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1855

# SMALL PROPULSION SYSTEMS

FOR

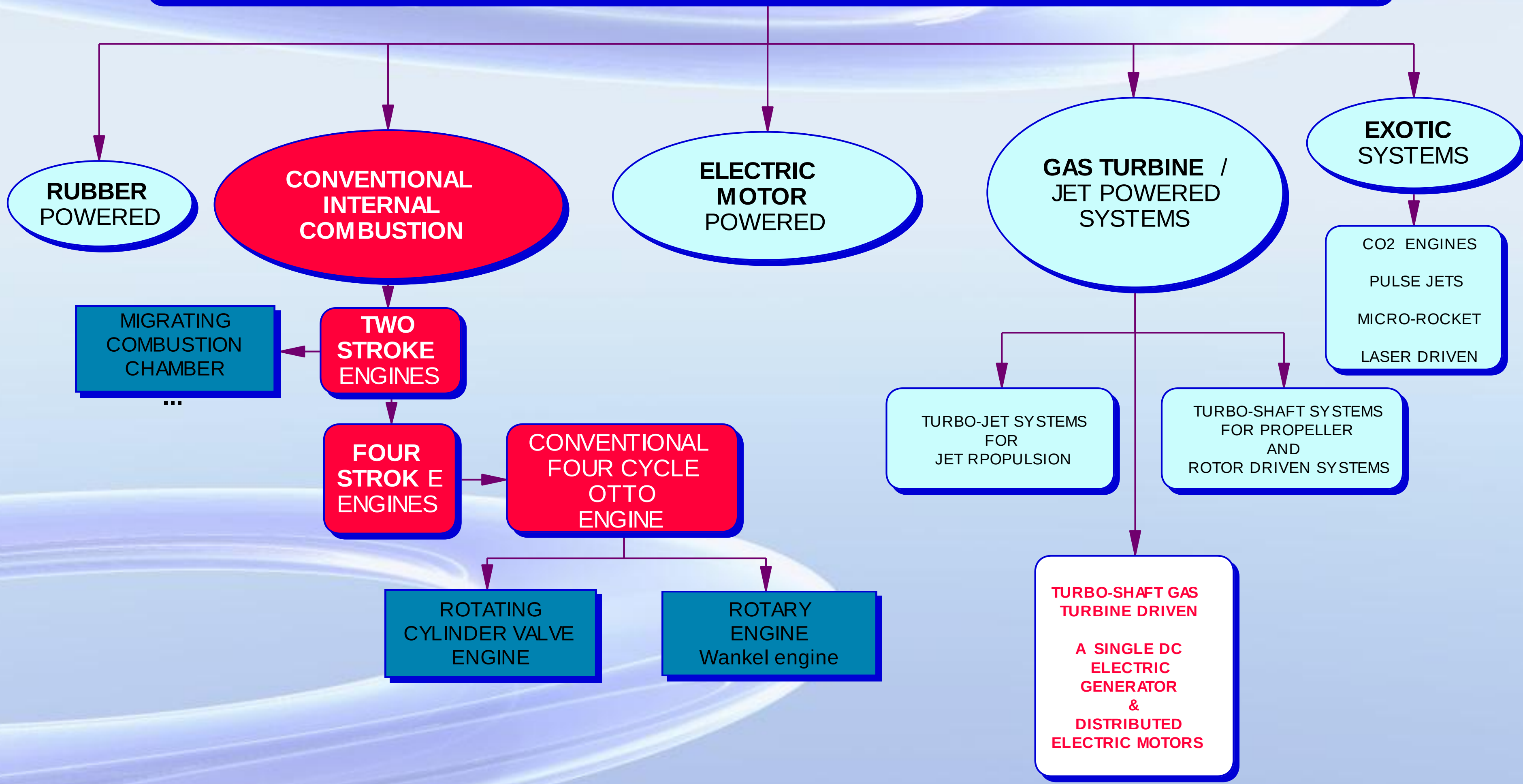
UN-MANNED AIR VEHICLES
&
MODEL AIRCRAFT

CENGIZ CAMCI

DEPARTMENT OF AEROSPACE ENGINEERING
THE PENNSYLVANIA STATE UNIVERSITY

PENNSTATE

# SMALL PROPULSION SYSTEMS FOR UNMANNED AND MODEL AIRCRAFT



# CONVENTIONAL INTERNAL COMBUSTION ENGINES

**TWO STROKE ENGINES**

**M**igrating **C**ombustion **C**hamber Engine **(MCC)**

**FOUR CYCLE ENGINES**

Conventional Four Cycle **(OTTO ENGINE)**

Rotary Engine **(WANKEL)**

**R**otating **C**ylinder **V**alve Engine **(RCV)**

# TWO STROKE ENGINES +

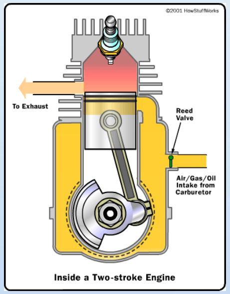
- Two-stroke engines do not have valves, which simplifies their construction and lowers their weight.

- Two-stroke engines fire once every revolution, while four-stroke engines fire once every other revolution. This gives two-stroke engines a significant power boost.

# TWO STROKE ENGINES +

These advantages make two-stroke engines **lighter, simpler and less expensive** to manufacture.

Two-stroke engines also have the potential to pack about **twice the power into the same space** because there are twice as many power strokes per revolution.



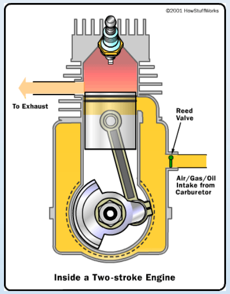
Inside a Two-stroke Engine

The combination of light weight and twice the power gives two-stroke engines a **great power-to-weight ratio** compared to many four-stroke engine designs.

# TWO STROKE ENGINES +

- Two-stroke engines can work in any orientation, which can be important in inverted flights or acrobatic flights.

- A standard four-stroke engine may have problems with oil flow unless it is upright, and solving this problem can add complexity to the engine.



# TWO STROKE ENGINES -

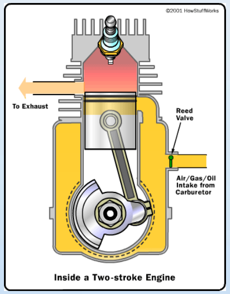
- Two-stroke engines don't last nearly as long as four-stroke engines. The lack of a dedicated lubrication system means that the parts of a two-stroke engine wear a lot faster.

- Two-stroke oil is expensive, and you need about 4 ounces of it per gallon of gas. You would burn about a gallon of oil every 1,000 miles if you used a two-stroke engine in a car.

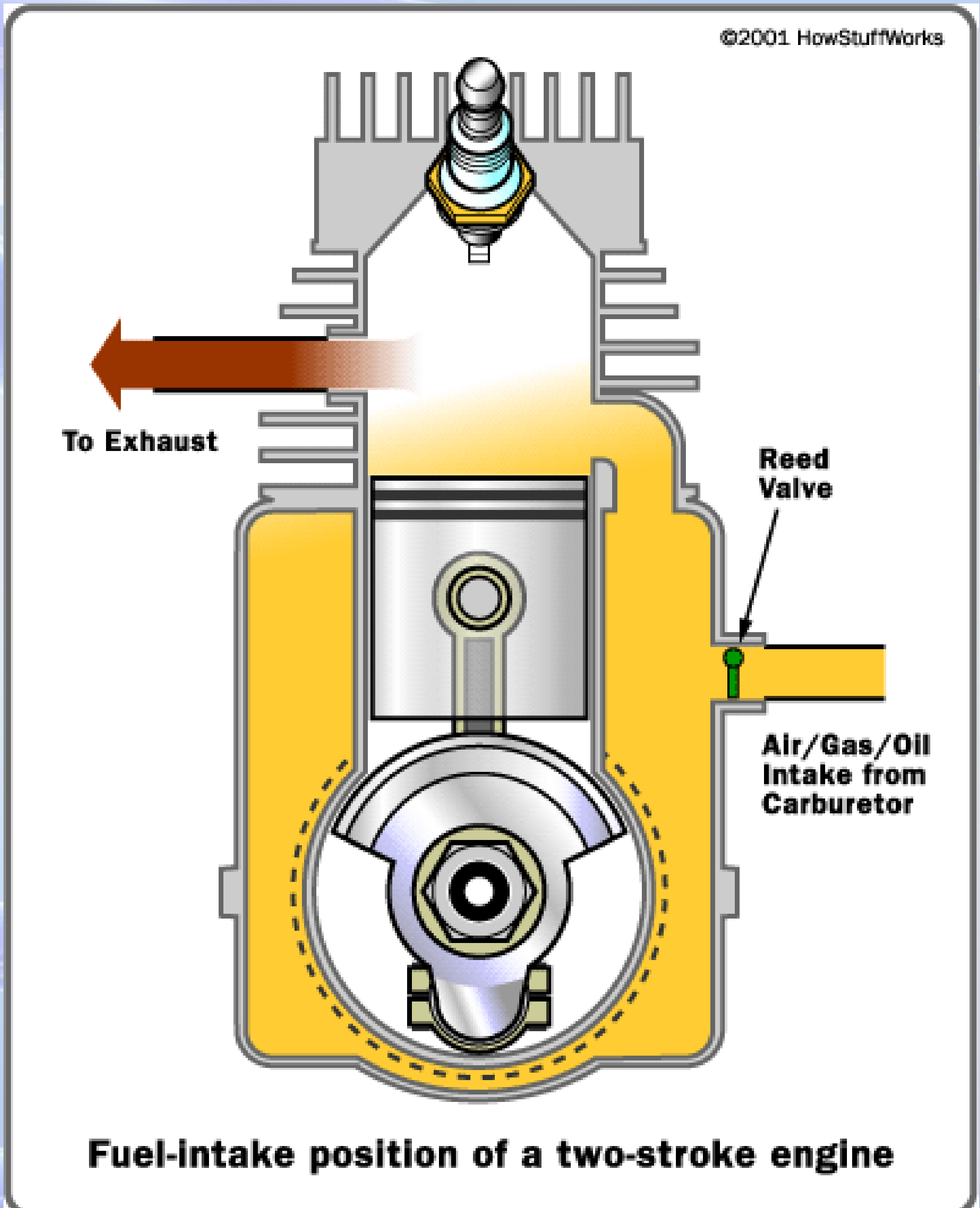
# TWO STROKE ENGINES -

- Two-stroke engines do not use fuel efficiently, so you would get fewer miles per gallon.

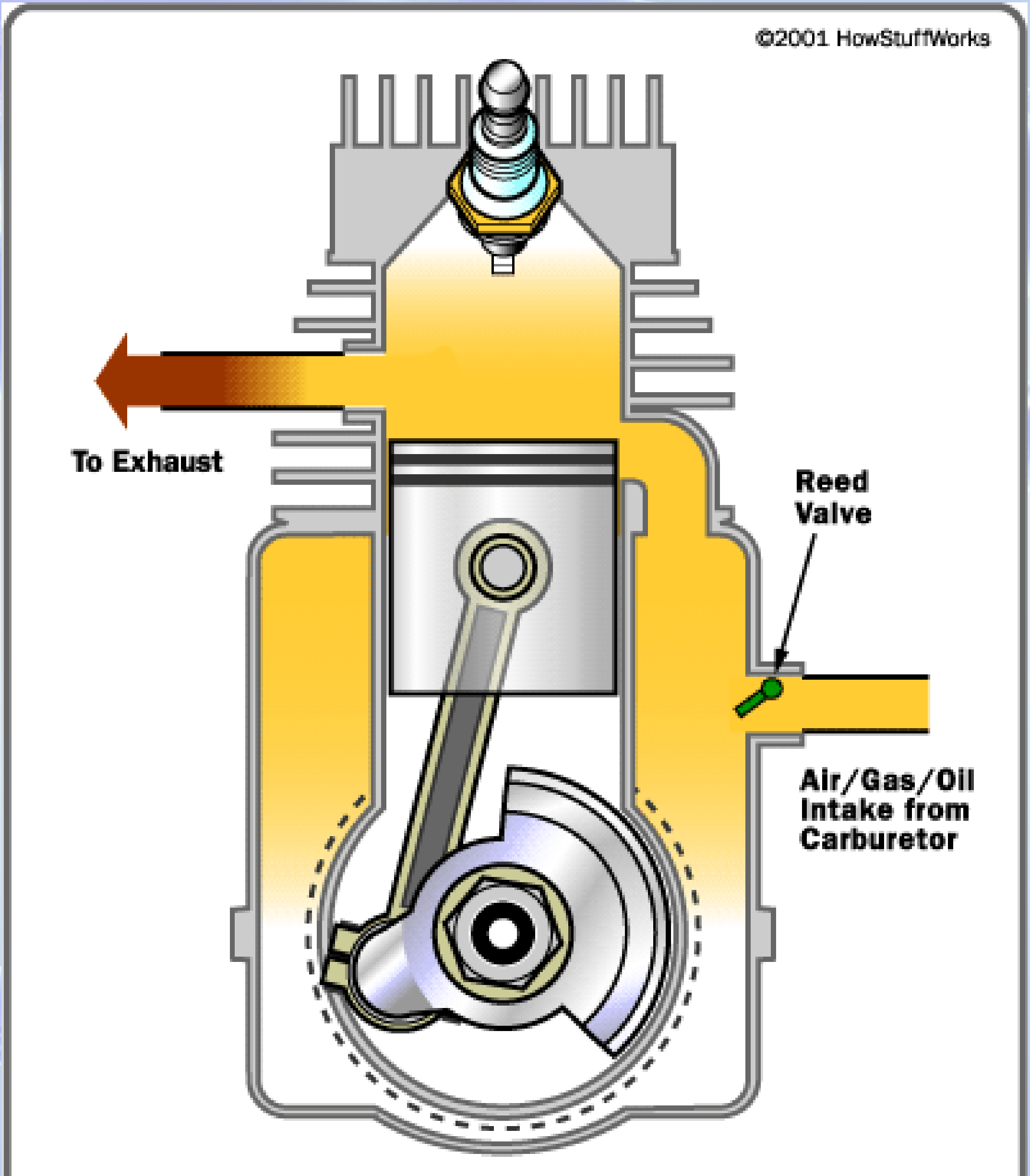
- Two-stroke engines produce a lot of pollution




-- so much, in fact, that it is likely that you won't see them around too much longer.

