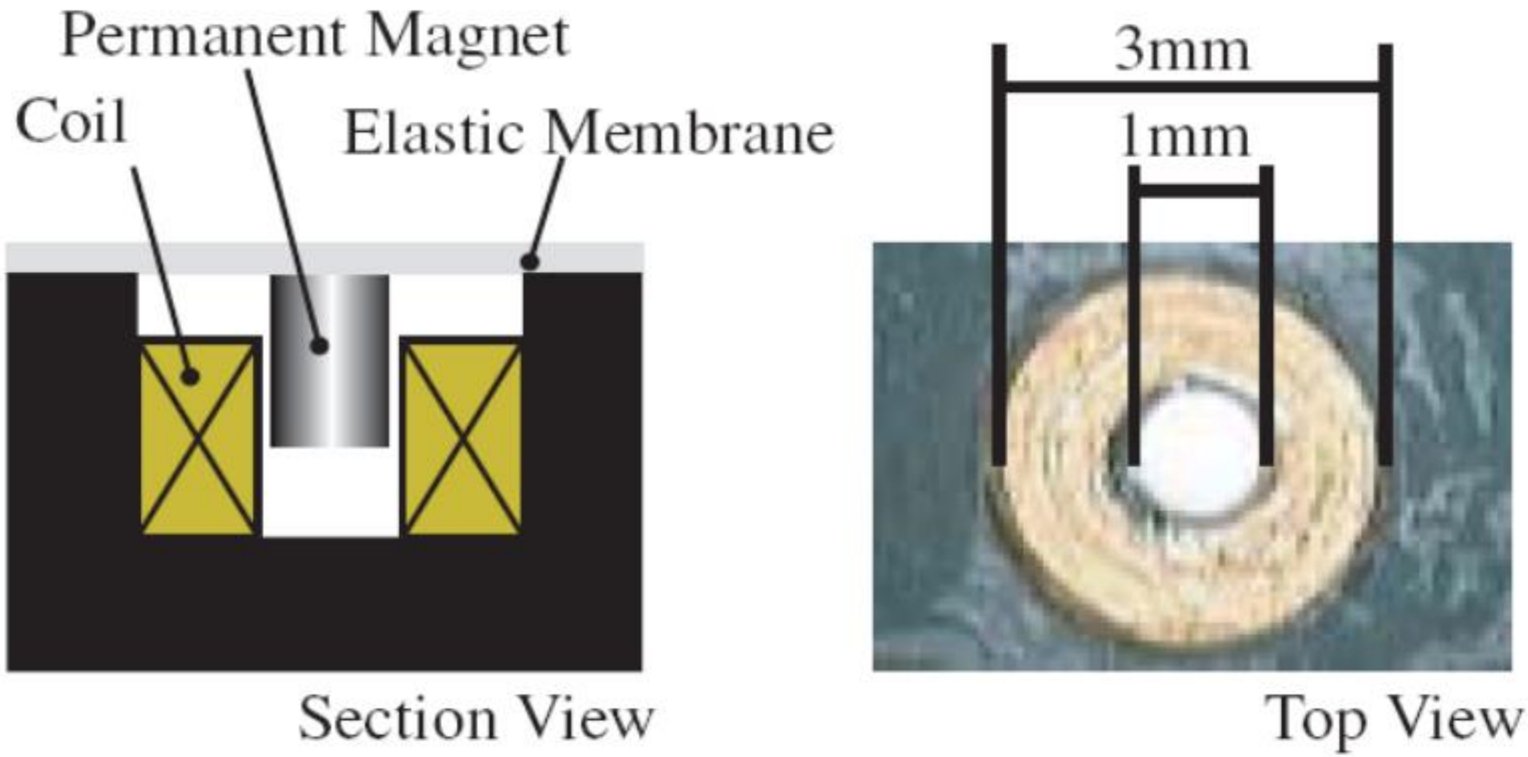
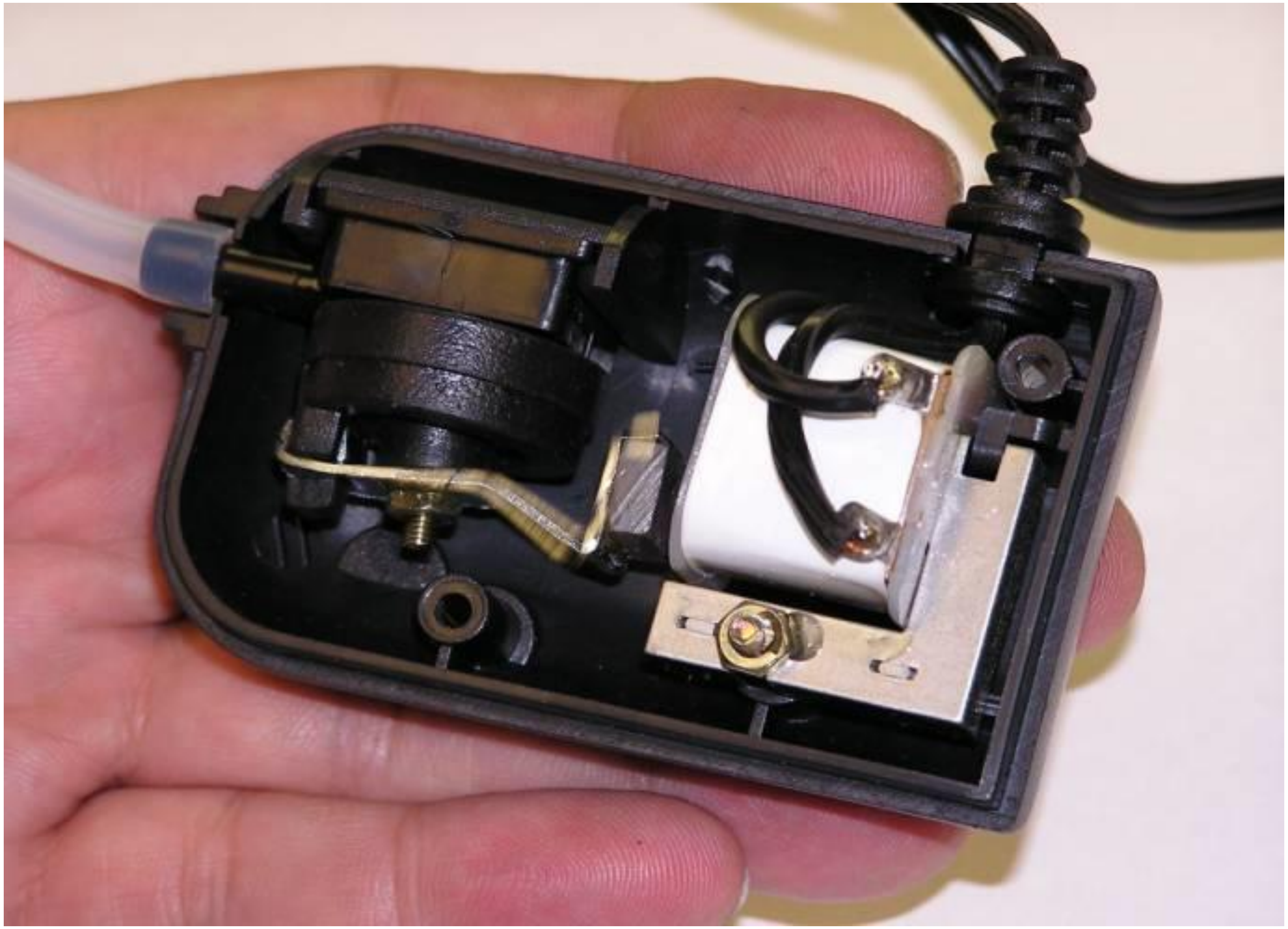


