CLASSIFICATION OF INTERNAL COMBUSTION ENGINES

VARIOUS TYPES OF ENGINES

CLASSIFICATION OF INTERNAL COMBUSTION ENGINES

1. Application
2. Basic Engine Design
3. Operating Cycle
4. Working Cycle
5. Valve/Port Design and Location
6. Fuel
7. Mixture Preparation
8. Ignition
9. Stratification of Charge
10. Combustion Chamber Design
11. Method of Load Control
12. Cooling

CLASSIFICATION OF INTERNAL COMBUSTION ENGINES

1. Application

1. Automotive: (i) Car
   (ii) Truck/Bus
   (iii) Off-highway
2. Locomotive
3. Light Aircraft
4. Marine: (i) Outboard
   (ii) Inboard
   (iii) Ship
5. Power Generation: (i) Portable (Domestic)
   (ii) Fixed (Peak Power)
6. Agricultural: (i) Tractors
   (ii) Pump sets
7. Earthmoving: (i) Dumpers
   (ii) Tippers
   (iii) Mining Equipment
8. Home Use: (i) Lawnmowers
   (ii) Snow blowers
   (iii) Tools
9. Others

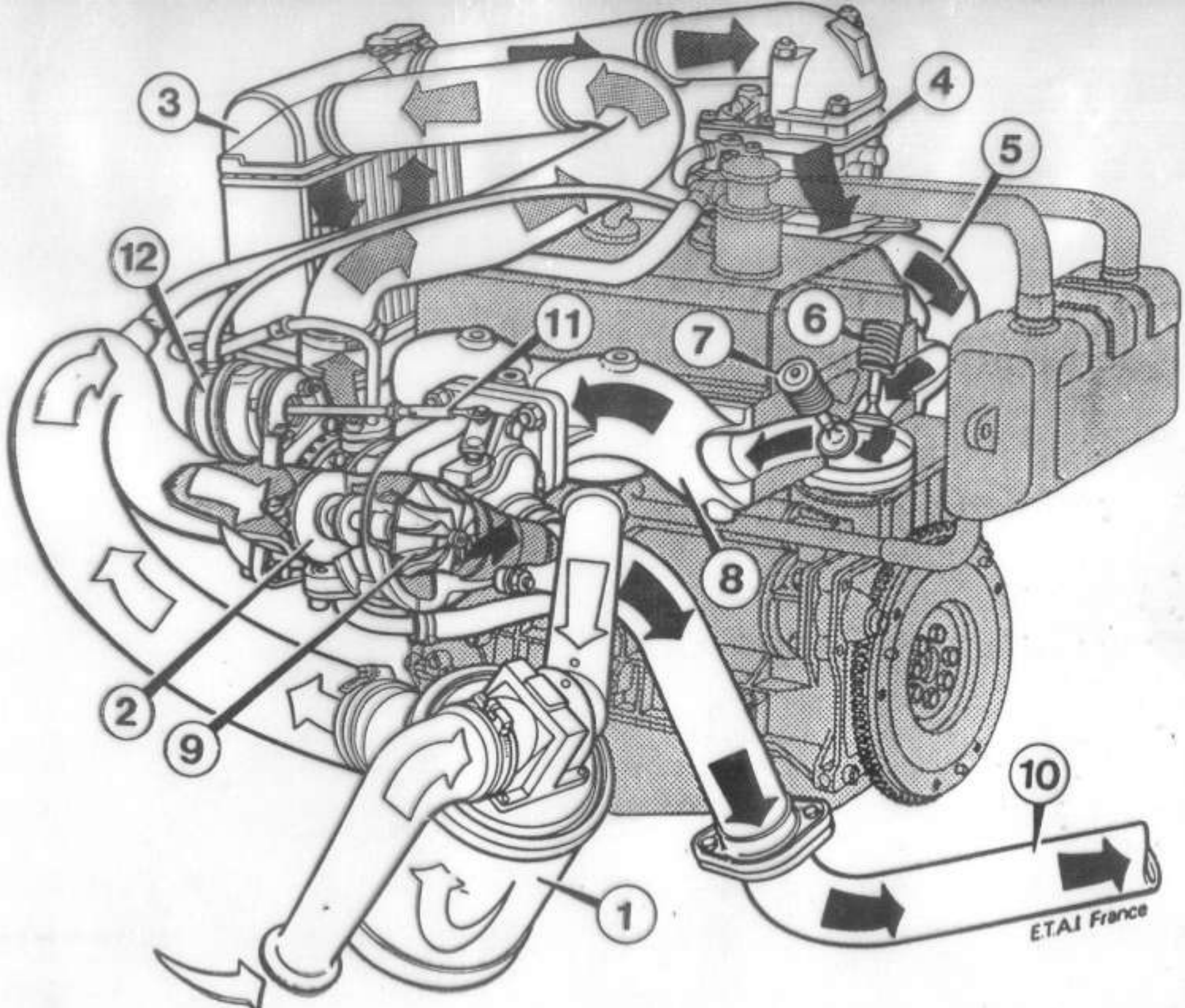
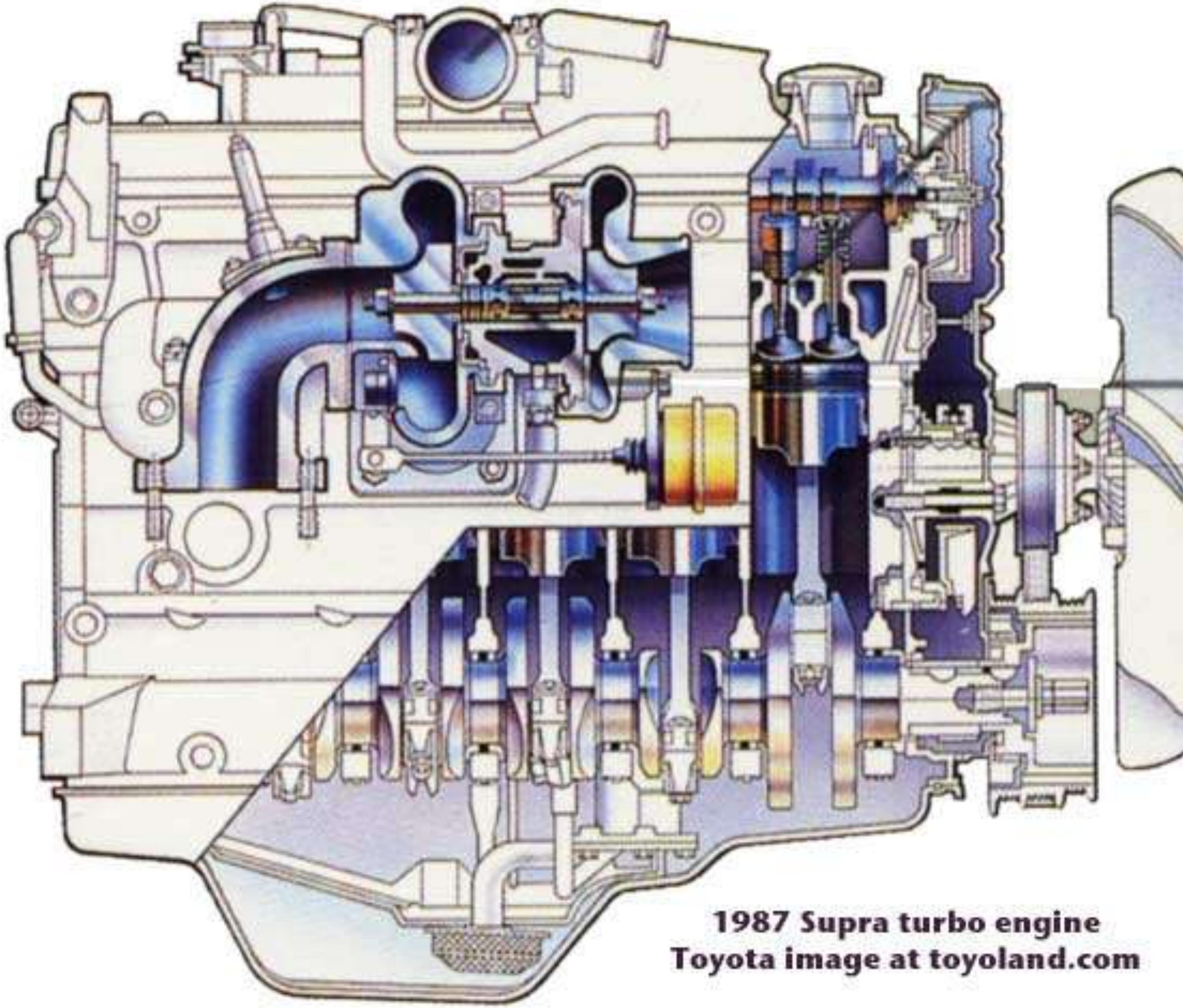
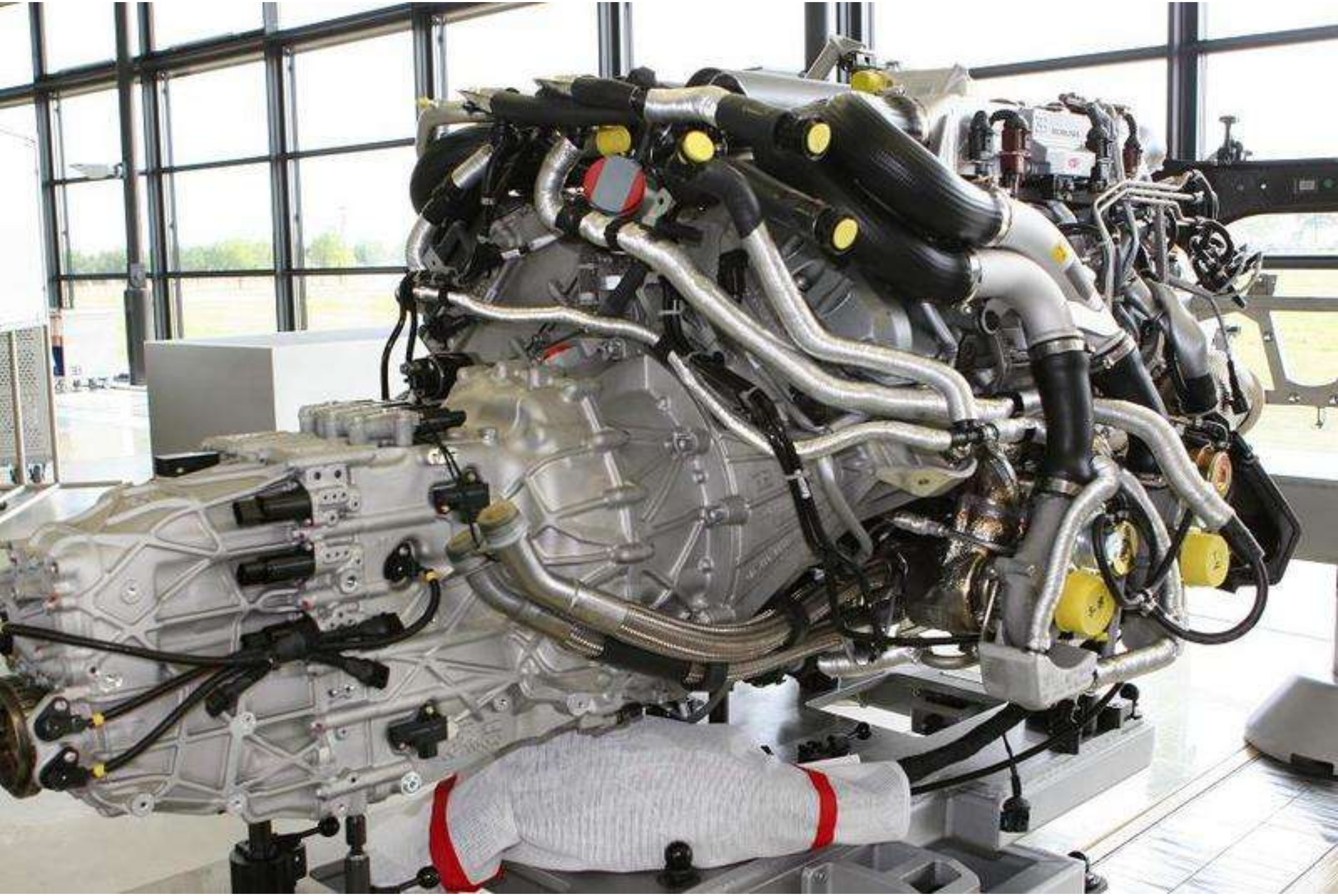


FIGURE 1-10
Turbocharged four-cylinder automotive spark-ignition engine. (*Courtesy Regie Nationale des Usines.*)



1987 Supra turbo engine
Toyota image at toyoland.com

The Bugatti-Veyron engine producing 1001 hp at 6000 rev/min, 8L V-16 engine



Automotive Diesel Engine

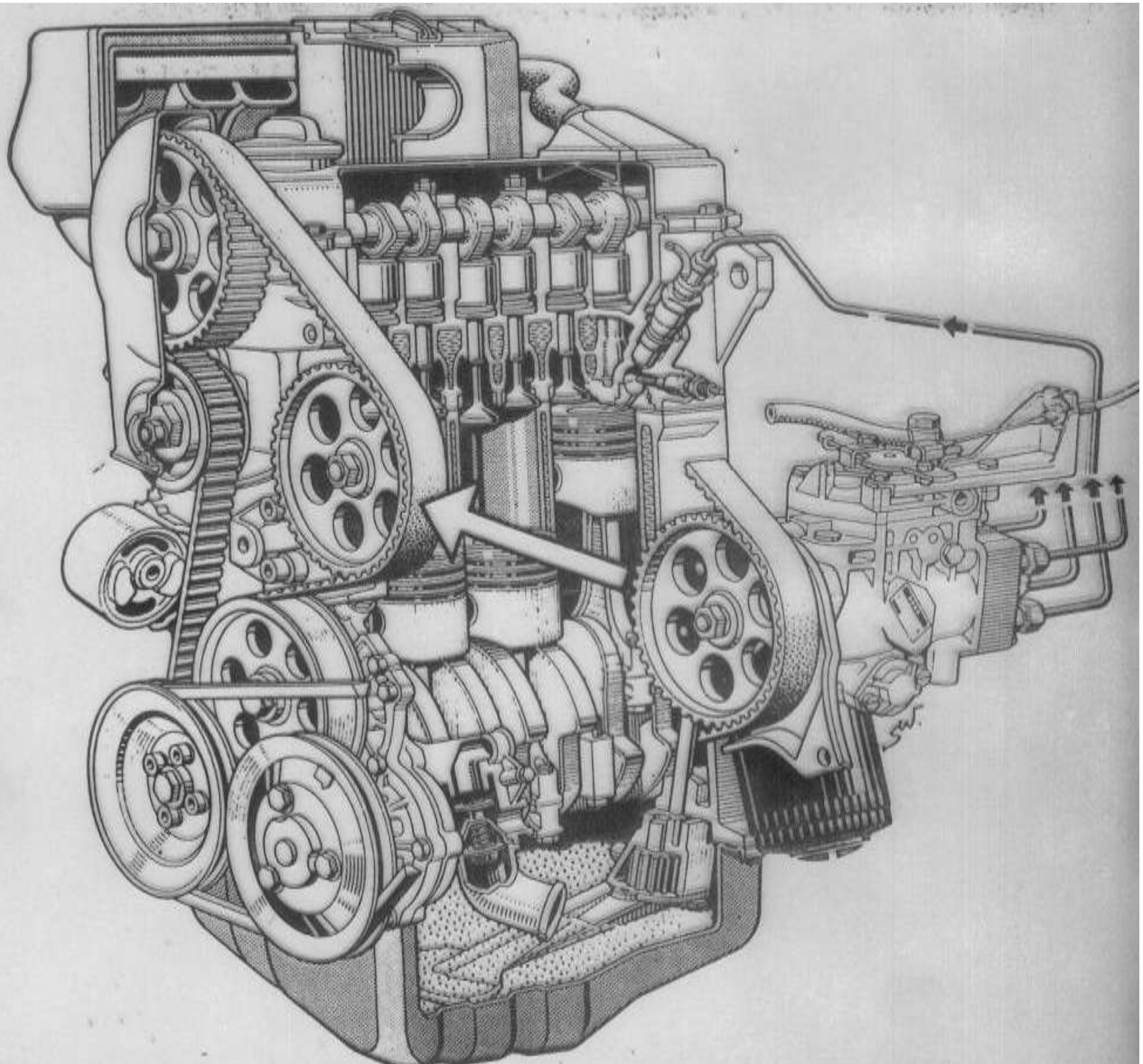


FIGURE 1-21
Four-cylinder naturally aspirated indirect-injection automobile Volkswagen diesel engine.[14] Four-cylinder naturally aspirated indirect-injection automobile Volkswagen diesel engine. Displaced volume 1.47 liters, bore 76.5 mm, stroke 80 mm, maximum power 37 kW at 5000 rev/min

Large Two-stroke Marine Engine

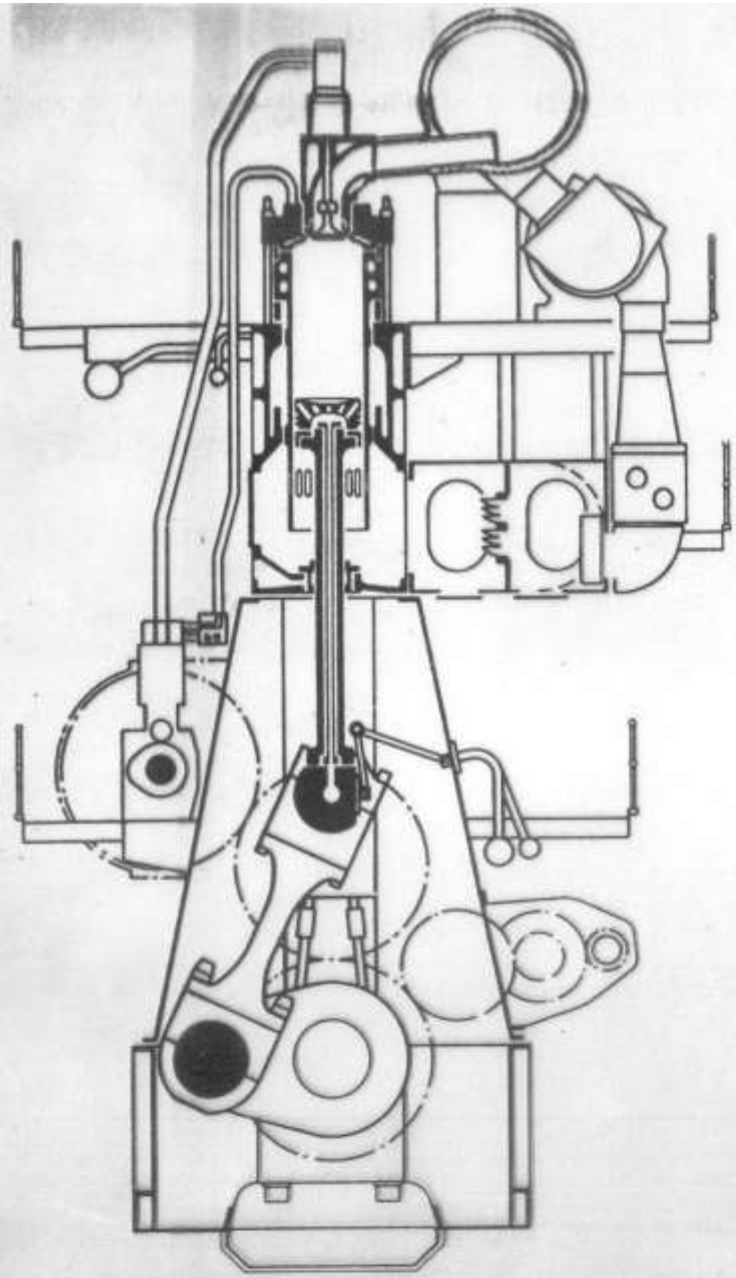


FIGURE 1-24
Large Sulzer two-stroke turbocharged marine diesel engine. Bore 840 mm, stroke 2900 mm, rated power 1.9 MW per cylinder at 78 rev/min, 4 to 12 cylinders. (*Courtesy Sulzer Brothers Ltd.*)