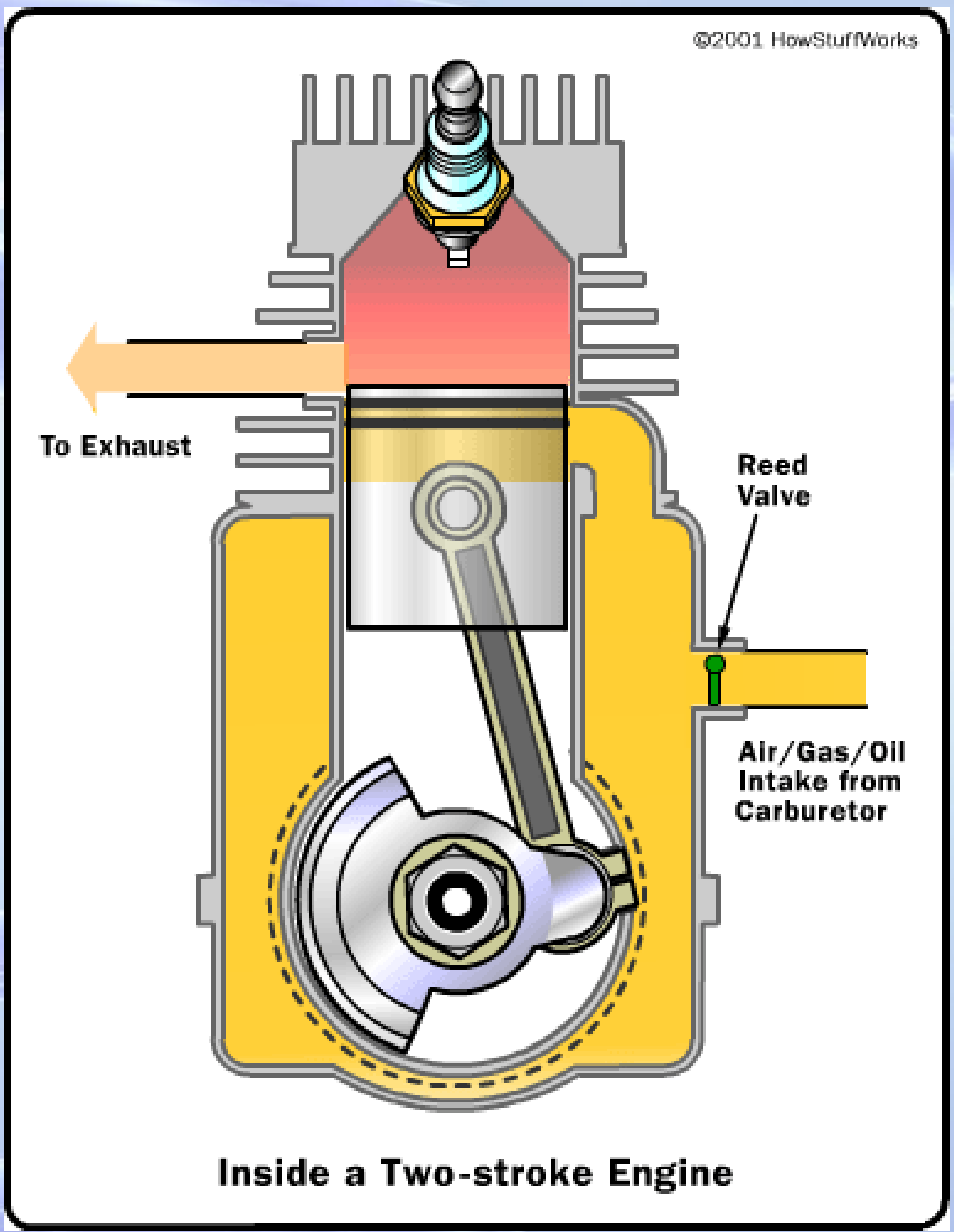

©2001 HowStuffWorks
To Exhaust
Reed Valve
Air/Gas/Oil Intake from Carburetor
Fuel-intake position of a two-stroke engine

# FUEL INTAKE

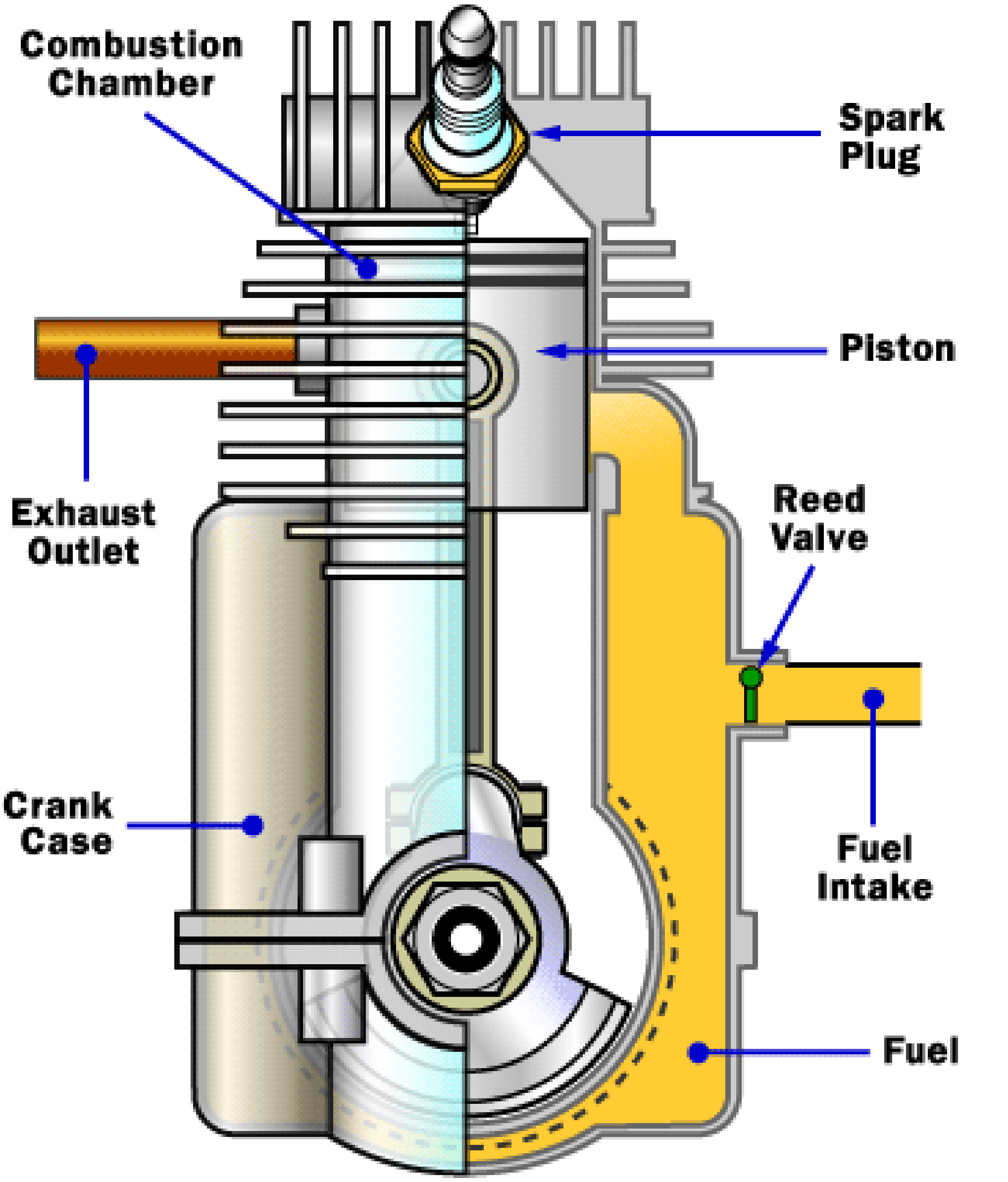


Compression action of a two-stroke engine

COMPRESSION




COMBUSTION
&
EXHAUST




The basic components of a two-stroke engine

# TWO STROKE OPERATION

# USEFUL ENGINE SIZING CORRELATION

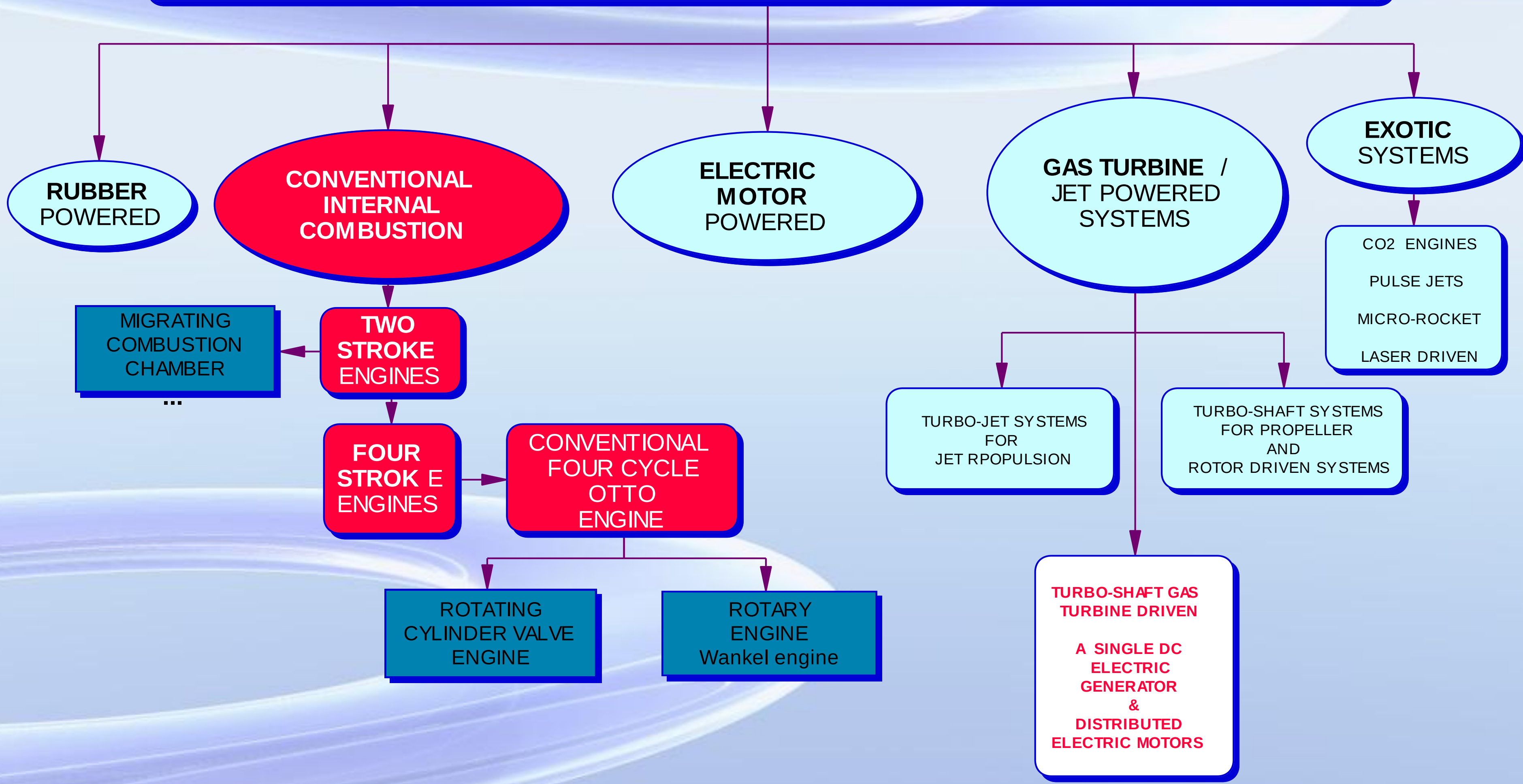
(only for two stroke engines)

1 cubic inch of displacement
will handle
10 lbs of aircraft weight

1 cubic inch is 16 cc

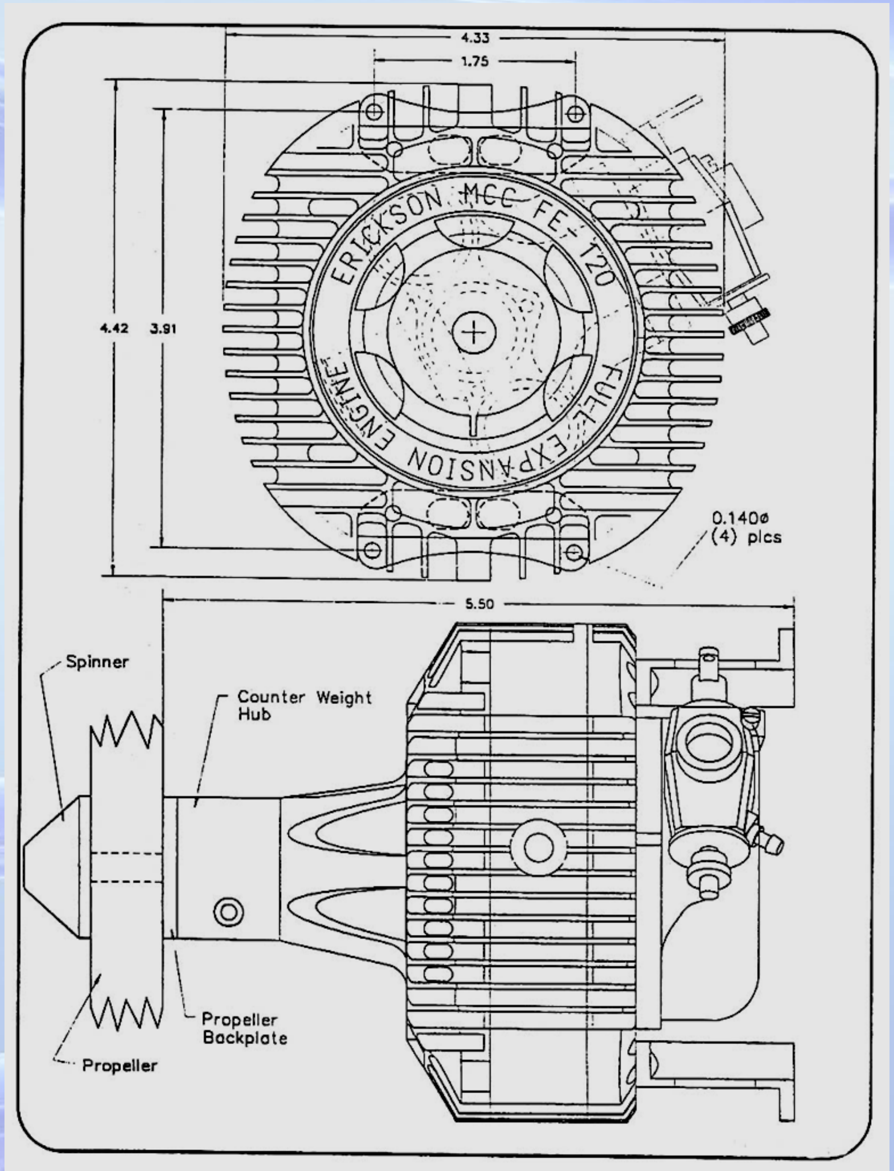
1 HP = 0.735 KW
1KW = 1.359 HP (metric)

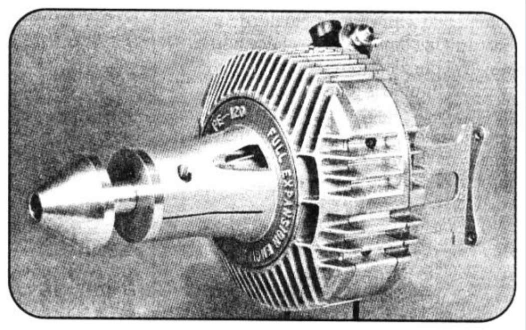
# SMALL PROPULSION SYSTEMS
# FOR
# UNMANNED AND MODEL AIRCRAFT