Fig. 7 Schematic of wall-deformation magnetic actuator.

Electromagnetic Actuation Diaphragm Pump



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Typical Diaphragm Micropump

INNOVATIVE
TECHNOLOGY
WORLDWIDE

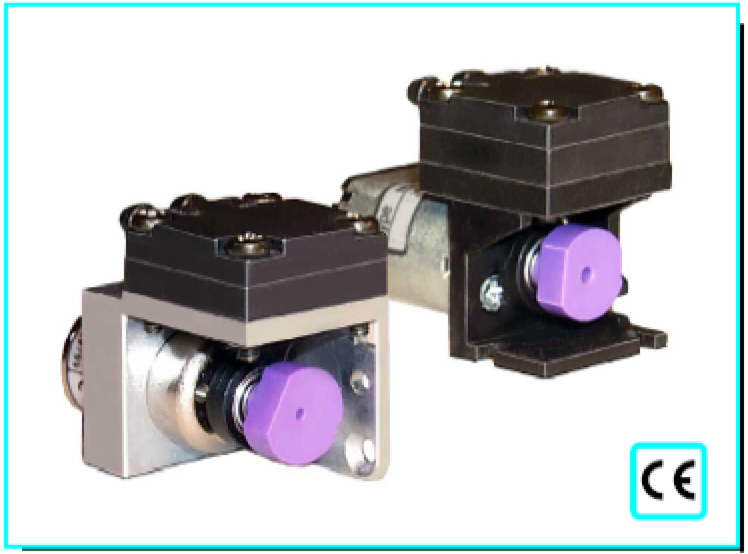
KNF NEUBERGER, INC.

SECTION 20.22

Type: NMP05

Micro-Diaphragm Pump and Compressor

Single Stage
OEM Installation Model
Standard DC, Brushless DC
Ironless-Core Motors



Shown with Ironless-core DC & Brushed DC Motor

STRUCTURED DIAPHRAGM

Max. Free-Flow Capacity:	250 - 450 mliters/min.
Max. Operating Vacuum:	to 500 mbar (15.2 in. Hg)
Max. Continuous Pressure:	to 400 mbar (5.8 psig)

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Typical Diaphragm Micropump

NMP05

KNF Performance Specifications

Model Number	Motor Volts DC	Free Flow ml/min.	Int. Vacuum mbar / "Hg	Continuous Vacuum mbar / "Hg	Continuous Pressure mbar / psig	Int. Pressure mbar / psig
NMP05 B	6	300	500 / 15.2	500 / 15.2	400 / 5.8	400 / 5.8
NMP05 L	6	450	500 / 15.2	750 / 7.8	250 / 3.6	450 / 6.5
NMP05 M	2.5	400	550 / 13.7	850 / 4.8	150 / 2.2	400 / 5.8
NMP05 M	6	300	500 / 15.2	850 / 4.8	150 / 2.2	400 / 5.8
NMP05 S	3*	250	500 / 15.2	850 / 4.8	150 / 2.2	250 / 3.6
NMP05 S	5*	400	500 / 15.2	850 / 4.8	150 / 2.2	350 / 5.1