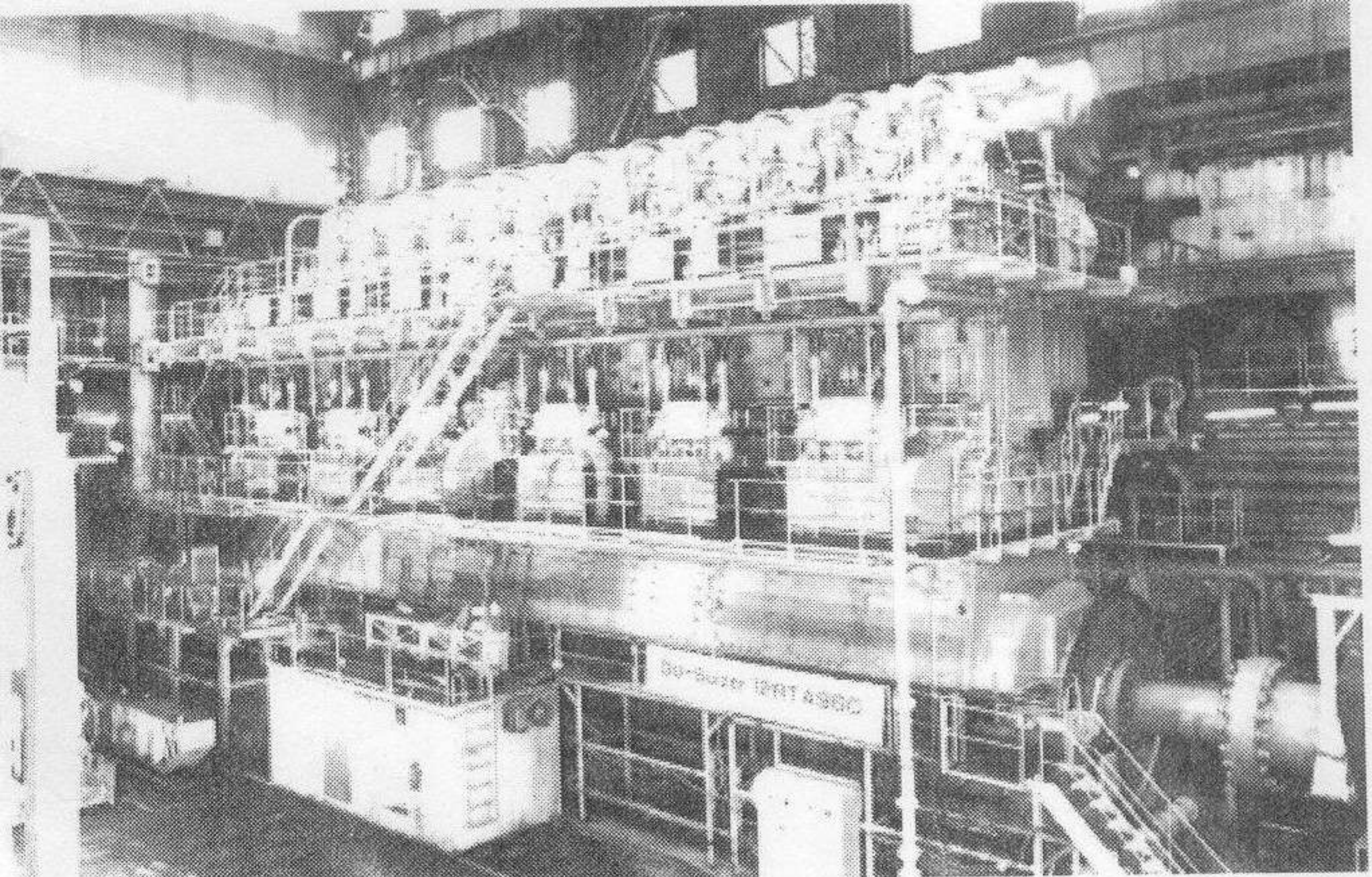
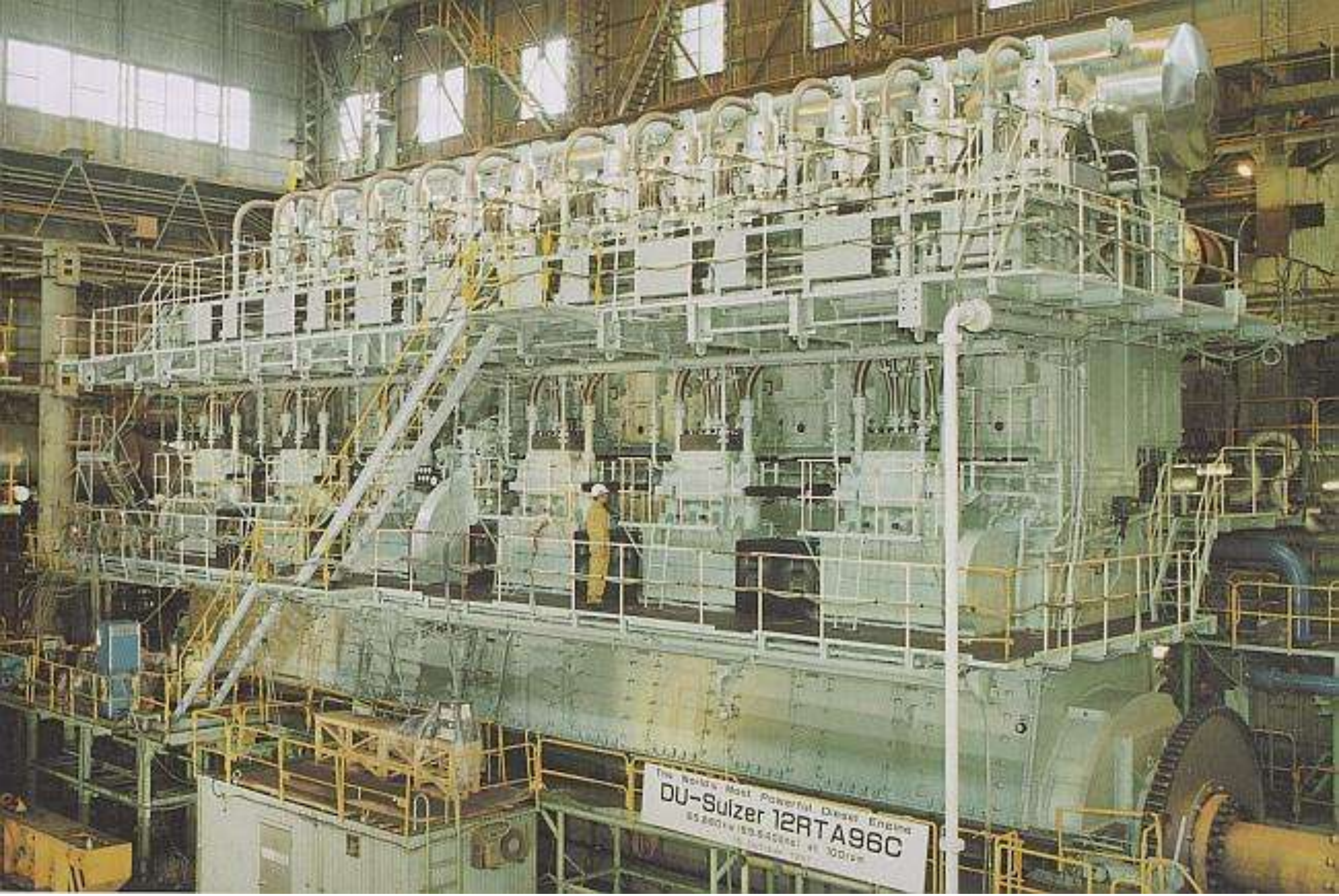


Figure 1.8 The world's most powerful diesel engine was tested by Diesel United in Japan in 1997. The 12-cylinder Sulzer RTA96C, destined for a containership, developed 65 880 kW at 100 rev/min



Another picture of the 12 cylinder engine

Some facts on the 14 cylinder version:

Total engine weight:2300 tons

(The crankshaft alone weighs 300 tons.)

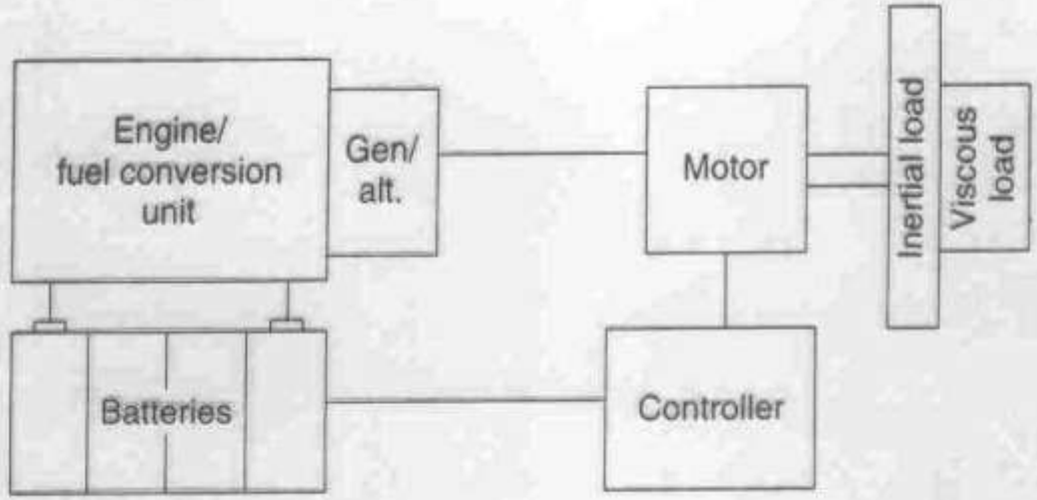
Length:89 feet (27.13 m)

Height:44 feet (13.4 m)

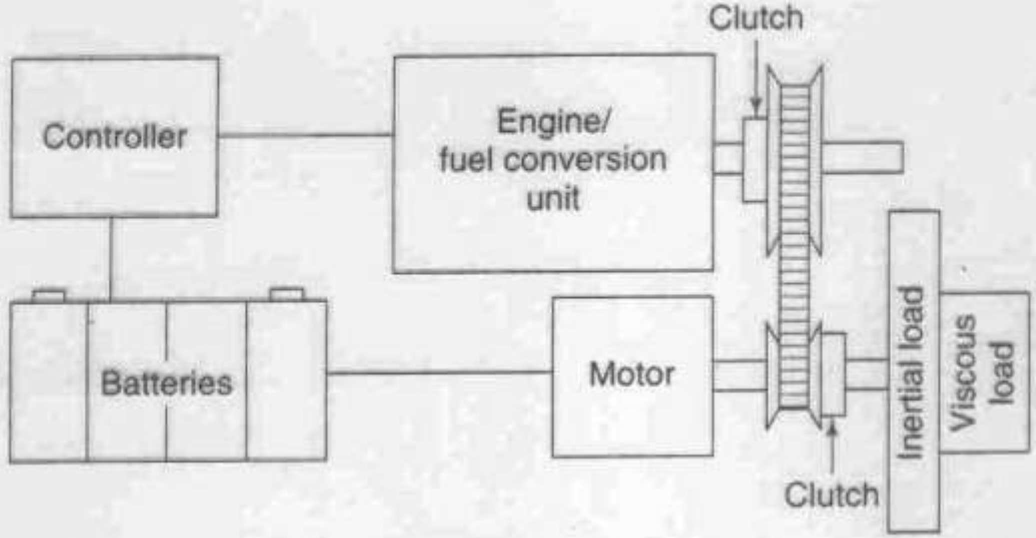
Maximum power:**108,920 hp at 102 rpm**

: 81,222 kW at 102 rpm

Maximum torque:**5,608,312 lb-ft at 102rpm**



(*a*) Series configuration



(*b*) Parallel configuration

Figure 1-25 Hybrid electric vehicle powertrain configurations.

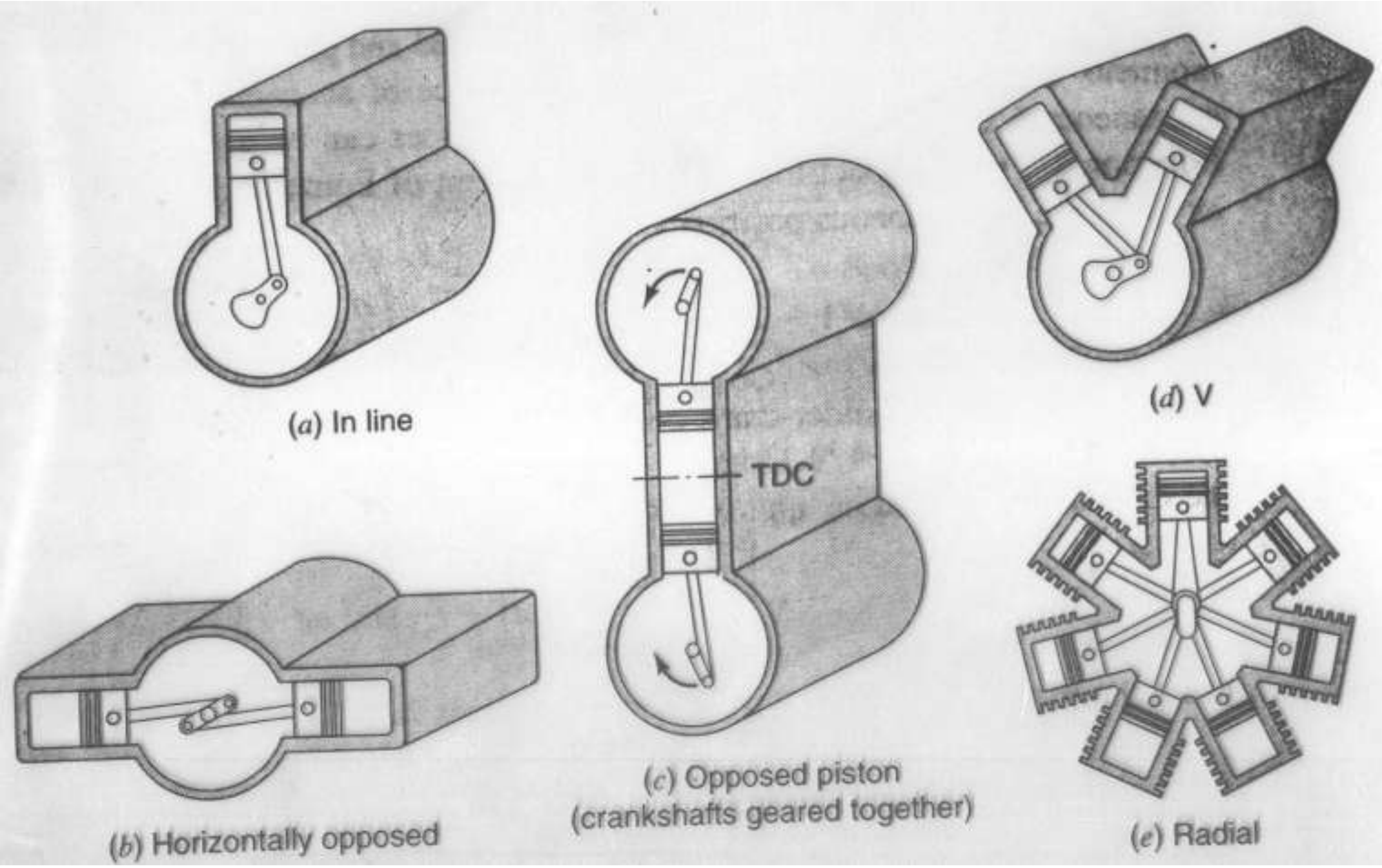
CLASSIFICATION OF INTERNAL COMBUSTION ENGINES

2. Basic Engine Design:

1. Reciprocating
   - (a) Single Cylinder
   - (b) Multi-cylinder
     - (I) In-line
     - (ii) V
     - (iii) Radial
     - (iv) Opposed Cylinder
     - (v) Opposed Piston