# MIGRATING COMBUSTION CHAMBER

## ERICKSON ENGINE



DUAL MIGRATING
COMBUSTION
CHAMBERS

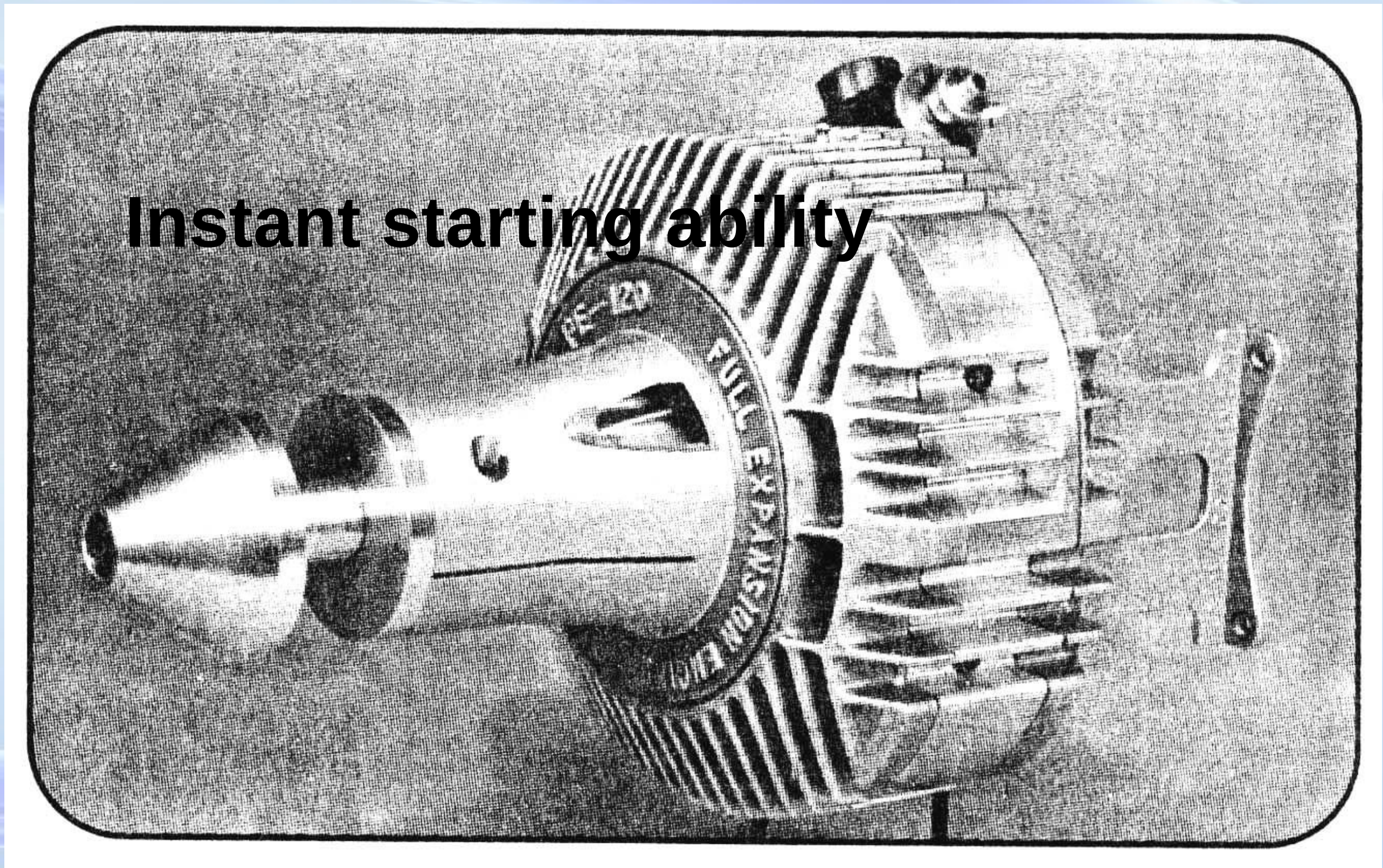
TWO STROKE CYCLE

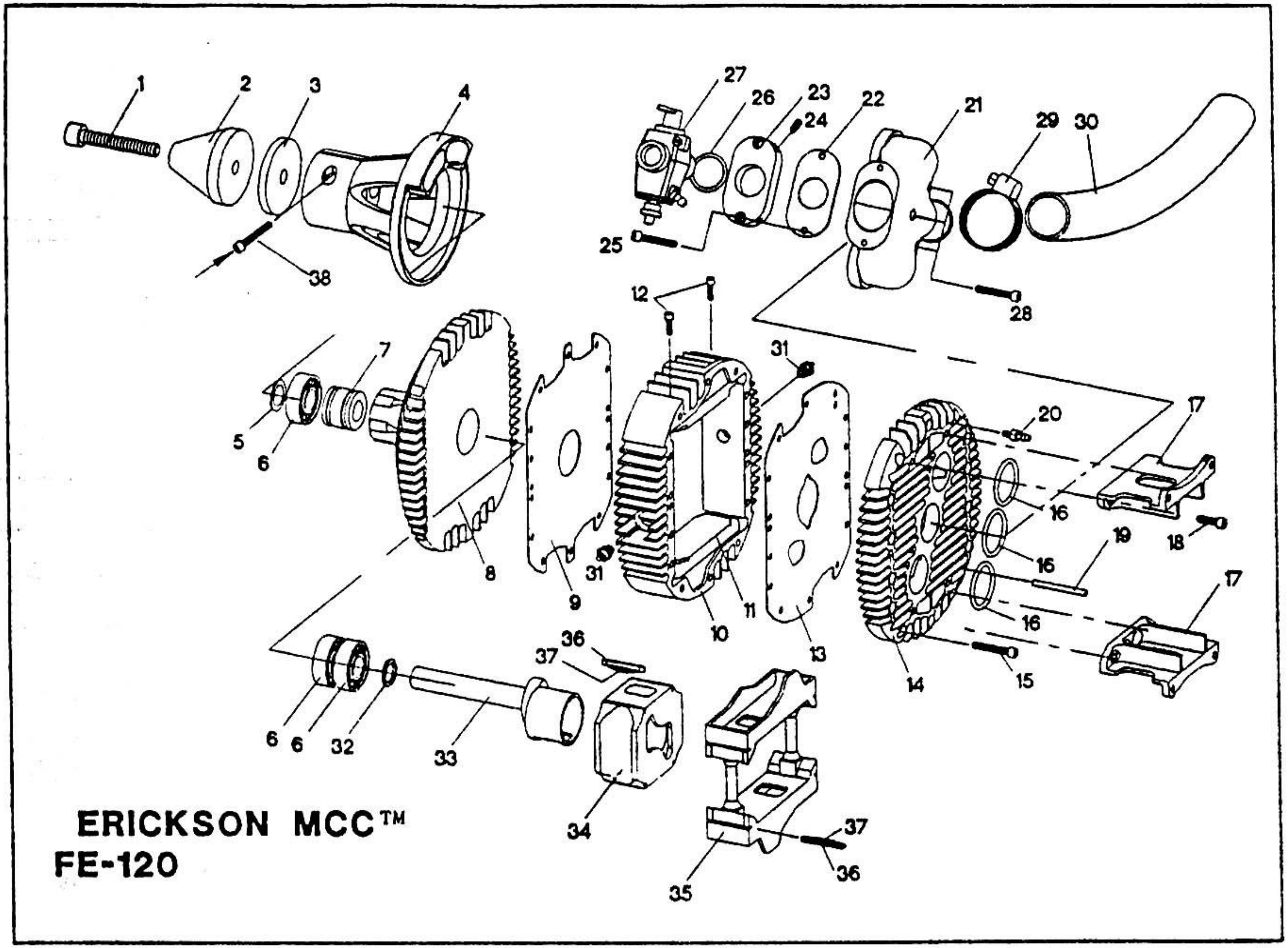
19.7 cm3 (1.2 cu.in)

2.2 HP @ 7000 rpm

Compression = 7.39
Weight = 38.7 oz.
1 oz./min

# Instant starting ability

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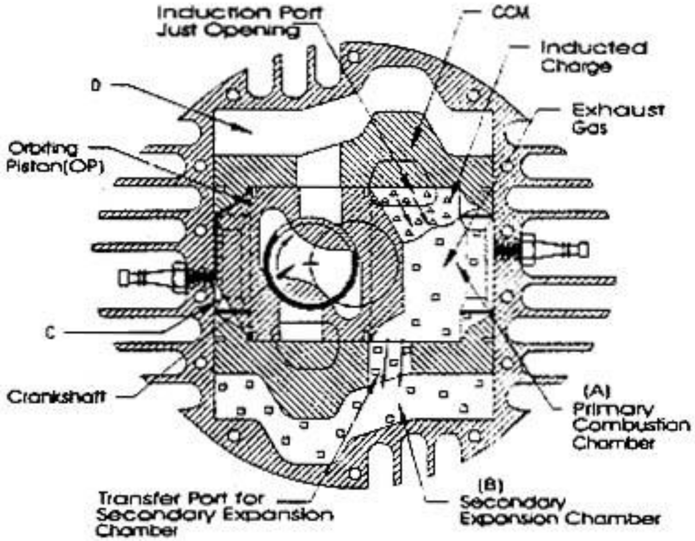
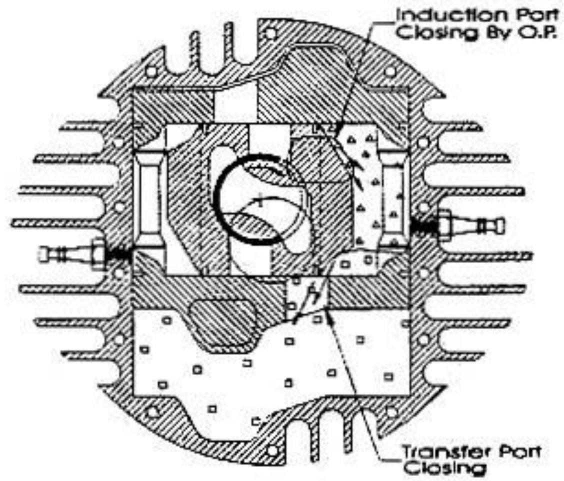
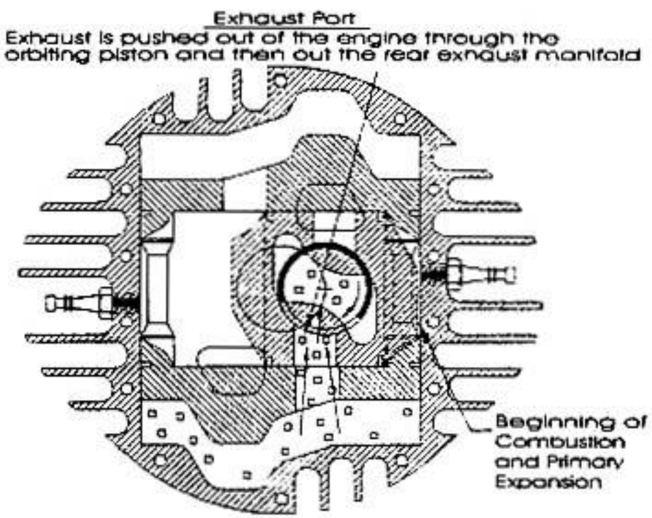
ERICKSON MCC™
FE-120