Electrical & Environmental

Model	NMP05 B	NMP05 L	NMP05 M	NMP05 S
Motor Type	Brushless DC	Premium Ironless-Core DC	Standard Ironless-Core DC	Brushed DC*
Net Weight	22 gr / .8 oz	27 gr / 1 oz	20 gr / .7 oz	18 gr / .7 oz
Max. Ambient & Media Temp.	+5°C to +40°C	+5°C to +40°C	+5°C to +40°C	+5°C to +40°C

Materials of Construction

	Head	Diaphragm	Valves
All Models	Ryton® (PPS)	EPDM	EPDM

Notes: Standard continuous performance ratings listed above are at sea level with an ambient temperature of 70° F (21° C) and nominal electrical supply. Dimensions and performance characteristics given are for reference only. Higher performance models, cost efficient OEM modifications, a wide variety of motor options and different materials of construction are available. These pumps are not suitable for aggressive gases and vapors, or where there is a risk of explosion. Other KNF products are available for that purpose. To prevent exceeding the maximum operating pressure, restriction of air flow should only be placed at the inlet port. Ryton® is a registered trademarks of the Phillips 66 Co. Specifications are subject to change without notice.

*NMP05S does not comply with the EC directive 89/336 EWG concerning electro-magnetic compatibility. If required, please use NMP05M.

Accessories: Noise & Dust Filters, Shock Mounts

Performance Characteristics/Outline Dimensions

Typical Diaphragm Micro Pump

KNF **Liquid OEM Pumps**

Basic Liquid OEM Pump Information

Liquid Micro OEM Pumps - .05 to 3 LPM

Liquid Metering Pumps - .03 to 80 mLPM

Liquid Pump Accessories & Specialty Pumps

Air & Gas Pumps - 0.25 to 300 LPM

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Request a Quote

Liquid Handling Pumps

KNF's newest model NF5.
Quite possibly the world's smallest liquid diaphragm pump. Extremely quiet operation.
All KNF liquid pumps are self-priming and can run dry indefinitely. Their compact size allows you to place the pump on location where you need it.

Datasheets are available for downloading, viewing and printing in the Acrobat PDF format by clicking on the pump model number below.
Information on how to obtain the free software is available HERE.

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Typical Diaphragm Micropump Performance

Pump Series (Download Datasheets)	Available Motors	Flow Rate LPM	Flow Rate GPH	Suction ft. Water	Discharge psig
NF5 (PDF: 282kb/2pg)	DC	.05	.8	13	15
NF10 (PDF:128kb/2pg)	AC/DC/BLDC	.1	1.6	10	15
NF11 (PDF:128kb/2pg)	Ironless Core	.1	1.6	10	15
NF1.11 (PDF:128kb/2pg)	Ironless Core	.1	1.6	10	85
NF1.30 (PDF:105kb/2pg)	Geared DC	.17	2.7	20	197
NF30 (PDF:105kb/2pg)	AC/DC/BLDC	.3	4.8	20	15
NF31 (PDF:105kb/2pg)	Ironless Core	.3	4.8	20	15
NFT30 (PDF:101kb/2pg)	DC	.6	9.5	20	15
NFT31 (PDF:101kb/2pg)	Ironless Core	.6	9.5	20	15
NF60 (PDF:101kb/2pg)	AC/DC/BLDC	.6	9.5	16	15
NF61 (PDF:101kb/2pg)	Ironless Core	.6	9.5	16	15
NF100 (PDF:185kb/2pg)	AC/DC/BLDC	1.2	19	13	15
NF1.100 (PDF:185kb/2pg)	AC/DC/BLDC	1.3	20.6	13	85
NF300 (PDF:200kb/2pg)	AC/DC	3	48	13	15
NF1.300 (PDF:200kb/2pg)	AC/DC	3	48	13	85
ND100 (PDF: 200kb/2pg)	AC/DC/BLDC	1	16	10	15
ND1.100 (PDF: 200kb/2pg)	AC/DC	1.4	22	10	60
NDT300.23AA (PDF:300kb/2pg)	AC	2 or 4	0.53 or 1	7	10

Yet Another Diaphragm Micro Pump

Catalog PLS01-1001/US

PUMPS **T2-04**

Ultra-Compact Performance Diaphragm Pump

T2-04

Miniature Pumps

The T2-04 is an ultra-compact pump available in single head (T2-04 SH) or twin head (T2-04 TH) and ideal for use in portable air and gas applications. Delivering flow up to 7 slpm, this pump works well in environments where DC operation, high performance, low cost, minimal weight, and compact size are critical.

Features

- Offers ultra-compact size, long life, and high efficiency.
- Provides quiet operation and low vibration.
- Contamination-free.
- Offers E-Z Mounting.
- Range of custom configurations and optional motors available to optimize "drop-in" size, performance, and cost.
- Alternative materials for chemical resistance to corrosive atmospheres available.