2. Rotary:
   - (a) Single Rotor
   - (b) Multi-rotor

Types of Reciprocating Engines



V Engine

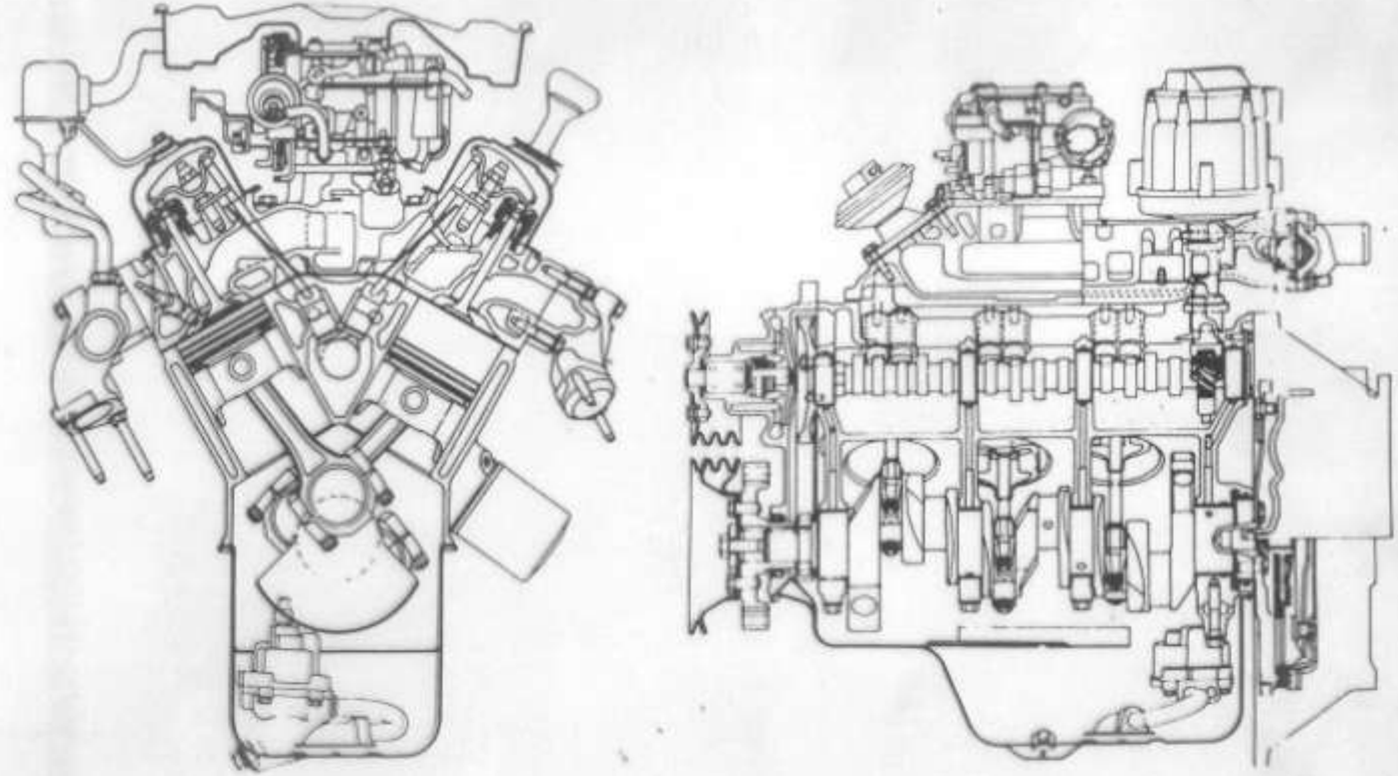
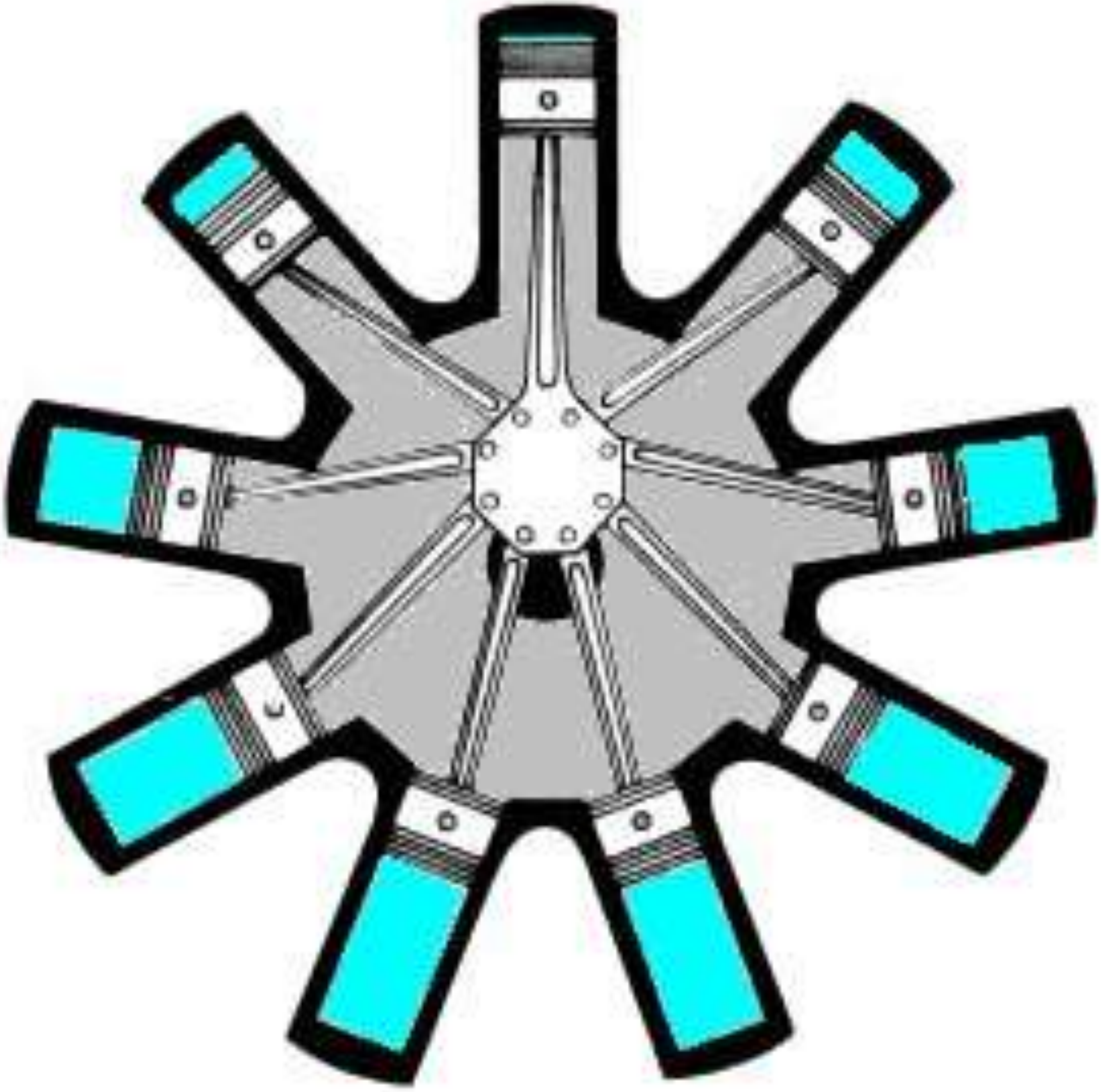
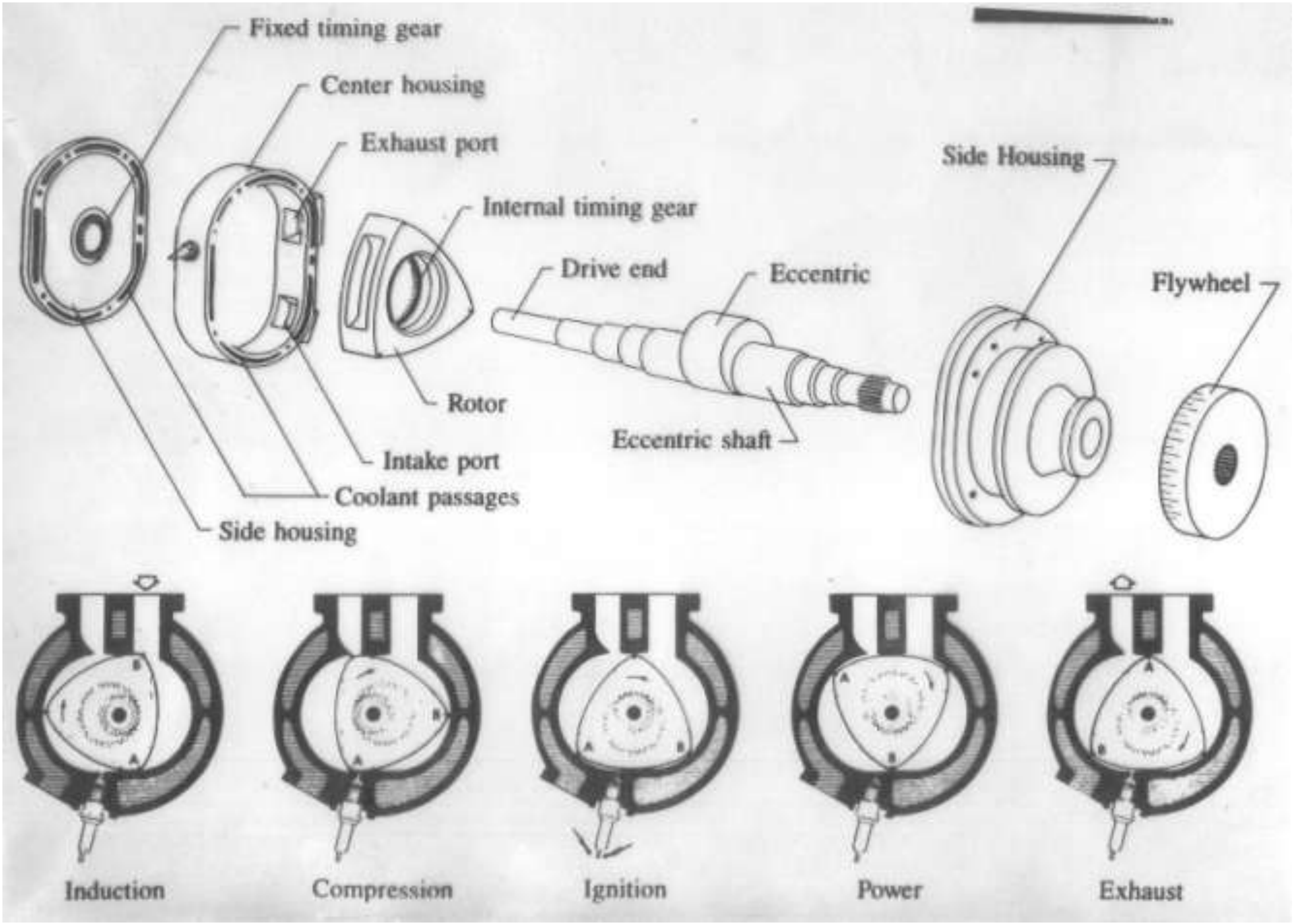


FIGURE 1-9
Cross-section drawings of General Motors 60 degree V-6 spark-ignition engine.[13] Displacement 2.8 liter, bore 89 mm, stroke 76 mm, compression ratio 8.5, maximum power 86 kW at 4800 rev/min



RADIAL
ENGINE

Wankel Rotary Piston Engine

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Types of Rotary Engines

FIGURE 7.1a A turbocharged RX-7 rotary engine. (Photo courtesy of Mazda Motors of America.)

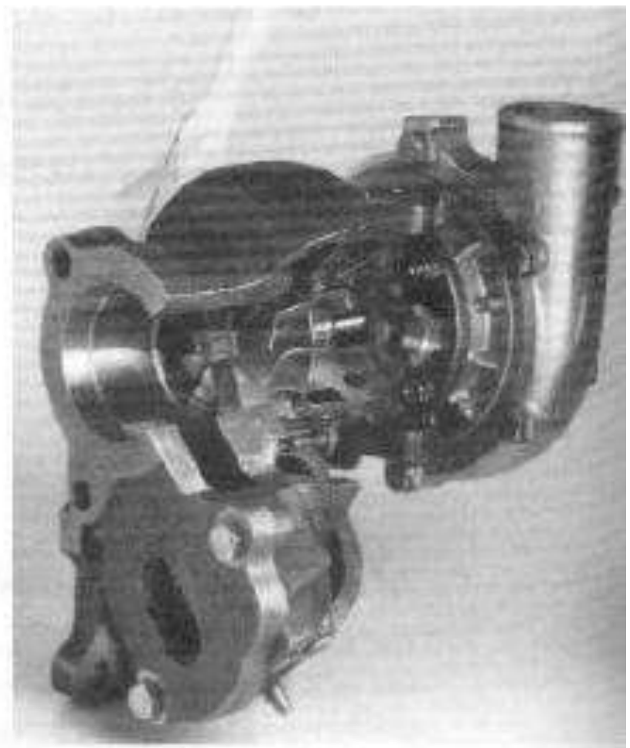


FIGURE 7.1b An RX-7 rotary engine turbocharger. (Photo courtesy of Mazda Motors of America.)

Wankel Engine Parts

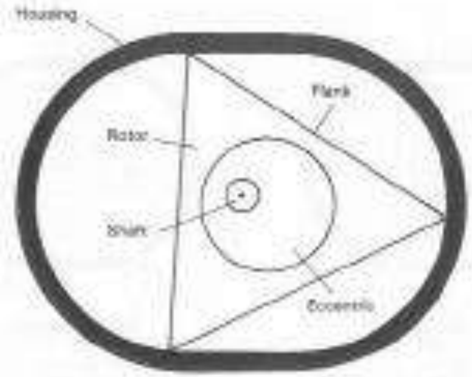


FIGURE 7.2 Rotary engine nomenclature

IGURE 7.3a John Deere model 2034R engine components: Crankshaft and one of two counterweights. (Courtesy of John Deere Technologies International Inc., Rotary Engine Div., Wood-Ridge, N.J.)

FIGURE 7.3b John Deere model 2034R engine components: Rotor housing, rotor, and rotor gear. (Courtesy of John Deere Technologies International Inc., Rotary Engine Div., Wood-Ridge, N.J.)

Twin-rotor Wankel

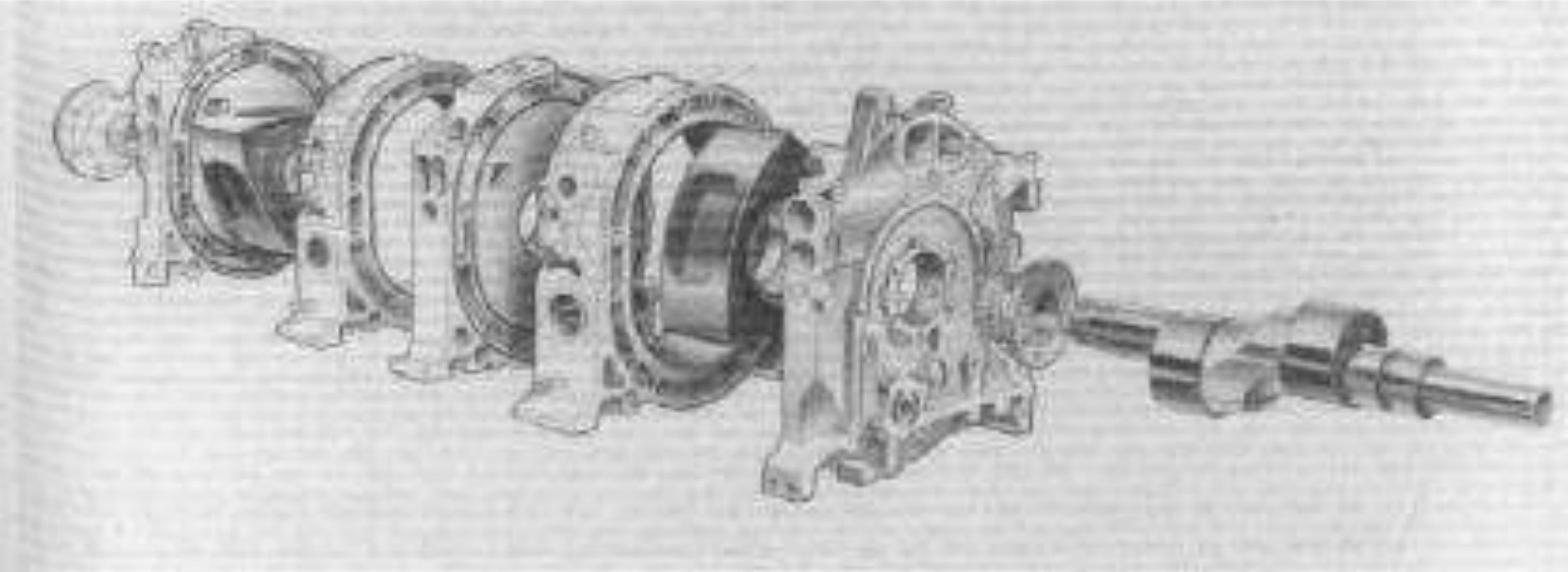


FIGURE 7.9 Exploded view of a twin-rotor rotary engine. (Courtesy of Mazda Motors of America.)

Apex Seals

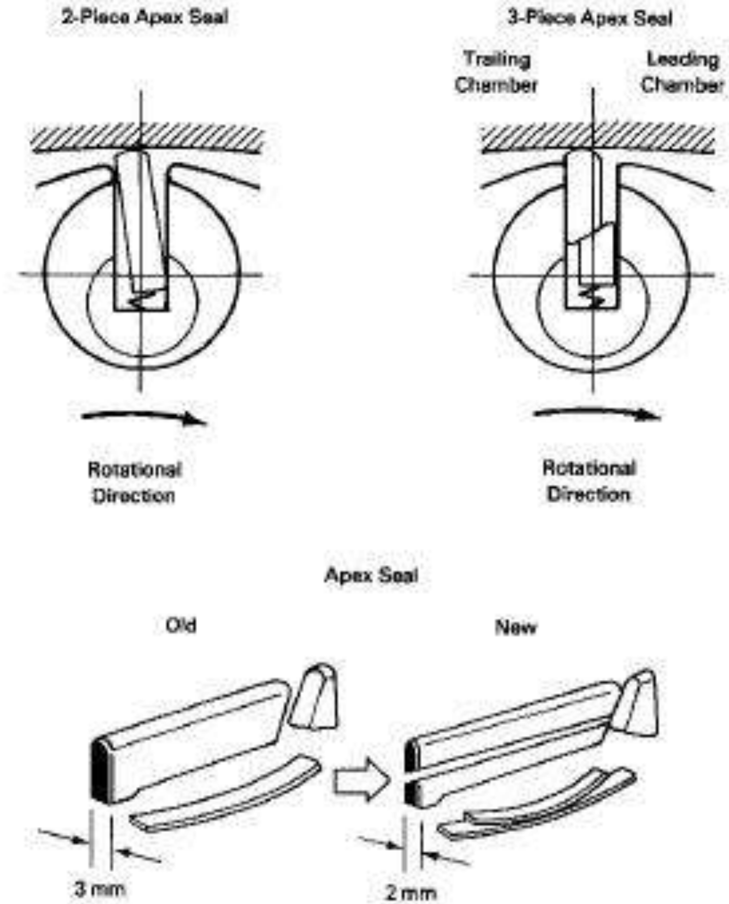


FIGURE 7.11 Design improvements in the apex seals of the Mazda RX-7 rotary engine. (Reprinted with permission. ©1987, Society of Automotive Engineers, Inc.) (See ref. 6.)