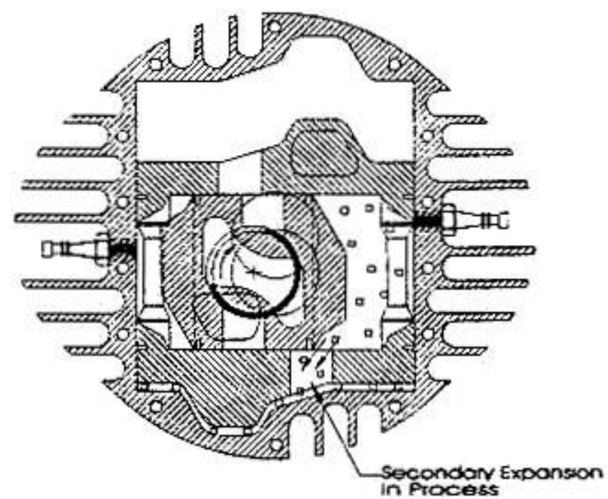

1. Combustion Expansion and Start of Induction



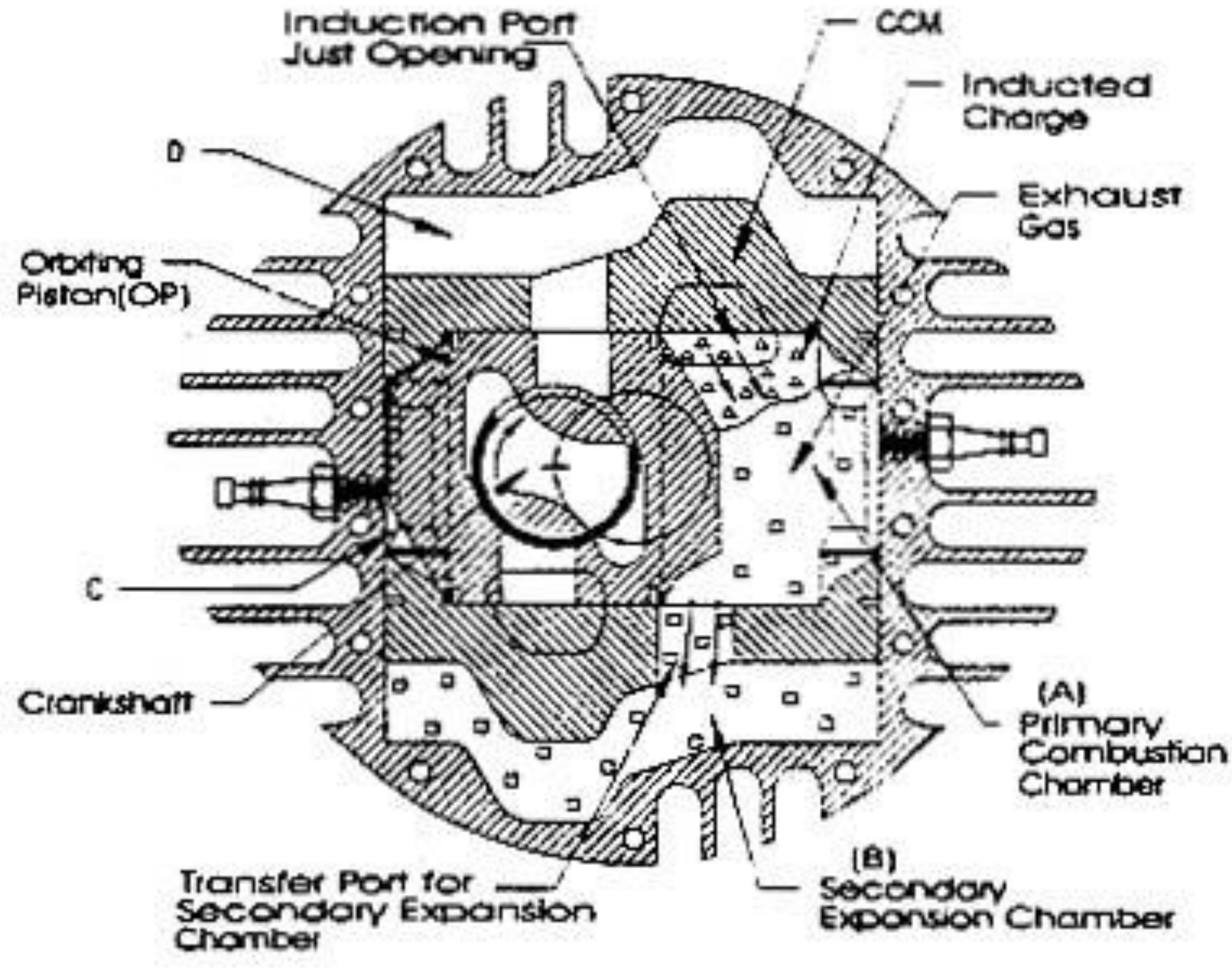

2. Continue Expansion Induction




3. Compression, Exhaust and Start of Primary Expansion

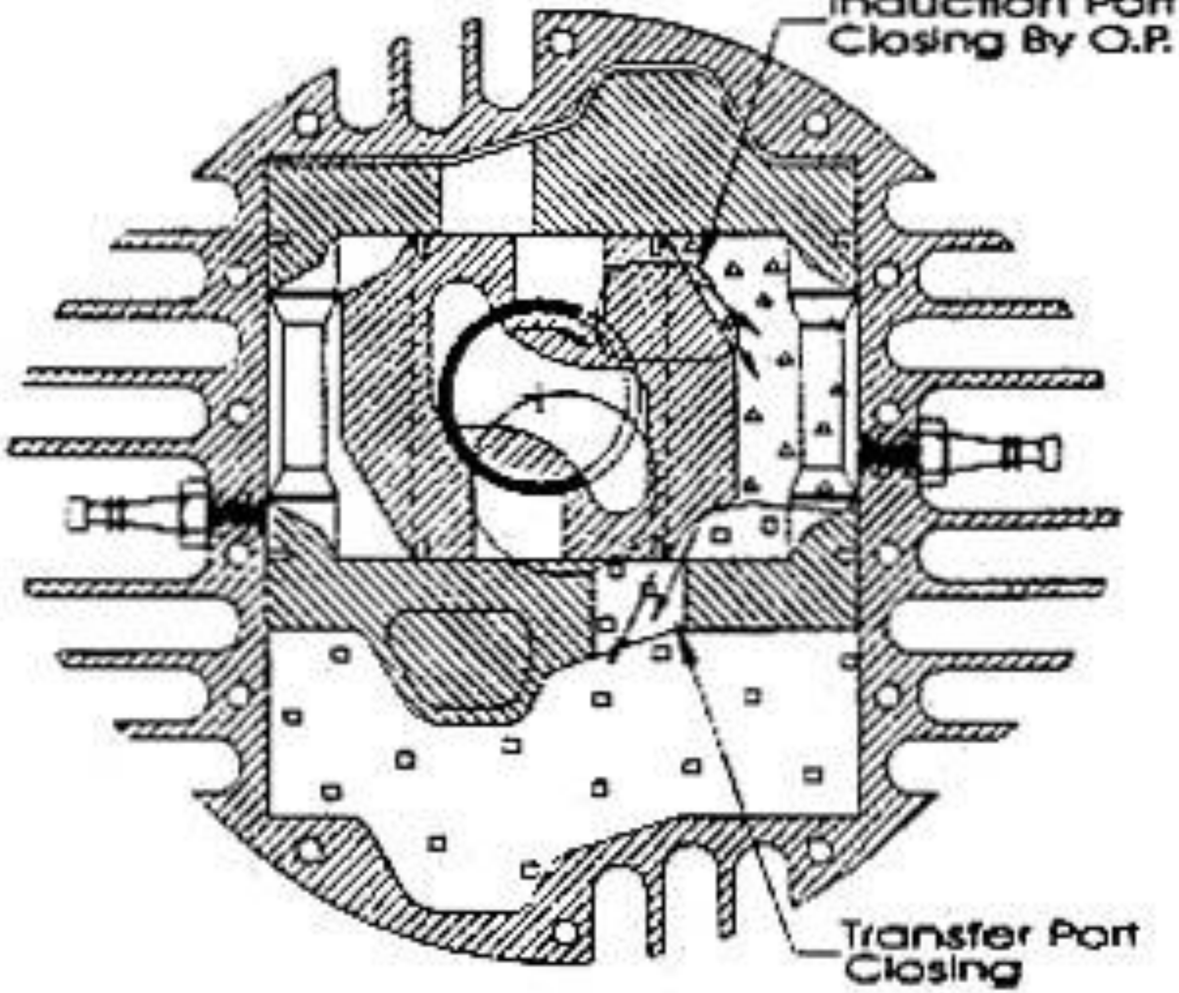



4. Exhaust Complete - Secondary Expansion in Process

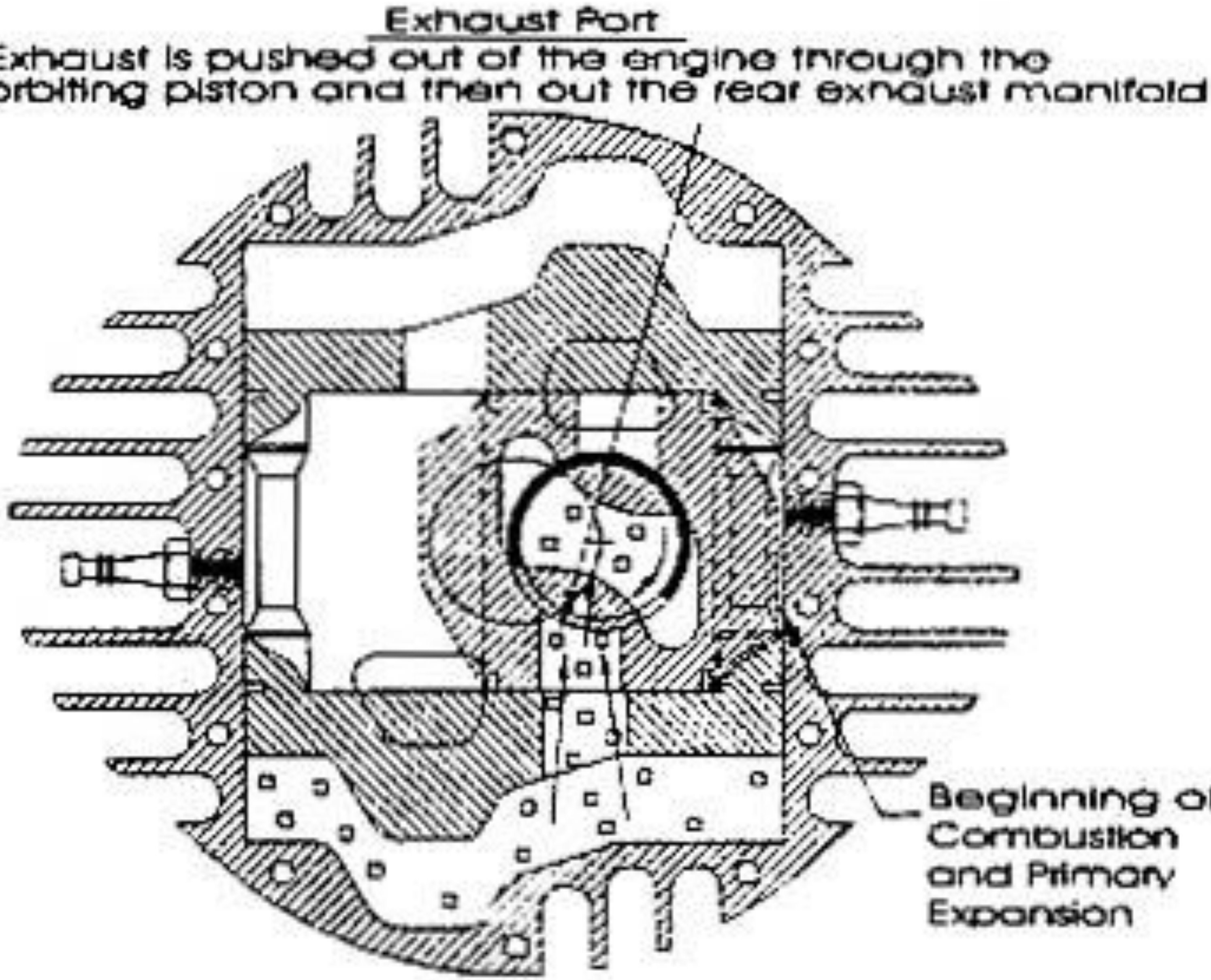



1. Combustion Expansion and Start of Induction

2.




2. Continue Expansion Induction




3. Compression, Exhaust and Start of Primary Expansion

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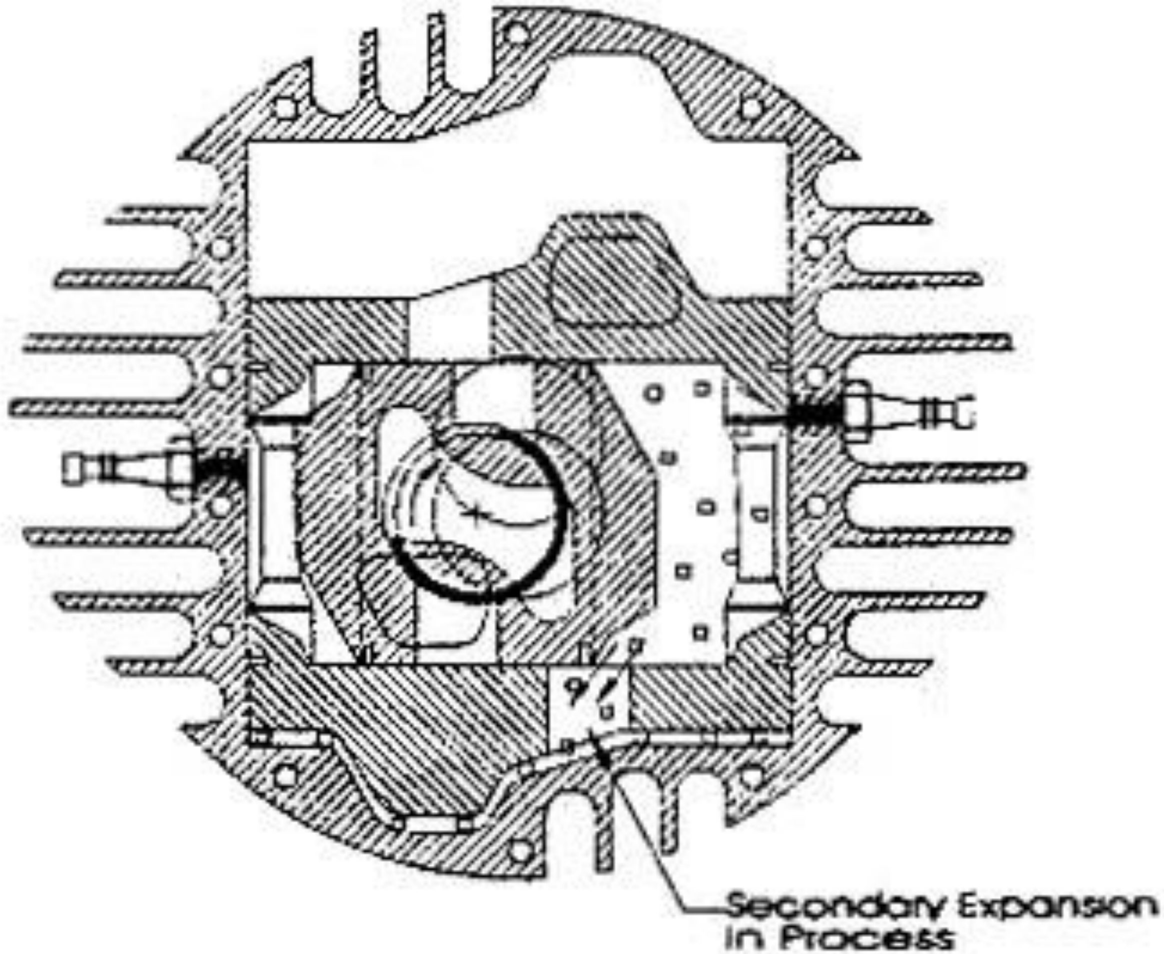
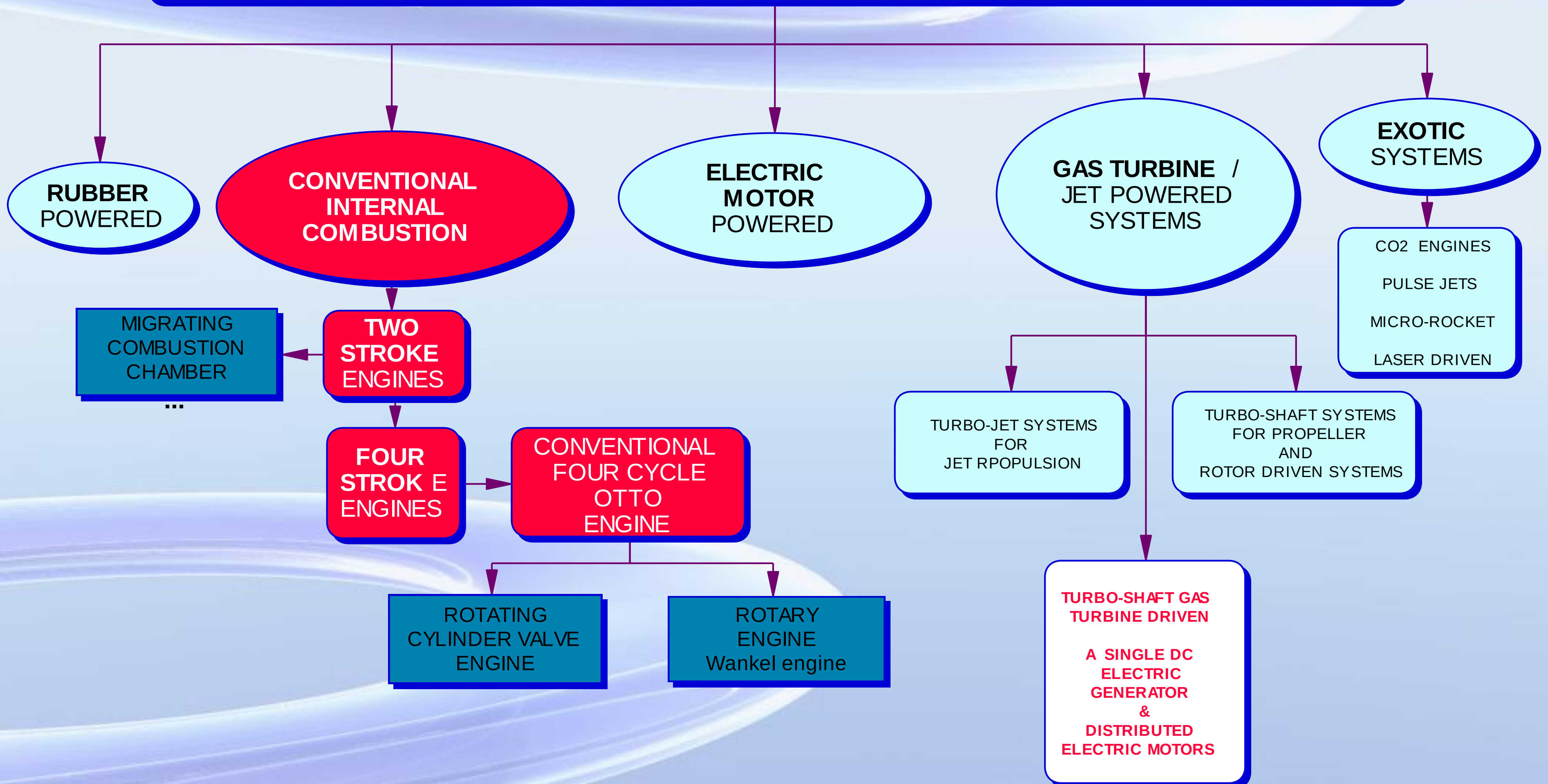