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Various Piezoelectric Pumps

Really Small

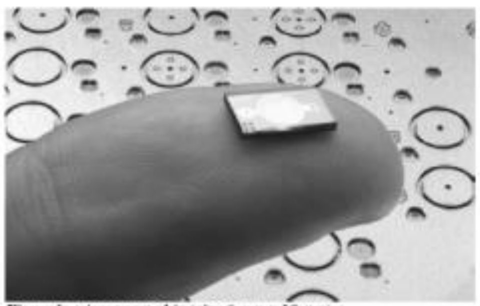
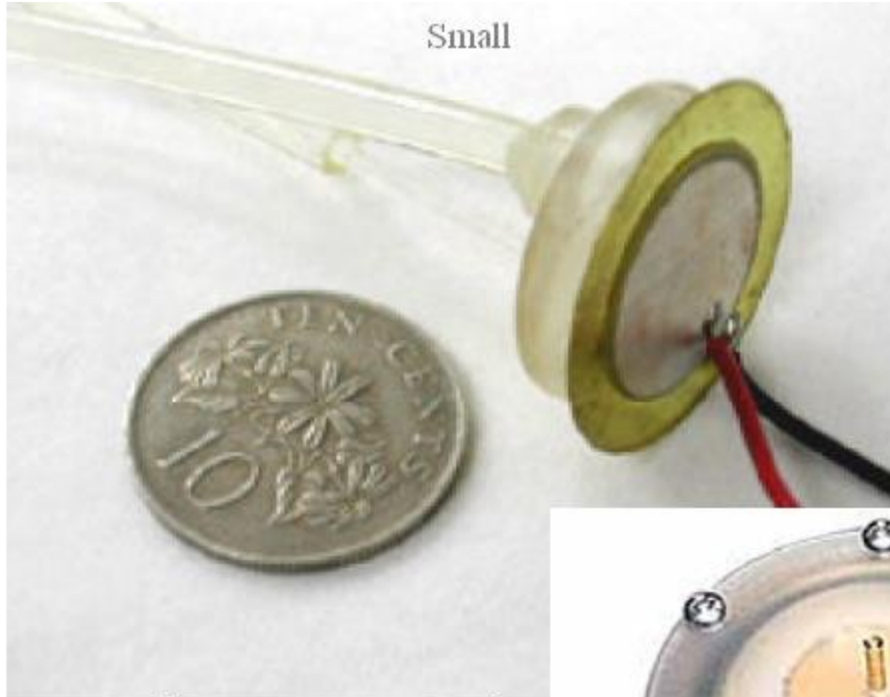
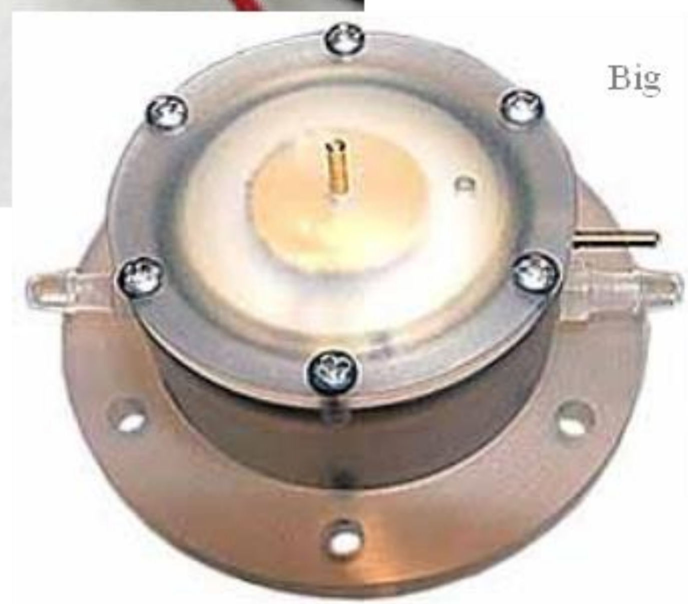


Figure1: micropump chip (size 6 mm x 10 mm)





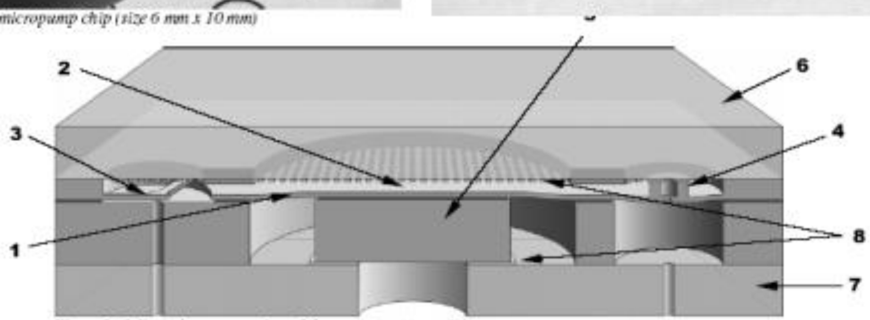


Figure2: Schematic cross section of the pump (not to scale)

