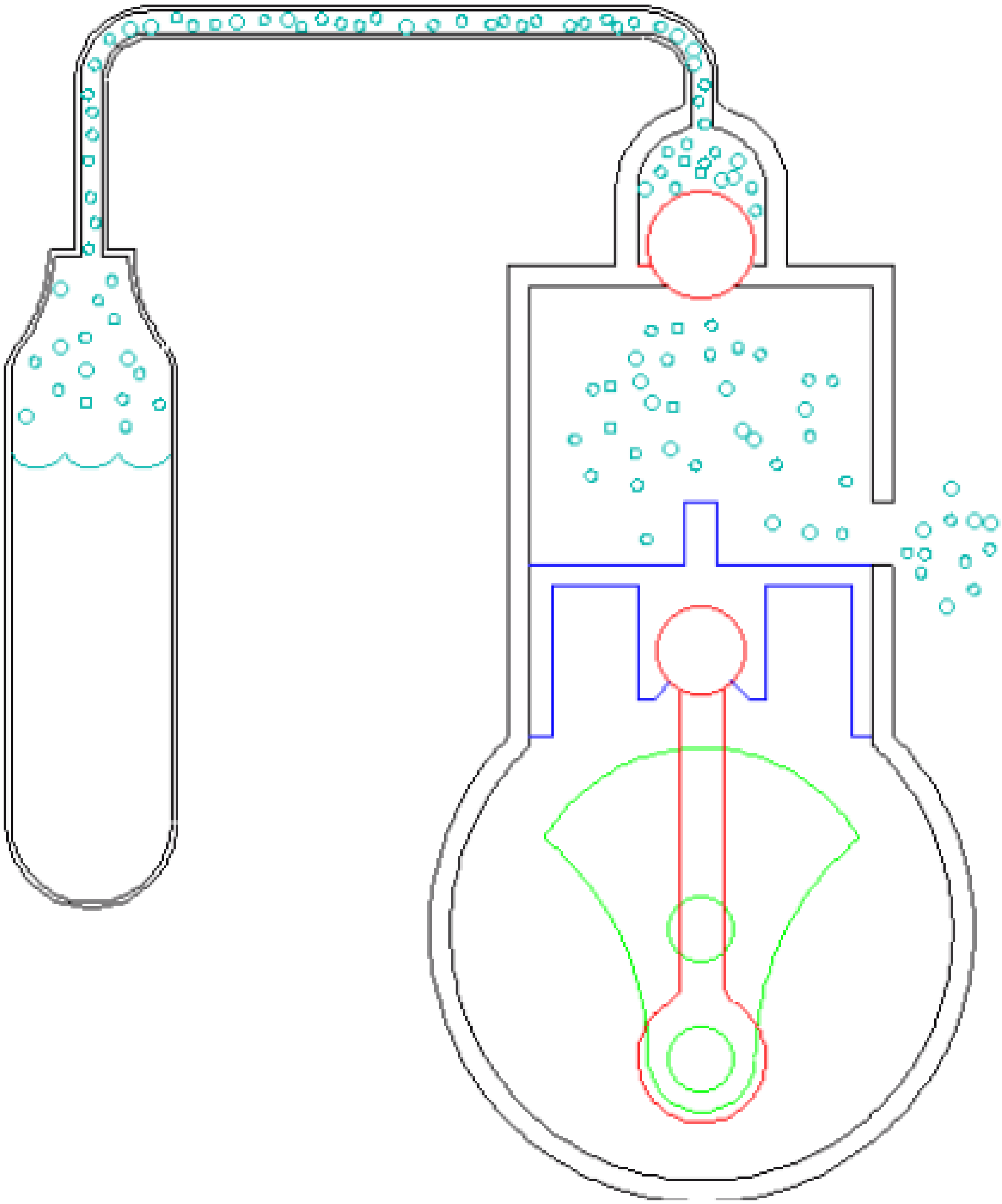
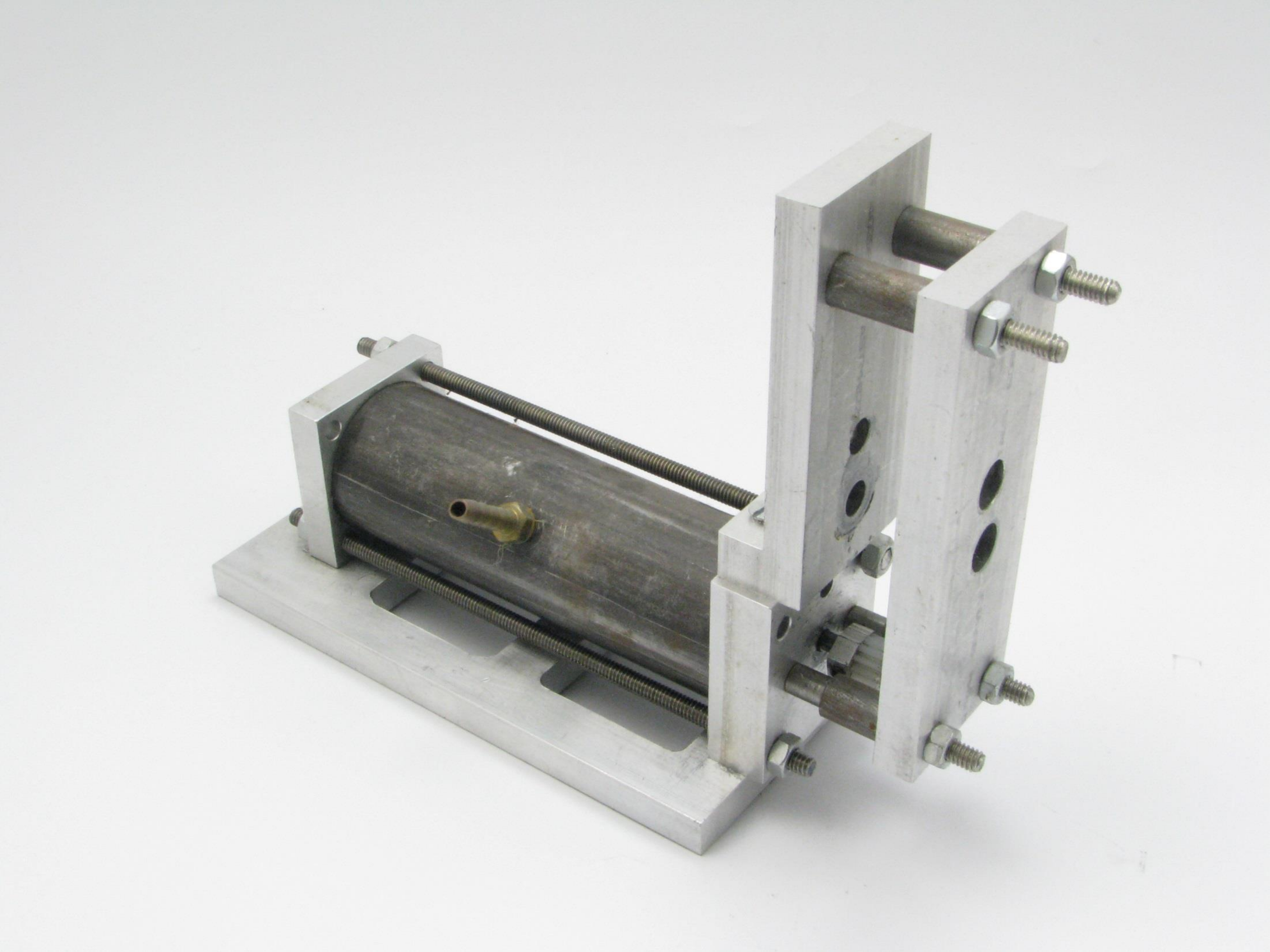
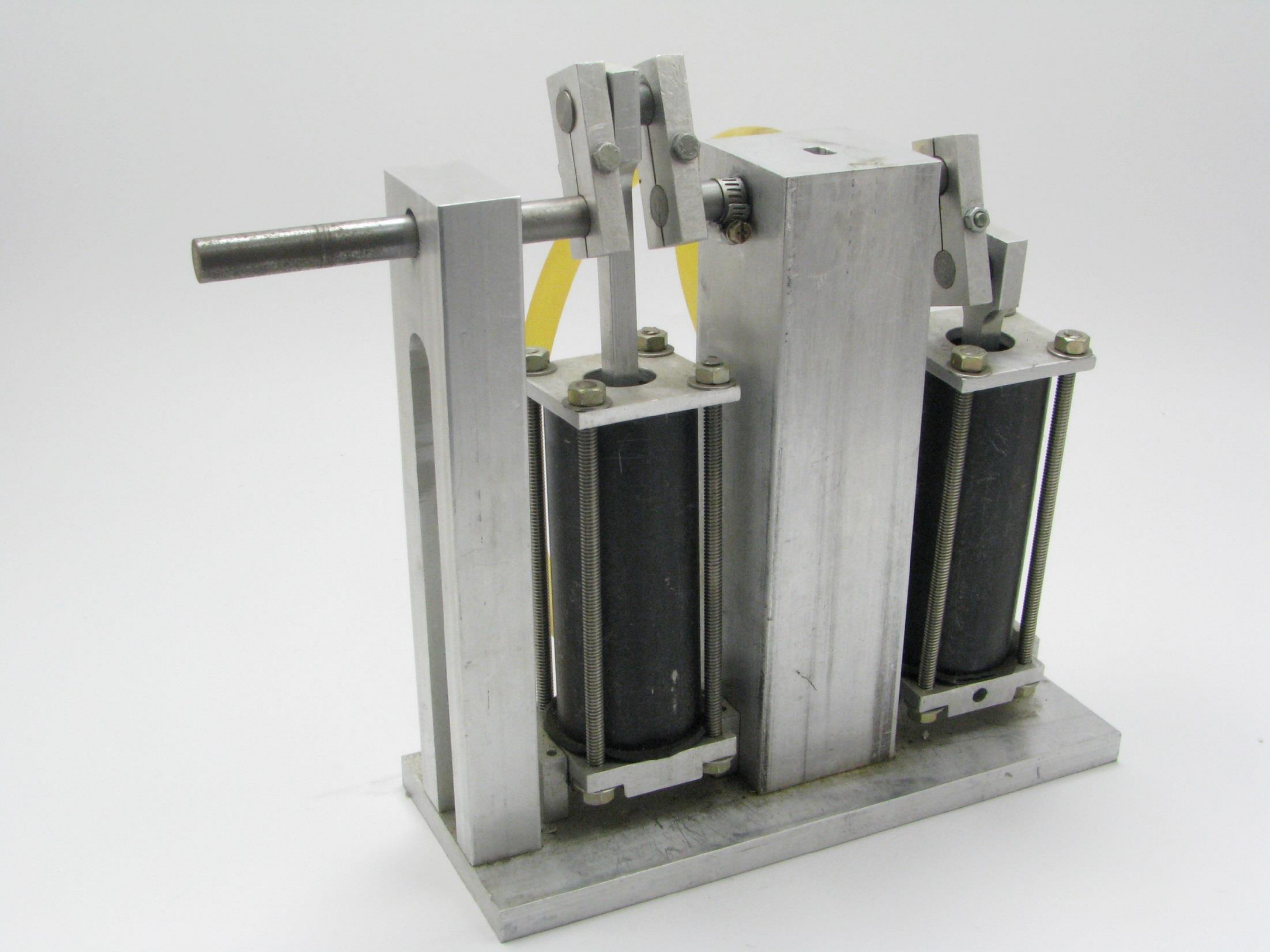
MAE 2250