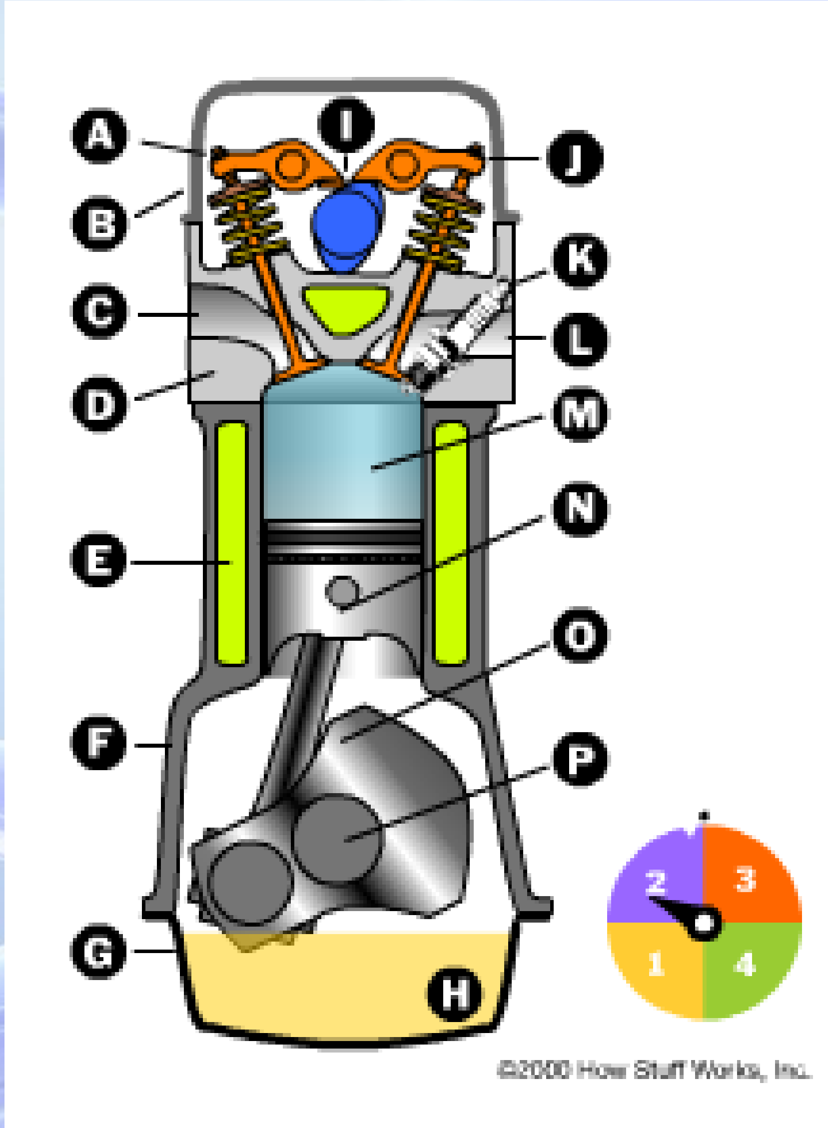

4. Exhaust Complete - Secondary Expansion
in Process

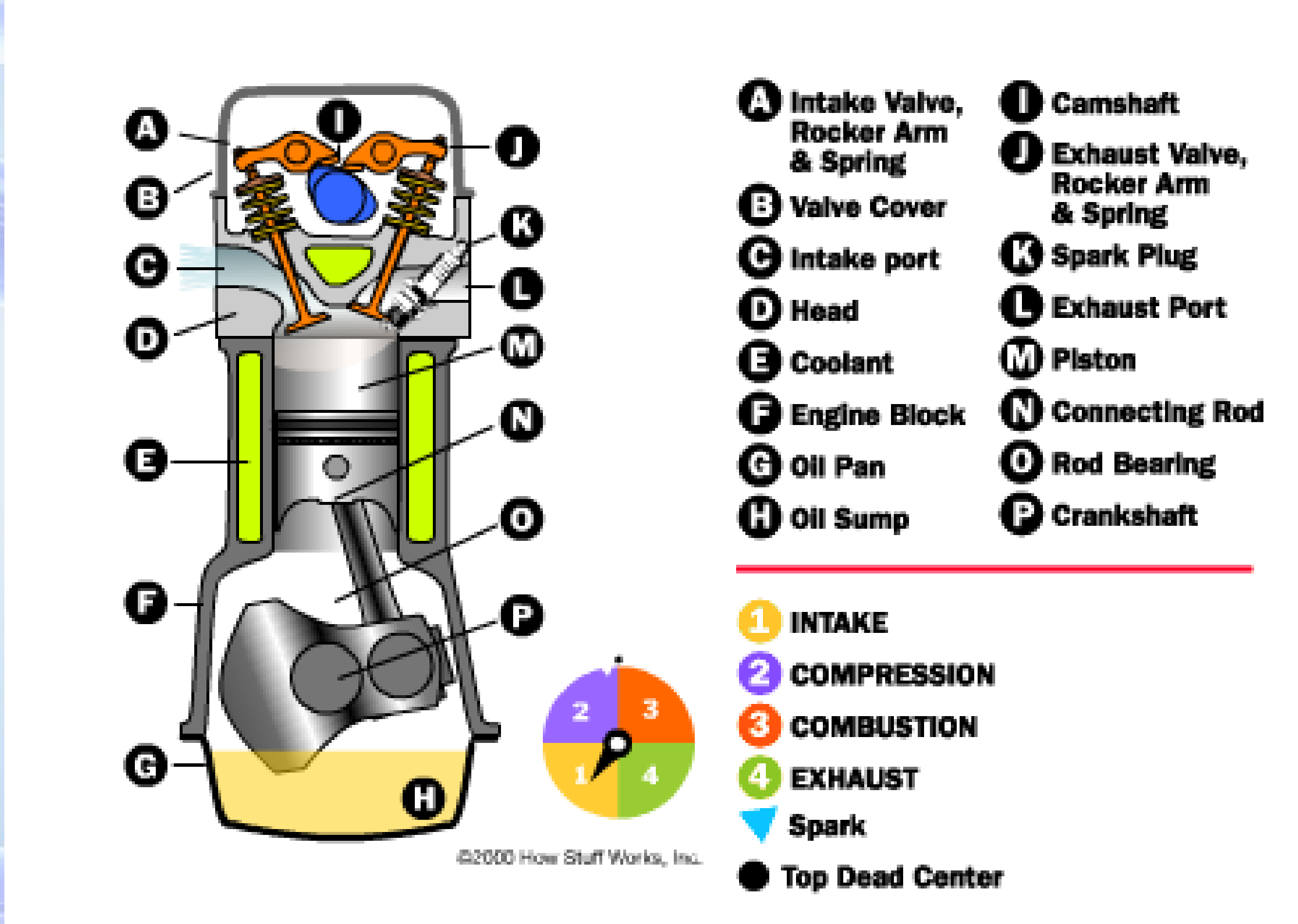
# SMALL PROPULSION SYSTEMS FOR UNMANNED AND MODEL AIRCRAFT



# FOUR CYCLE ENGINES

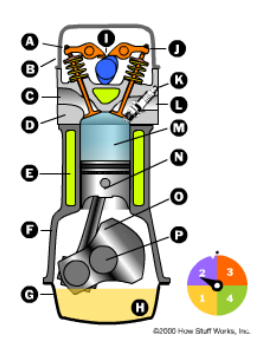
## conventional Otto engines






FOUR CYCLE ENGINE OPERATION

# FOUR CYCLE ENGINE CHARACTERISTICS



**FOUR STROKE ENGINES LASTS LONGER THAN TWO STROKE ENGINES**. The lack of a dedicated lubrication system means that the parts of a two-stroke engine wear a lot faster.

**FOUR STROKE ENGINES DON'T BURN OIL IN COMBUSTION CHAMBER**. Two-stroke oil is expensive, and you need about 4 ounces of it per gallon of gas. You would burn about a gallon of oil every 1,000 miles if you used a two-stroke engine in a car.

**FOUR STROKE ENGINES ARE MORE FUEL EFFICIENT**. Two-stroke engines do not use fuel efficiently, so you would get fewer miles per gallon.

**FOUR STROKE ENGINES ARE CLEANER**. Two-stroke engines produce a lot of pollution

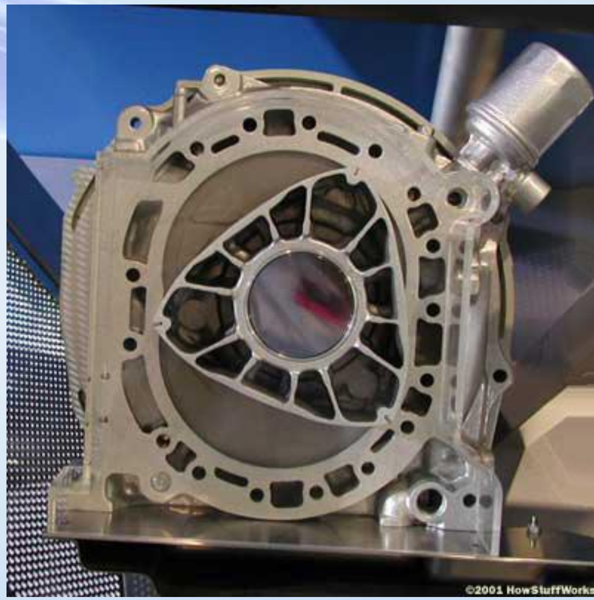
**INVERTED FLIGHTS MAY NOT BE EASY IN FOUR STROKE ENGINES.** Two-stroke engines can work in any orientation, which can be important in acrobatic flights. A standard four-stroke engine may have problems with oil flow unless it is upright, and solving this problem can add complexity to the engine.

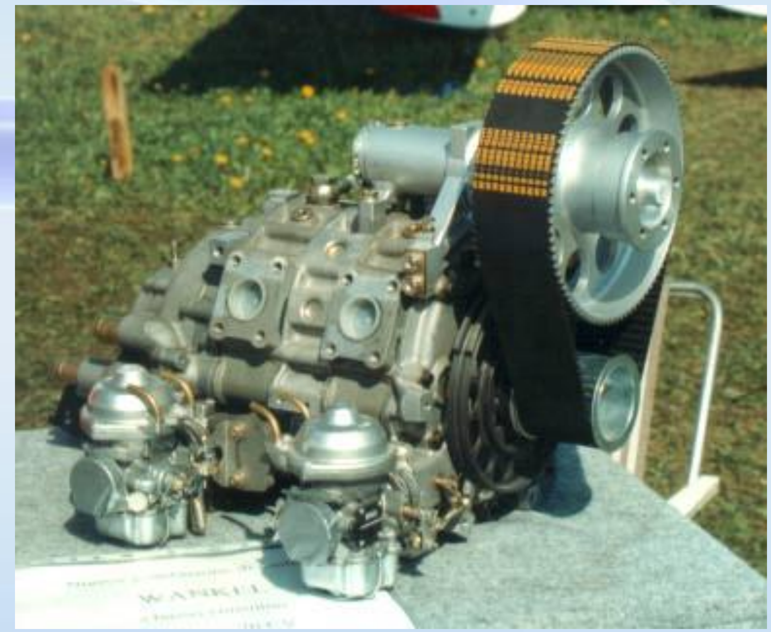
# Unusual Four stroke engines for UAV/MAV applications

ROTARY ENGINES — WANKEL ENGINE

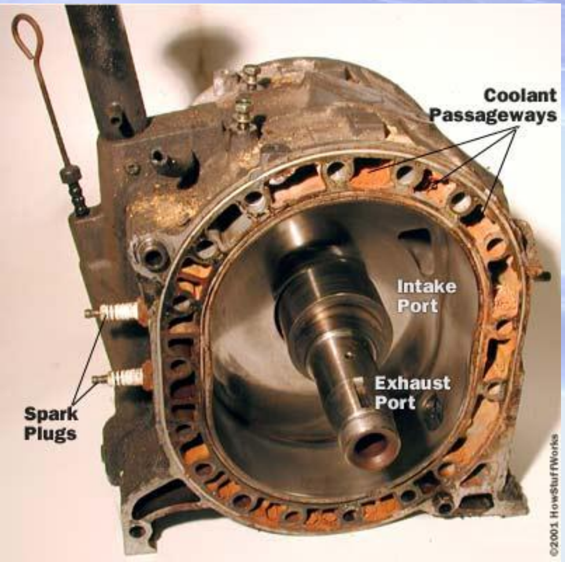
ROTARY CYLINDER VALVE ENGINE — RCV ENGINE

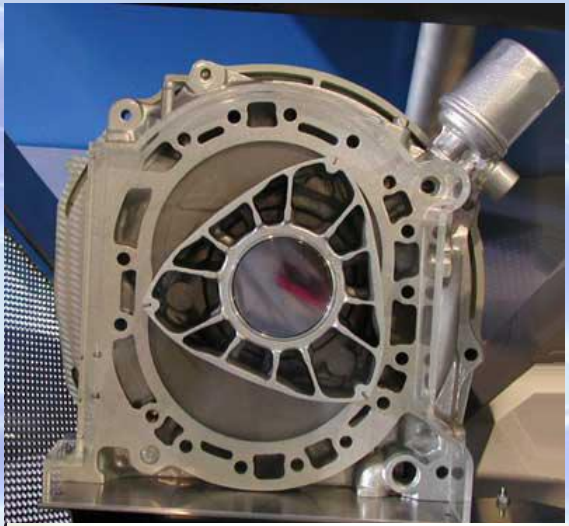
# ROTARY ENGINES
## Wankel Engine

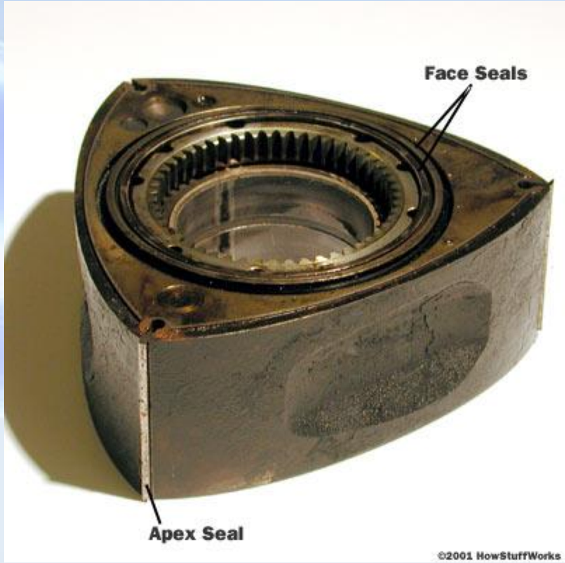


Rotary engines use the four-stroke combustion cycle, which is the same cycle that four-stroke piston engines use. But in a rotary engine, this is accomplished in a completely different way.

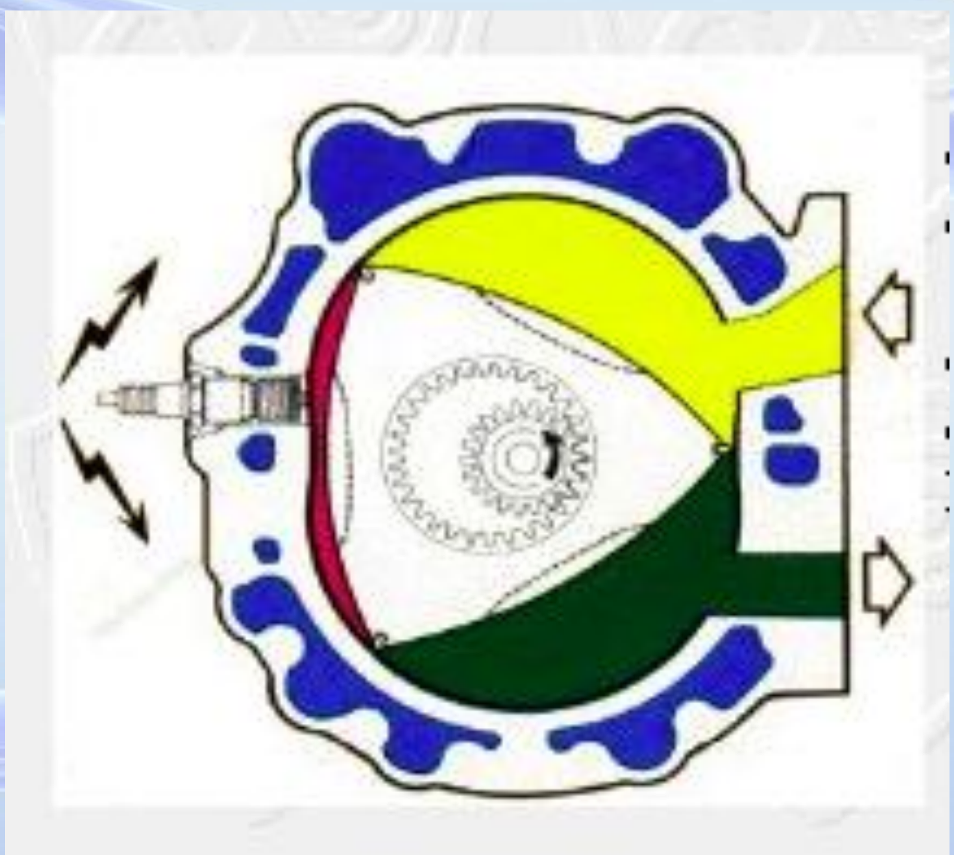



**The heart of a rotary engine is the rotor.** This is roughly the equivalent of the pistons in a piston engine. The rotor is mounted on a large circular lobe on the output shaft. This lobe is offset from the centerline of the shaft and acts like the crank handle on a winch, giving the rotor the leverage it needs to turn the output shaft. As the rotor orbits inside the housing, it pushes the lobe around in tight circles, turning **three times** for every one revolution of the rotor.