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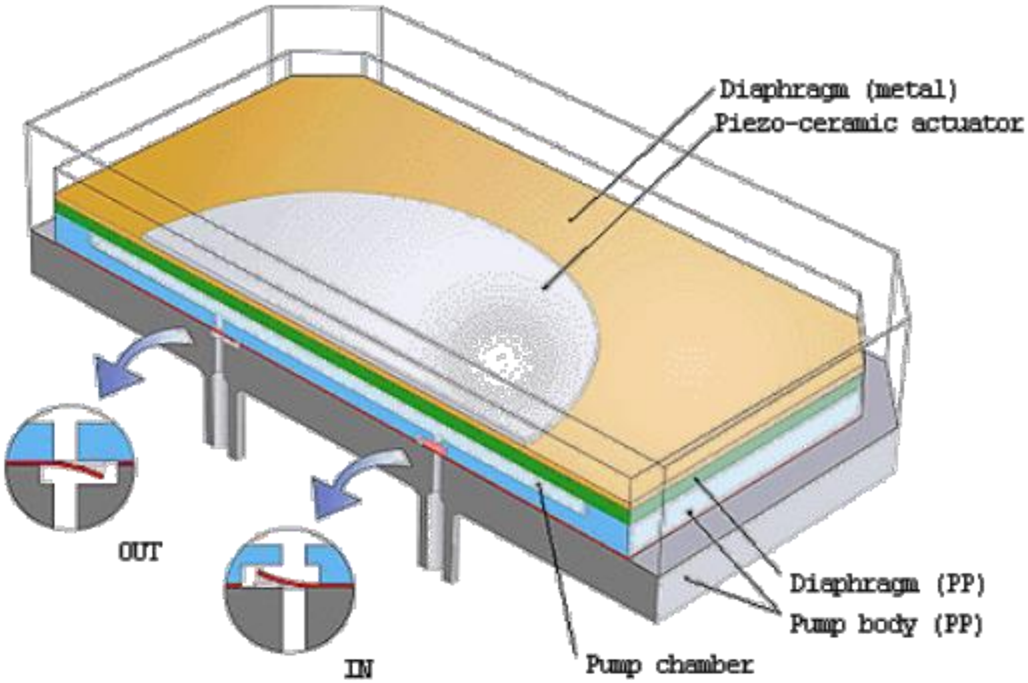
Typical Small Piezo Pump - Star-Micronics Corp.



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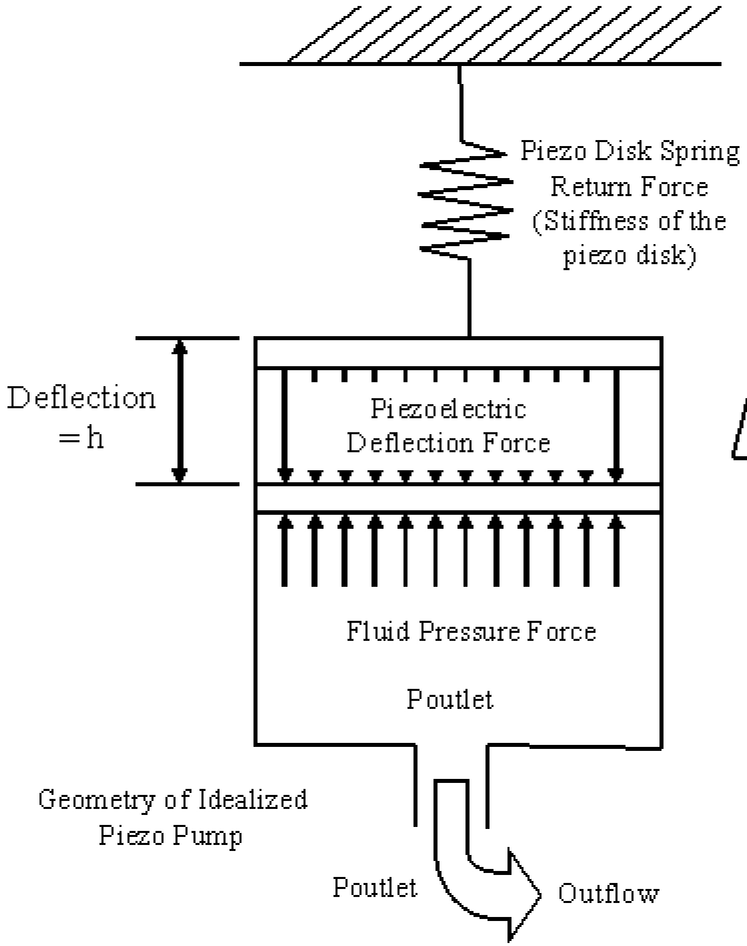
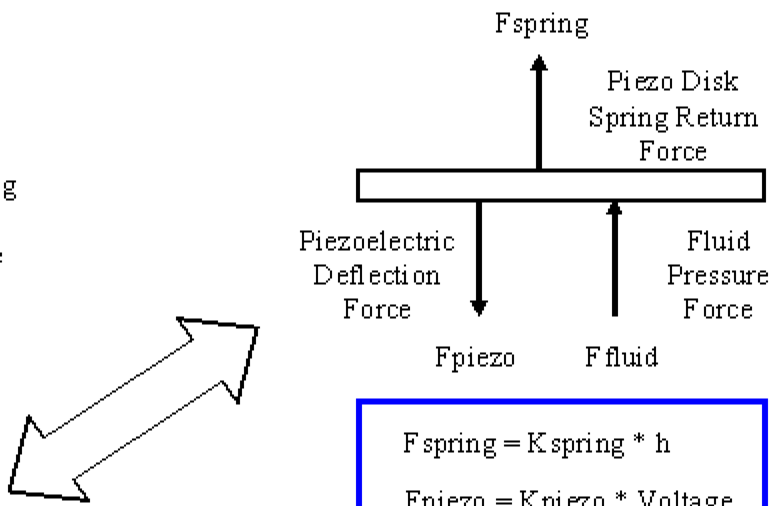
Derivation of a Simplified Piezo Pump Design Equation