Engine Information

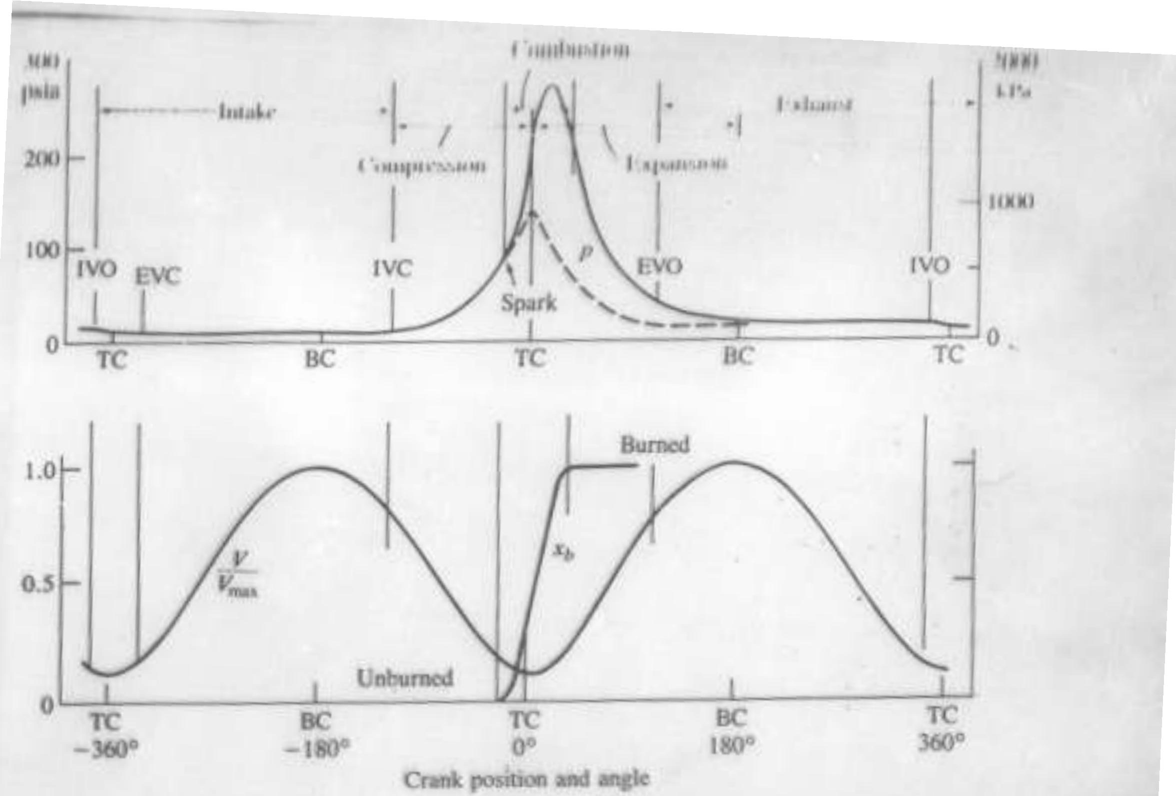


FIGURE 1-8

Sequence of events in four-stroke spark-ignition engine operating cycle. Cylinder pressure p (solid line, firing cycle; dashed line, motored cycle), cylinder volume V/V_{max}, and mass fraction burned x_b are plotted against crank angle.

TABLE 12.2

Typical size and output of diesel engines

Bore (mm)	45	80	127	280	400	840
Stroke (mm)	37	80	120	300	460	2900
Displacement (liter/cylinder)	0.06	0.402	1.77	18.5	57.82	1607
Number of cylinders	1	4L*	8V†	6–9L	6–9L	4–12L
Output/cylinder(kW)	0.7	10	40	325	550	3380
Rated speed (rpm)	3600	4800	2100	1000	514–520	55–76
BMEP (atm)	4	7.5	13	22	22.2	16.6

*L designates in-line cylinder arrangement.

†Designates V-shaped cylinder arrangement.

TABLE 12.1
Best thermal efficiency estimates for various power plants

Power plant type	Efficiency (%)
Spark-ignited, port-injected, stoichiometric	31.5
Direct-injected, spark-ignited, stoichiometric	33
Direct-injected, spark-ignited, lean, early injection	34.5
Indirect-injected diesel	35.5
Direct-injected, spark-ignited, lean, late injection	38
Gas turbine	38
High-speed, direct-injected diesel	43
Heavy-duty, direct-injected diesel (HDDI)	46
Fuel cell	52
Turbocompounded, HDDI diesel	54

Table 1-1 Comparison of Three Internal Combustion Engines

Characteristics	Model Airplane	Automotive	Marine
Bore (m)	0.0126	0.089	0.737
Stroke (m)	0.0131	0.080	1.016
Displacement per cylinder (m^3)	1.6×10^{-6}	4.98×10^{-3}	0.433
Power per cylinder (kW)	0.1	16.8	529
Engine speed (rpm)	11,400	2500	160
Mass per cylinder (kg)	0.12	34.3	3.56×10^4
Mean piston speed (m/s)	5.0	6.6	5.6
Bmep (bar)	3.2	8.0	4.5
Power/Volume (kW/m^3)	6.3×10^4	3.4×10^4	1.2×10^3
Mass/Volume (kg/m^3)	7.5×10^{-2}	8.2×10^{-2}	6.9×10^{-2}
Power/Mass (kW/kg)	8.4×10^5	4.1×10^5	1.7×10^4

CLASSIFICATION OF INTERNAL COMBUSTION ENGINES

3. Operating Cycle

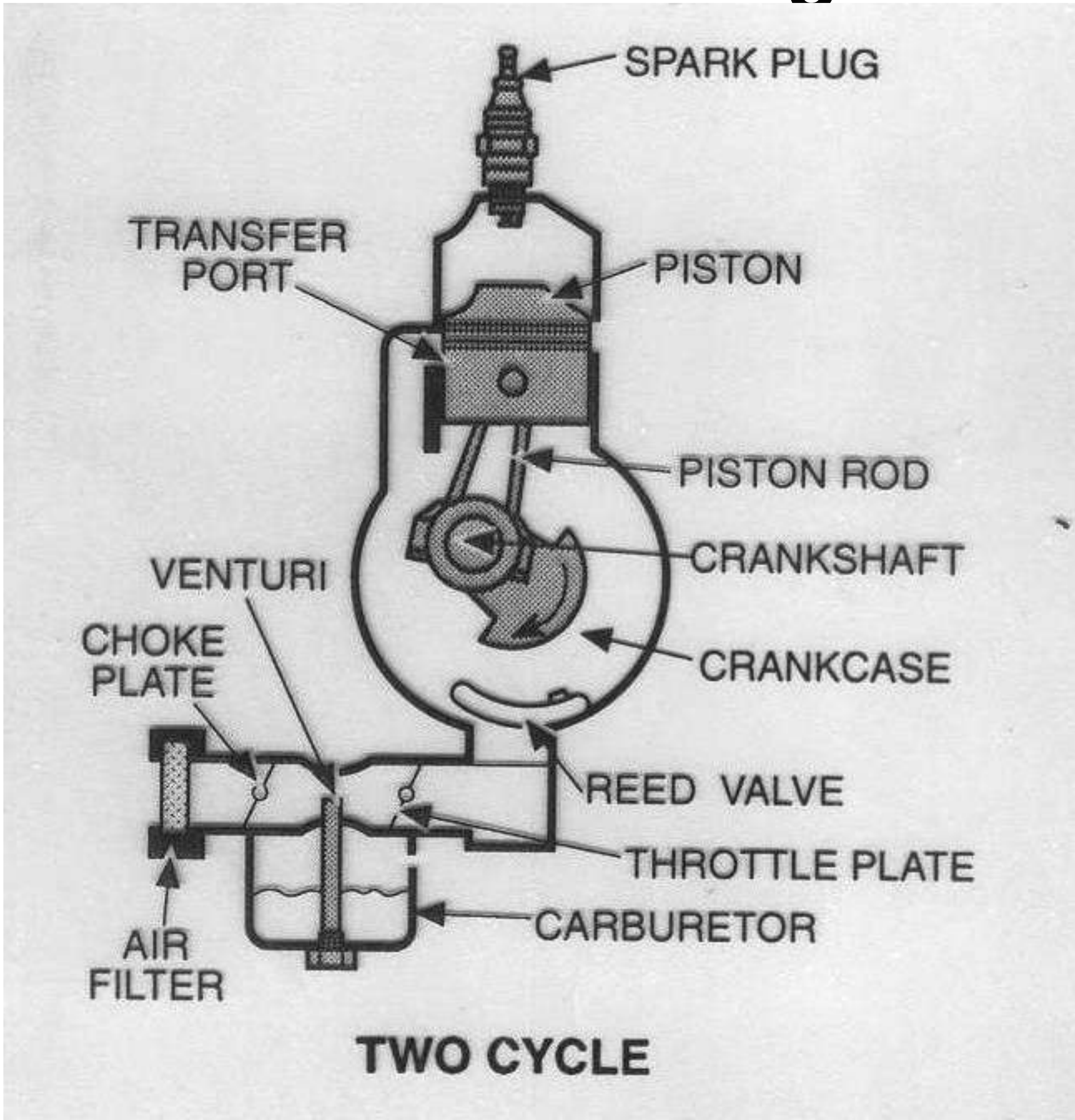
- Otto (For the Conventional SI Engine)
- Atkinson (For Complete Expansion SI Engine)
- Miller (For Early or Late Inlet Valve Closing type SI Engine)
- Diesel (For the Ideal Diesel Engine)
- Dual (For the Actual Diesel Engine)

CLASSIFICATION OF INTERNAL COMBUSTION ENGINES

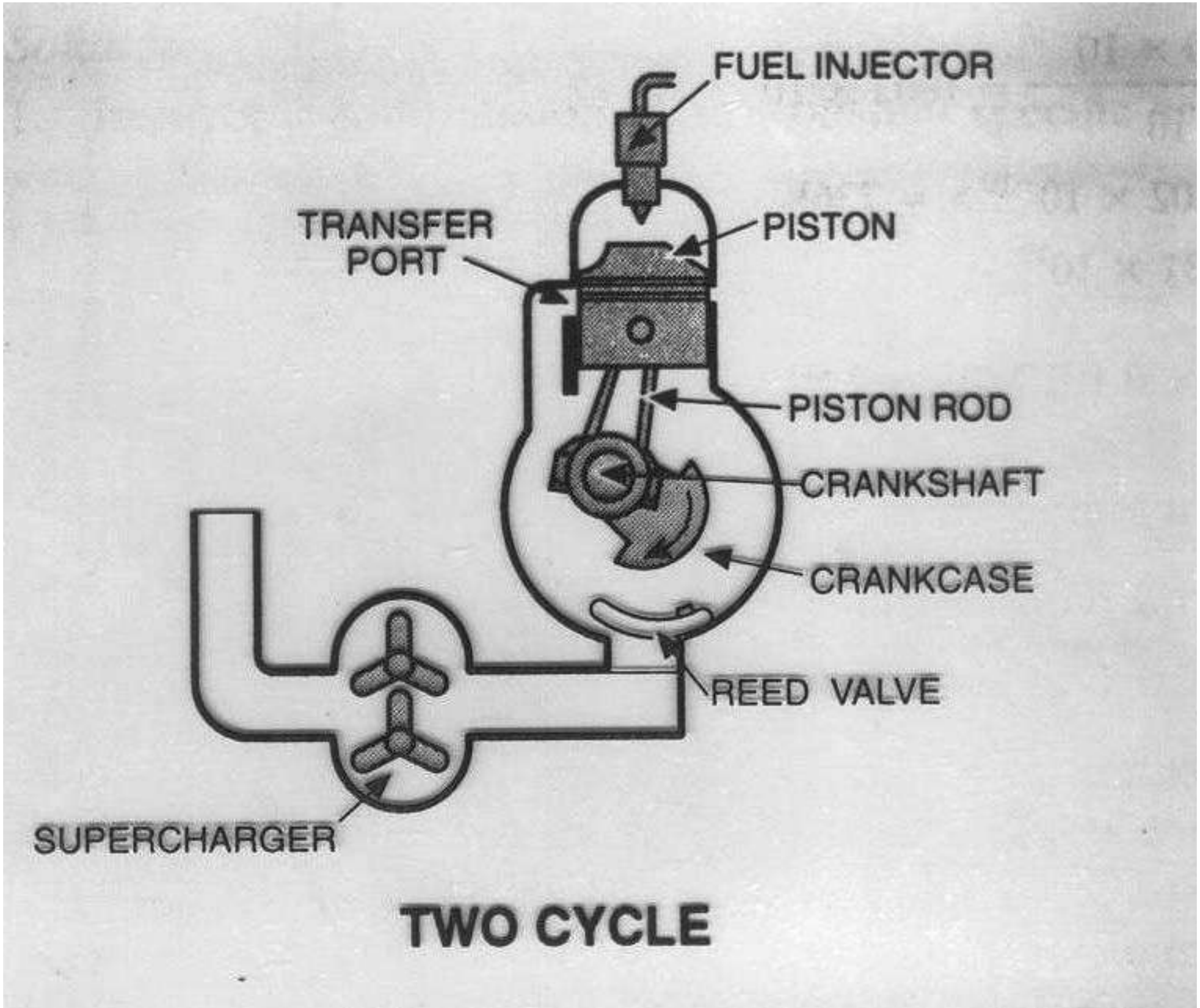
4. Working Cycle (Strokes)

1. **Four Stroke Cycle:(a) Naturally Aspirated**
   (b)Supercharged/Turbocharged
2. **Two Stroke Cycle: (a) Crankcase Scavenged**
   (b) Uniflow Scavenged
   (i) Inlet valve/Exhaust Port
   (ii) Inlet Port/Exhaust Valve
   (iii) Inlet and Exhaust Valve
   May be Naturally Aspirated Turbocharged

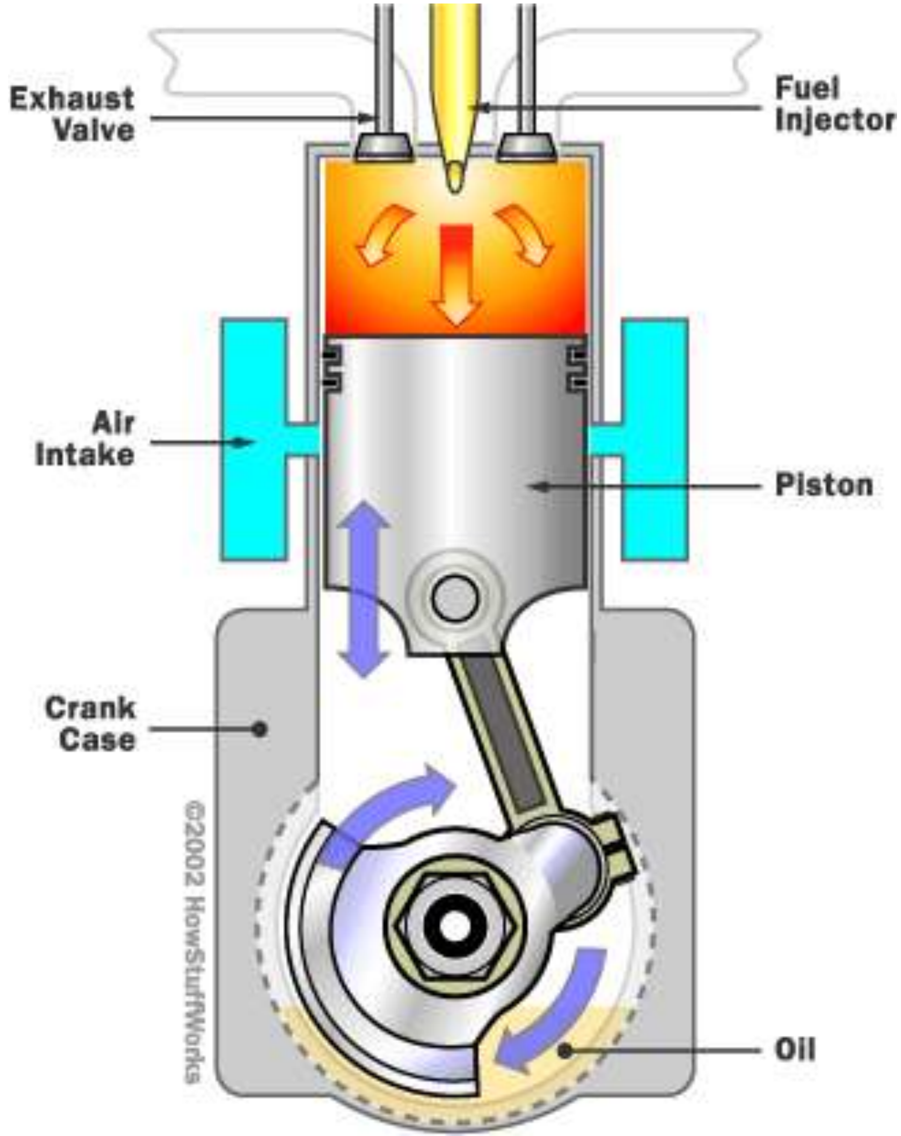
Two stroke SI Engine



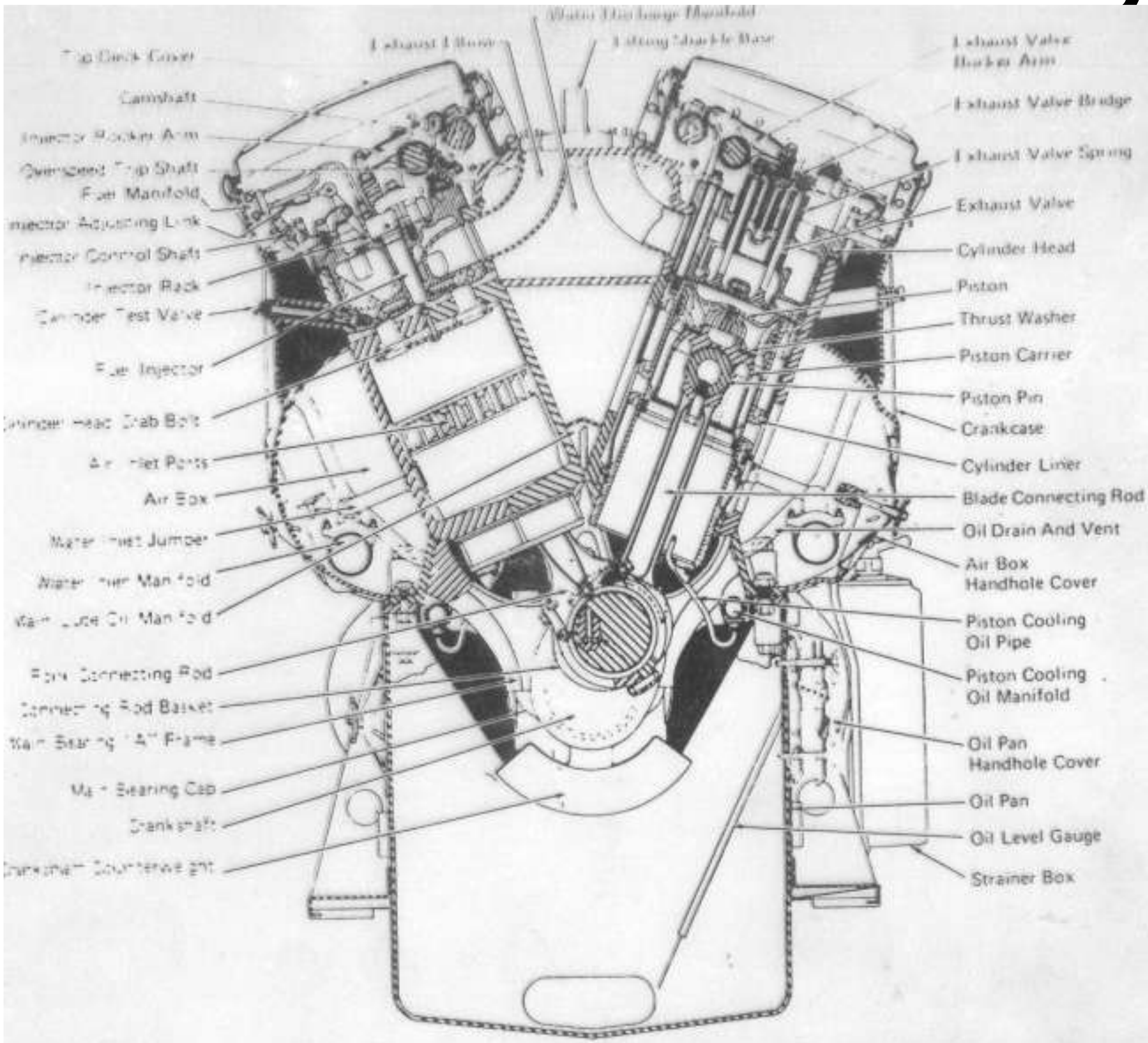
Two Stroke CI Engine



This is a type where the intake is operated through ports and exhaust through valves