# How Rotary Engines Work

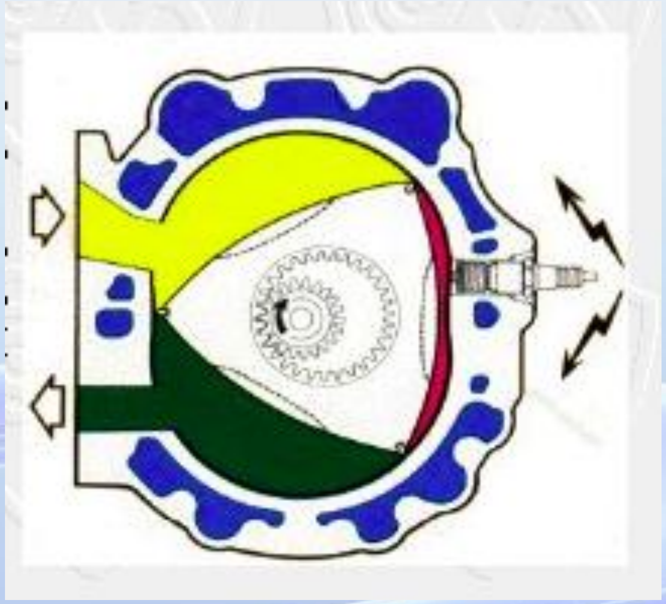


For every three rotations of the engine shaft corresponds to one complete piston rotation (360 degrees)

WANKEL ENGINE OPERATION

# How Rotary Engines Work

**If you watch carefully, you'll see the offset lobe on the output shaft spinning three times for every complete revolution of the rotor.**



As the rotor moves through the housing, the three chambers created by the rotor change size. This size change produces a pumping action. Let's go through each of the four stokes of the engine looking at one face of the rotor.

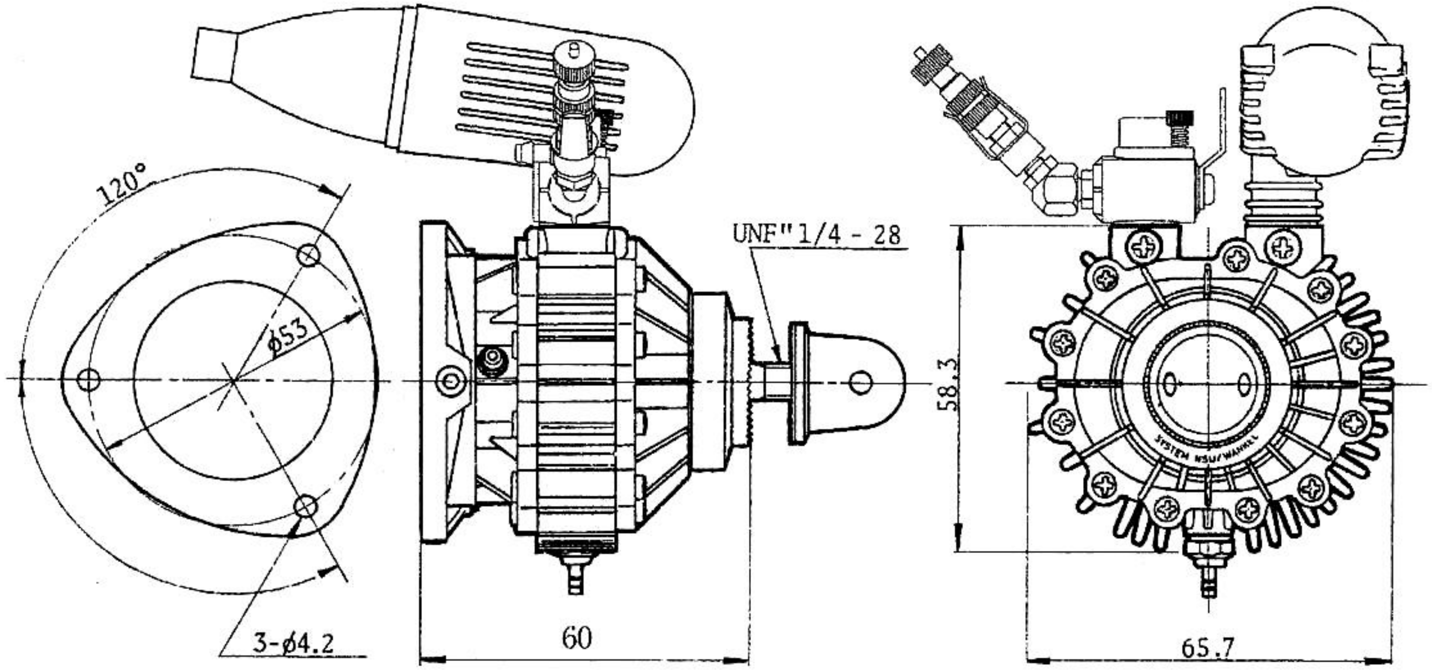
# A subminiature rotary engine for unmanned aircraft

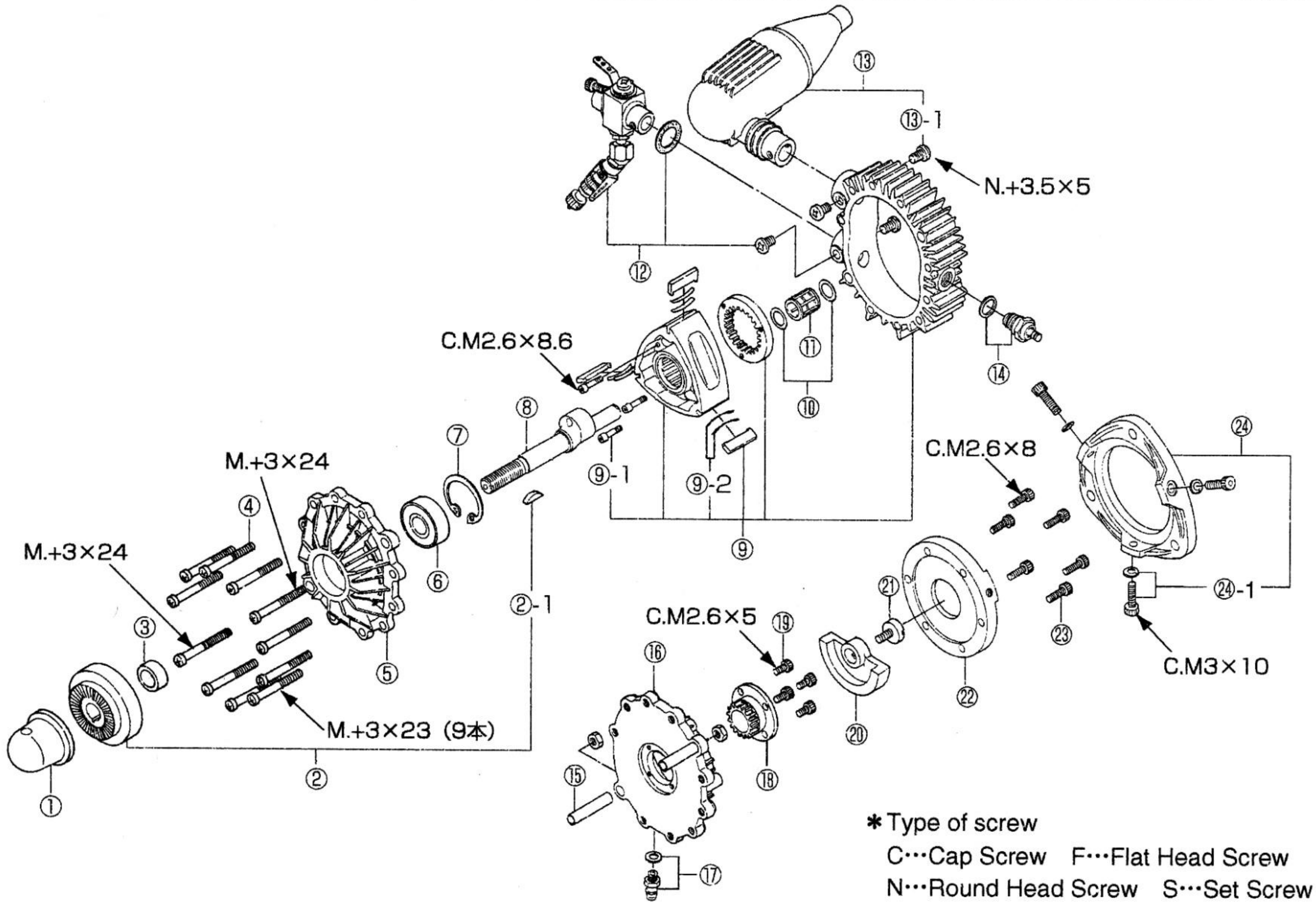
**THREE VIEW DRAWING**

Dimensions(mm)

**SPECIFICATIONS**

| | |
|---|---|
| ■ Displacement | 4.97 cc (0.303cu.in.) |
| ■ Bore | ———— |
| ■ Stroke | ———— |
| ■ Practical R.P.M. | 2,500〜18,000 r.p.m. |
| ■ Power output | 1.27bhp / 17,000 r.p.m. |
| ■ Weight | 335g (11.8oz.) |