Geometry of Idealized Piezo Pump



Fspring = Kspring * h

Fpiezo = Kpiezo * Voltage

Ffluid = Pout * Disk Area

At the end of a pump "exhale" phase disk motion stops and:

Fpiezo = Fspring + Ffluid   or:

Kpiezo * Voltage = Kspring * h + Pout * Disk Area

Therefore:

Pout = (Kpiezo * Voltage - Kspring * h) / Disk Area

Force Balance Analysis for an Idealized Piezo Pump at the End of the "Exhale" Phase

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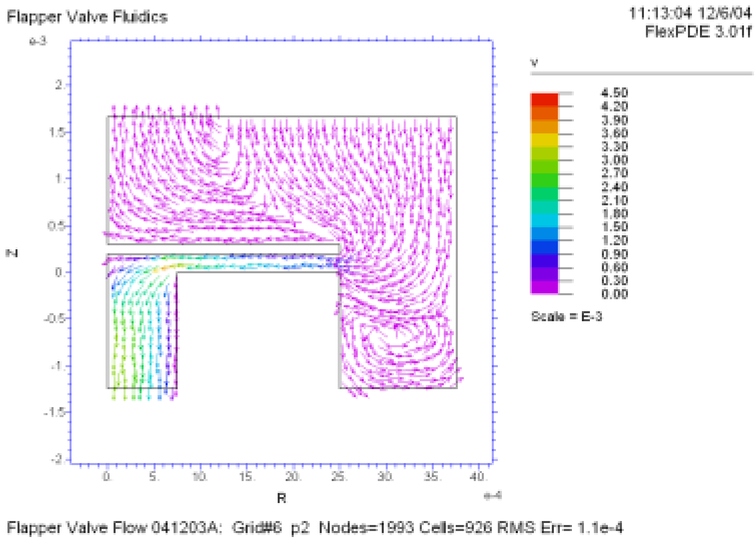
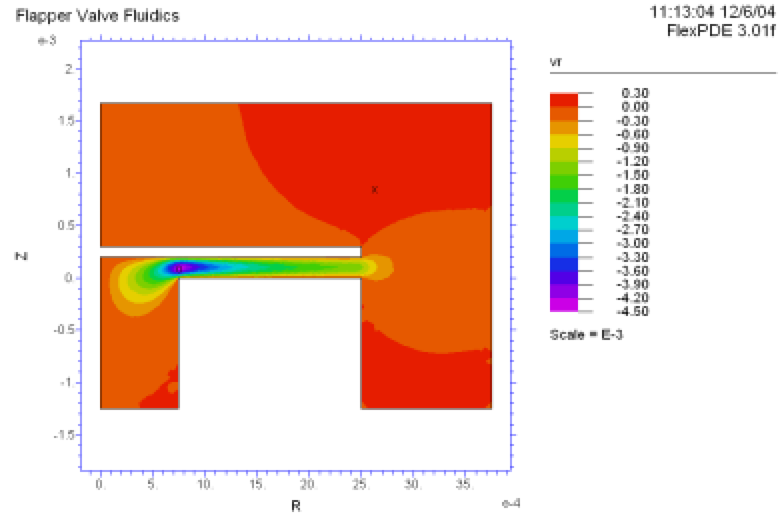
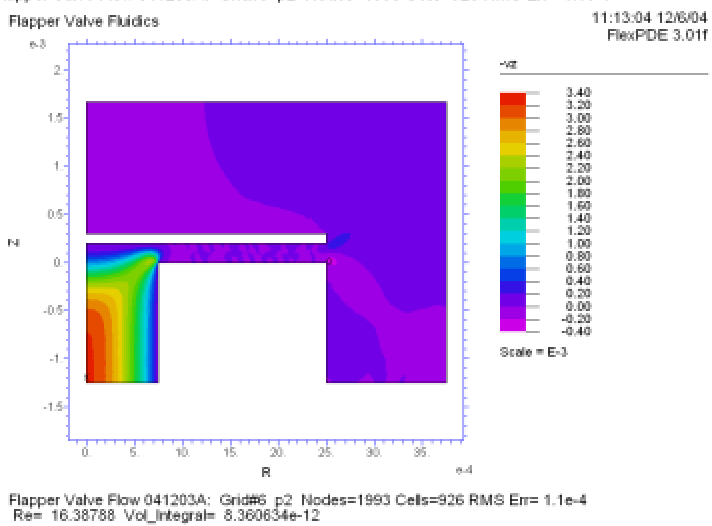
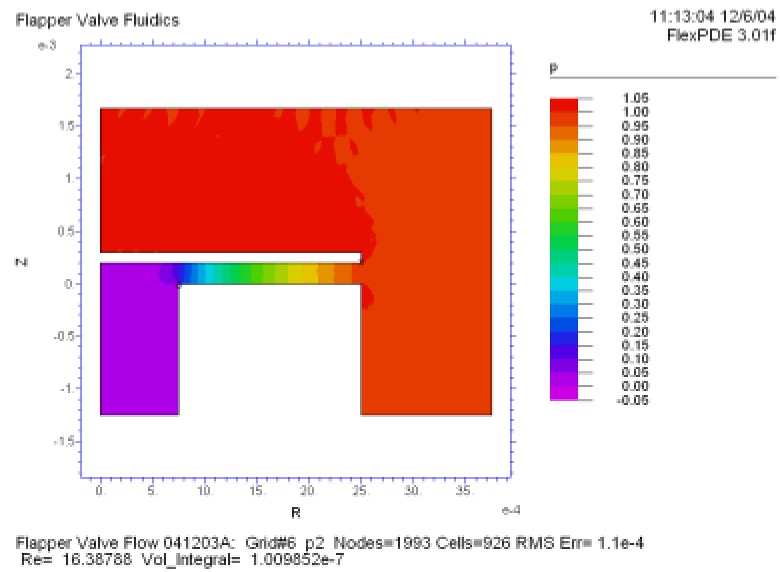
Finite Element Analysis (FEA) of a Flapper Valve using flexPDE