Two-stroke Engine
Inlet Port/Exhaust Valve Type



Supercharging Types

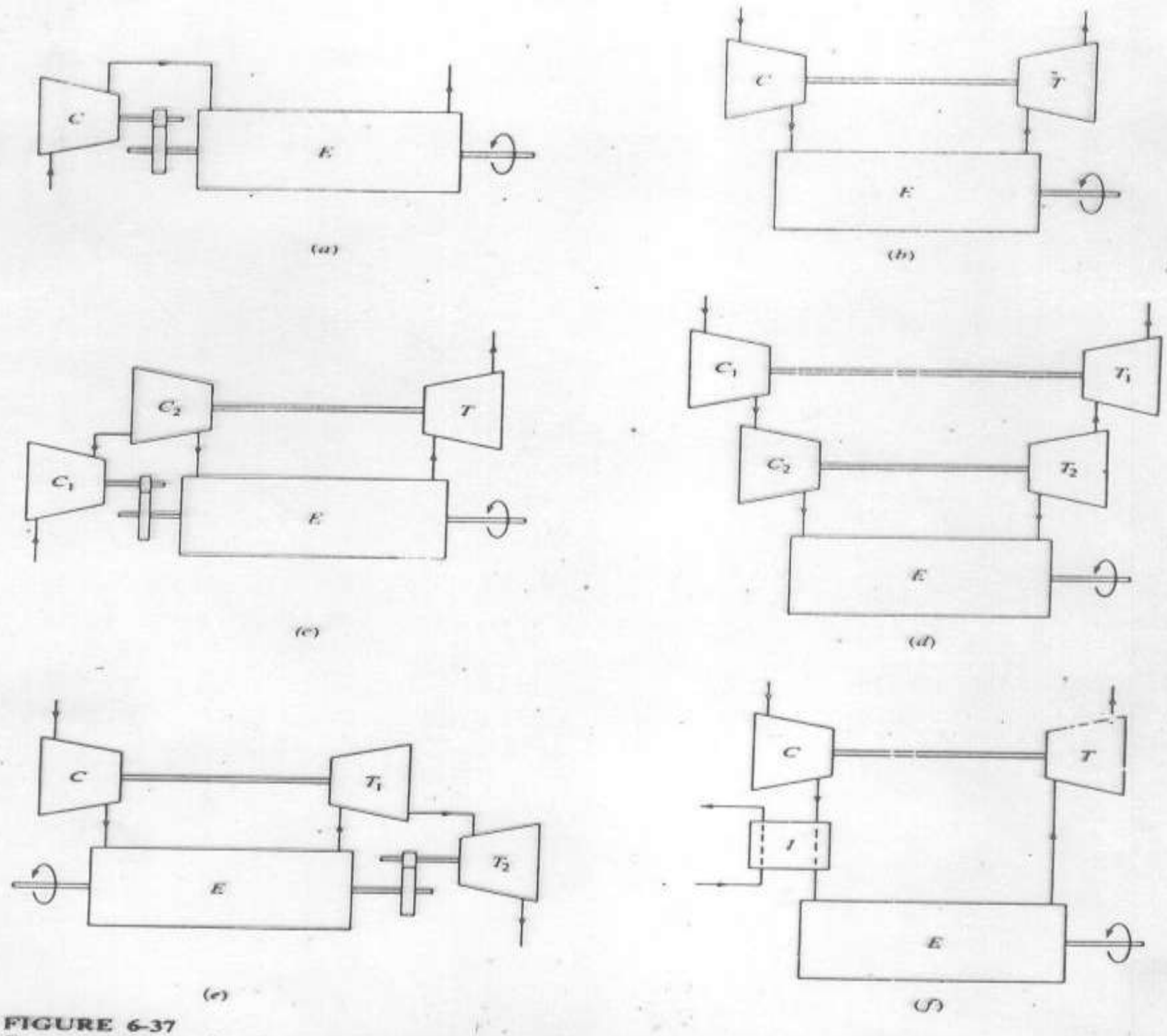
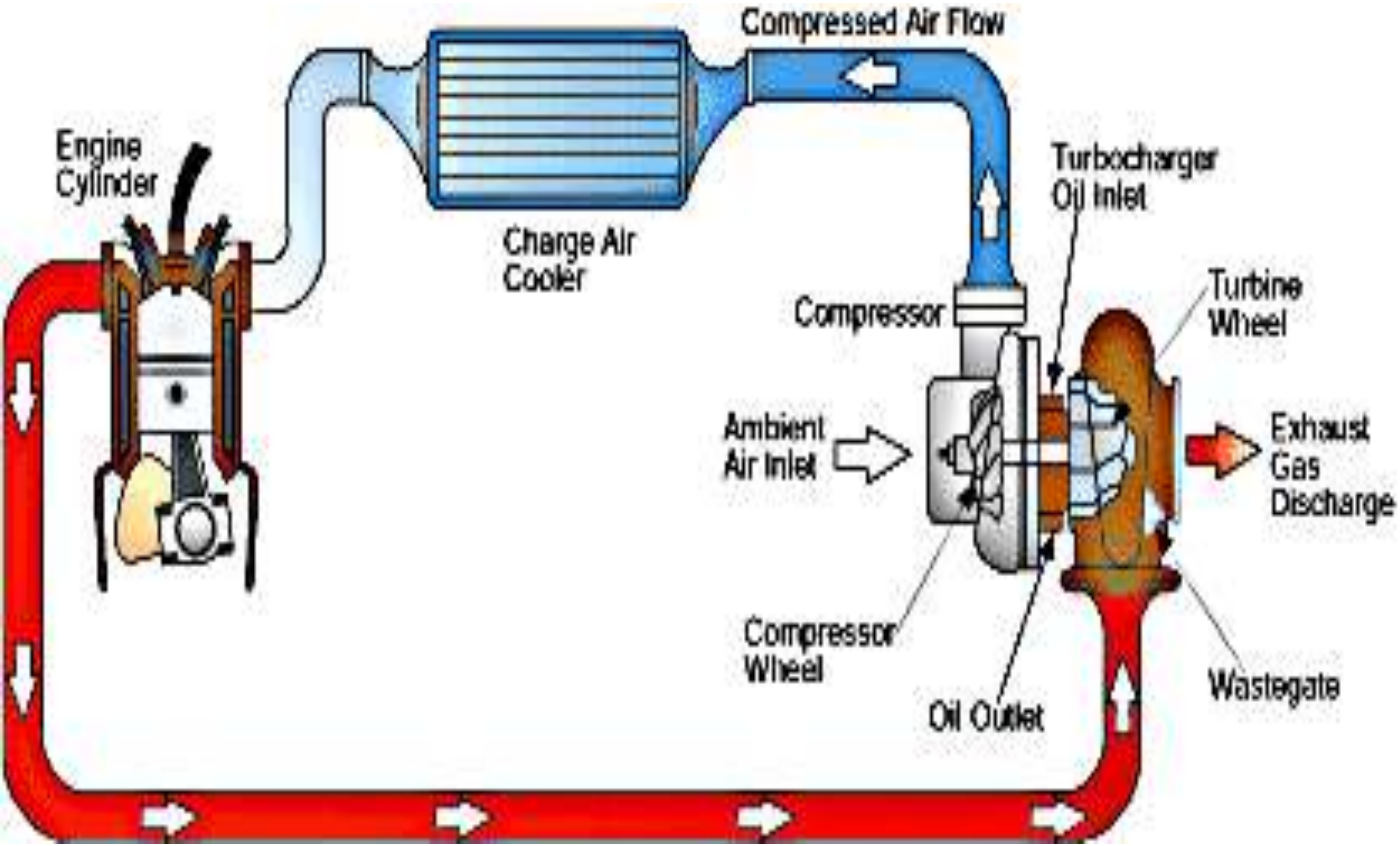
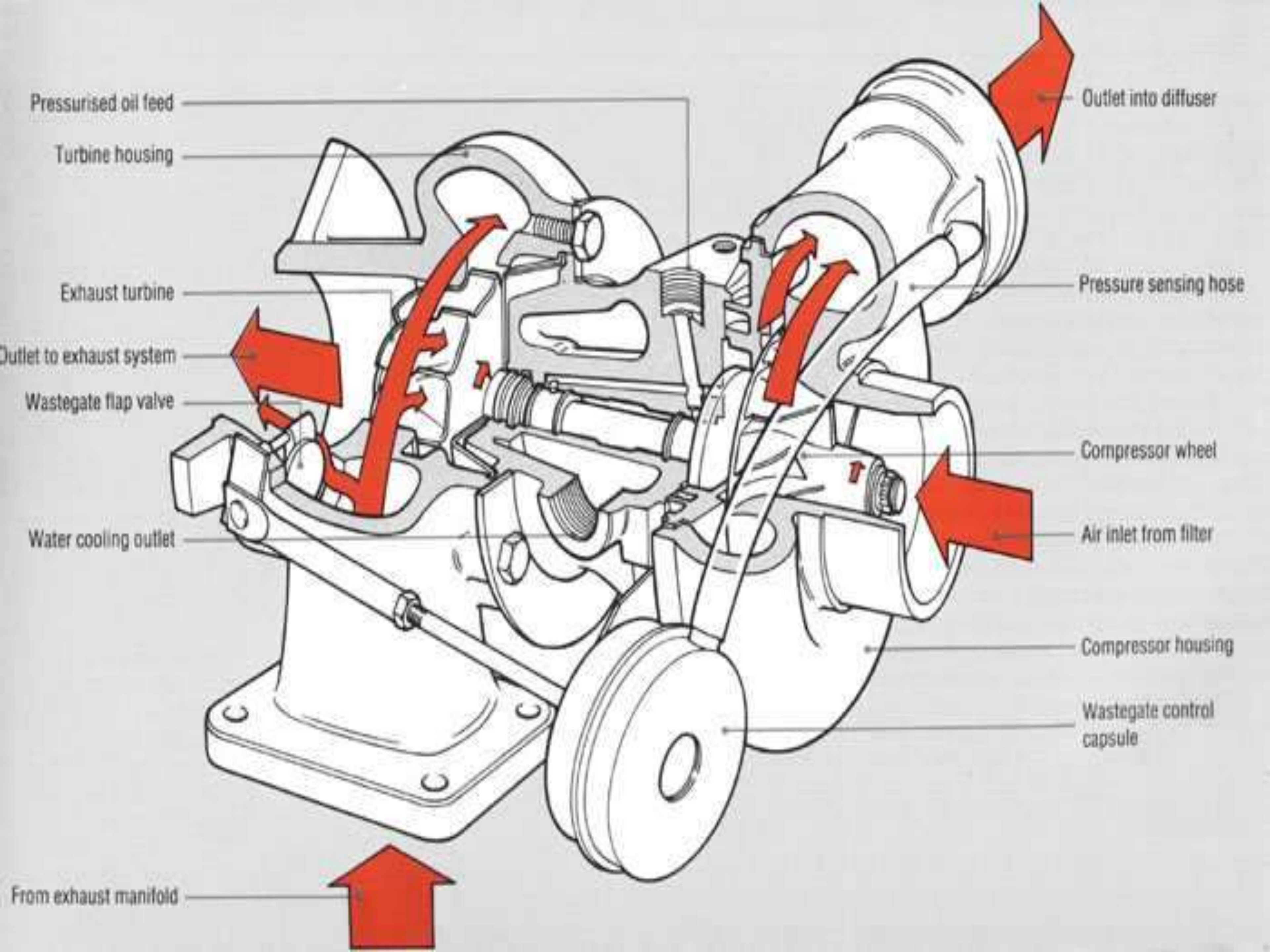


FIGURE 6-37
Supercharging and turbocharging configurations: (*a*) mechanical supercharging; (*b*) turbocharging; (*c*) engine-driven compressor and turbocharger; (*d*) two-stage turbocharging; (*e*) turbocharging with turbocompounding; (*f*) turbocharger with intercooler. *C* Compressor, *E* Engine, *I* Inter-cooler, *T* Turbine.



Compressed Air Flow
Engine Cylinder
Charge Air Cooler
Turbocharger Oil Inlet
Turbine Wheel
Compressor
Ambient Air Inlet
Exhaust Gas Discharge
Compressor Wheel
Wastegate
Oil Outlet


Pressurised oil feed
Turbine housing
Exhaust turbine
Outlet to exhaust system
Wastegate flap valve
Water cooling outlet
From exhaust manifold
Outlet into diffuser
Pressure sensing hose
Compressor wheel
Air inlet from filter
Compressor housing
Wastegate control capsule

Difference between supercharger and turbocharger

The key difference between a turbocharger and a supercharger is its **power supply**.

Something has to supply the power to run the air compressor.

In a supercharger, there is a **belt** that connects directly to the engine. It gets its power the same way that the water pump or alternator does.

A turbocharger, on the other hand, gets its power from the **exhaust stream**. The exhaust runs through a turbine, which in turn spins the compressor

Difference between supercharger and turbocharger

There are tradeoffs in both systems.

In theory, a turbocharger is more efficient because it is using the "wasted" energy in the exhaust stream for its power source.

On the other hand, a turbocharger causes some amount of back pressure in the exhaust system and tends to provide less boost until the engine is running at higher engine speeds.

Superchargers are easier to install but tend to be more expensive.

CLASSIFICATION OF INTERNAL COMBUSTION ENGINES

5. (a) Valve/Port Design

1. Poppet Valve
2. Rotary Valve
3. Reed Valve
4. Piston Controlled Porting

5. (b) Valve Location

1. The T-head
2. The L-head
3. The F-head
4. The I-head: (i) Over head Valve (OHV)

   (ii) Over head Cam (OHC)

Poppet Valve

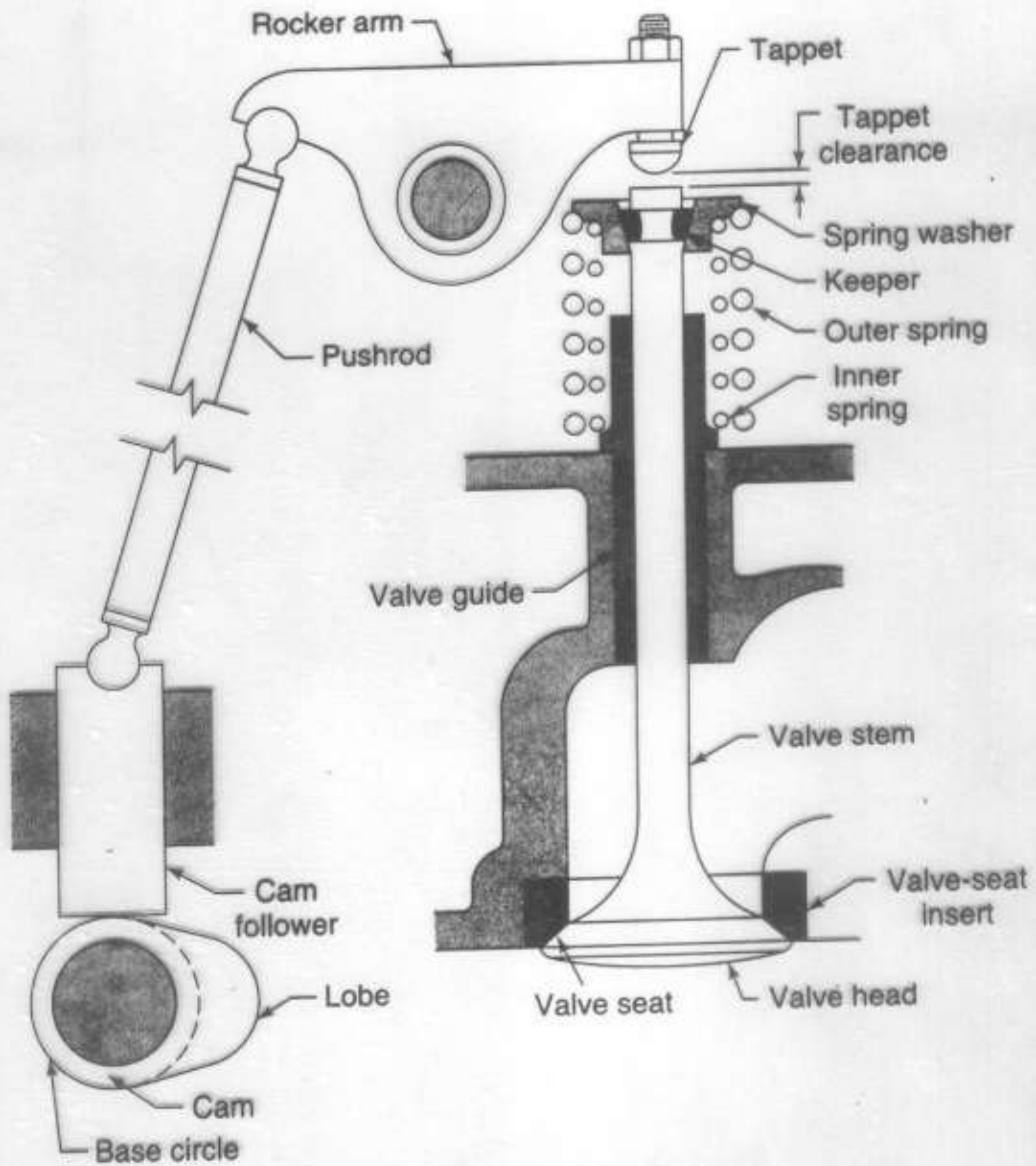
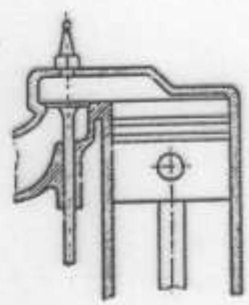
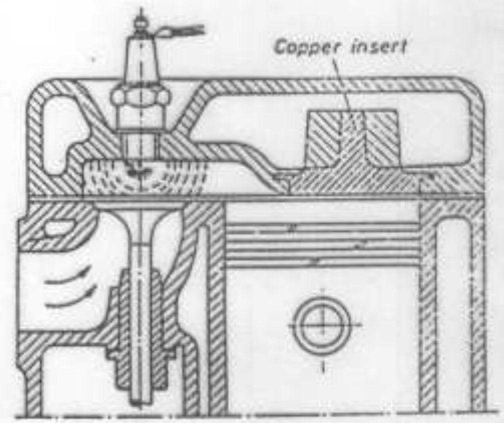


Figure 1-12 Poppet-valve nomenclature (Taylor, 1985).