Air Motor



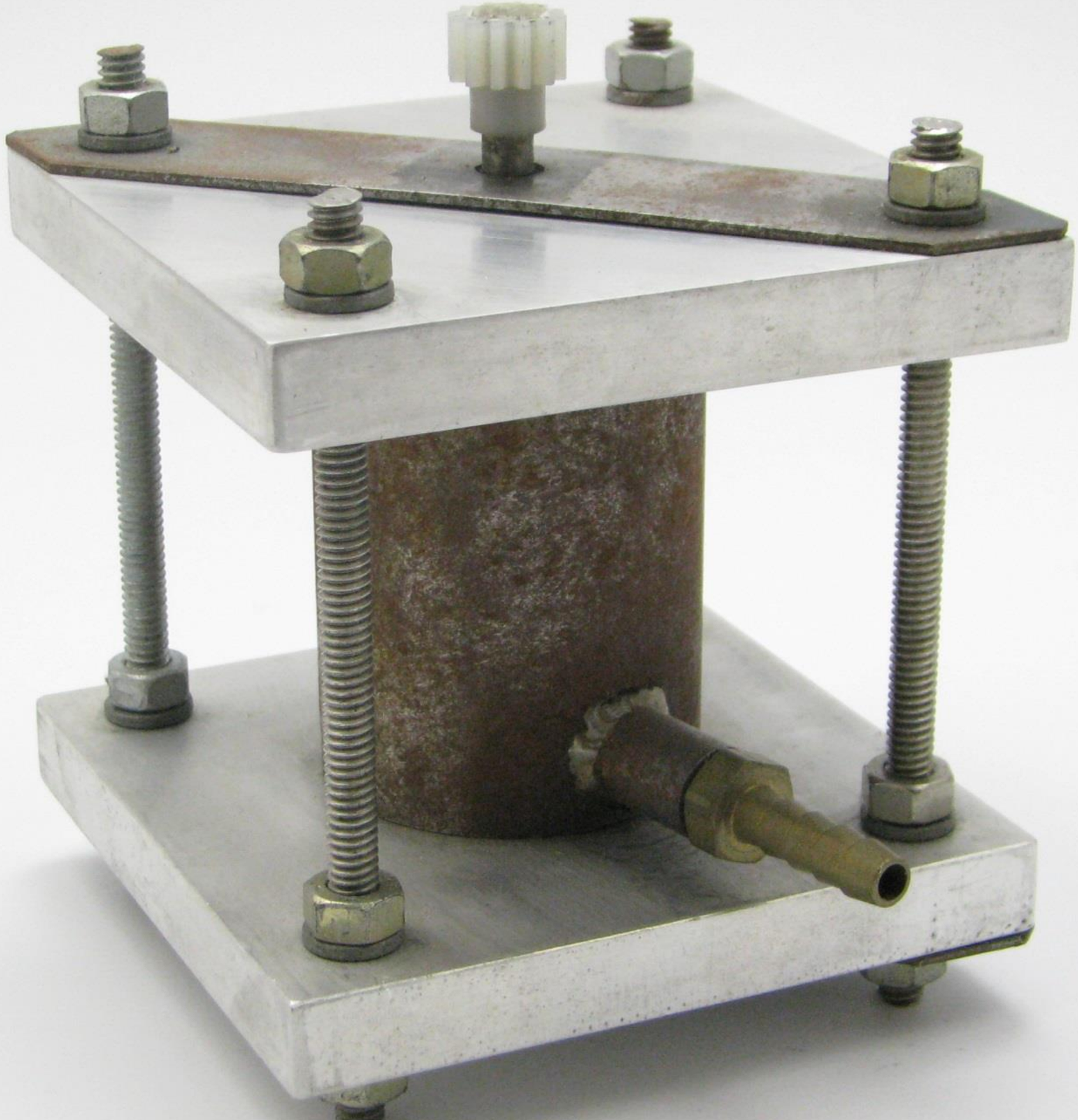
http://www.animatedengines.com/co2.html

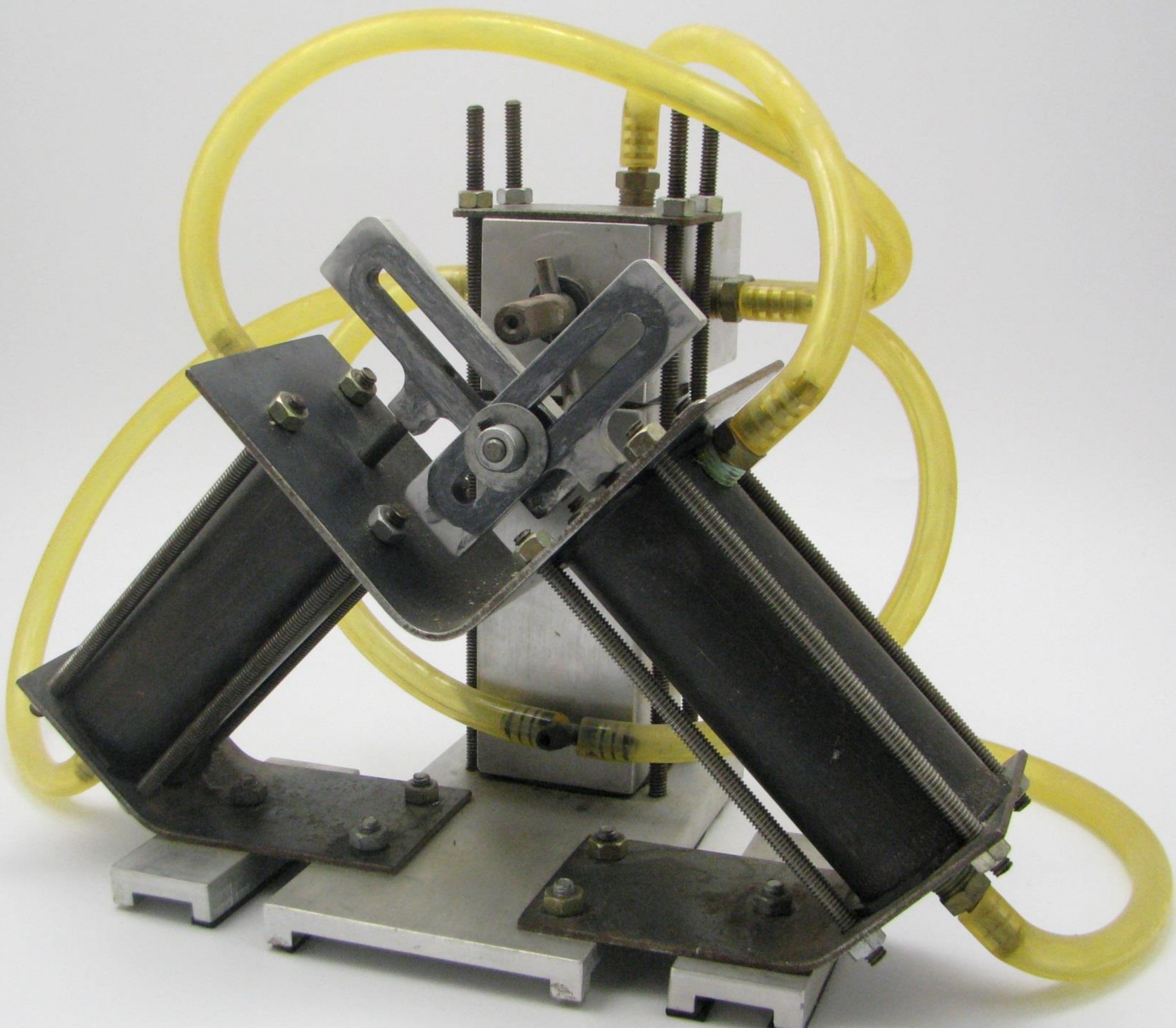


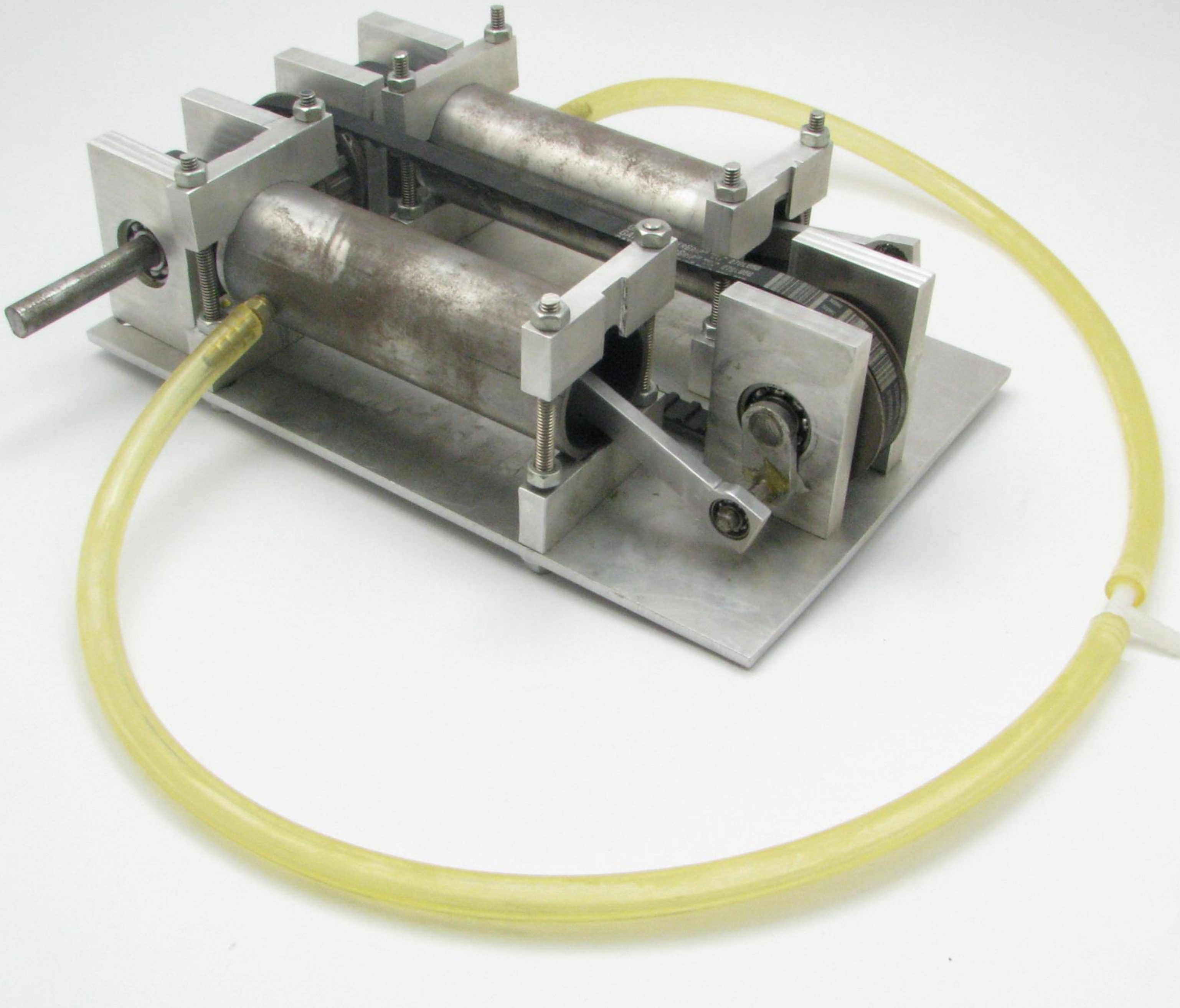


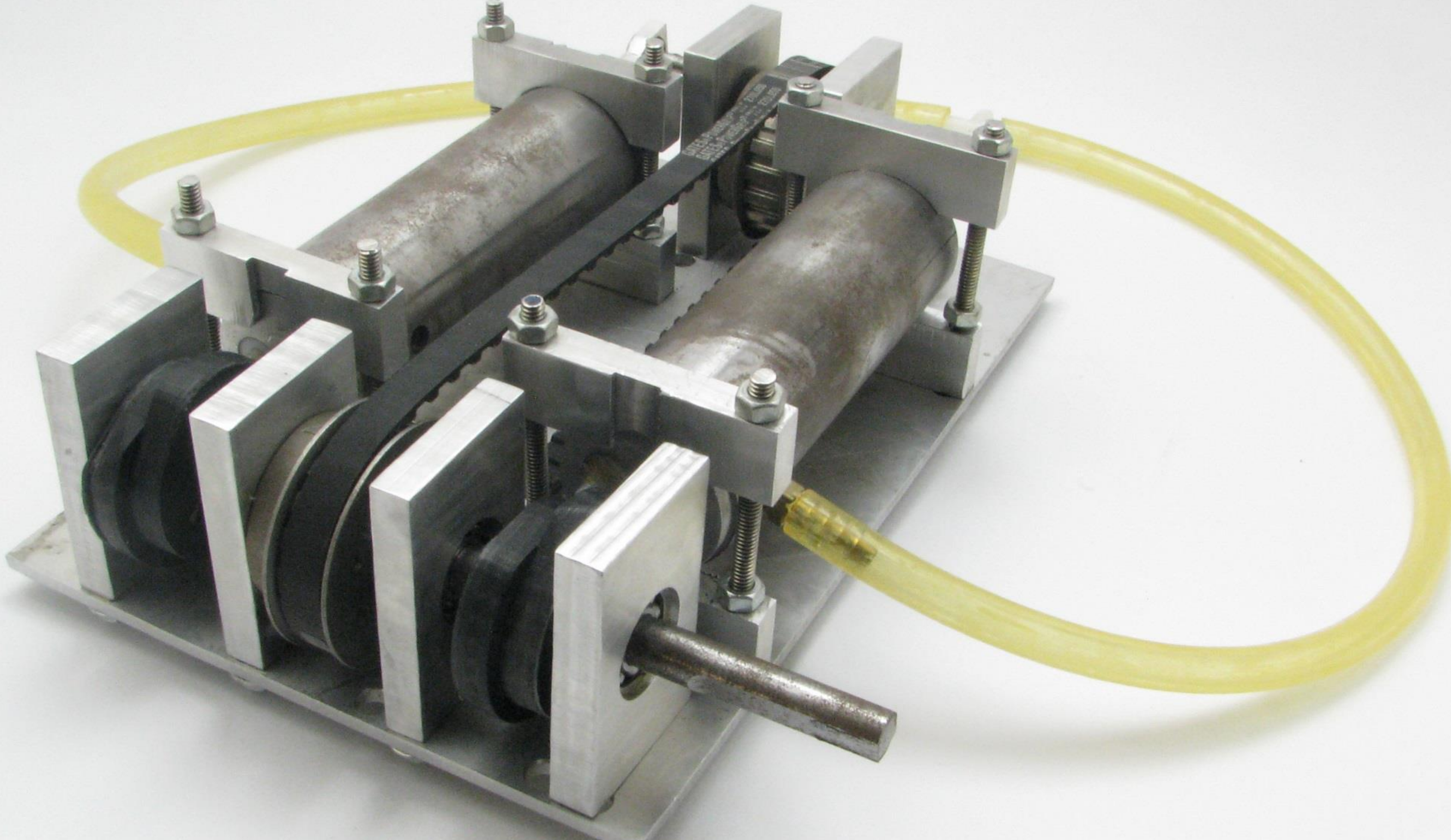
Ingersoll-Rand 2317G Edge Pro Wrench

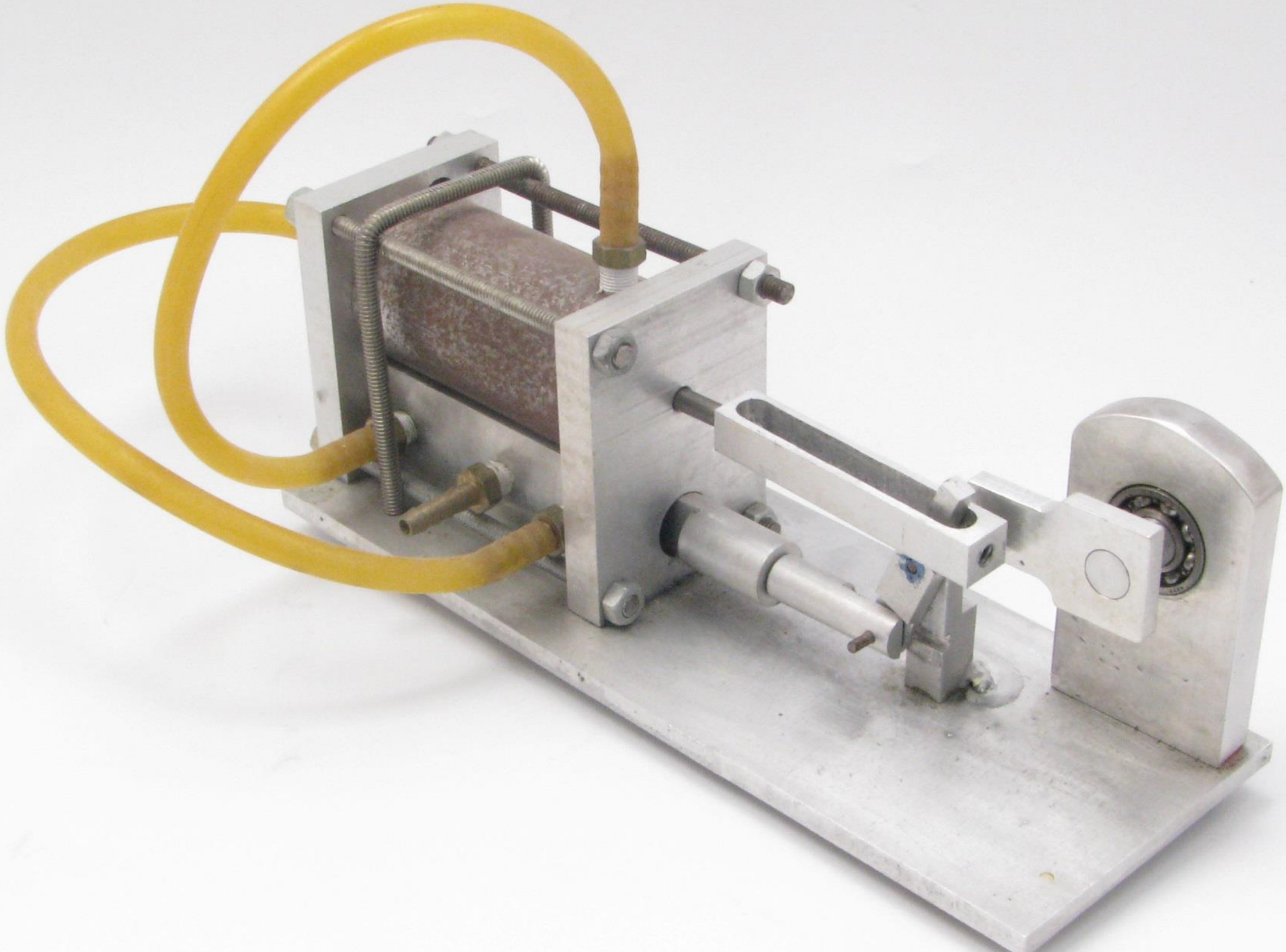
Proto 3/4" Drive Air Impact Wrench

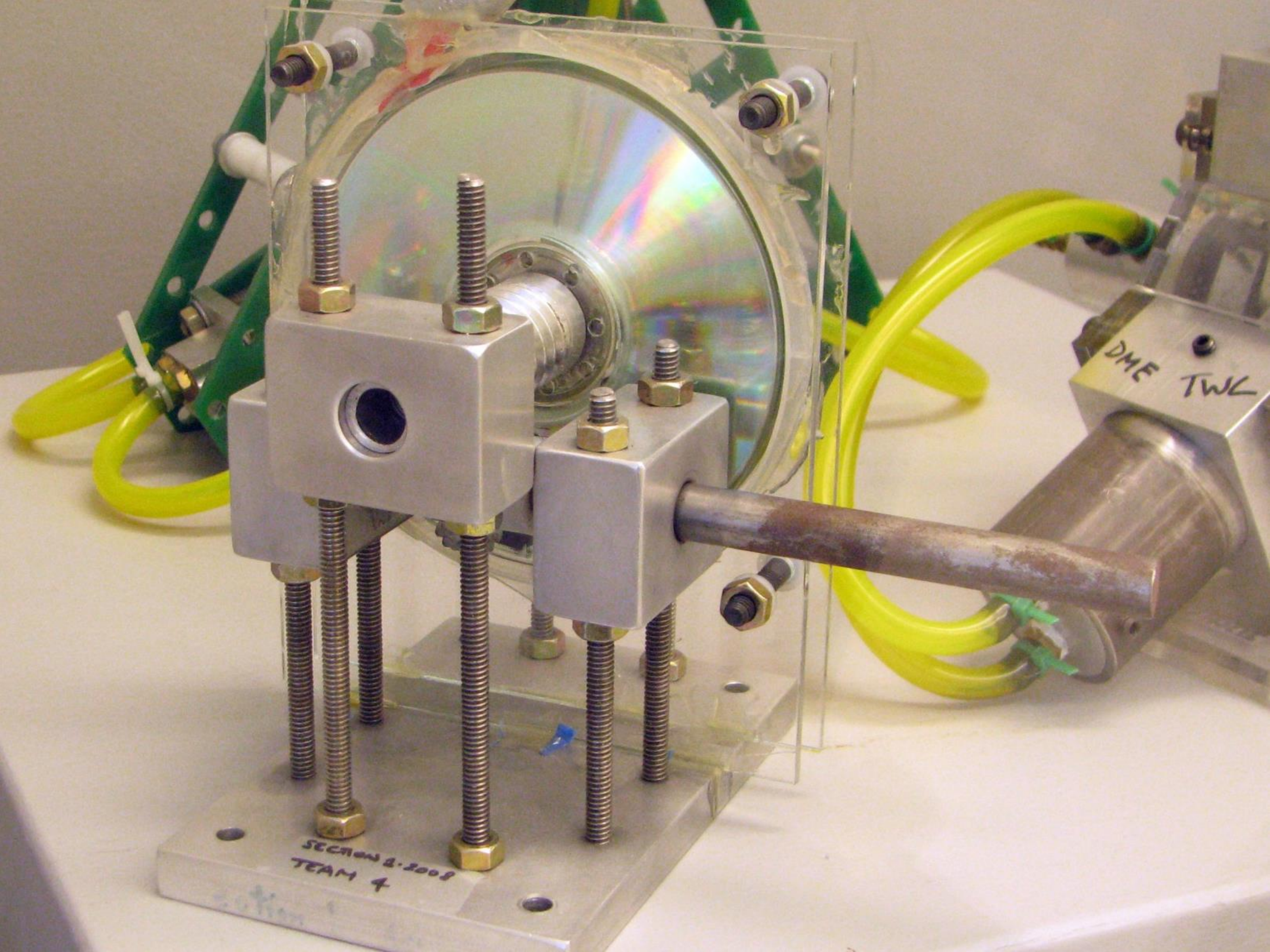


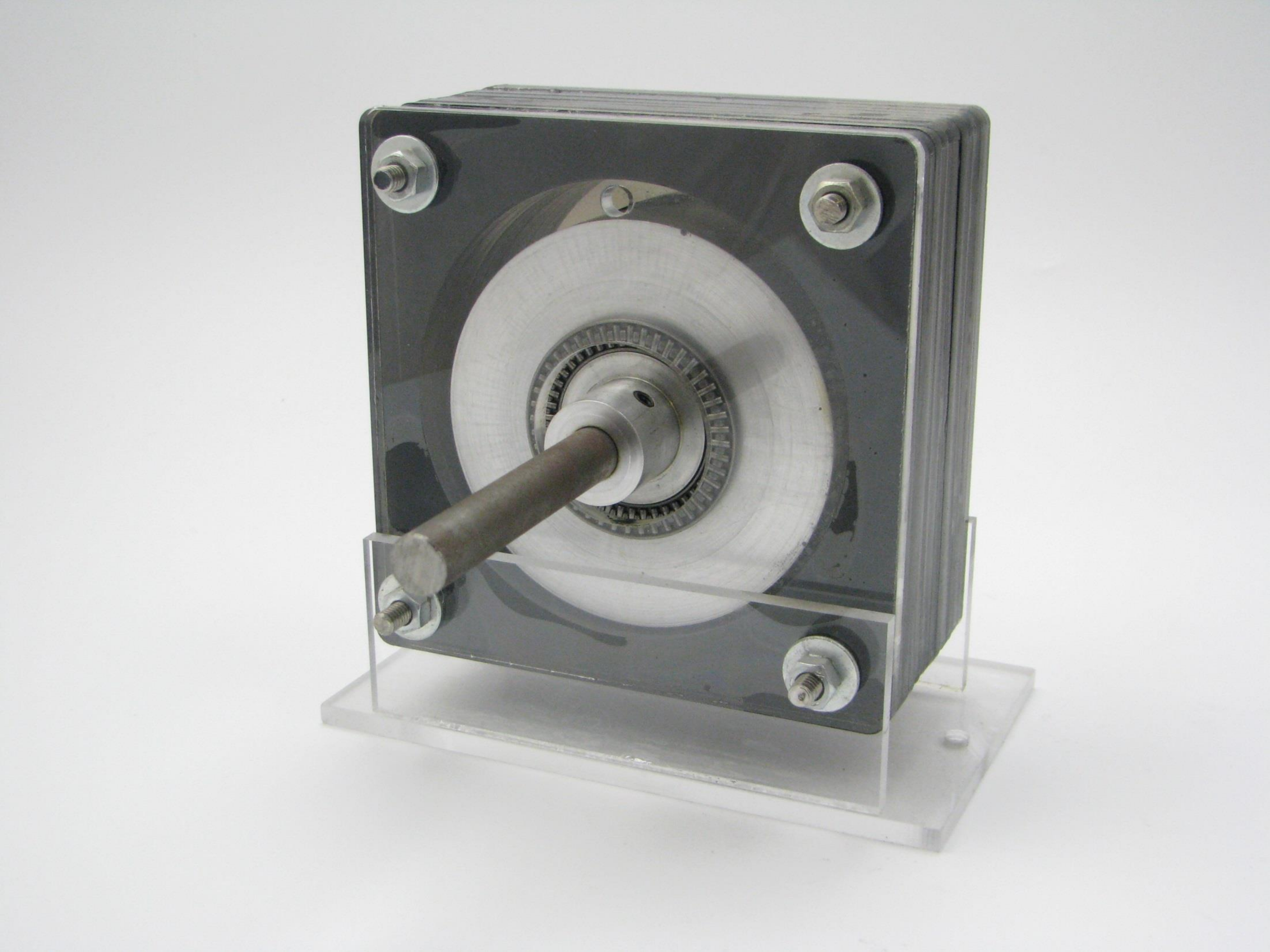


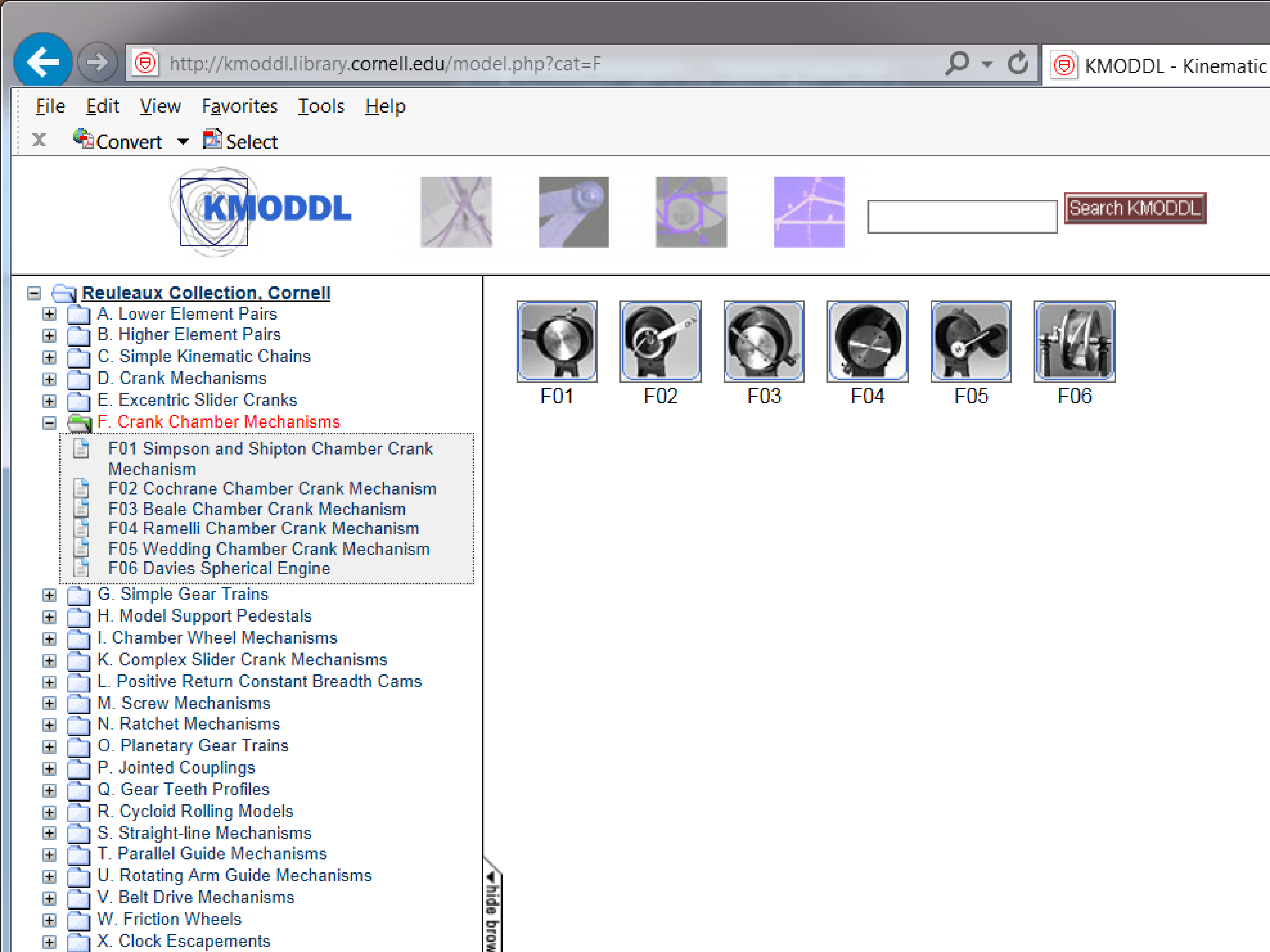







DME TWL
SECTION 2 · 2008
TEAM 4

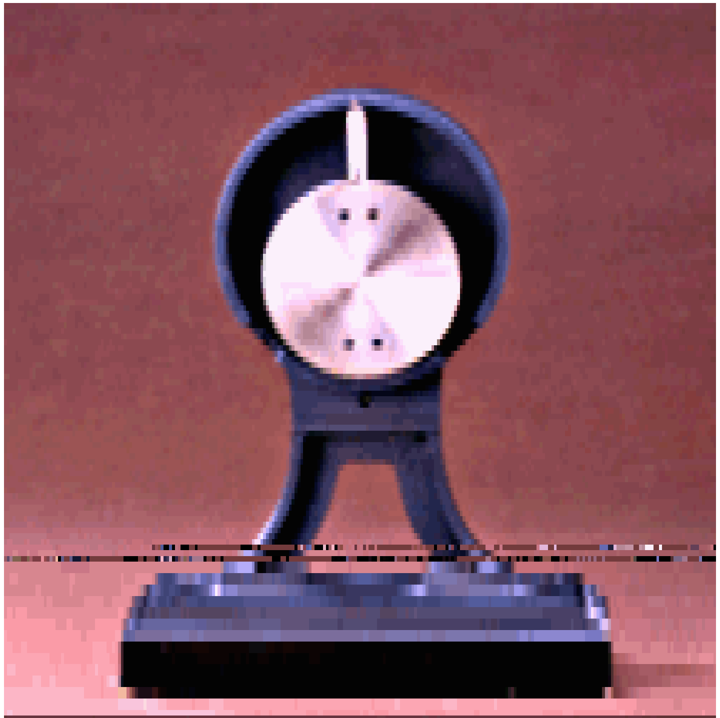
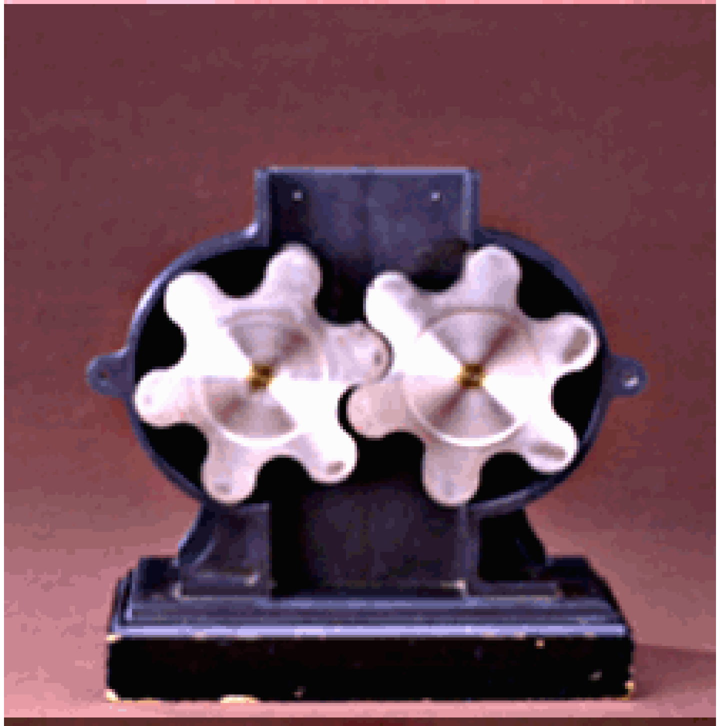




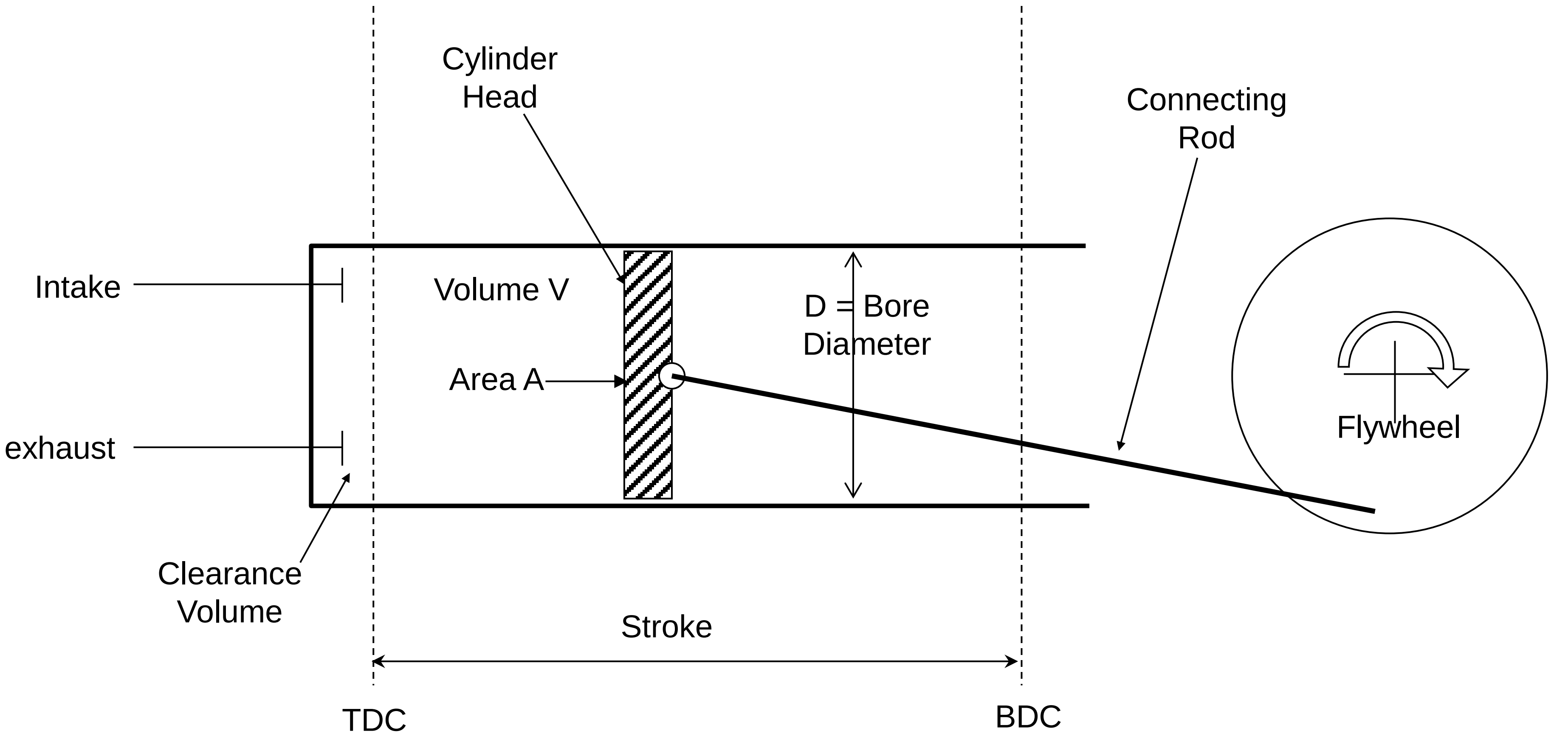
http://kmoddl.library.cornell.edu/model.php?cat=F
KMODDL - Kinematic
File Edit View Favorites Tools Help
Convert Select
KMODDL
Search KMODDL
Reuleaux Collection, Cornell
A. Lower Element Pairs
B. Higher Element Pairs
C. Simple Kinematic Chains
D. Crank Mechanisms
E. Excentric Slider Cranks
F. Crank Chamber Mechanisms
F01 Simpson and Shipton Chamber Crank Mechanism
F02 Cochrane Chamber Crank Mechanism
F03 Beale Chamber Crank Mechanism
F04 Ramelli Chamber Crank Mechanism
F05 Wedding Chamber Crank Mechanism
F06 Davies Spherical Engine
G. Simple Gear Trains
H. Model Support Pedestals
I. Chamber Wheel Mechanisms
K. Complex Slider Crank Mechanisms
L. Positive Return Constant Breadth Cams
M. Screw Mechanisms
N. Ratchet Mechanisms
O. Planetary Gear Trains
P. Jointed Couplings
Q. Gear Teeth Profiles
R. Cycloid Rolling Models
S. Straight-line Mechanisms
T. Parallel Guide Mechanisms
U. Rotating Arm Guide Mechanisms
V. Belt Drive Mechanisms
W. Friction Wheels
X. Clock Escapements
F01
F02
F03
F04
F05
F06
hide brow