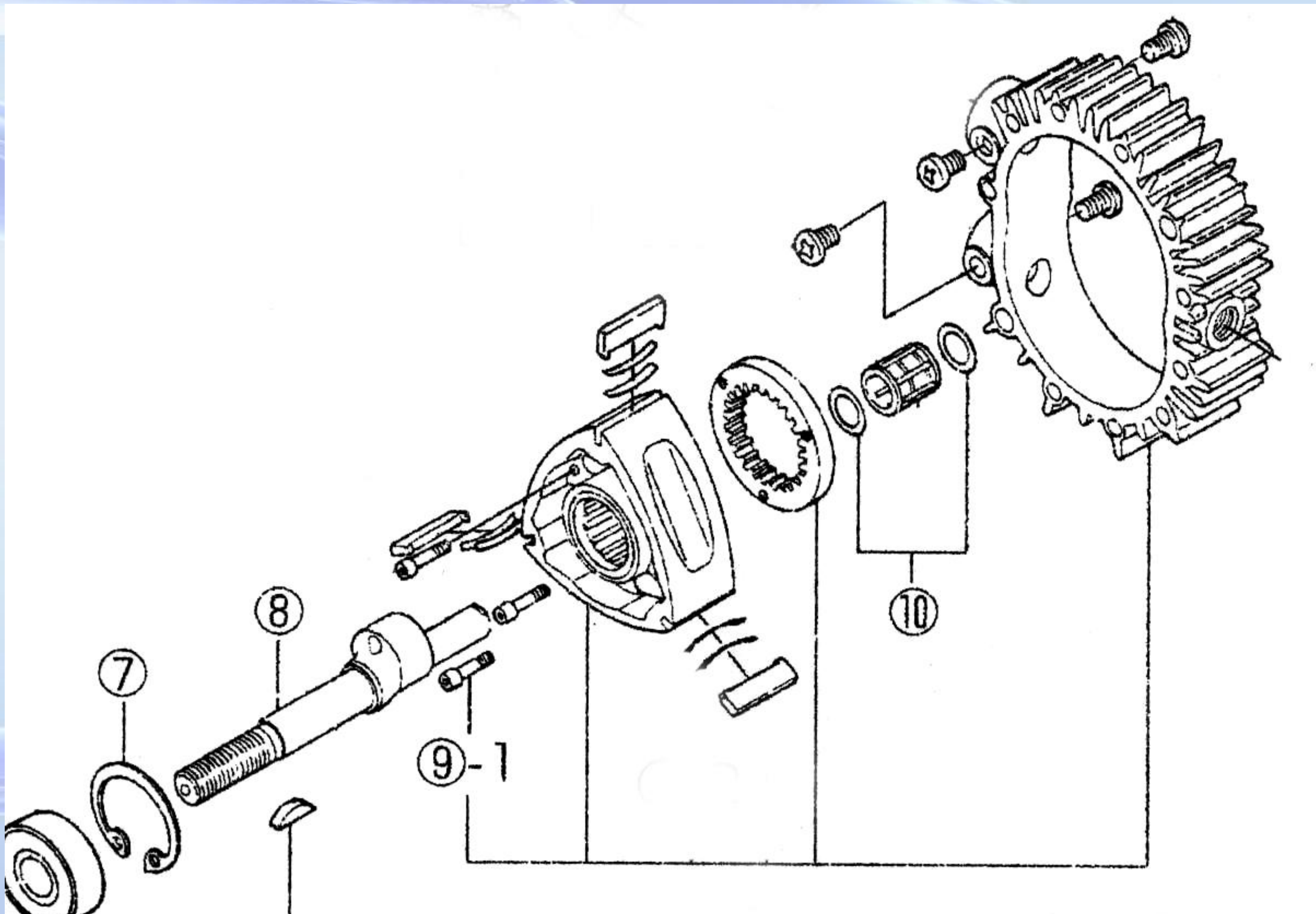





✱ Type of screw

C···Cap Screw F···Flat Head Screw

N···Round Head Screw S···Set Screw



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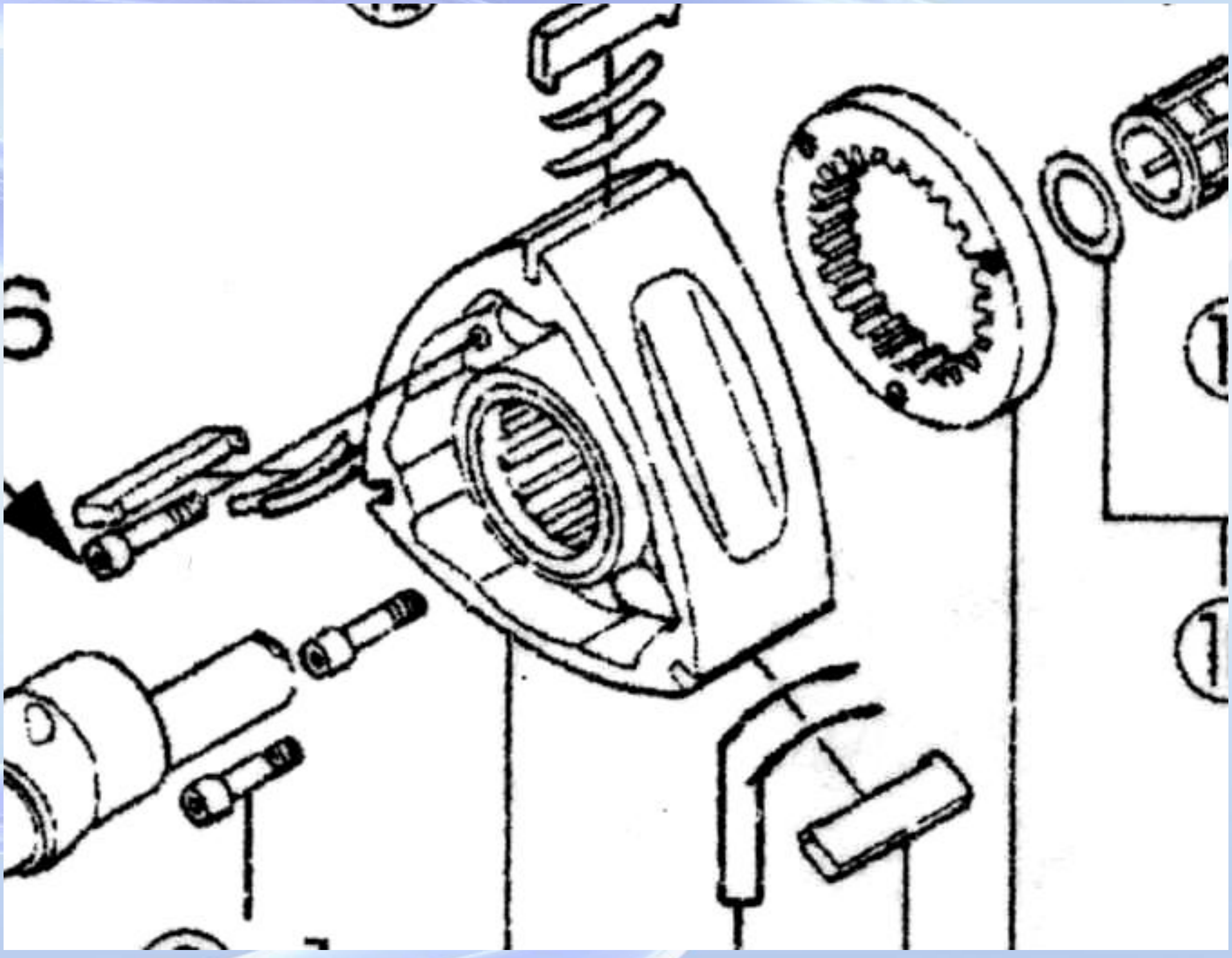
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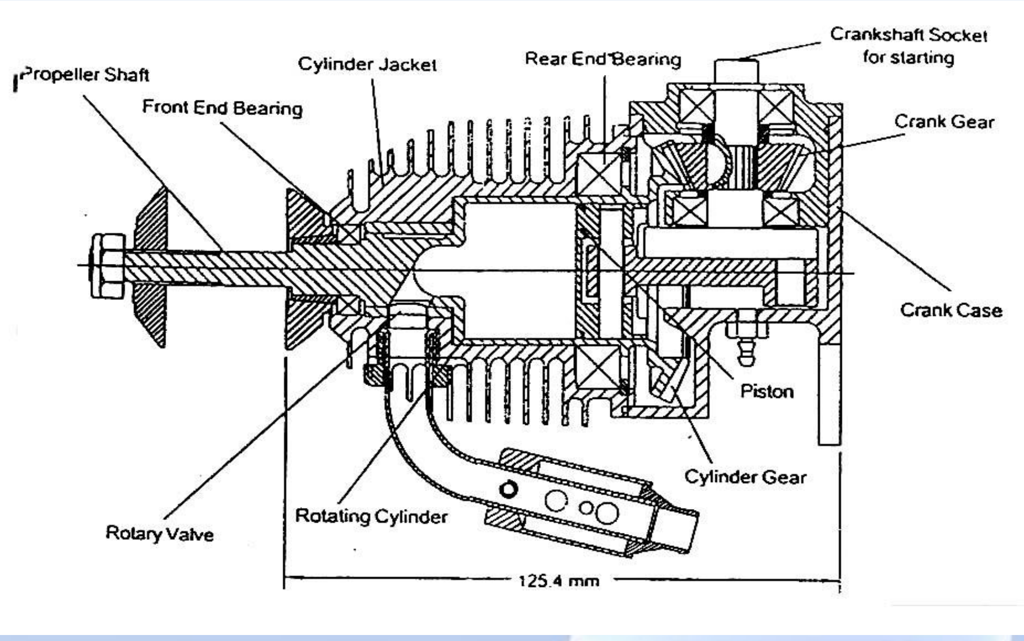
# ROTATING CYLINDER VALVE ENGINE

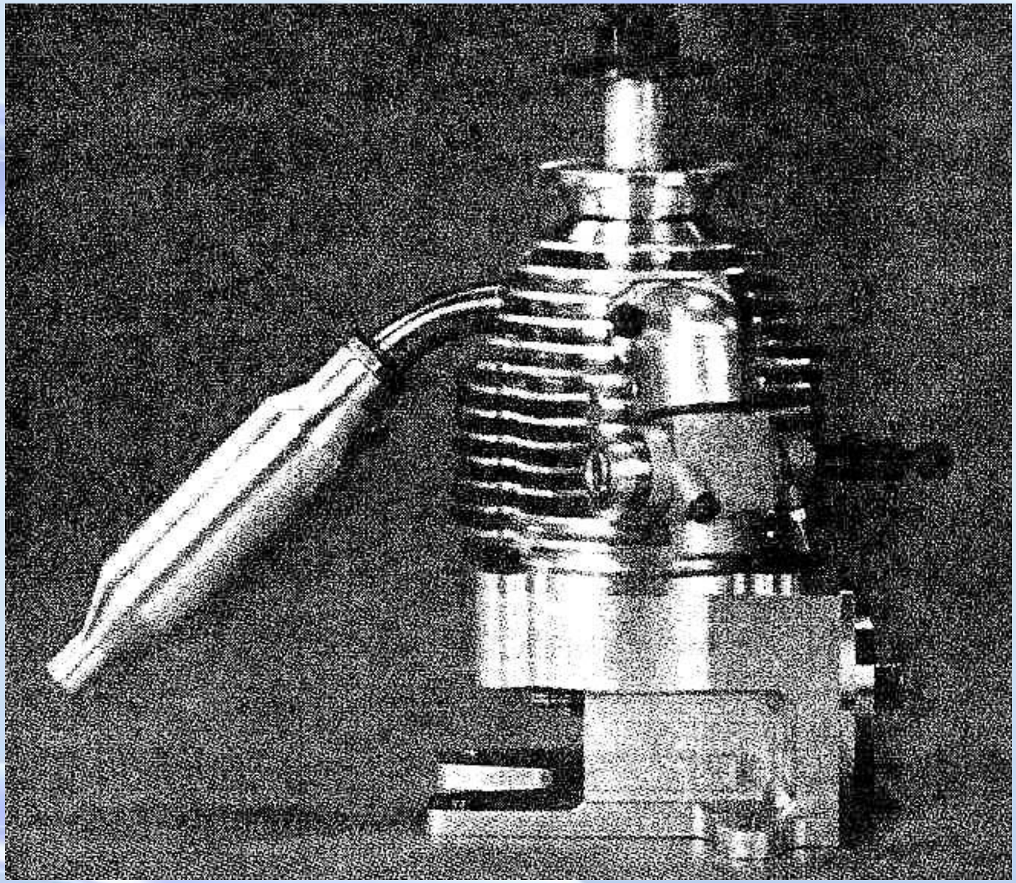



## SINGLE CYLINDER
## 4-STROKE CYCLE

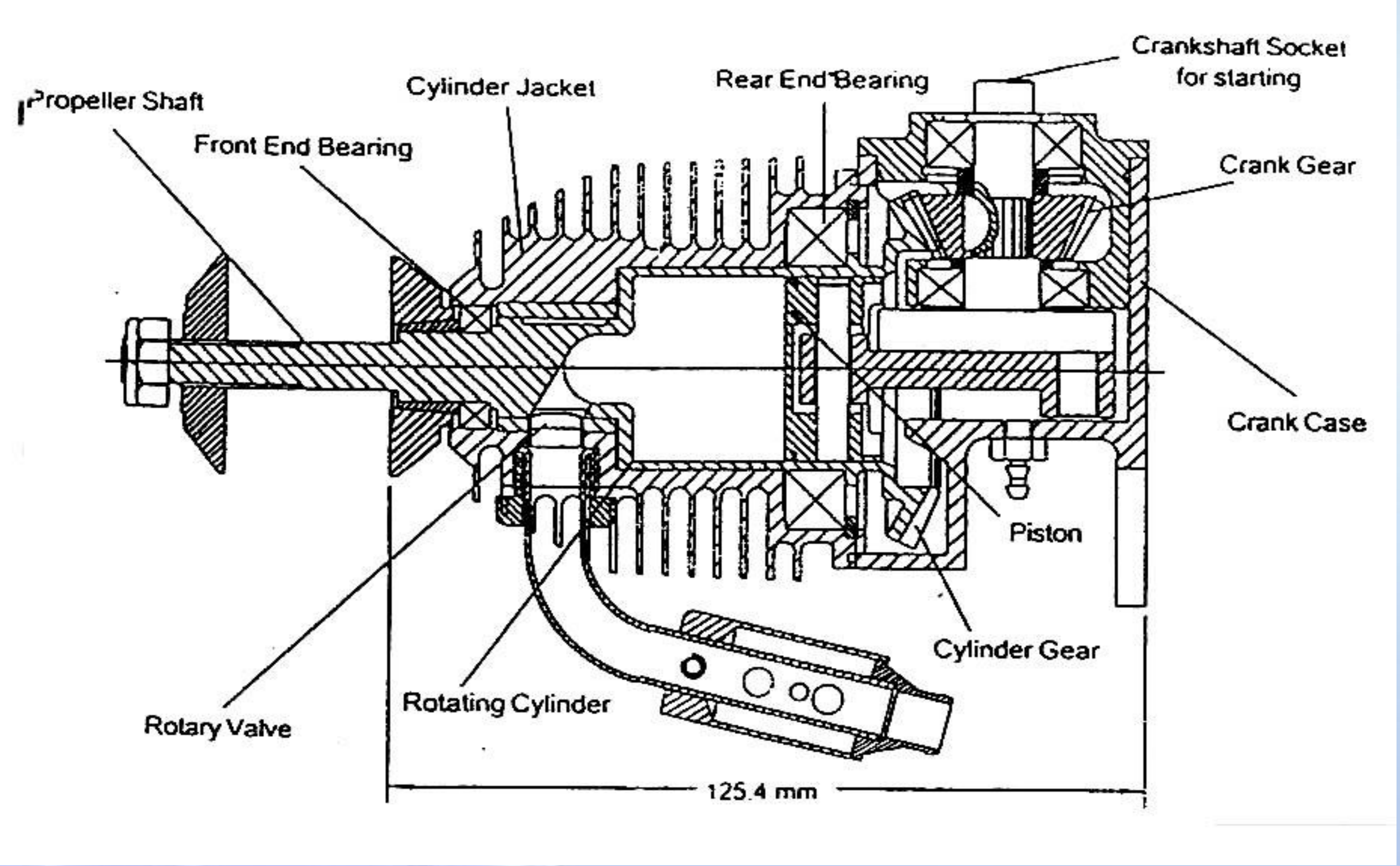
20.02 cm$^3$ (1.2 cu.in.)
weight = 37.1 oz.

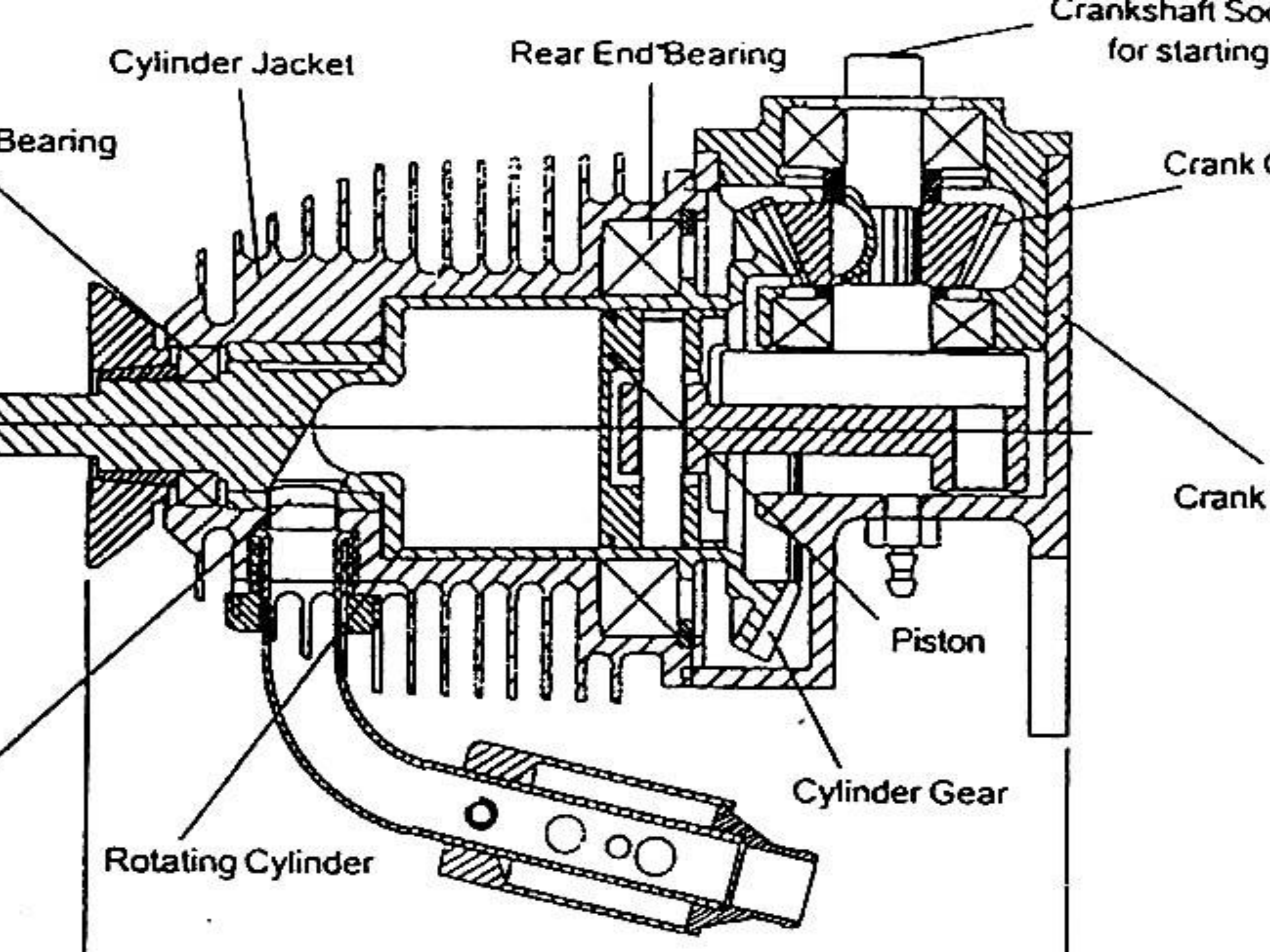
Compression = 10.5

1.8 HP @ 5,800 rpm
.85 oz/min

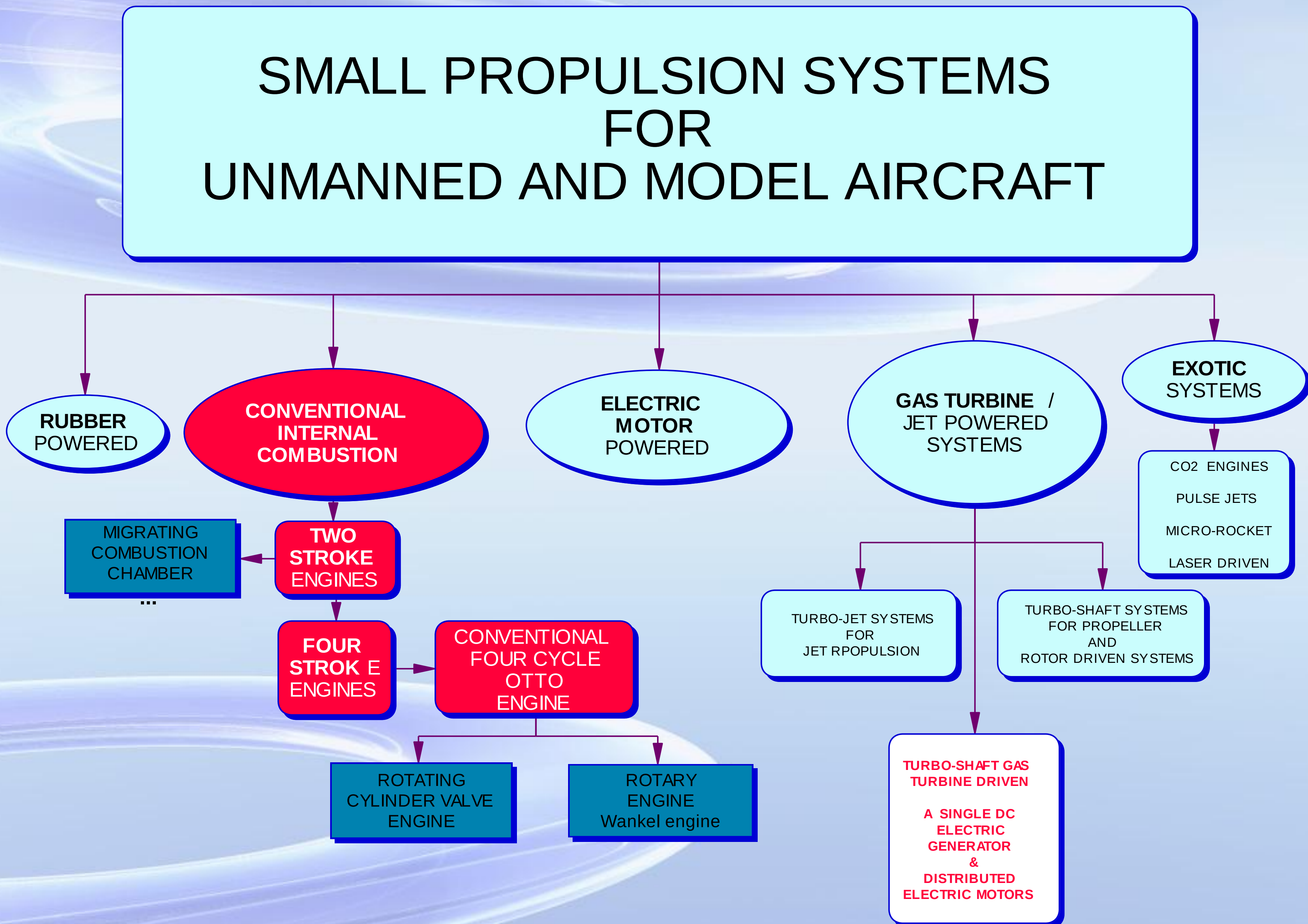


# ROTARY CYLINDER VALVE ENGINE





Crankshaft Soc
for starting
Cylinder Jacket
Rear End Bearing
Bearing
Crank C
Crank
Piston
Cylinder Gear
Rotating Cylinder