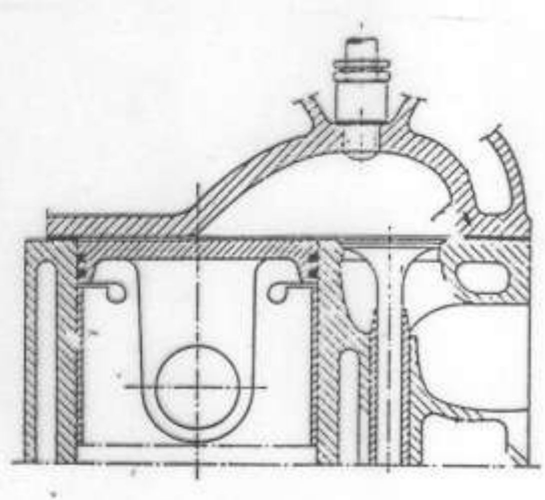
Valve Locations



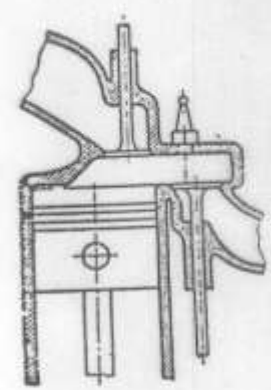
Side-valve combustion chamber in *L*-type engine head [1]



Combustion chamber in *L*-type engine head; copper insert prevents self-ignition of remaining mixture



Combustion chamber in *L*-type engine head patented by Ricardo



Combustion chamber in *F*-type engine head; inlet valve mounted in head

Valve Timing Profile

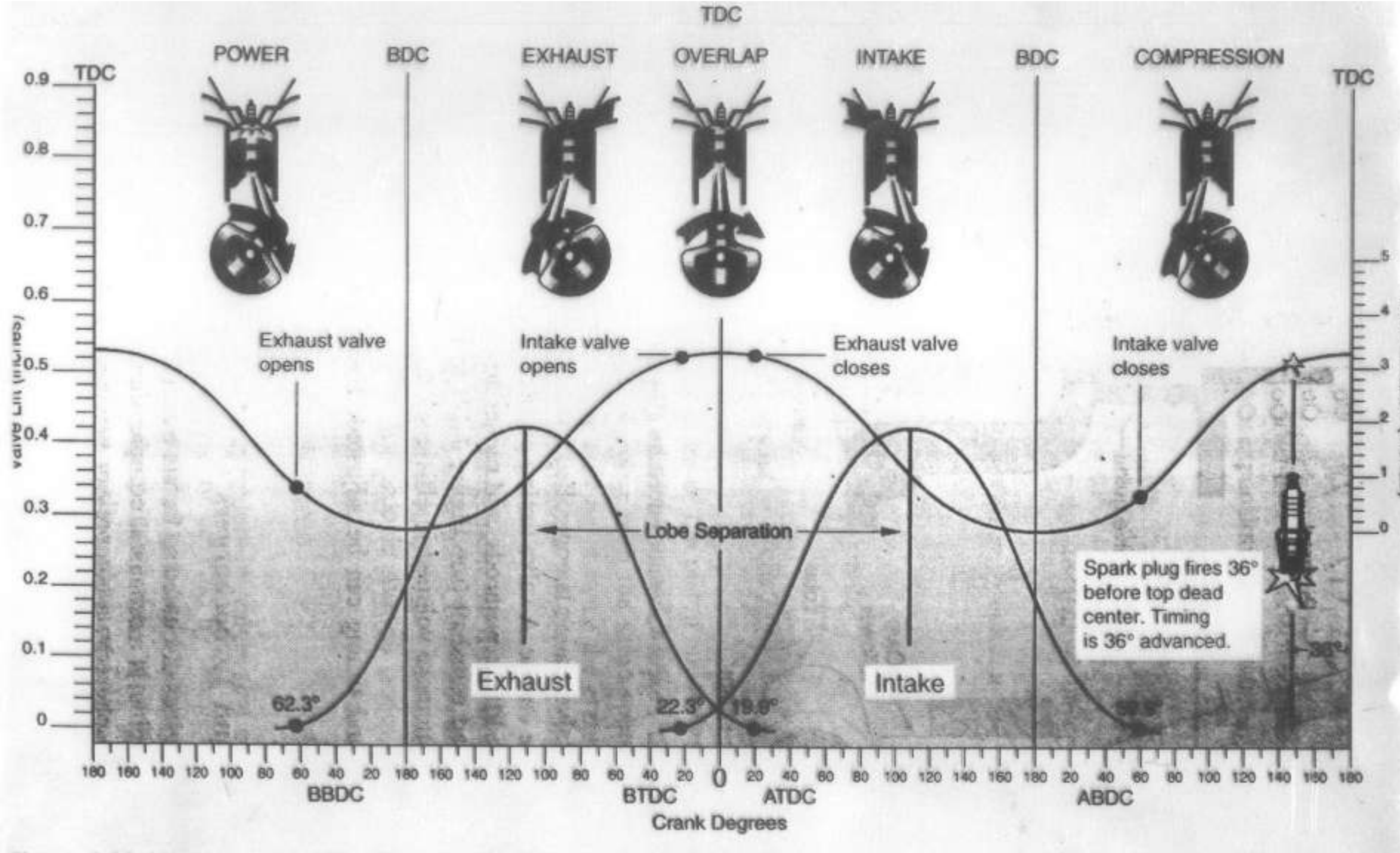
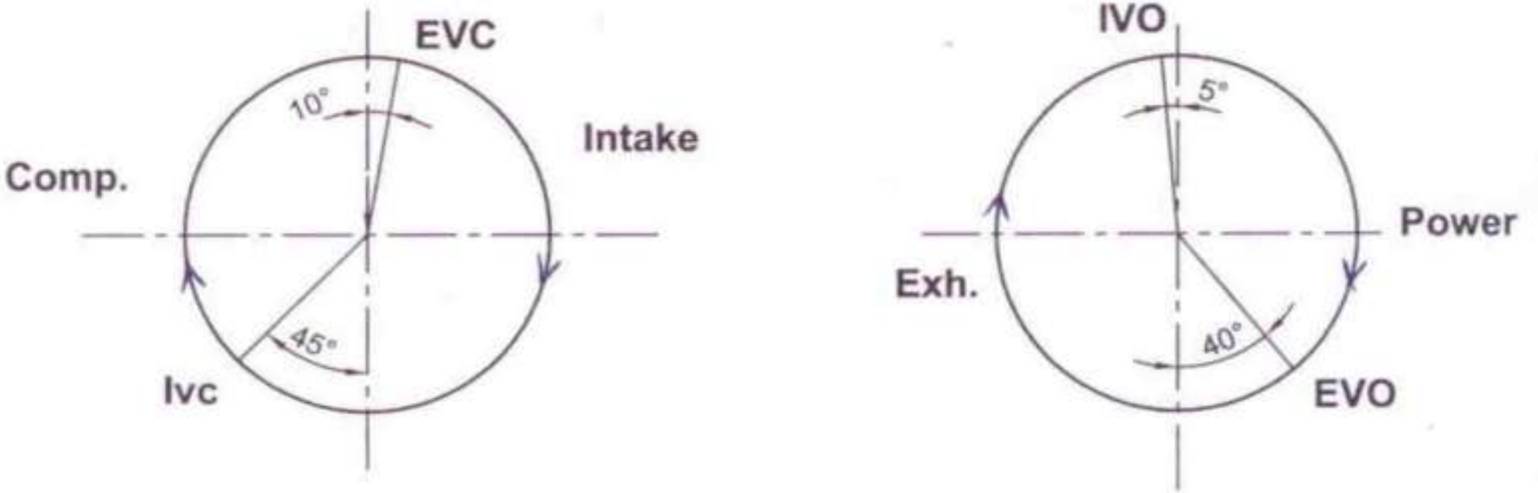
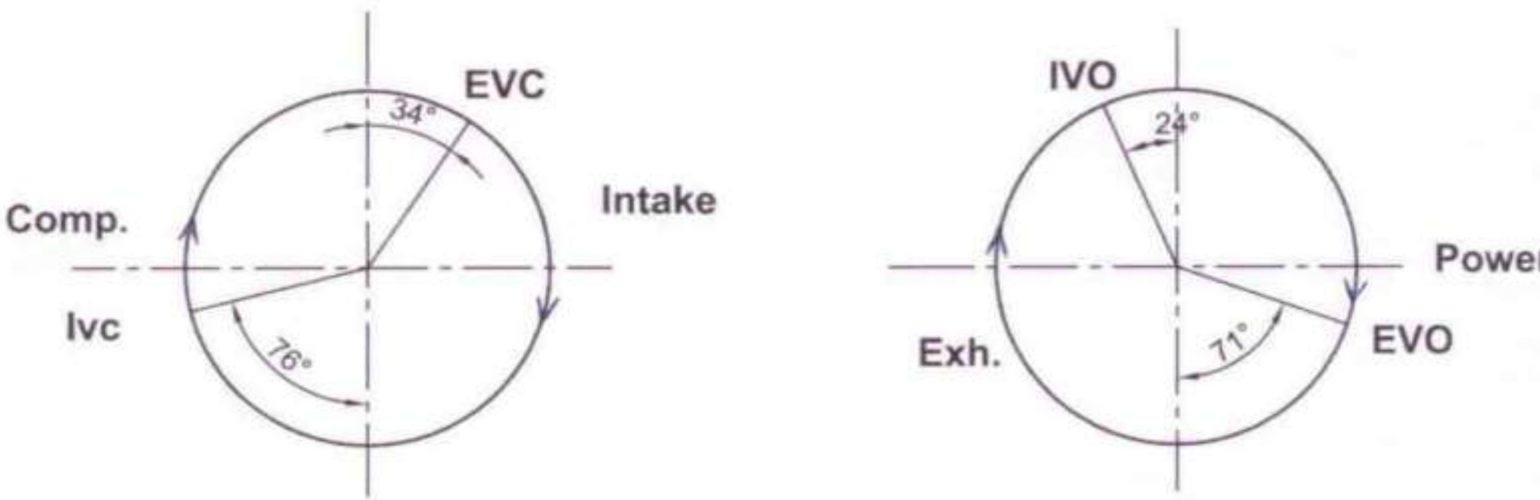


Figure 1-13 Valve timing profile. (Courtesy of Competition Cams, Inc.)



Inlet and exhaust duration 230°
Valve overlap 15°



Inlet and exhaust duration 285°
Valve overlap 58°

CLASSIFICATION OF INTERNAL COMBUSTION ENGINES

6. Fuel

1.Conventional: (a) Crude oil derived (i) Petrol
(ii) Diesel
(b) Other sources: (i) Coal
(ii) Wood (includes bio-mass)
(iii)Tar Sands
(iv)Shale

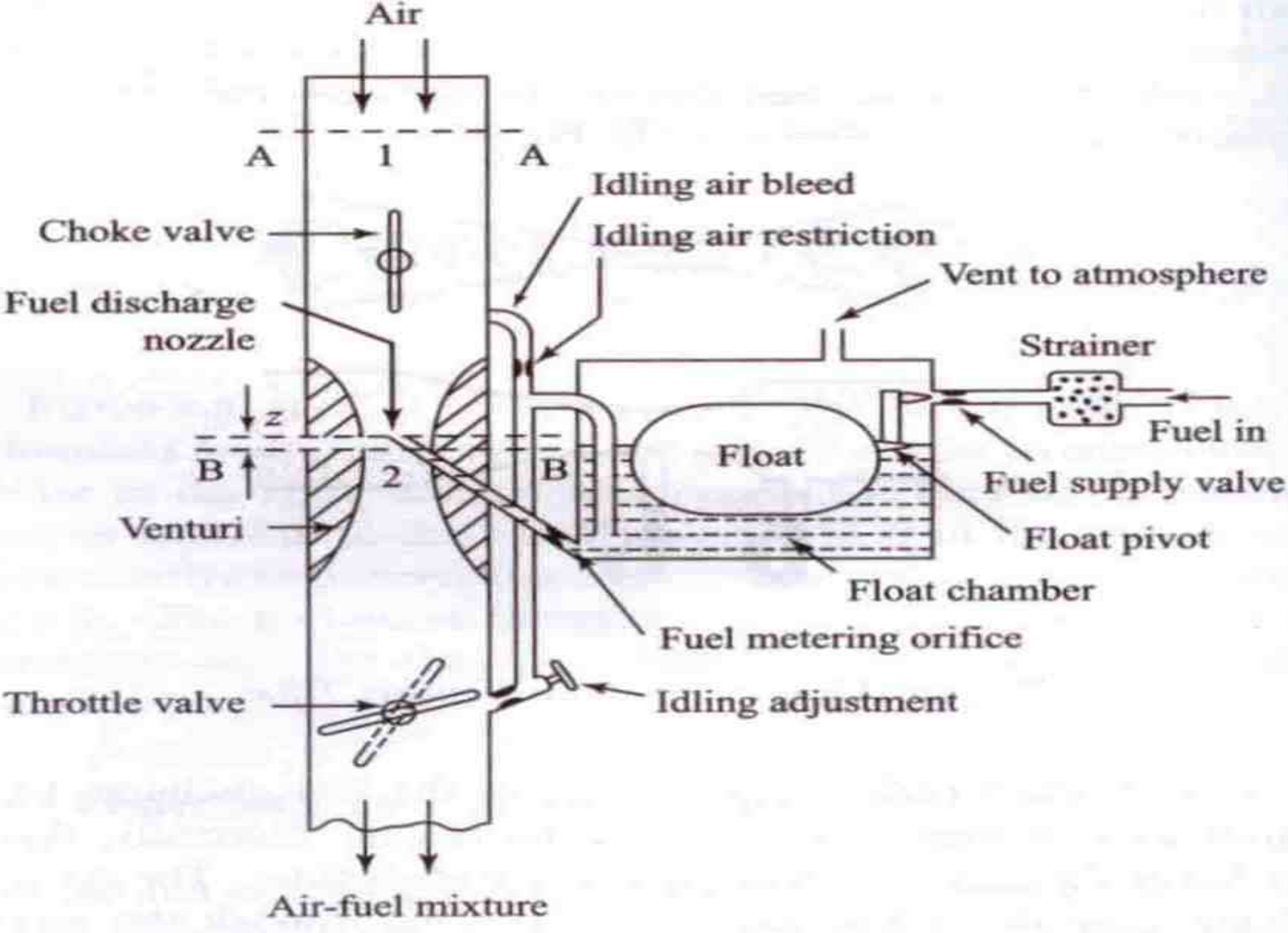
2. Alternate: (a) Petroleum derived (i) CNG
(Total Replacement) (ii) LPG
(b) Bio-mass Derived (i) Ethanol
(ii) Vegetable oils
(iii) Producer gas
(iv) Biogas
(iv) Hydrogen

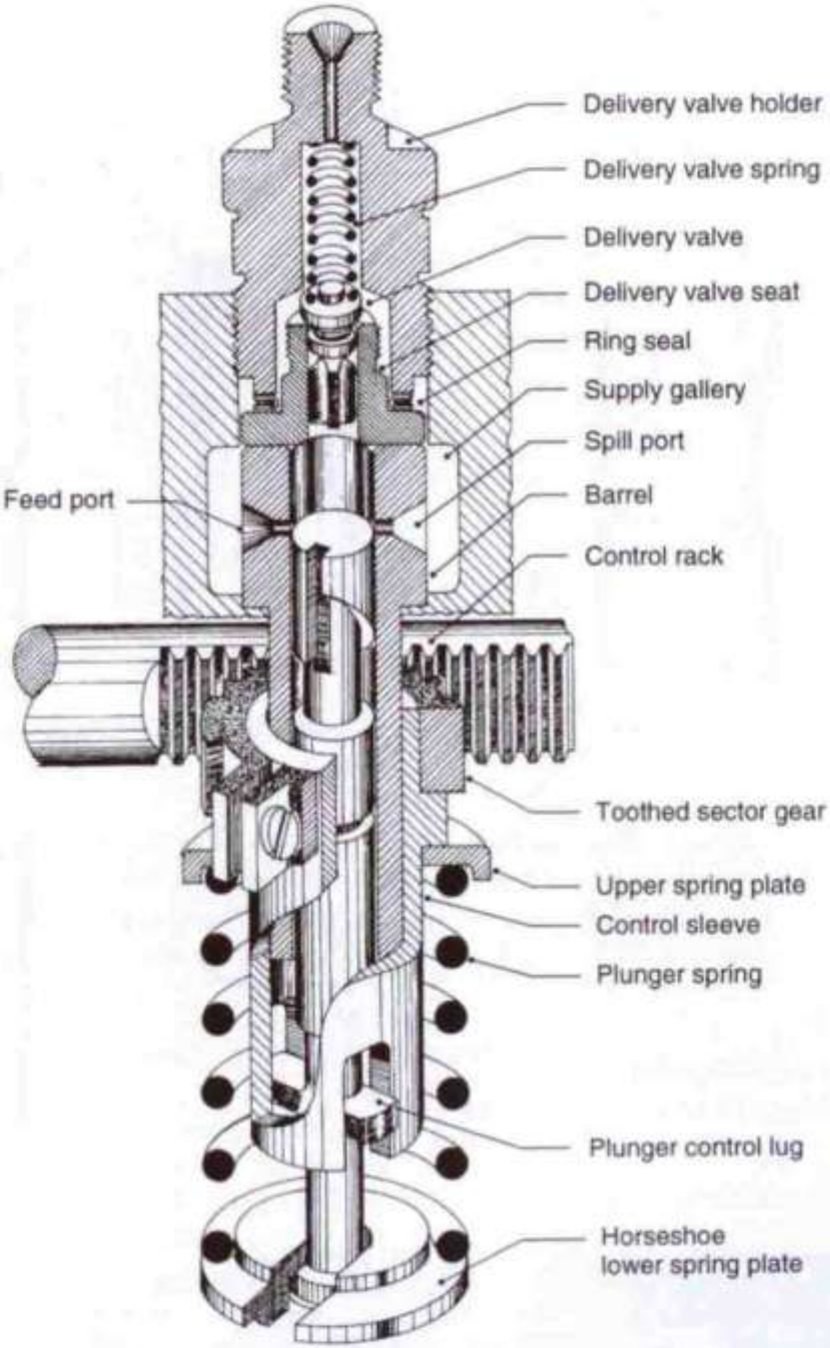
Partial Replacement: 1. Blending
2. Dual fueling

CLASSIFICATION OF INTERNAL COMBUSTION ENGINES

7. Mixture Preparation

1. **Carburetion – perhaps soon to be obsolete.**
2. **Fuel Injection**
   - (i) Diesel
   - (ii) Gasoline
     - (a) Manifold
     - (b) Port
     - (c) Cylinder