F4


F3

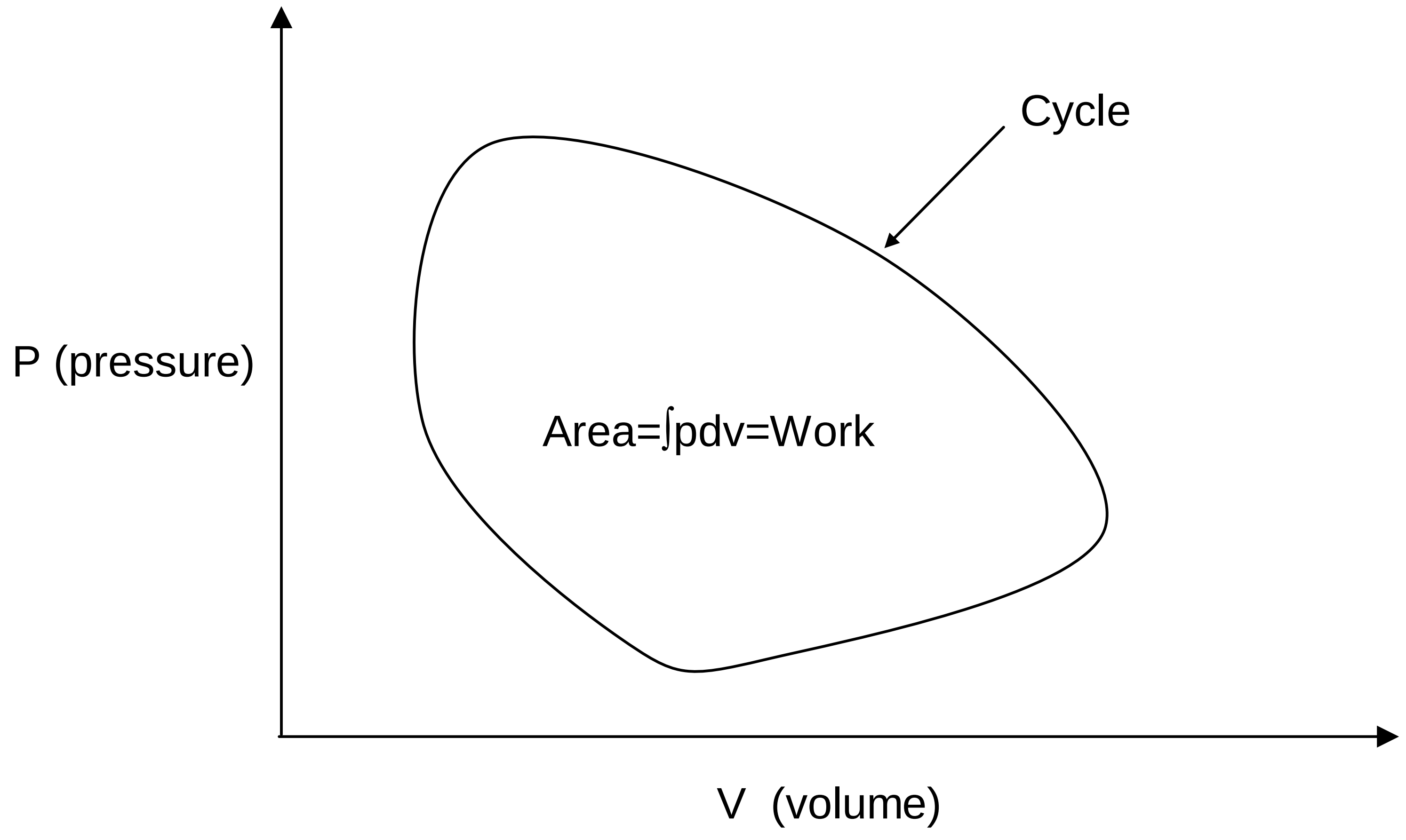
ANALYSIS


Cylinder
Head
Connecting
Rod
Intake
Volume V
D = Bore
Diameter
Area A
exhaust
Flywheel
Clearance
Volume
Stroke
TDC
BDC

1. **Cylinder Head**- The top, or cap, of the cylinder
2. **Top-Dead-Center (TDC)-** This is the highest point of travel of the top of the piston.
3. **Bottom-Dead-Center (BDC)-** This is the lowest point of travel of the top of the piston.
4. **Stroke (S)-** 1 The movement of the piston from one extreme to the other. 2The distance between TDC and BDC: S = TDC - BDC
    1. Power Stroke- Stroke in which high pressure acts on the piston producing work.
    2. Exhaust Stroke- Stroke in which used gasses are ejected from the cylinder.
    3. Intake Stroke- (4 stroke IC engine) Stroke in which fresh fuel/air mixture is drawn into the cylinder.
    4. Compression Stroke- (4 stroke IC engine) Stroke in which fuel/air mixture is compressed to high temperature and pressure. This stroke requires work.

1. **Bore** (D)- The diameter of one cylinder
2. **Clearance Volume** (Vc)- This is the volume of air between the top of the cylinder and the piston at TDC.
3. **Displacement** (V)- The volume of air displaced by the piston. It is defined as the area of the bore times the stroke times the number of cylinders: $V = n \cdot 0.25\pi D2S$
4. **Intake valve**- This valve allows the high pressure air (or the fuel/air mixture) into the cylinder.
5. **Exhaust valve-** This valve allows used air (or combustion products) out of the cylinder.
6. **Crankshaft-** This is a rotating rod with an eccentric arm. This enables the linear motion of the piston to be changed to rotary motion.
7. **Connecting Rod**- A linkage connecting the piston to the crankshaft with pin joints on each end

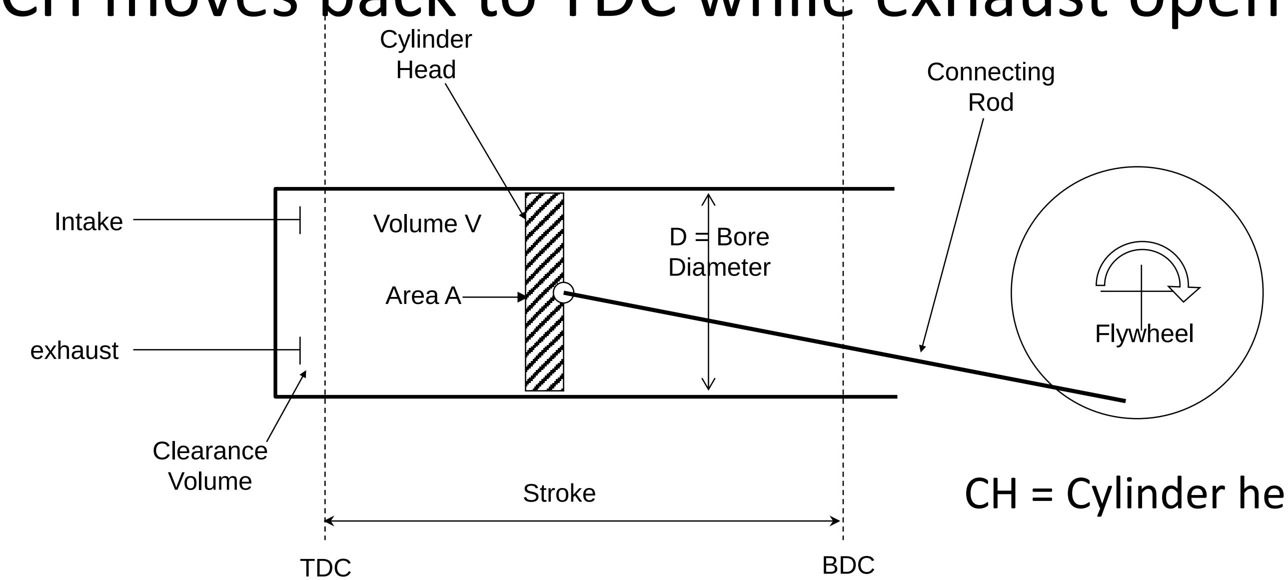
1. **Fly Wheel**- A rotating disk with a high moment of inertia placed on the crankshaft. This makes the rotation smoother due to its high inertia, and also does the work of ejecting exhaust gases in a four toke IC engine.
2. **Timing**- This refers to the coordination between the movement of the piston and the opening/ closing of the valves.
3. **Speed (rpm)**- The rotational speed of the crankshaft in revolutions per minute.
4. **Angular Velocity (w)**- The rotational speed of the crankshaft in radians per second. $w = 2\pi(rpm)/60$



1. Power = energy / time
2. Energy (work) = Force x distance:
   1. w = f dx = p dv
   2. (f = p A;   dx = dv/A)
   3. When they are changing, w = ∫pdv

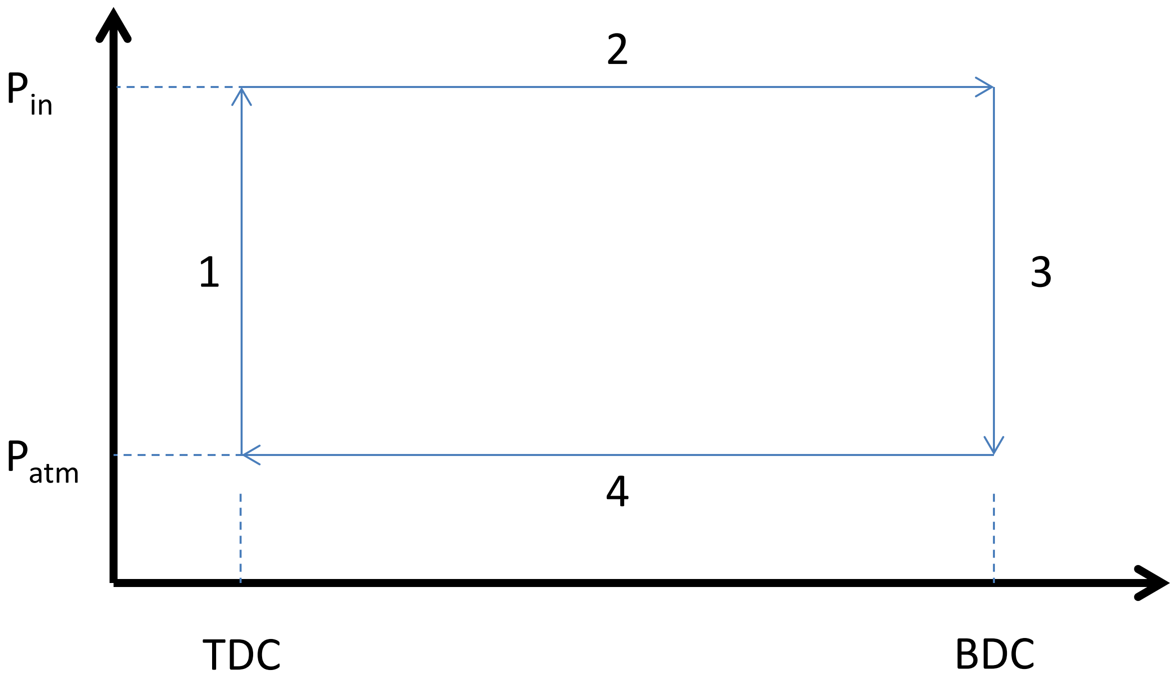
Draw PV diagram

- For a cycle comprising the following four steps
  1. CH at TDC, exhaust closed, intake open to $P_{in,}$
  2. CH moves to BDC while intake remains open
  3. Intake closes, exhaust opens to P_{atm}
  4. CH moves back to TDC while exhaust open



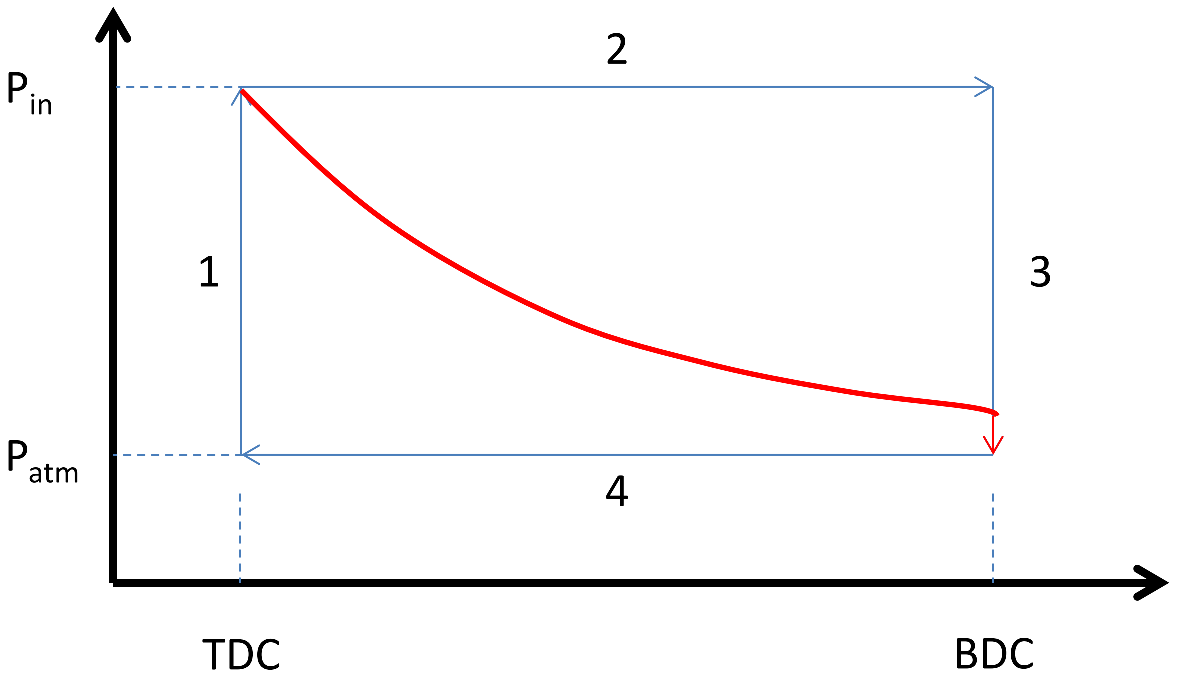
CH = Cylinder head

Draw PV diagram



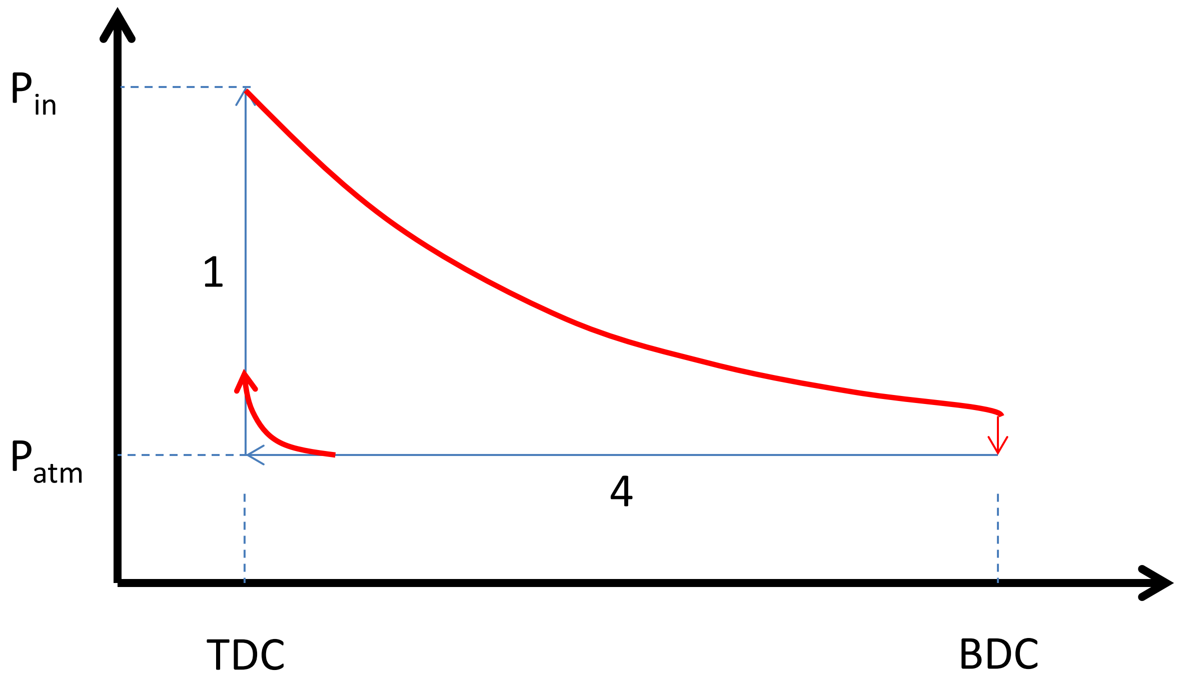
- For a cycle comprising the following four steps
  1. CH at TDC, exhaust closed, intake open to $P_{in,}$
  2. CH moves to BDC while intake remains open
  3. Intake closes, exhaust opens to P_{atm}
  4. CH moves back to TDC while exhaust open