SMALL PROPULSION SYSTEMS
FOR
UNMANNED AND MODEL AIRCRAFT
RUBBER POWERED
CONVENTIONAL INTERNAL COMBUSTION
ELECTRIC MOTOR POWERED
GAS TURBINE / JET POWERED SYSTEMS
EXOTIC SYSTEMS
CO2 ENGINES
PULSE JETS
MICRO-ROCKET
LASER DRIVEN
MIGRATING COMBUSTION CHAMBER
...
TWO STROKE ENGINES
FOUR STROK E ENGINES
CONVENTIONAL FOUR CYCLE OTTO ENGINE
ROTATING CYLINDER VALVE ENGINE
ROTARY ENGINE Wankel engine
TURBO-JET SYSTEMS FOR JET RPOPULSION
TURBO-SHAFT SYSTEMS FOR PROPELLER AND ROTOR DRIVEN SYSTEMS
TURBO-SHAFT GAS TURBINE DRIVEN
A SINGLE DC ELECTRIC GENERATOR
&
DISTRIBUTED ELECTRIC MOTORS

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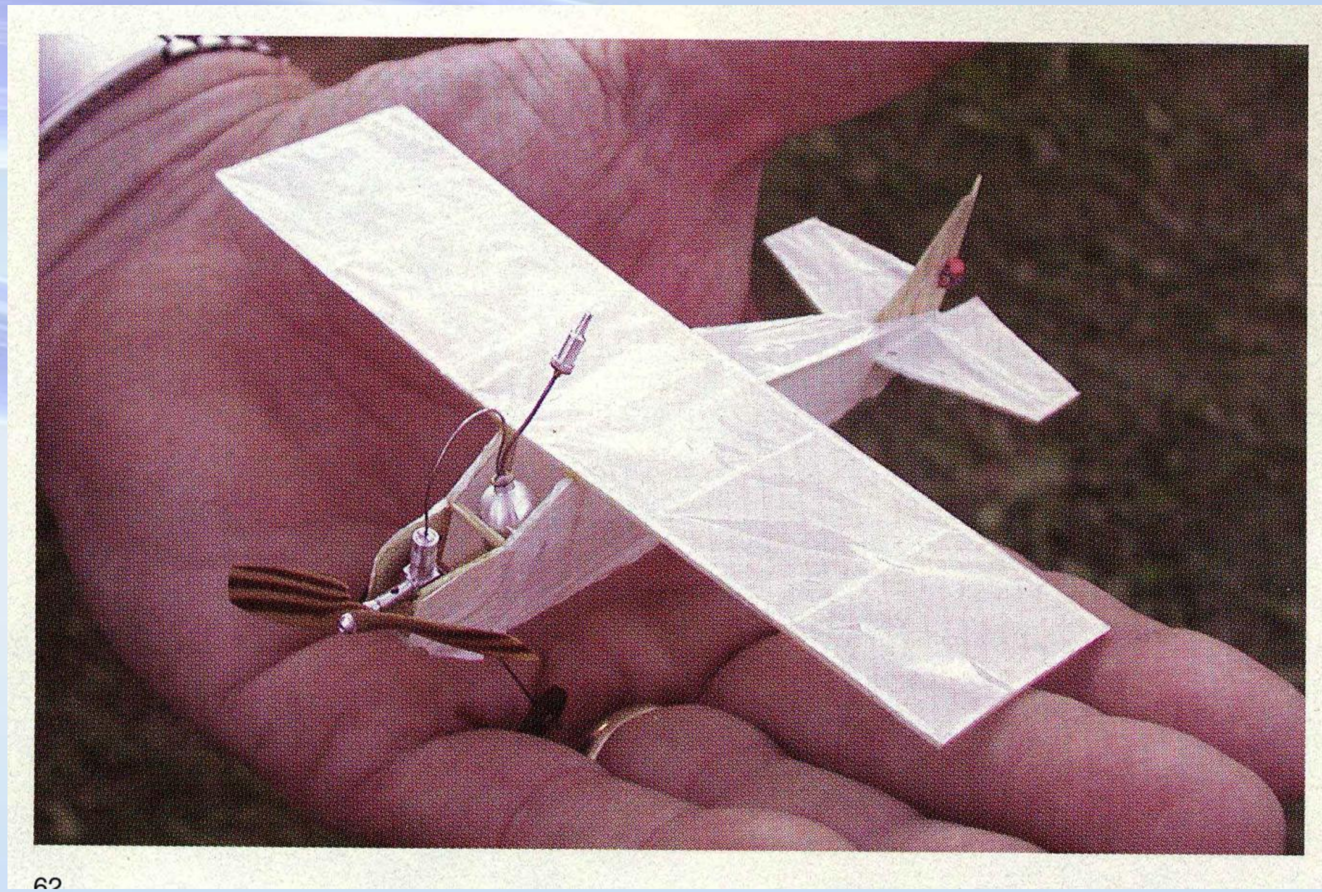
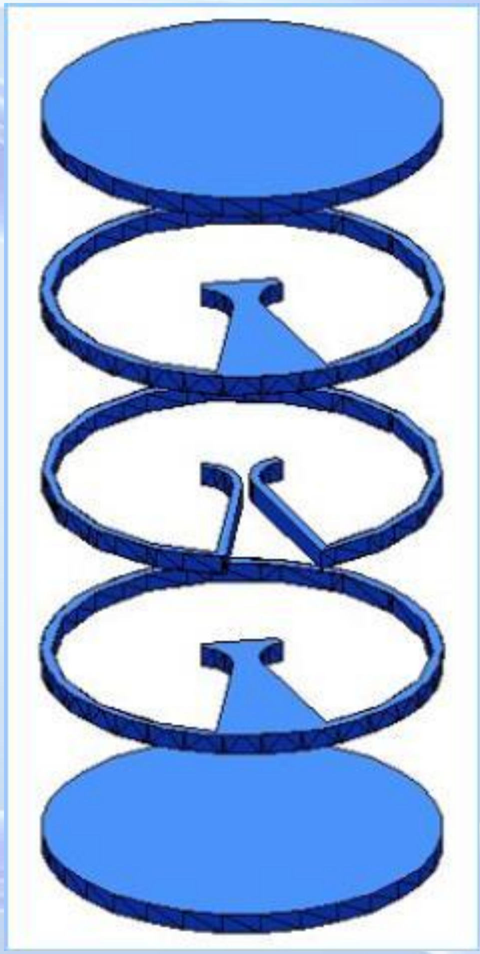
# OTHER SYSTEMS

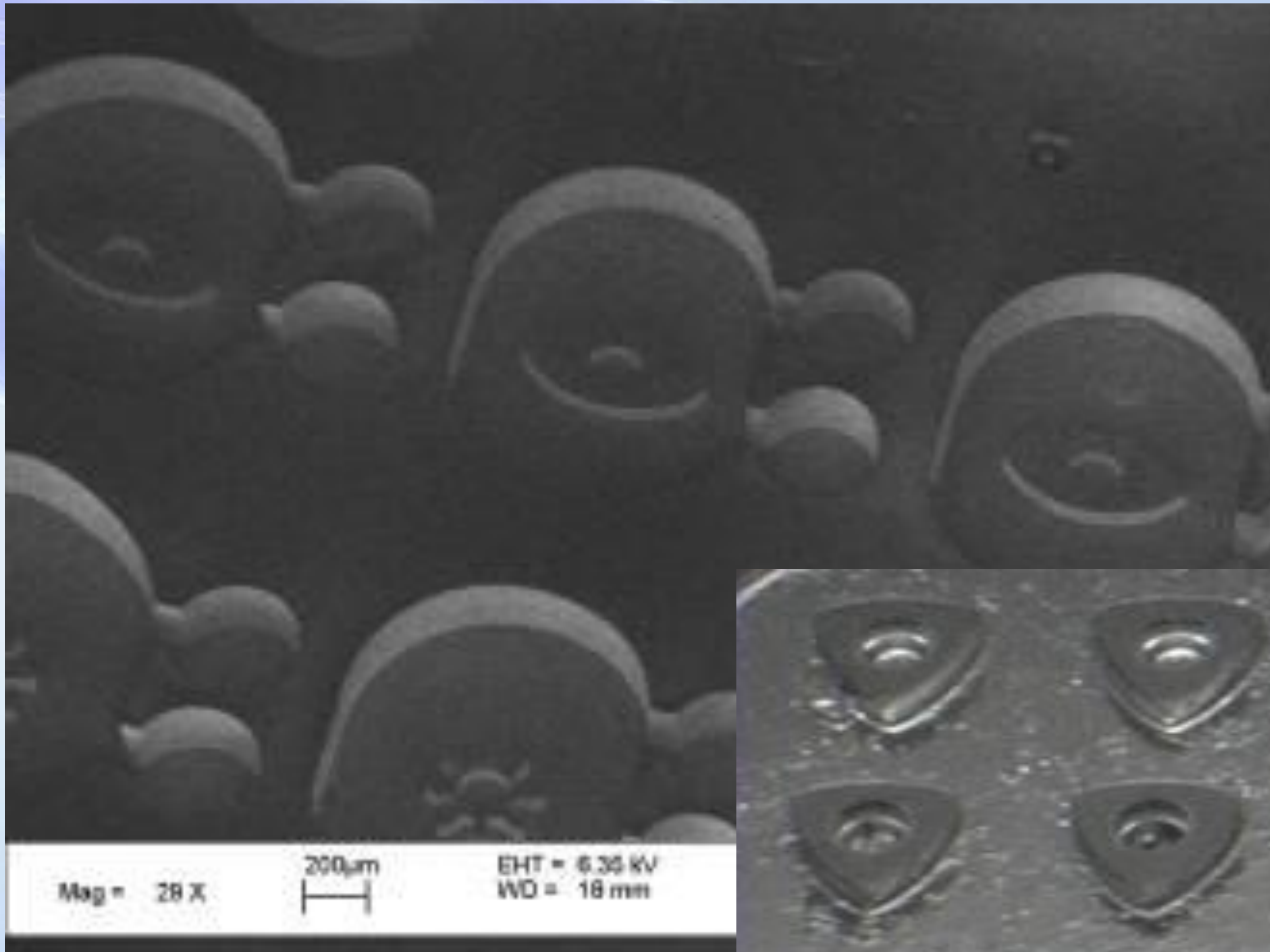


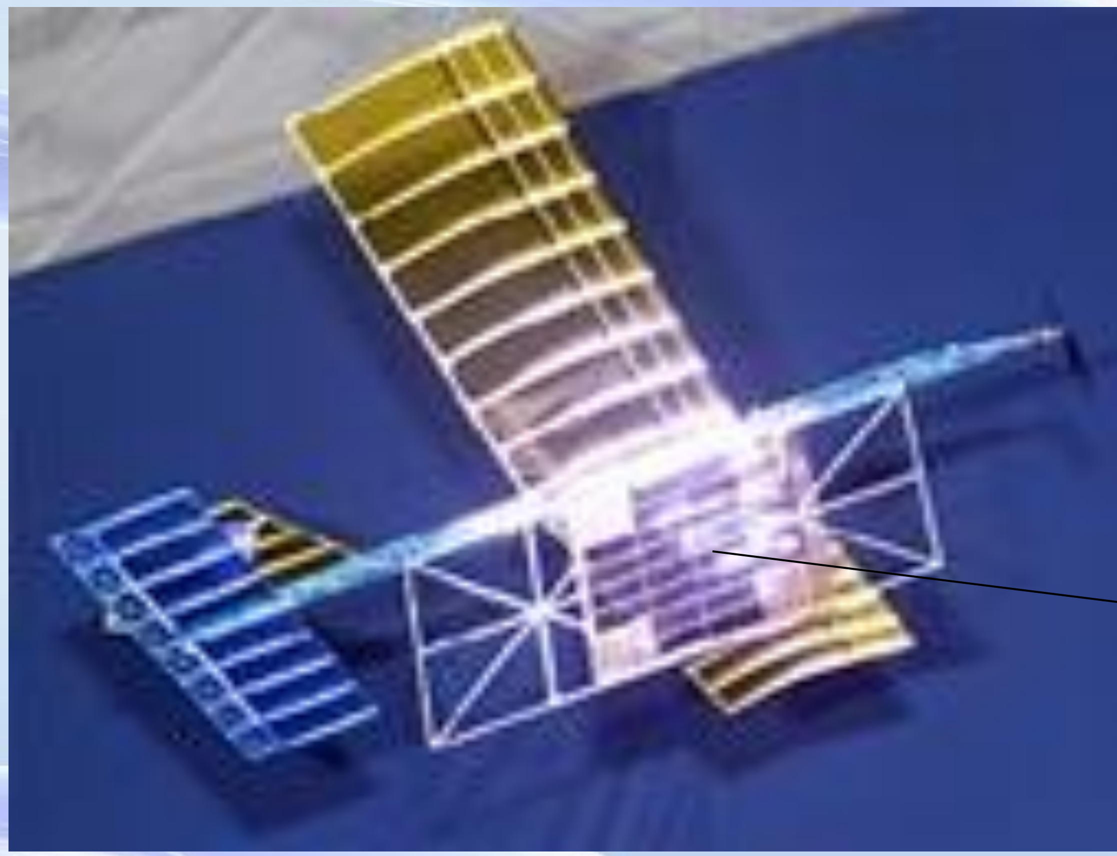
**Small enough**? That's Henry Pasquet's $4\frac{7}{8}$-inch Lacey M-10 **(at left)**: It proves how feasible tiny R/C models really have become with readily available commercial equipment.

YUV420 codec decompressor
are needed to see this picture.




1:27 PM
JAN. 17, 2001


Mag = 28 X
200µm
EHT = 6.35 kV
WD = 18 mm


NASA-CW LASER POWERED MODEL AIRCRAFT

SEIKO-EPSON FLYING CAMERA

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1. C. Hall "Skip" Jones, "Converting Auto Engines For Aircraft Applications," *Sport Aviation*, April 1993.

2. Edward F. Obert, *Internal Combustion Engines*, 3rd ed. (Scranton, PA: International Textbook Company, 1968).