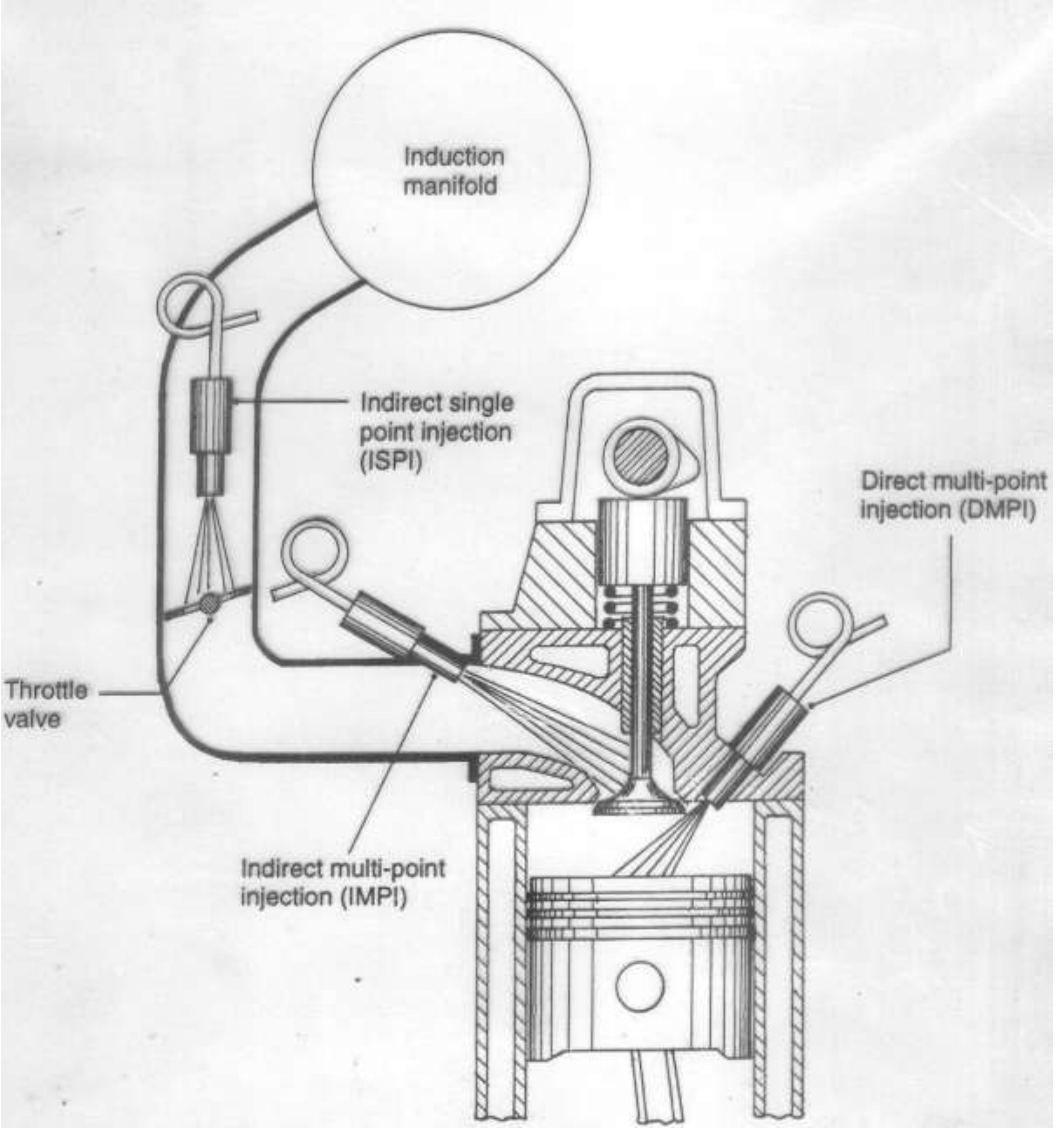

Air
A
1
A
Idling air bleed
Idling air restriction
Choke valve
Vent to atmosphere
Fuel discharge nozzle
Strainer
z
Fuel in
B
2
B
Float
Fuel supply valve
Venturi
Float pivot
Float chamber
Fuel metering orifice
Throttle valve
Idling adjustment
Air-fuel mixture



Injection pump pumping element assembly (Bosch Type PE..A and CAV Type AA)

BOSCH DIESEL PUMP & INJECTOR

Gasoline Fuel Injection



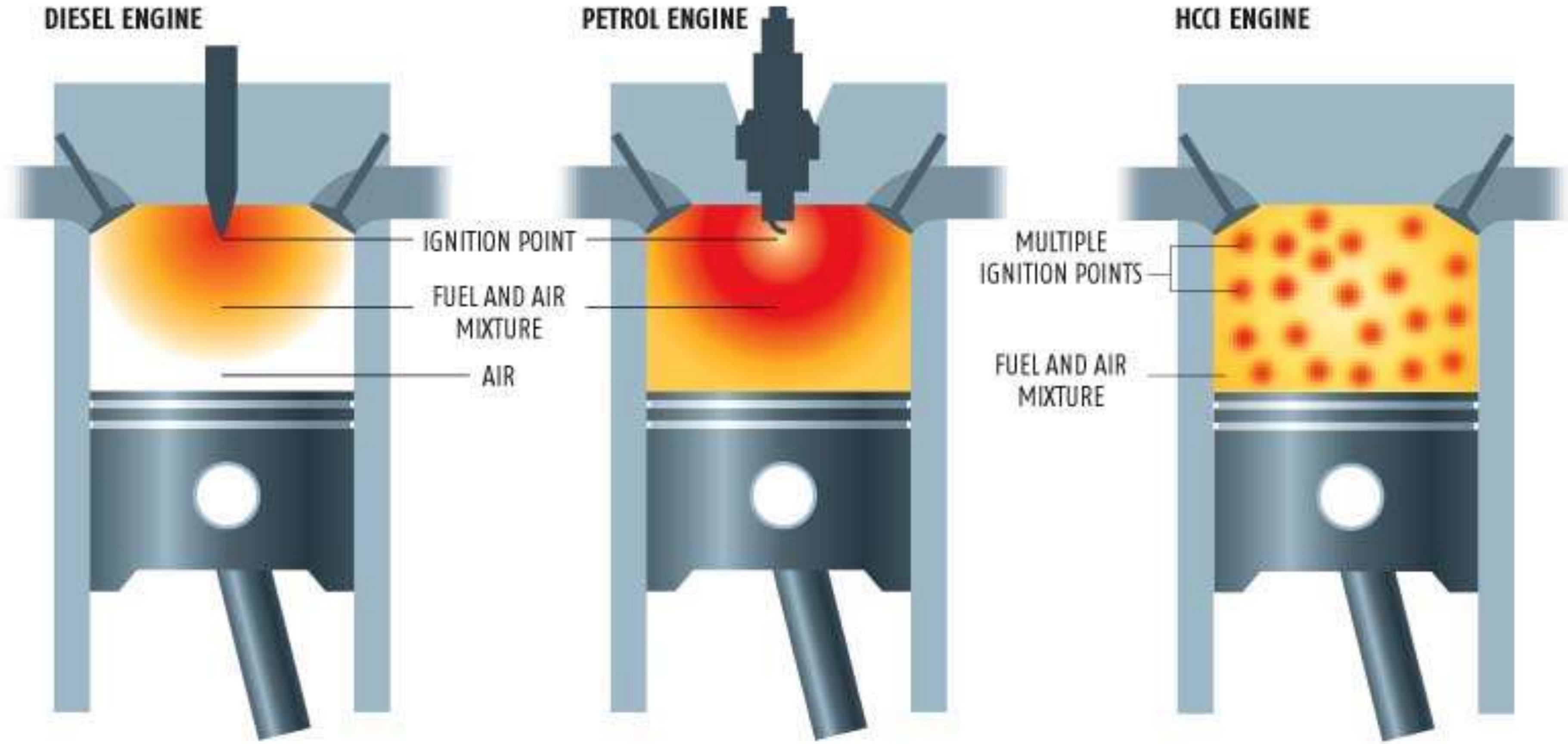
CLASSIFICATION OF INTERNAL COMBUSTION ENGINES

8. Ignition

1. Spark Ignition - homogeneous charge
   - (a) Conventional
     - (i) Battery
     - (ii) Magneto
   - (b) Other methods
2. Compression Ignition - heterogeneous charge (conventional)
3. Compression ignition - homogeneous charge (hcci)

REDUCING SOOT AND NOx EMISSIONS

In HCCI and petrol engines, the fuel and air are mixed before combustion, preventing the soot emissions of diesel engines. Only HCCI engines have multiple ignition points throughout the chamber. This plus their lean burn keeps temperatures low, preventing formation of nitogen oxides (NOx)



CLASSIFICATION OF INTERNAL COMBUSTION ENGINES

9. Charge Stratification

1. Homogeneous Charge (Also Pre-mixed charge)

2. Stratified Charge (i) With carburetion

   (ii) With fuel injection

Charge Stratification

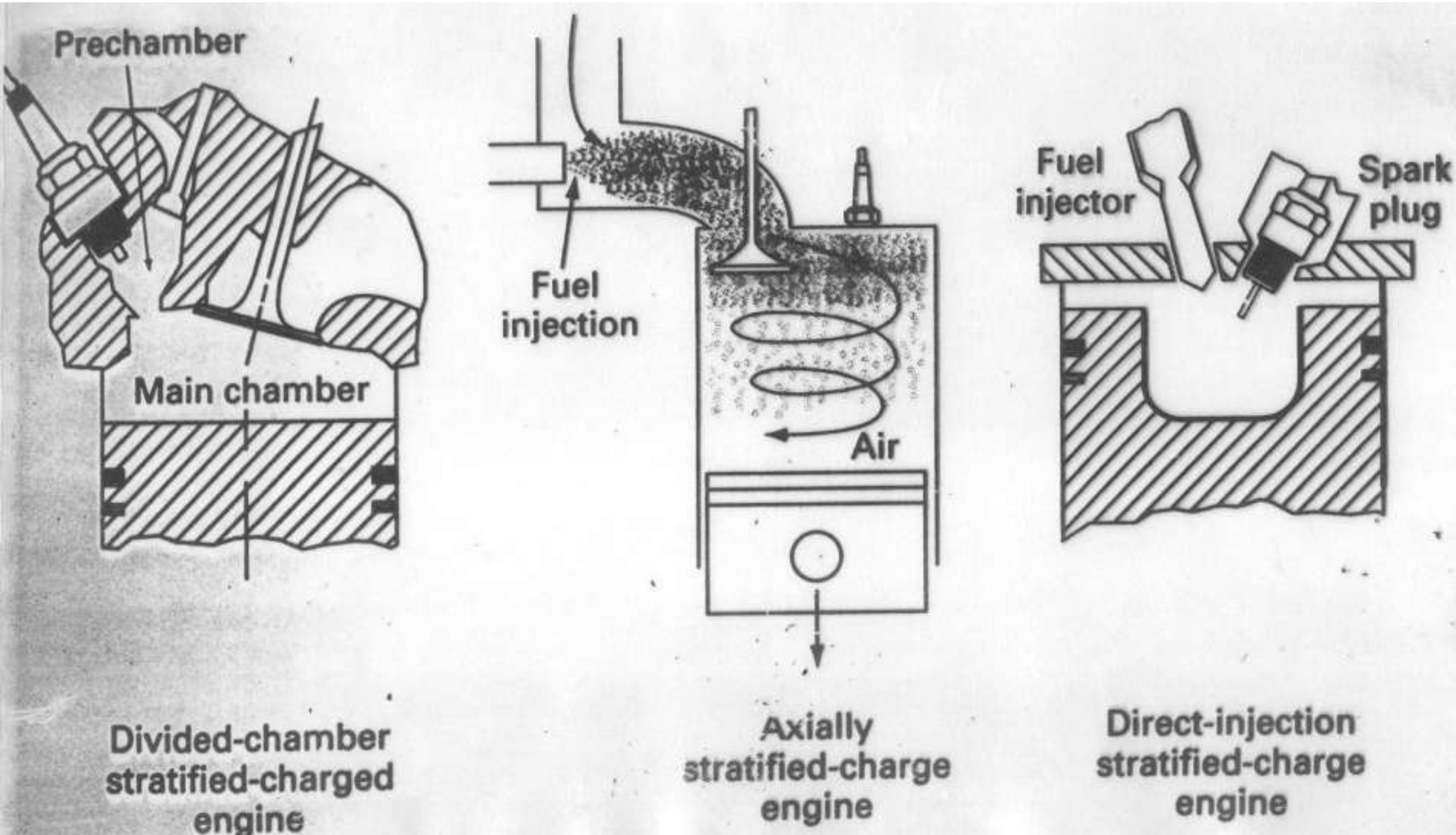


FIGURE 7.20
Types of spark-ignited-stratified charge engines [Amann, by courtesy of General

CLASSIFICATION OF INTERNAL COMBUSTION ENGINES

10. Combustion Chamber Design

1. Open Chamber:
   - (i) Disc type
   - (ii) Wedge
   - (iii) Hemispherical
   - (iv) Bowl-in-piston
   - (v) Other design
2. Divided Chamber:
   - (For CI):
     - (i) Swirl chamber
     - (ii) Pre-chamber
   - (For SI)
     - (i) CVCC
     - (ii) Other designs

Combustion Chamber Designs

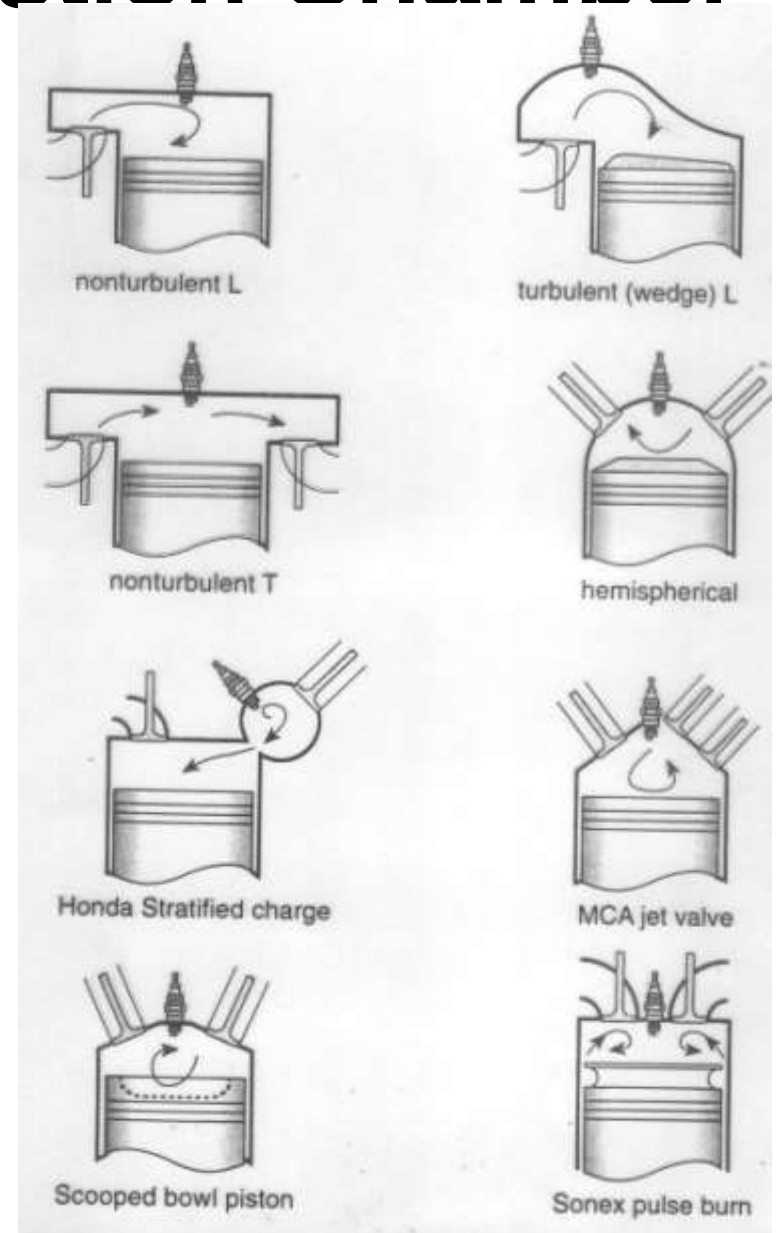


Figure 10.11 Various SI combustion chamber designs.