Draw PV diagram



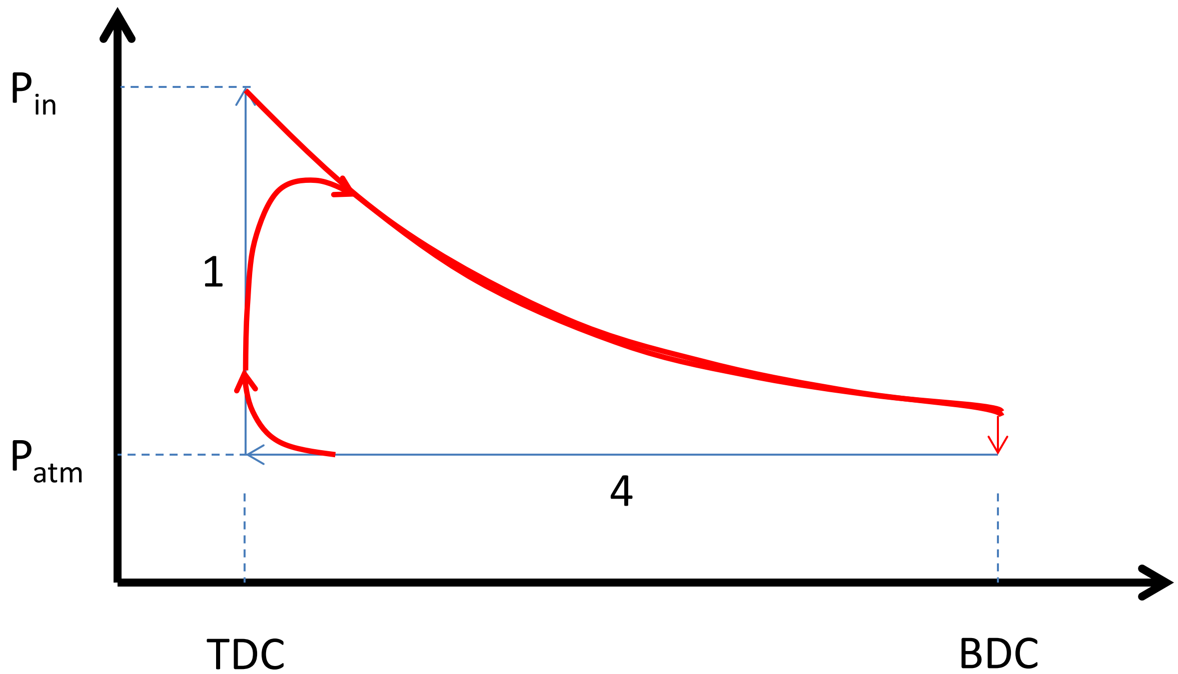
- For a cycle comprising the following four steps
  1. CH at TDC, exhaust closed, intake open to $P_{in,}$
  2. CH moves to BDC while intake ~~remains open~~ closes
  3. Intake closes, exhaust opens to P_{atm}
  4. CH moves back to TDC while exhaust open

Draw PV diagram

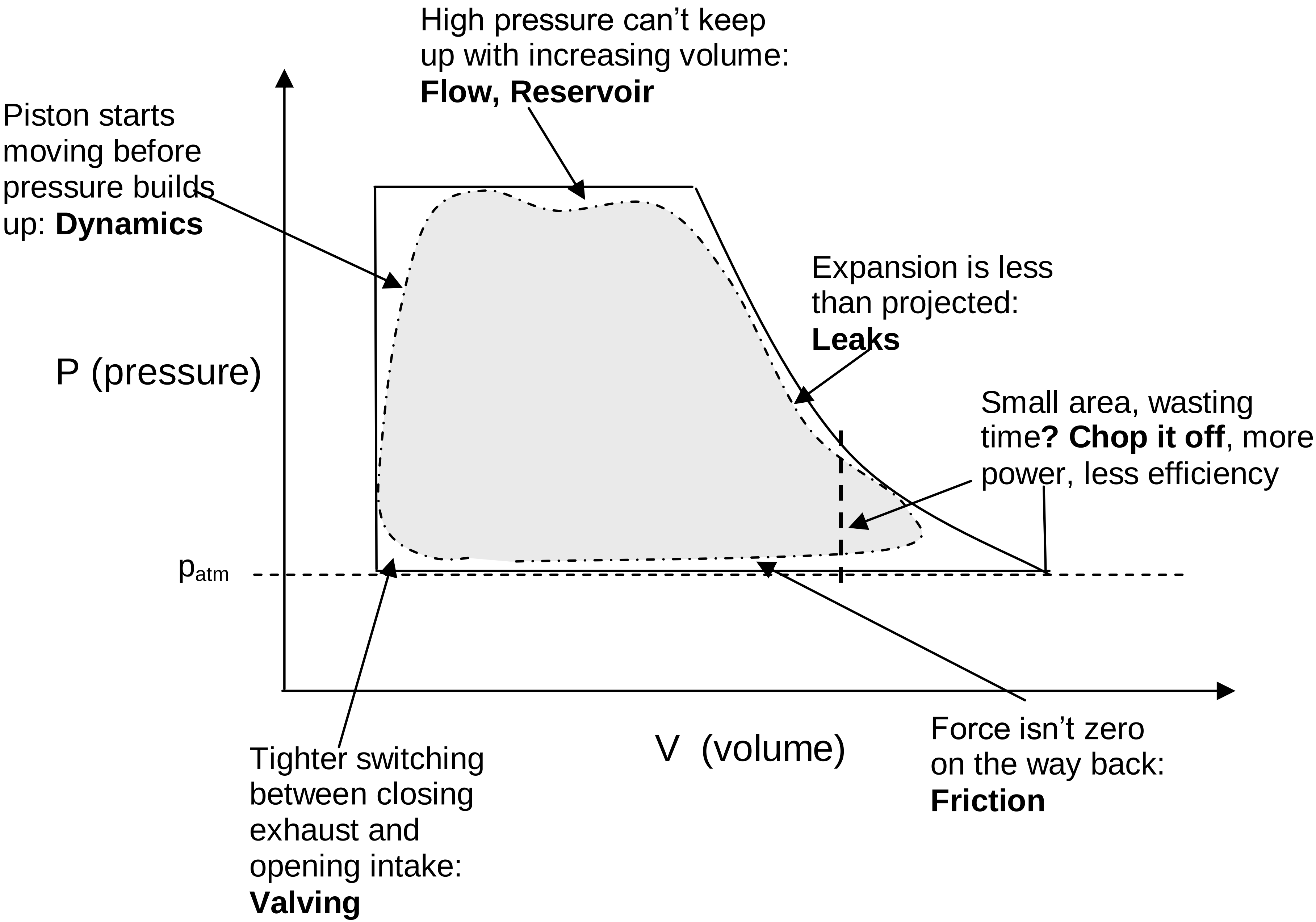


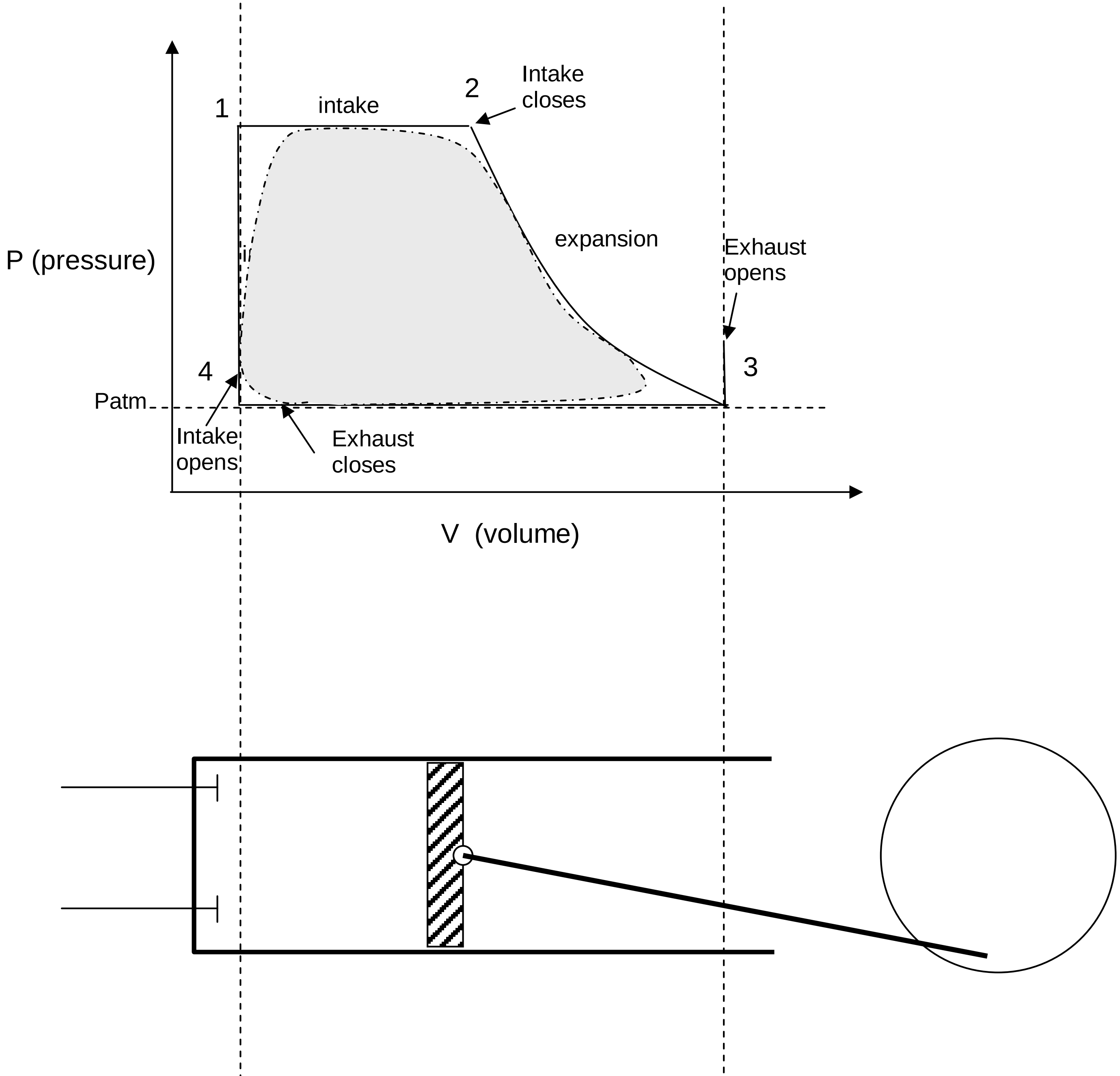
- For a cycle comprising the following four steps
  1. CH at TDC, exhaust closed, intake open to $P_{in,}$
  2. CH moves to BDC while intake ~~remains open~~ closes
  3. Intake closes, exhaust opens to P_{atm}
  4. CH moves back to TDC while exhaust open, but closes before TDC

Draw PV diagram

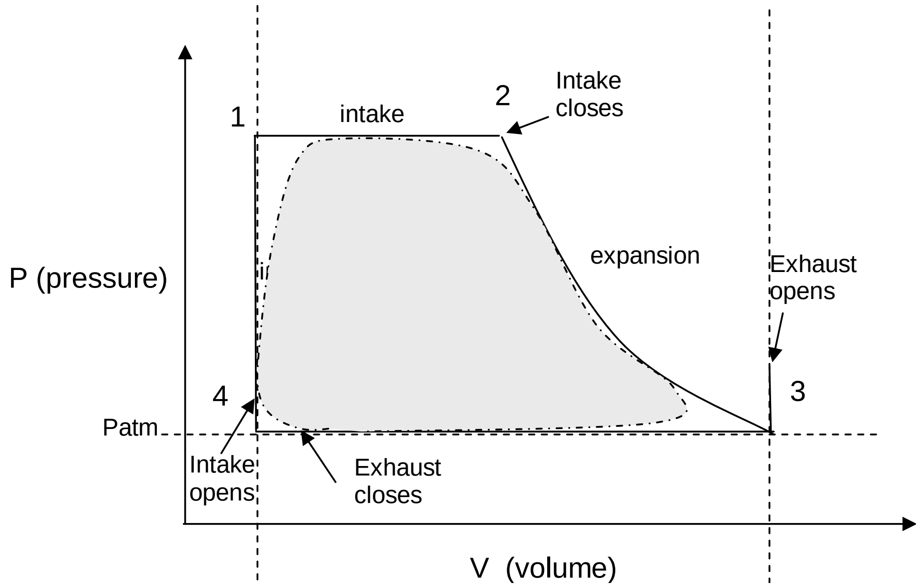


- For a cycle comprising the following four steps
    1. CH at TDC, exhaust closed, intake open to P_{in} while CH accelerates
    2. CH moves to BDC while intake ~~remains open~~ closes
    3. Intake closes, exhaust opens to P_{atm}
    4. CH moves back to TDC while exhaust open, but closes before TDC


High pressure can't keep up with increasing volume: **Flow, Reservoir**
Piston starts moving before pressure builds up: **Dynamics**
Expansion is less than projected: **Leaks**
P (pressure)
Small area, wasting time? **Chop it off**, more power, less efficiency
p_{atm}
V (volume)
Tighter switching between closing exhaust and opening intake: **Valving**
Force isn't zero on the way back: **Friction**



1
intake
2
Intake
closes
expansion
Exhaust
opens
P (pressure)
3
4
Patm
Intake
opens
Exhaust
closes
V (volume)



a. Leg 4→1 is constant volume, so $w_{41}=0$
b. Leg 1→2 is constant pressure, so $w_{12}=(p_1-p_{atm})*(v_2-v_1)$
c. Leg 2→3 is adiabatic (isentropic, const entropy) expansion
   i. During isentropic expansion, $p\,v^k$ =const ($k=c_p/c_v=1.4$ for ideal air)
   ii. $$w23=\int_2^3 (p-p_{atm})dv=\int_2^3 pdv-p_{atm}(v_3-v_2)$$
   iii. $$\int_2^3 pdv=\int_2^3 pv^k\frac{dv}{v^k}=pv^k\int_2^3 p\frac{dv}{v^k}=\frac{pv^k}{(1-k)}\left(v_3^{1-k}-v_2^{1-k}\right)=\frac{p_2v_2-p_3v_3}{1-k}$$
      1. because pv^k=const it can be taken out of the integral
   iv. $$w_{23}=\frac{p_2v_2-p_3v_3}{1-k}-p_{atm}(v_3-v_2)$$
   v. Note: p3v3/p1v1 = T3/T1; cooling will occur! Avoid frost
d. Leg 3→4 is constant pressure, sp $w_{34}=(p_3-p_{atm})*(v_1-v_3)$