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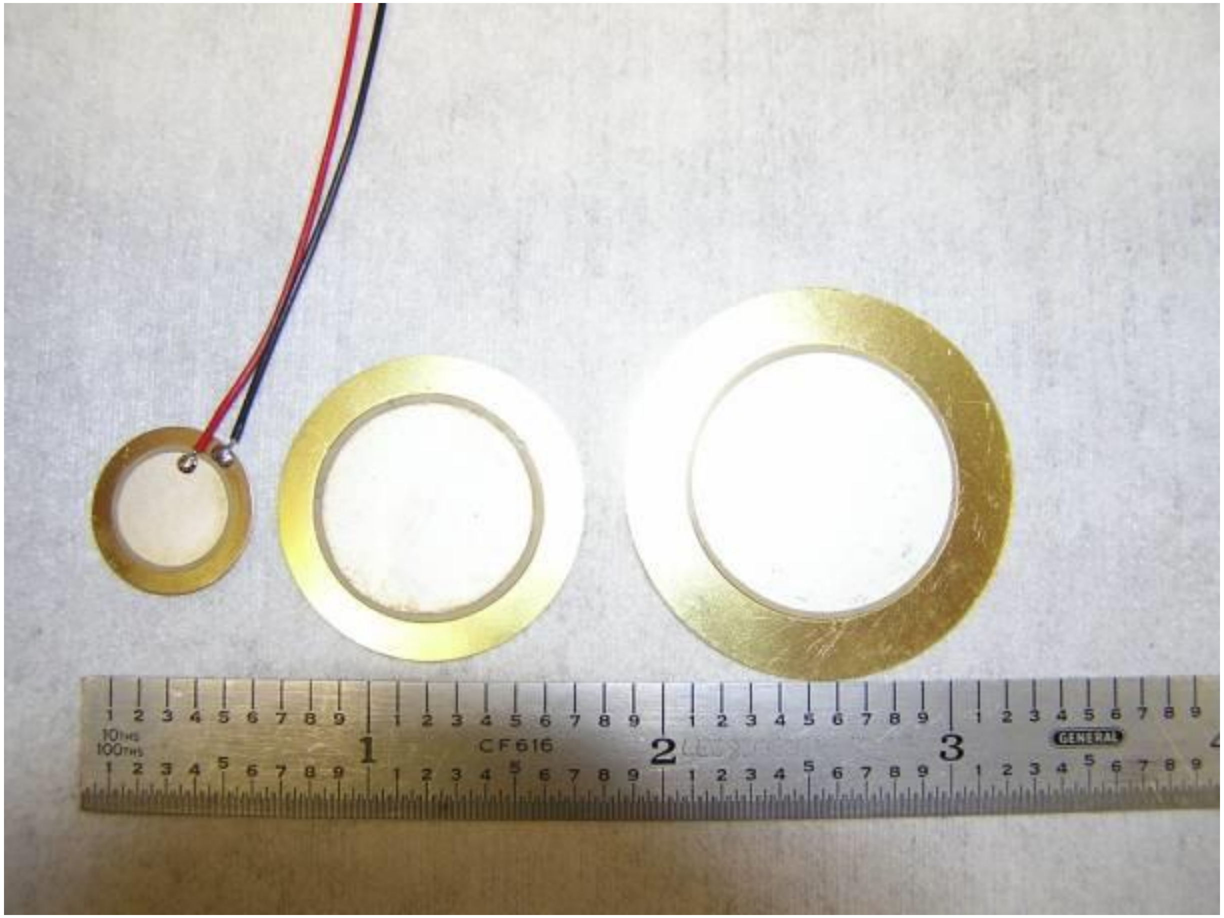
Piezo Disk Pump Elements