Combustion Chamber Design

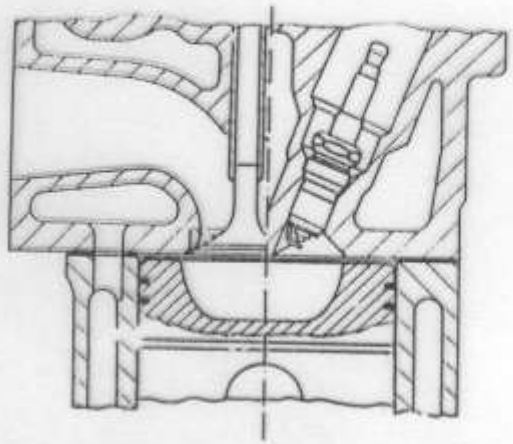


Fig. 14- Combustion space of the AVL HCLB-engine

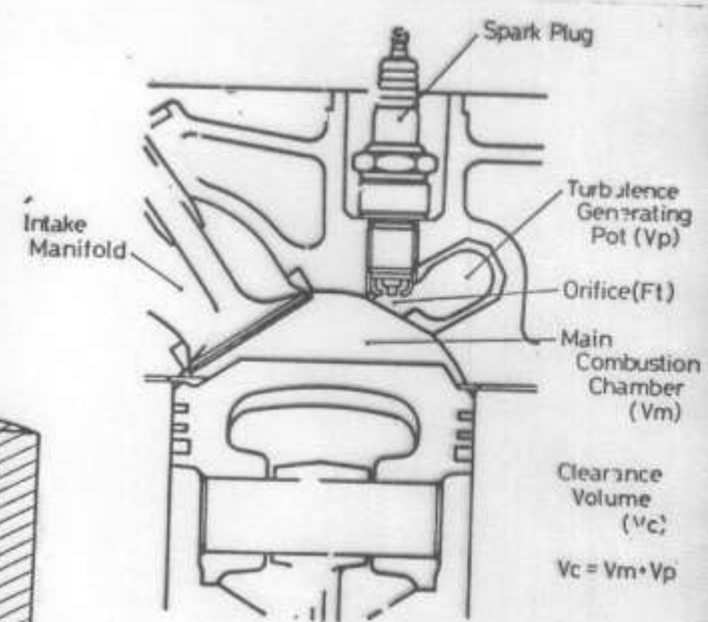


Fig. 15 - Configuration of the main combustion chamber and the TGP

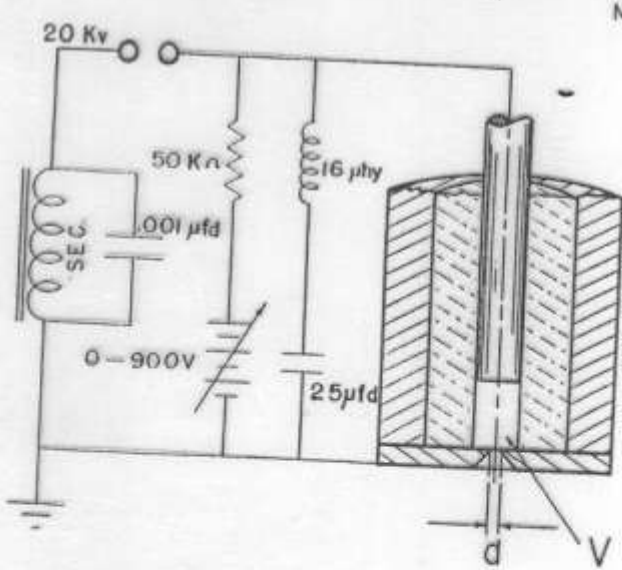


Fig. 16- Schematic of a plasma jet igniter, d= 1 mm, V = 10 mm^3

Combustion Chamber Design

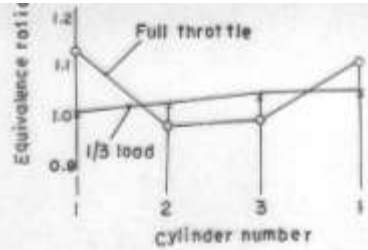


FIG. 1 TYPICAL VARIATION OF EQ. RATIO BETWEEN CYLINDERS OF A 4 CYL. ENGINE WITH SINGLE CARBURETOR

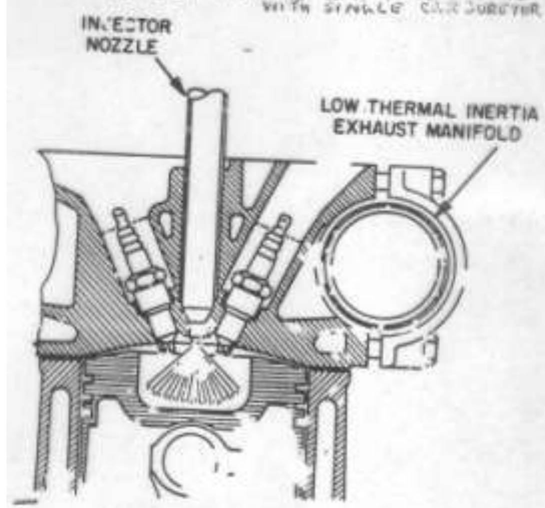


Fig. 2 - Combustion chamber of Ford PROCO engine

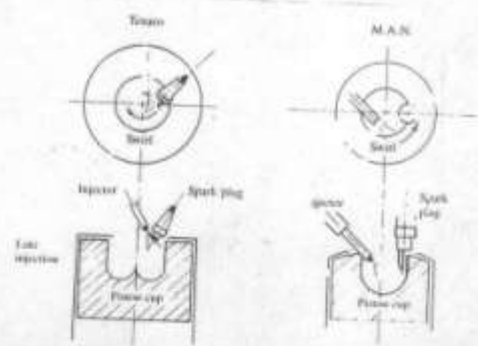
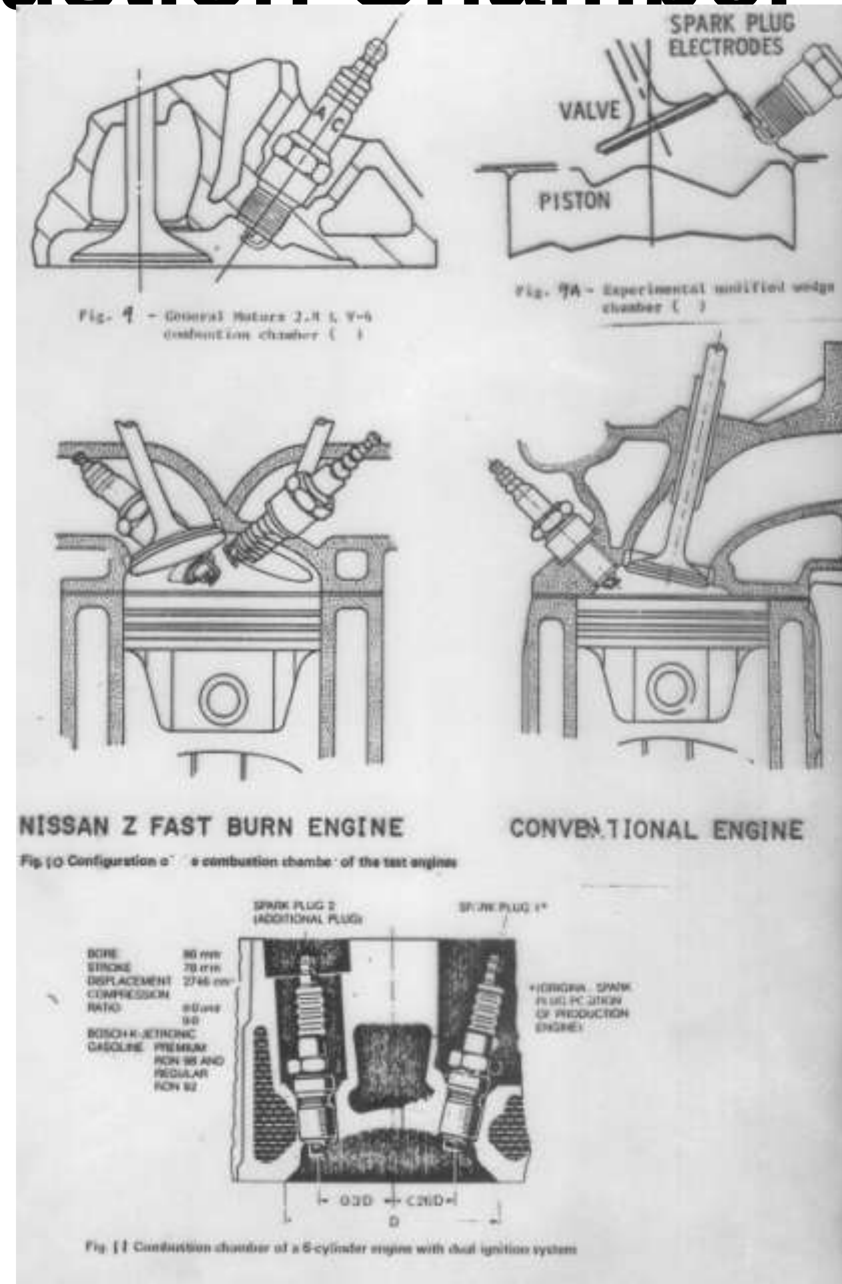


FIGURE 3
Two multifuel stratified-charge engines which have been used in commercial practice: the Texaco Controlled Combustion System (TCCS) and the M.A.N.-FM System.

Combustion Chamber Design



Combustion Chamber Design

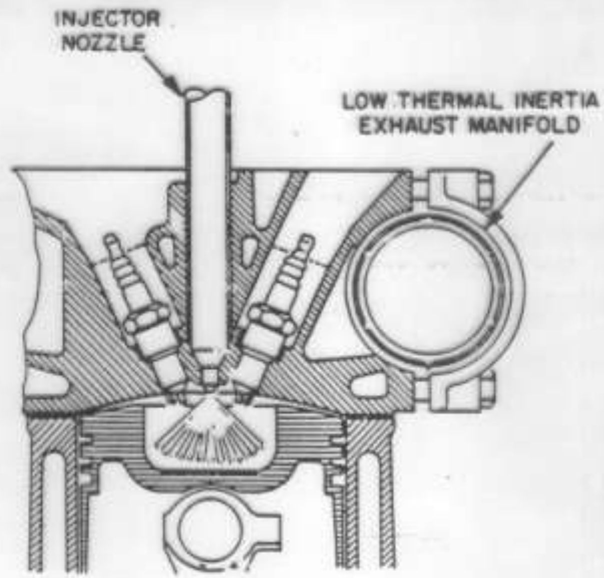


Fig. 11 - Combustion chamber of Ford PROCO engine

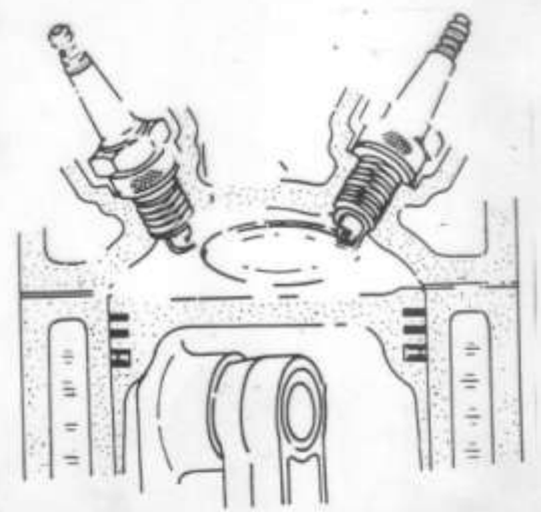


Fig. 12 - Configuration of dual spark plugs

Combustion Chamber Design

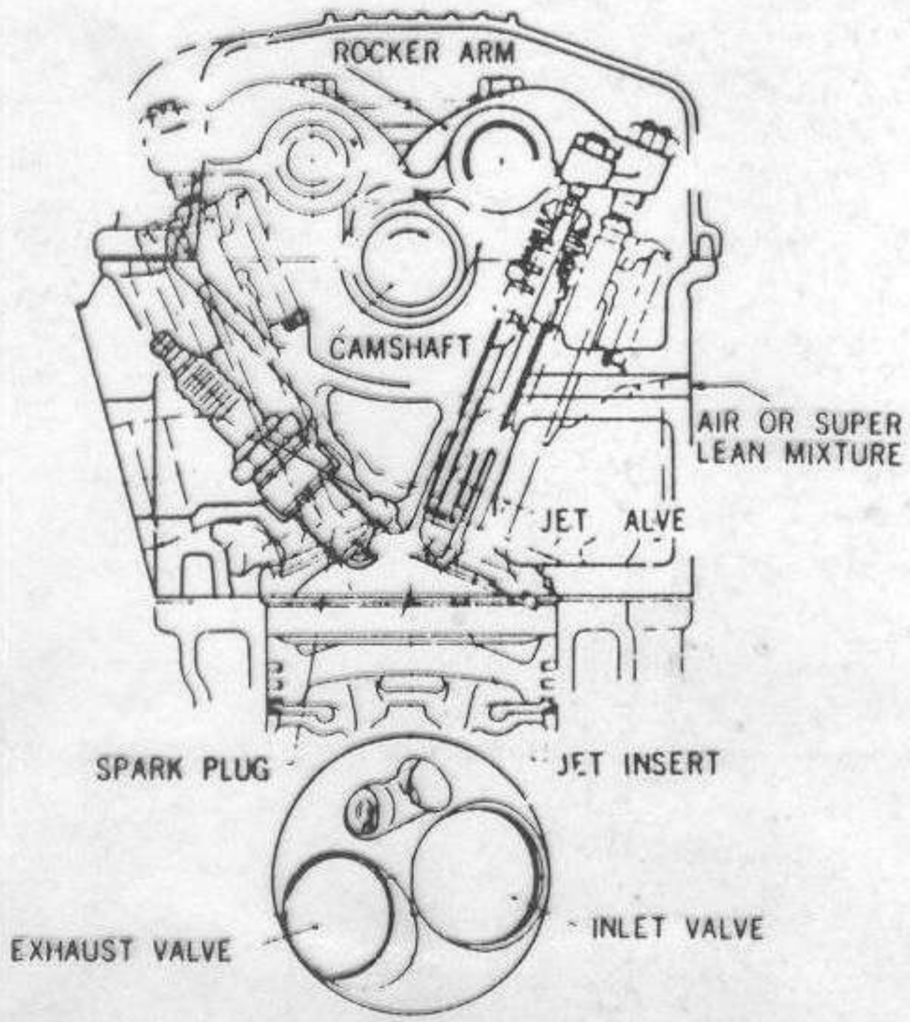


Fig. 13 - Mitsubishi MCA-JET combustion chamber ( )

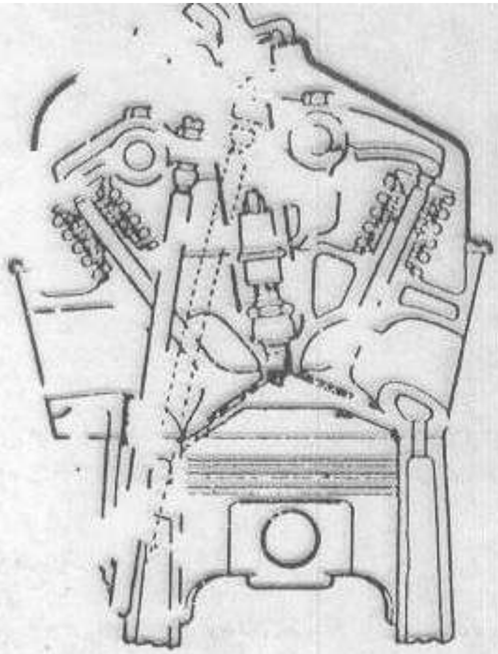
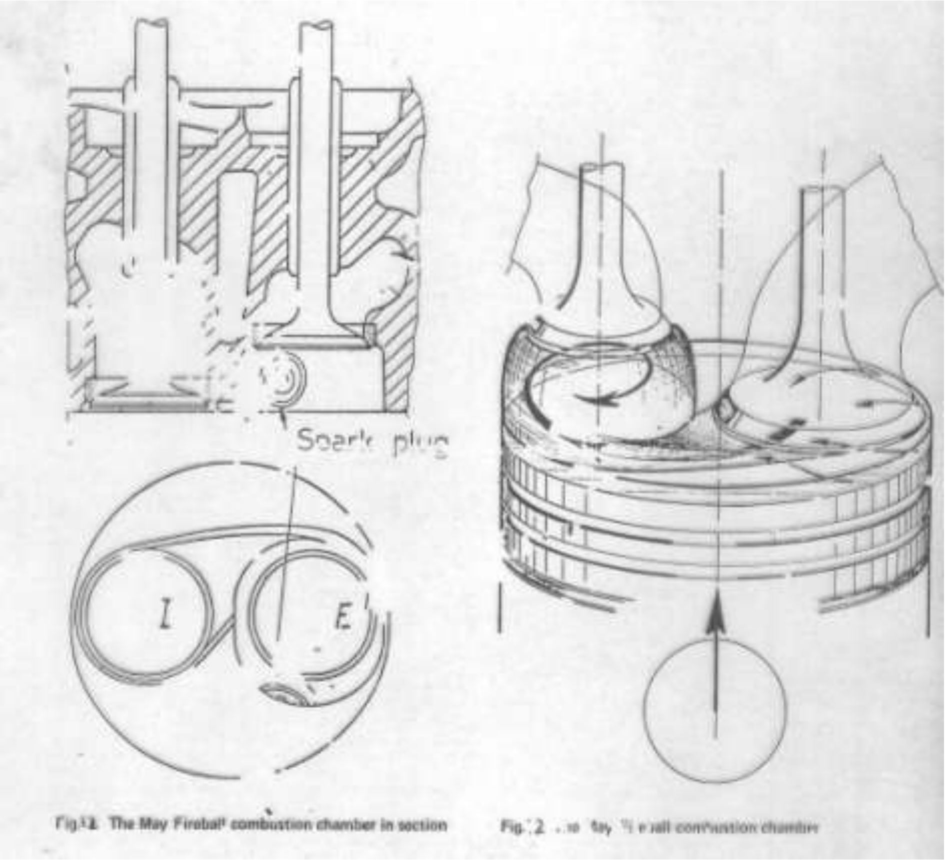
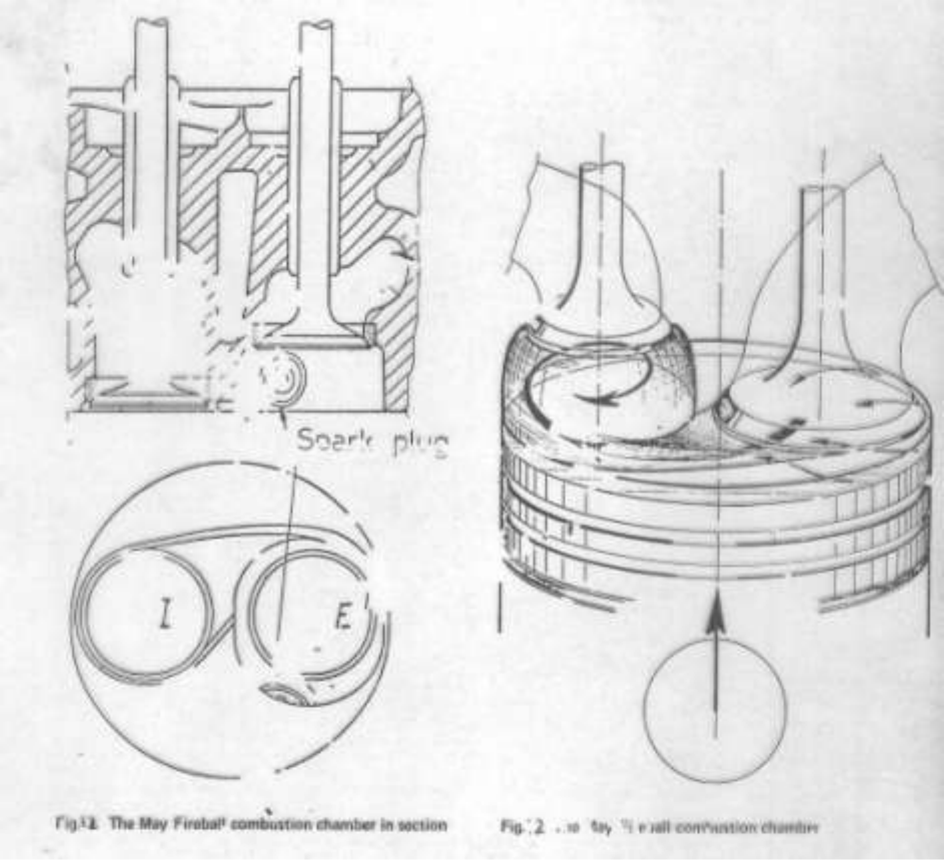


Fig. 13A - Chrysler hemi combustion chamber ( )

Combustion Chamber Design





CLASSIFICATION OF INTERNAL COMBUSTION ENGINES

11. Method of Load Control

1. **Throttling: (To keep mixture strength constant) Also called Charge Control**

   Used in the Carbureted S.I. Engine

2. **Fuel Control (To vary the mixture strength according to load)**

   Used in the C.I. Engine

3. **Combination**

   Used in the Fuel-injected S.I. Engine.

CLASSIFICATION OF INTERNAL COMBUSTION ENGINES

12. Cooling

1. Direct Air-cooling

2. Indirect Air-cooling (Liquid Cooling)

3. Low Heat Rejection (Semi-adiabatic) engine.