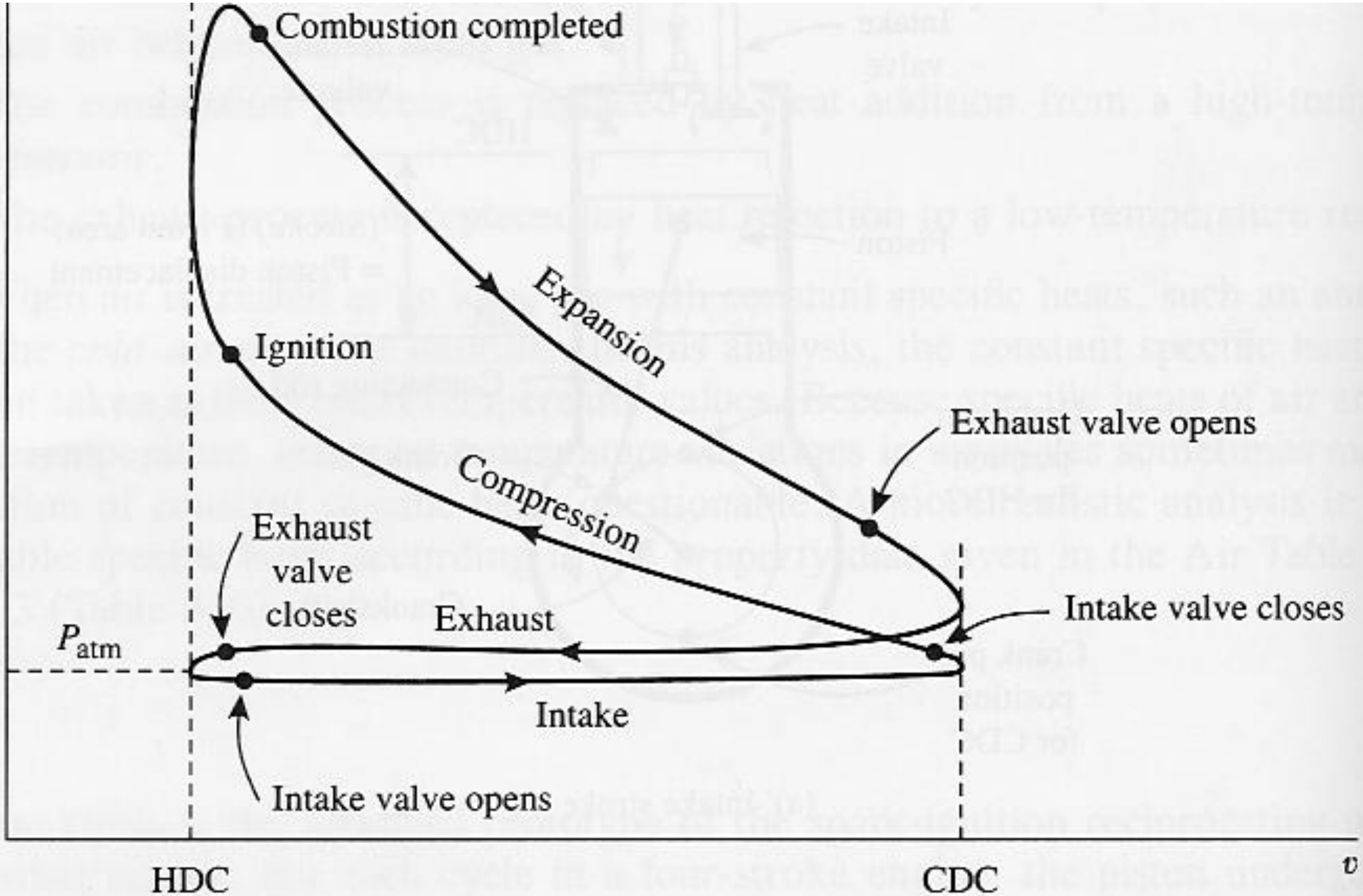


Figure 10-2 Typical p–v diagram for an actual spark-ignition engine.

Improving performance

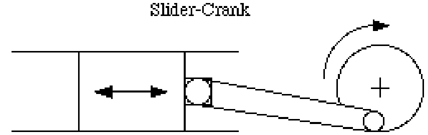
- List design aspects that will improve performance
  - Perfectly synchronized valve timing
  - Crisp valve switching
  - Low friction in piston, joints
  - High flow, low resistance and pressure drops
  - High pressure supply: reservoir
  - Minimum leaks around piston, valves
  - Deliberate power/efficiency tradeoff

Requirements

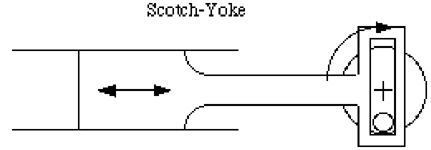
- Weekly project report
  - uploaded to CMS by end of every week.
- Preliminary design review
  - (10 min presentation): 1st week of your project
- Critical design review
  - (10 min presentation): 2nd week of your project
- Prototype demonstration
  - (5 min presentation): 4th week of your project
- Final presentation
  - (15 min): 5th week of your project
- Final report:
  - Upload to CMS on the 5th week of your project
- Team assessment

Mechanisms

Slider-Crank

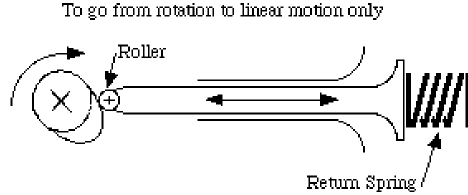


Scotch-Yoke



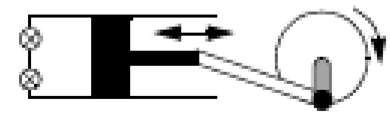
Cam

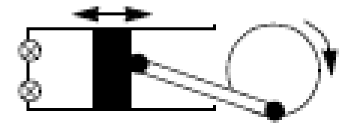
To go from rotation to linear motion only



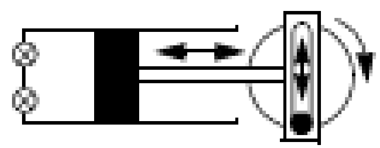
Rotary <-> Linear

Slider-crank

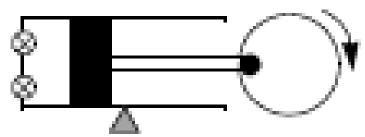


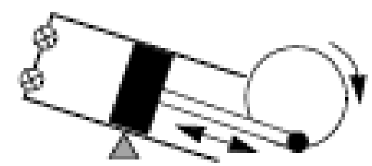


Scotch yoke

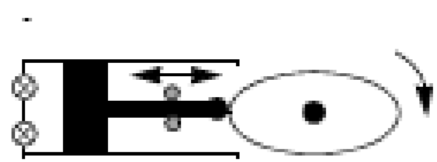


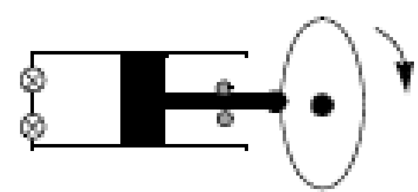
Pivoting cylinder





Cam-follower





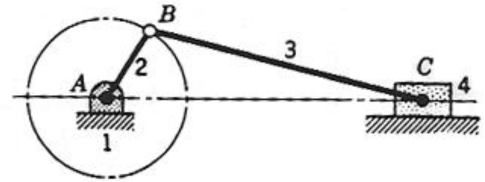


Fig. 2-9 Slider-crank mechanism.

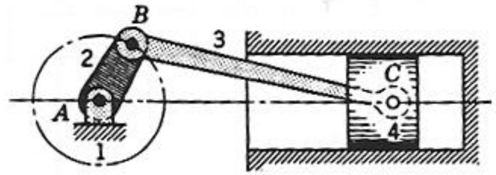


Fig. 2-19 The first inversion of the slider-crank mechanism.

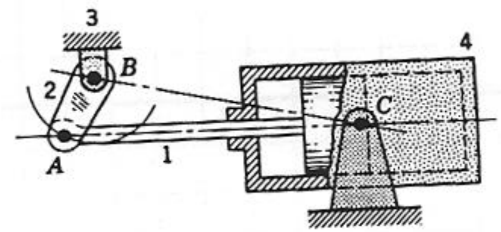


Fig. 2-20 The second inversion of the slider-crank mechanism.

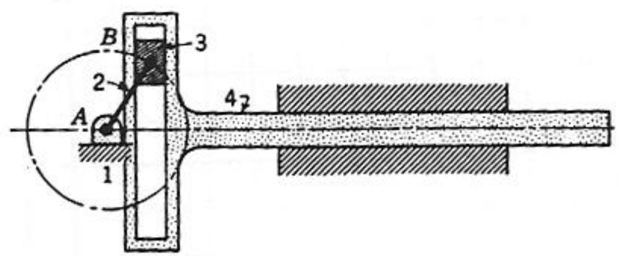


Fig. 2-15 Scotch-yoke mechanism.

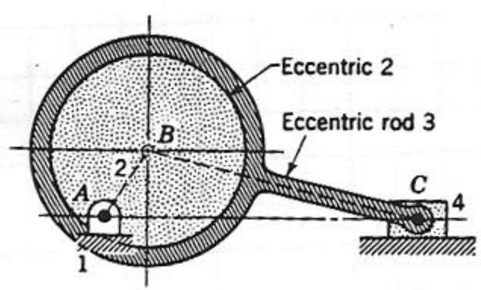


Fig. 2-12 Eccentric-and-rod mechanism.

FUNDAMENTALS OF MECHANICAL DESIGN

Third Edition

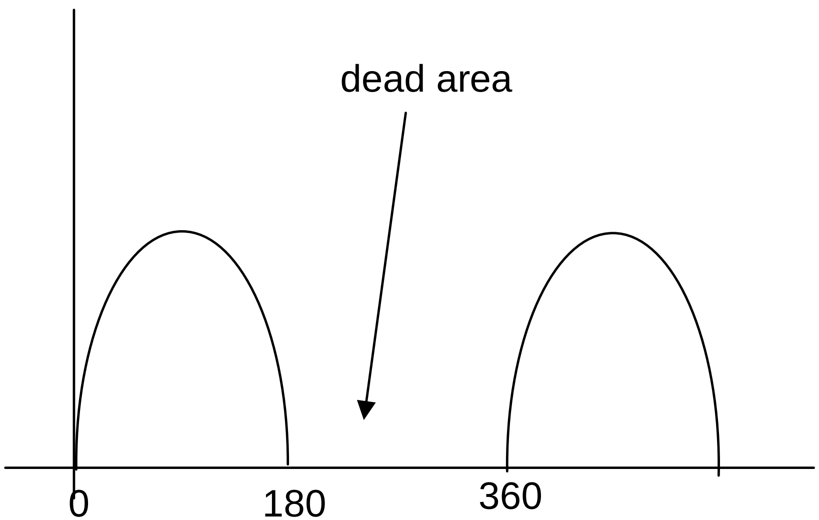
RICHARD M. PHELAN

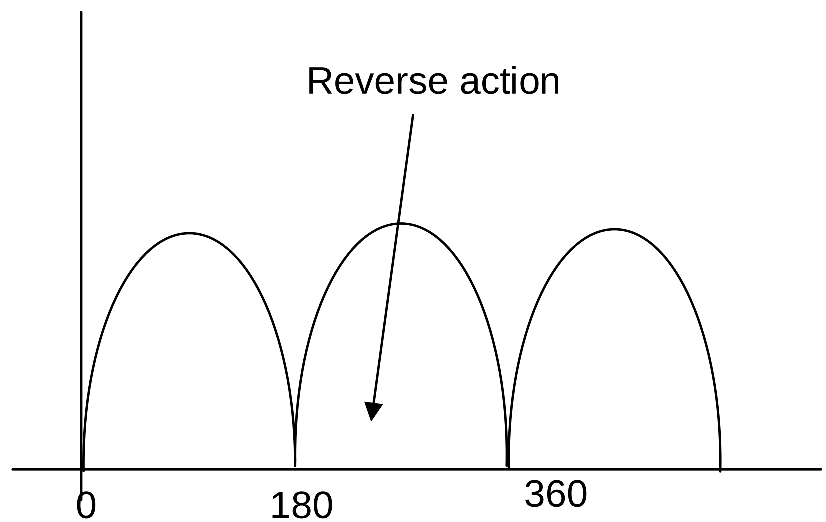
Professor of Mechanical Engineering, Cornell University