15, 27 and 35 mm Piezo Disks

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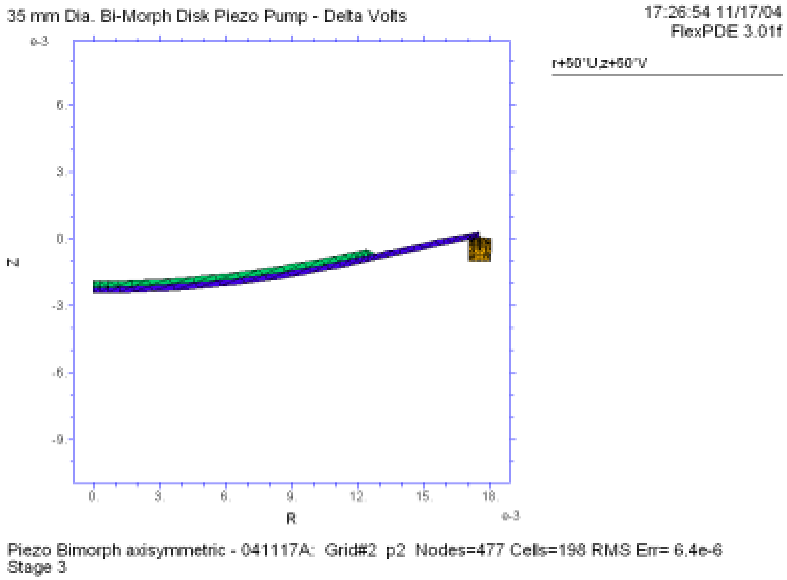
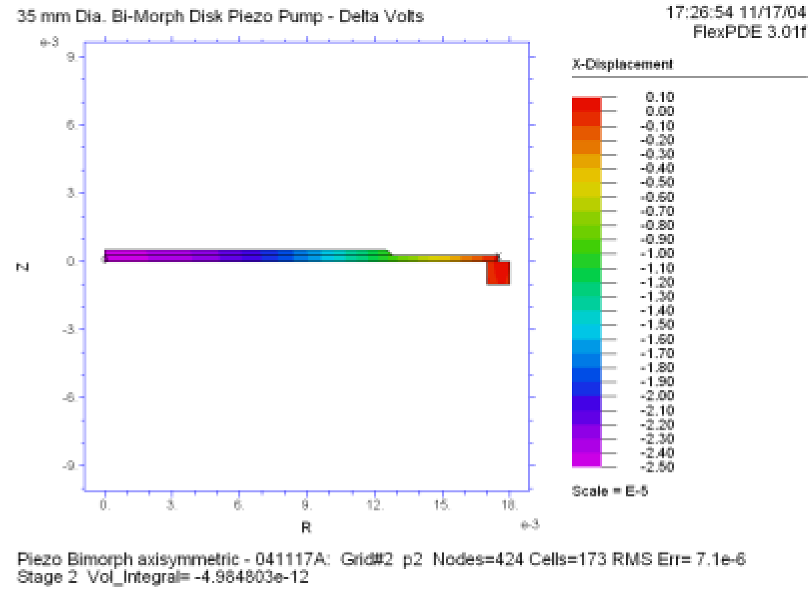
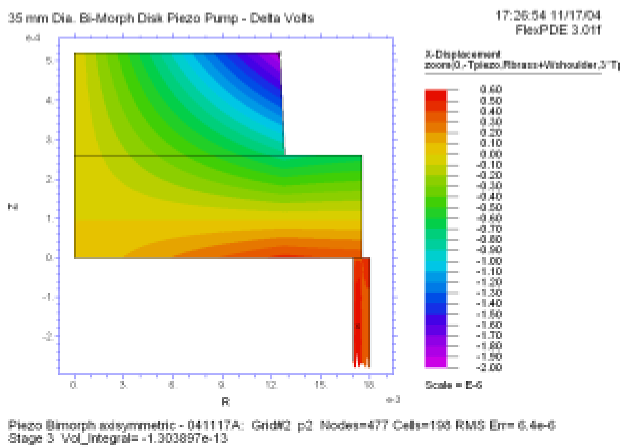
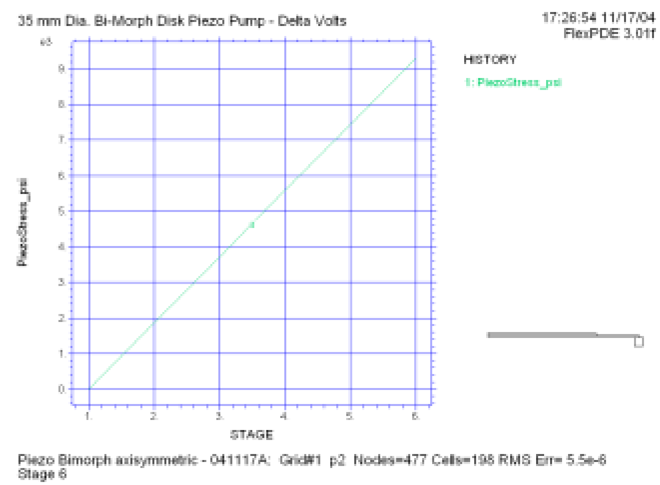
Finite Element Model (FEA) of a Piezo Diaphragm using flexPDE









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Summary

A variety of pumps suitable for transferring gas and liquids have been presented along with fluid dynamic operating equations.

Some of these pumps are of normal scale and others are fabricated on a microfluidic – micropump scale.

Depending on the application, any one of the pumps presented may be of practical value.