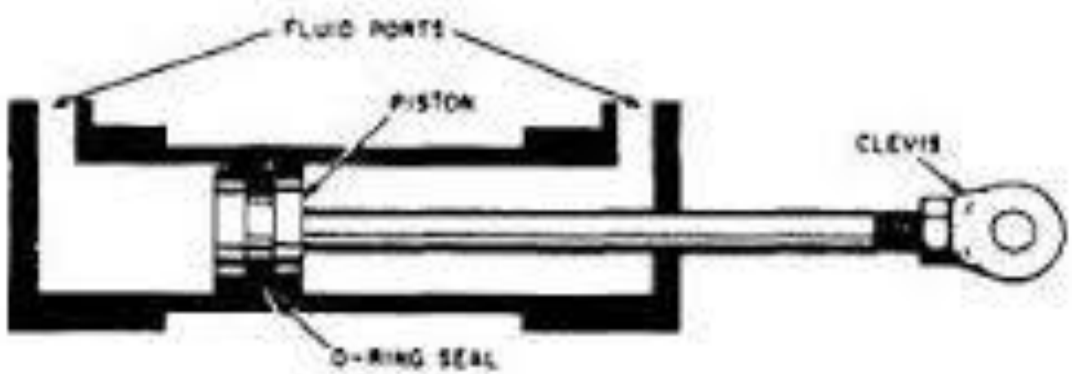
McGRAW-HILL BOOK COMPANY


E1

Single/Double acting

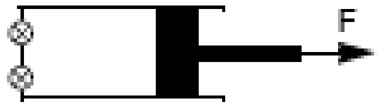




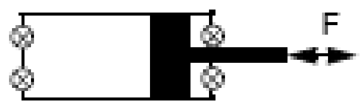


Types of piston engines

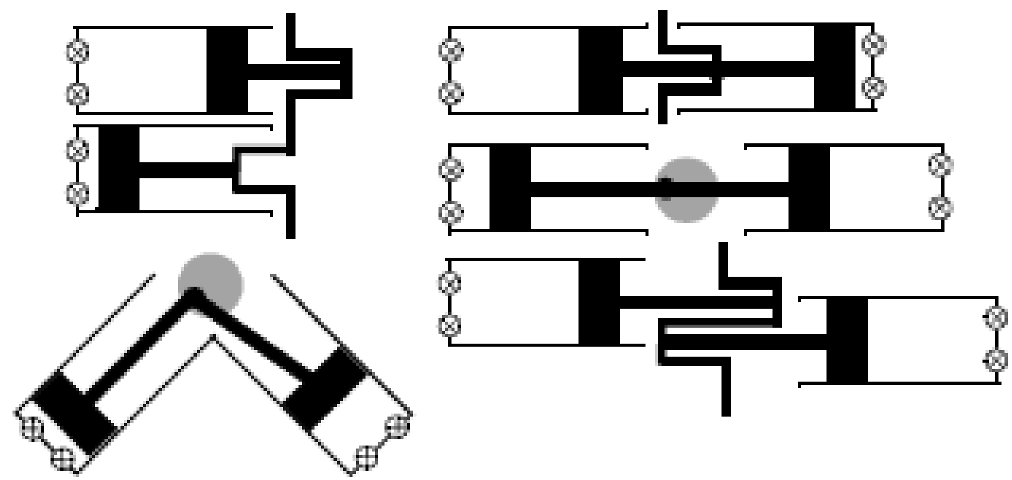
Single-cylinder, single-acting



Single-cylinder, dual-acting

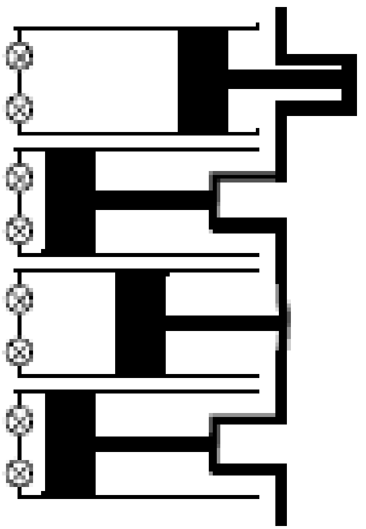


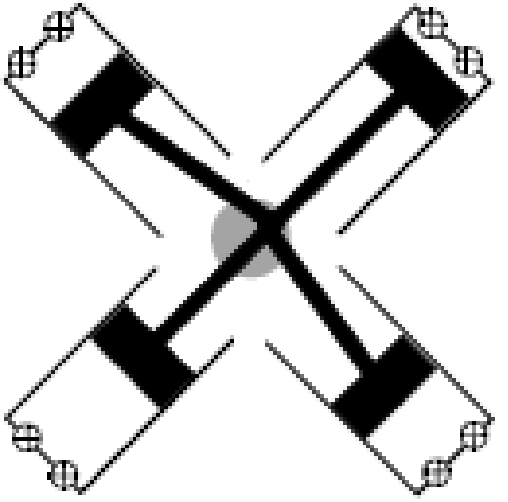
Double-cylinder, single-acting

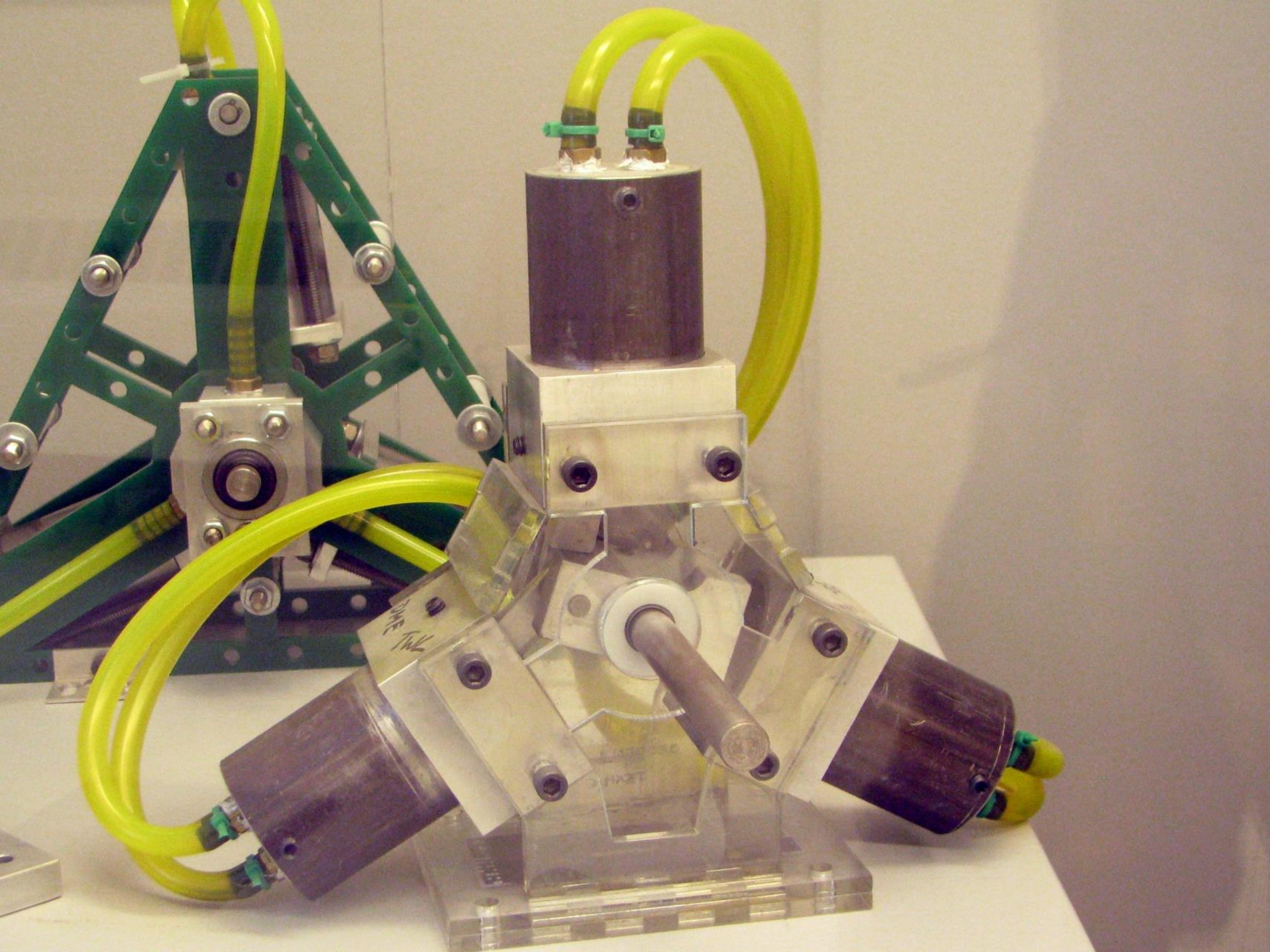


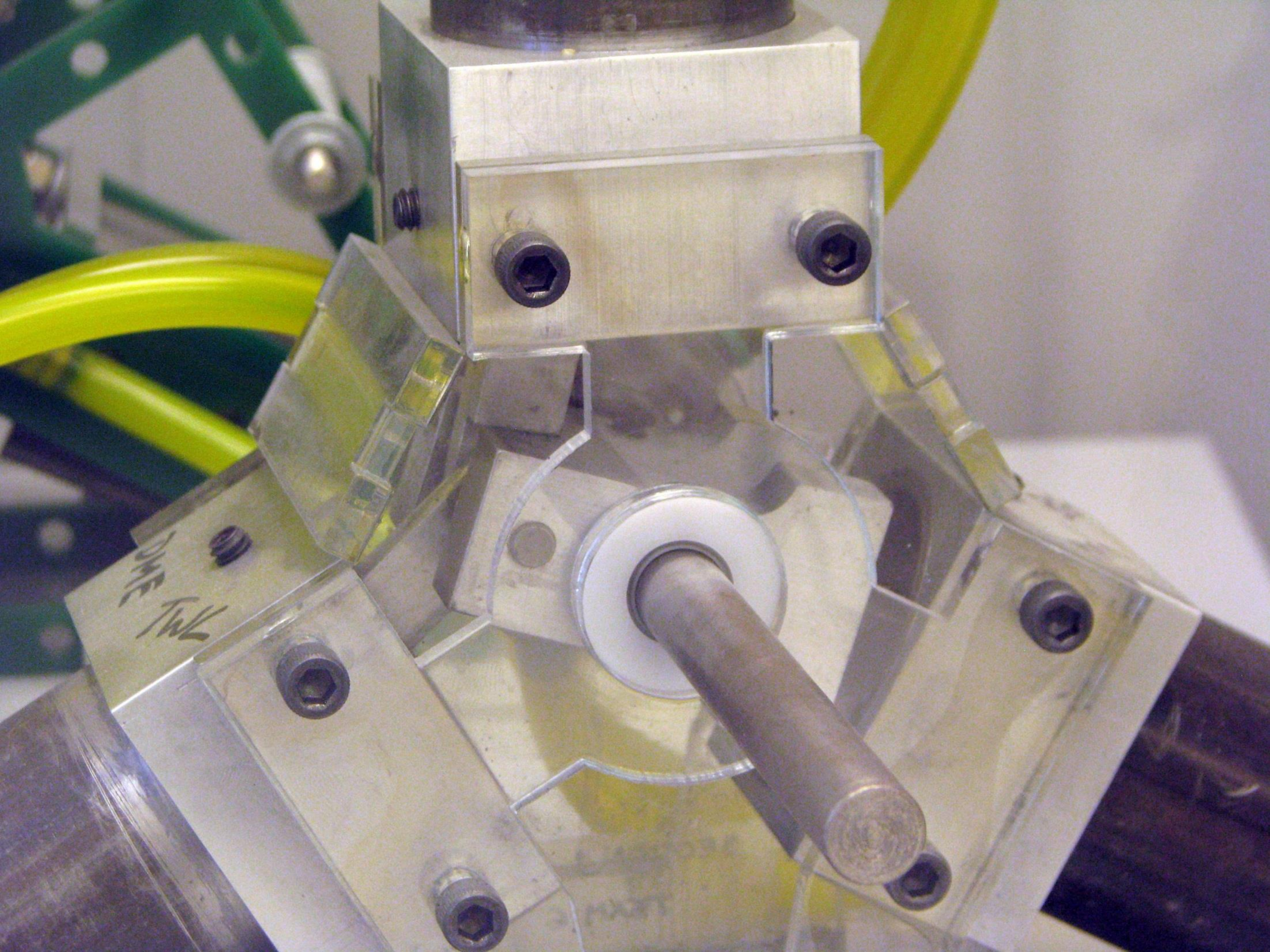
Types of piston engines

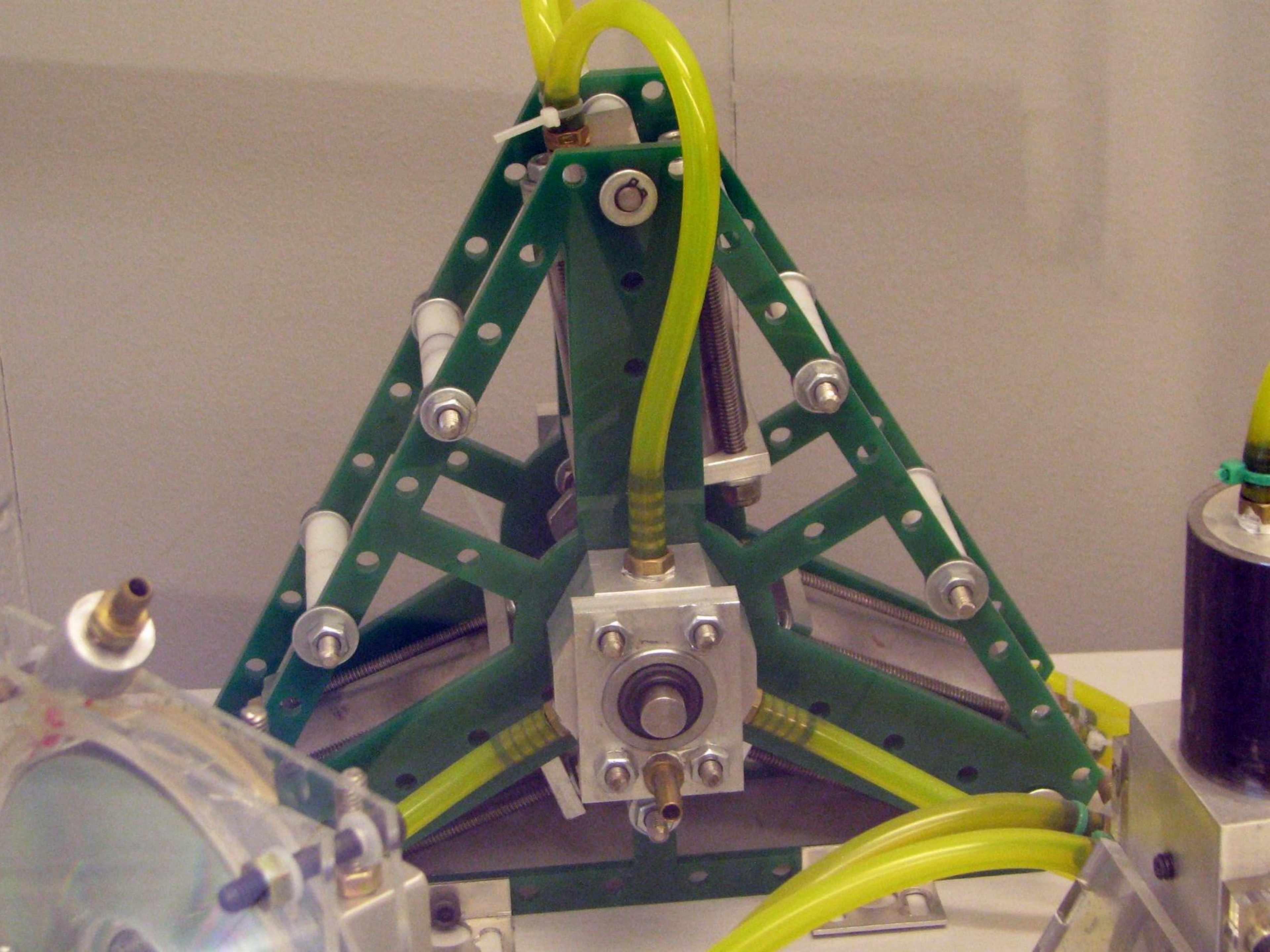
Multiple cylinders





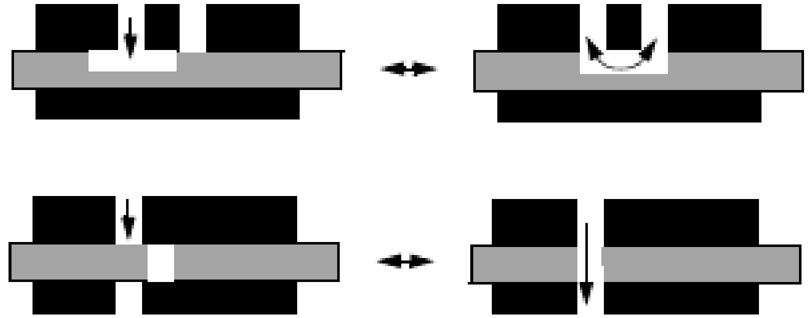



DME TWL

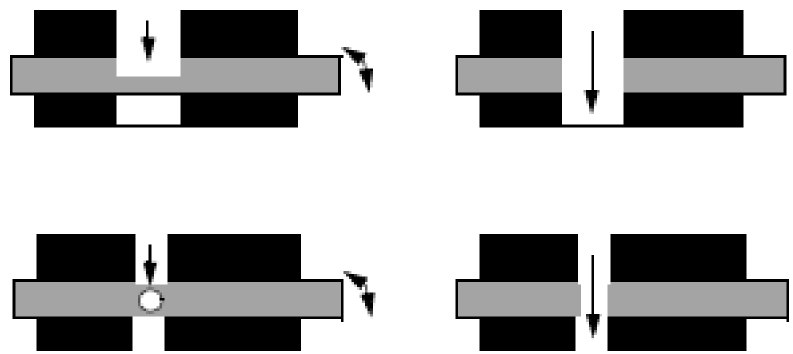


Valve designs

Slider valves

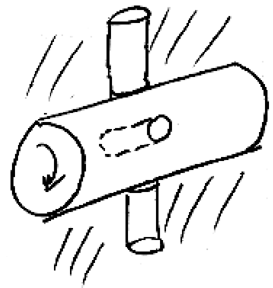


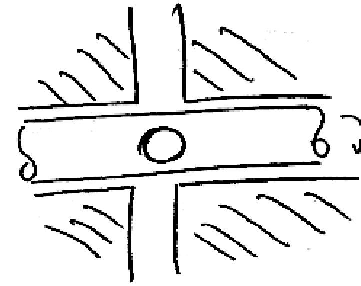
Rotary



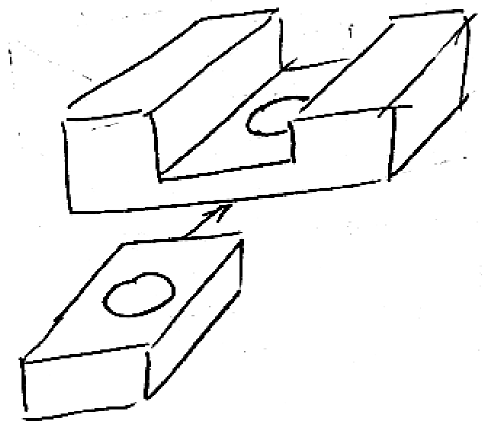
es

Rotary valve

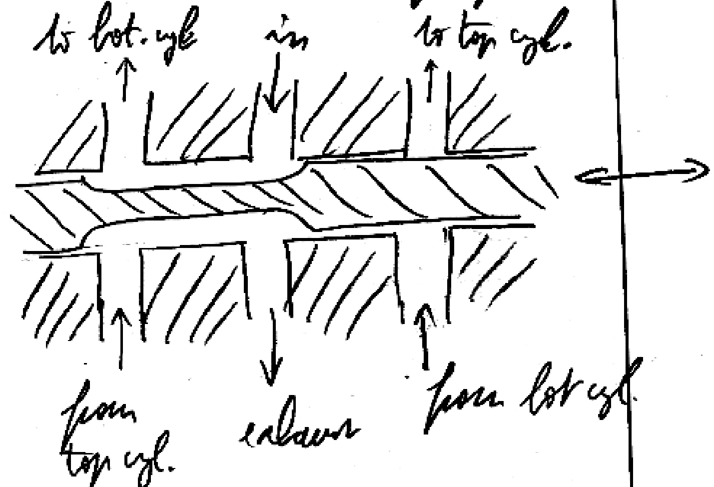




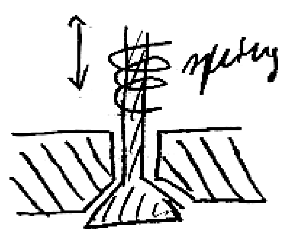
or sliding valve



For double-acting cylinder:



Tappet valve

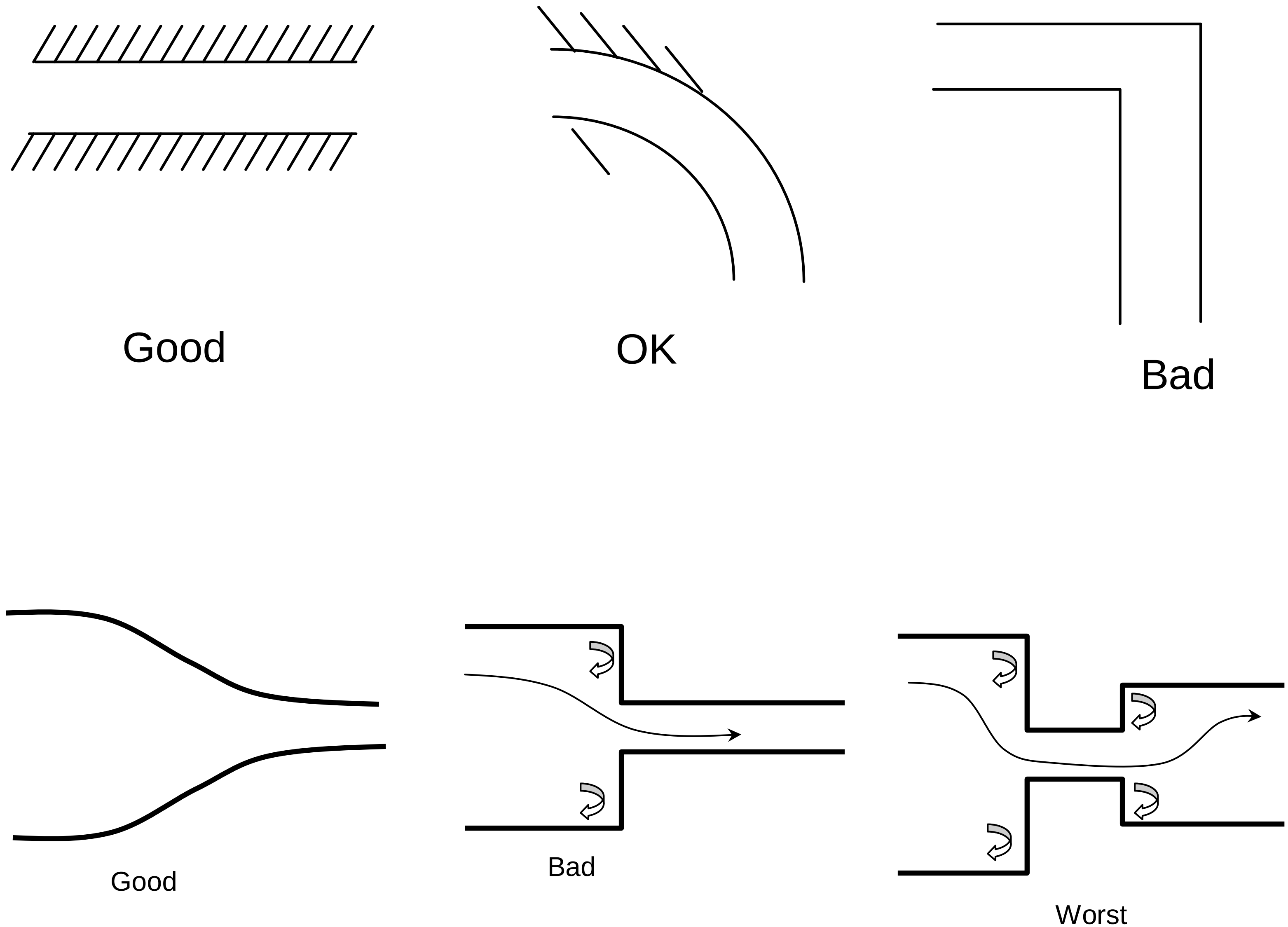


hard to manufacture & line up

(not recommended – good for high T)

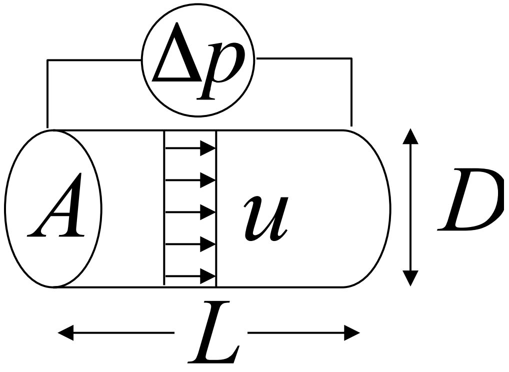
Controlling friction

- Material choices (metal to metal is good; Teflon)
- Lubrication, oils
- Ball bearings (use stock bearings)
- Surface finish, tolerances
- Design: Minimize force normal to surface
  - (e.g upright piston vs. side piston)
- Transmission


Good
OK
Bad
Good
Bad
Worst

Line losses

$$\frac{\Delta p}{L} = \frac{f}{D}\frac{1}{2}\rho u^2$$

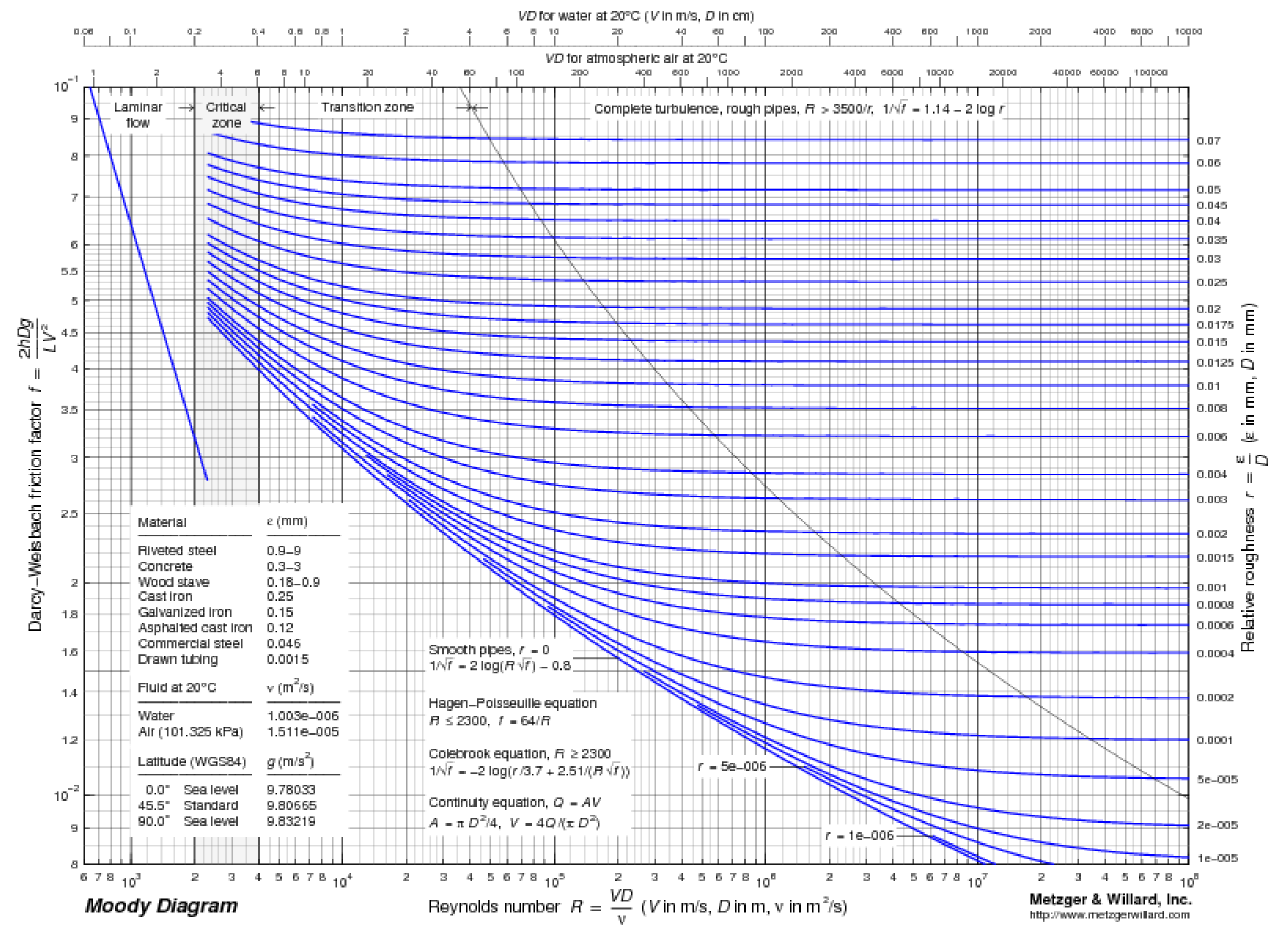


$$\dot{Q} = uA$$

$$A = \frac{\rho}{4}D^2$$

$$\frac{\Delta p}{L} \approx \frac{8}{\pi^2} f \rho \frac{\dot{\mathrm{Q}}^2}{\mathrm{D}^5}$$

Lewis Moody (1944) diagram



http://www.mathworks.com/matlabcentral/files/7747/moody.png

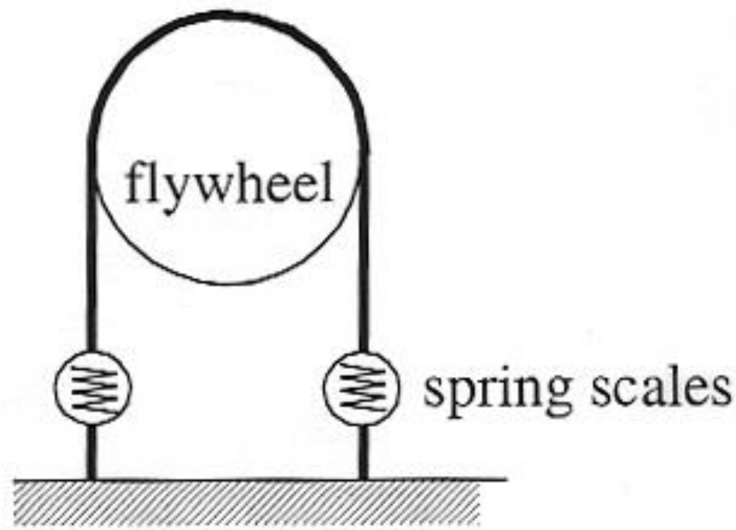

0.3
0.2
压力表
MPa
0.1
0.5
0
2.5
0.6
上海宜川仪表厂


Air supply hose provided
40 PSI outlet at
0.012 m^3/s
Buy this barbed connector
from Emerson and include in
your design

Testing of Air Motor Power:

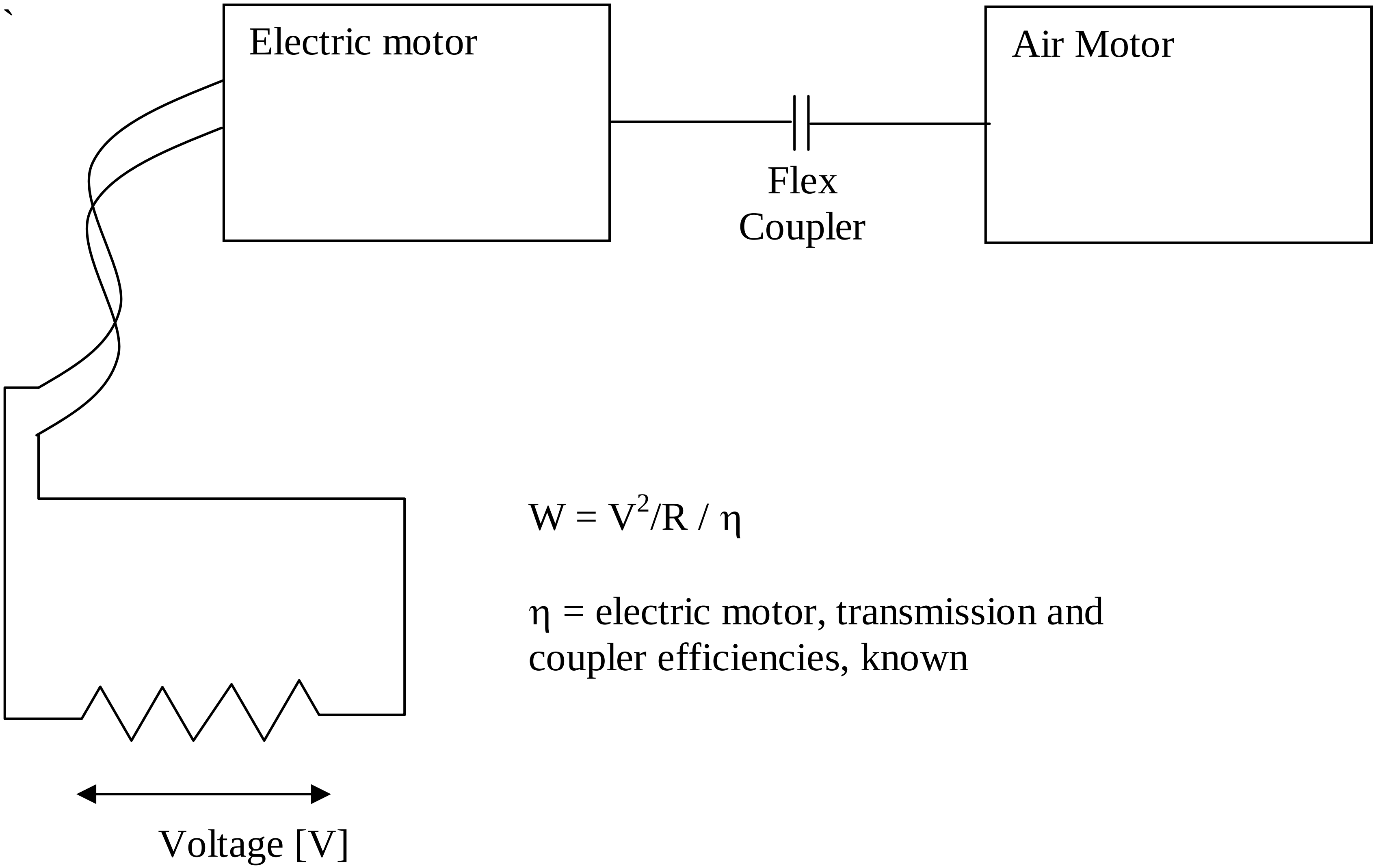
flywheel mounted on output shaft
force measurement by spring scales

Test setup:



Power = (Torque) (angular velocity)

angular velocity obtained using a strobe (rpm)
torque = force * moment arm of flywheel
force = force across spring scales



$$W = V^2/R / \eta$$

η = electric motor, transmission and coupler efficiencies, known

Logistics

- Presentations in section
- Machining + standard parts only (no 3DP, Laser)
- TA consolidates McMaster orders
- Wordpress website at blog.cornell.edu