FUEL–AIR CYCLES AND THEIR ANALYSIS

$\eta_{air\text{-}standard}$=56.5%, **$\eta_{actual}$=28%**

Due to:

- Progressive burning of fuel
- Incomplete burning of fuel
- Valve operations
- Working fluid (Air + Fuel + Residual gases)
- Cp and Cv not constant
- Dissociation of products of combustion

Fuel-Air Cycle: Assumptions

- Prior to combustion –No chemical change in either fuel or air
- After combustion –Chemical equilibrium
- Adiabatic walls –Frictionless compression & expansion processes
- Reciprocating engines –Fluid motion ignored within cylinder
- Instantaneous burning at TDC (Otto)
- Fuel completely vaporised & mixed with air (Otto), Proper mixing (Diesel-Heterogeneous)

Actual composition of Cylinder Gases :

–Cylinder gasses –Fuel + Air + Water vapor + Residual Gases
–F/A ratio changes during operation (Changing CO, CO2& H2O vapor in exhaust
–Amount of left gases and fuel also (in clearance etc.) varies with speed and load
–These facts are considered and analysed (Numerically)

Temp, K	Cp	Cv	R=Cp-Cv	γ
300	1.005	0.717	0.288	1.401
200	1.345	1.057	0.288	1.272

Dissociation

:

–Disintegration of combustion products at higher temperature

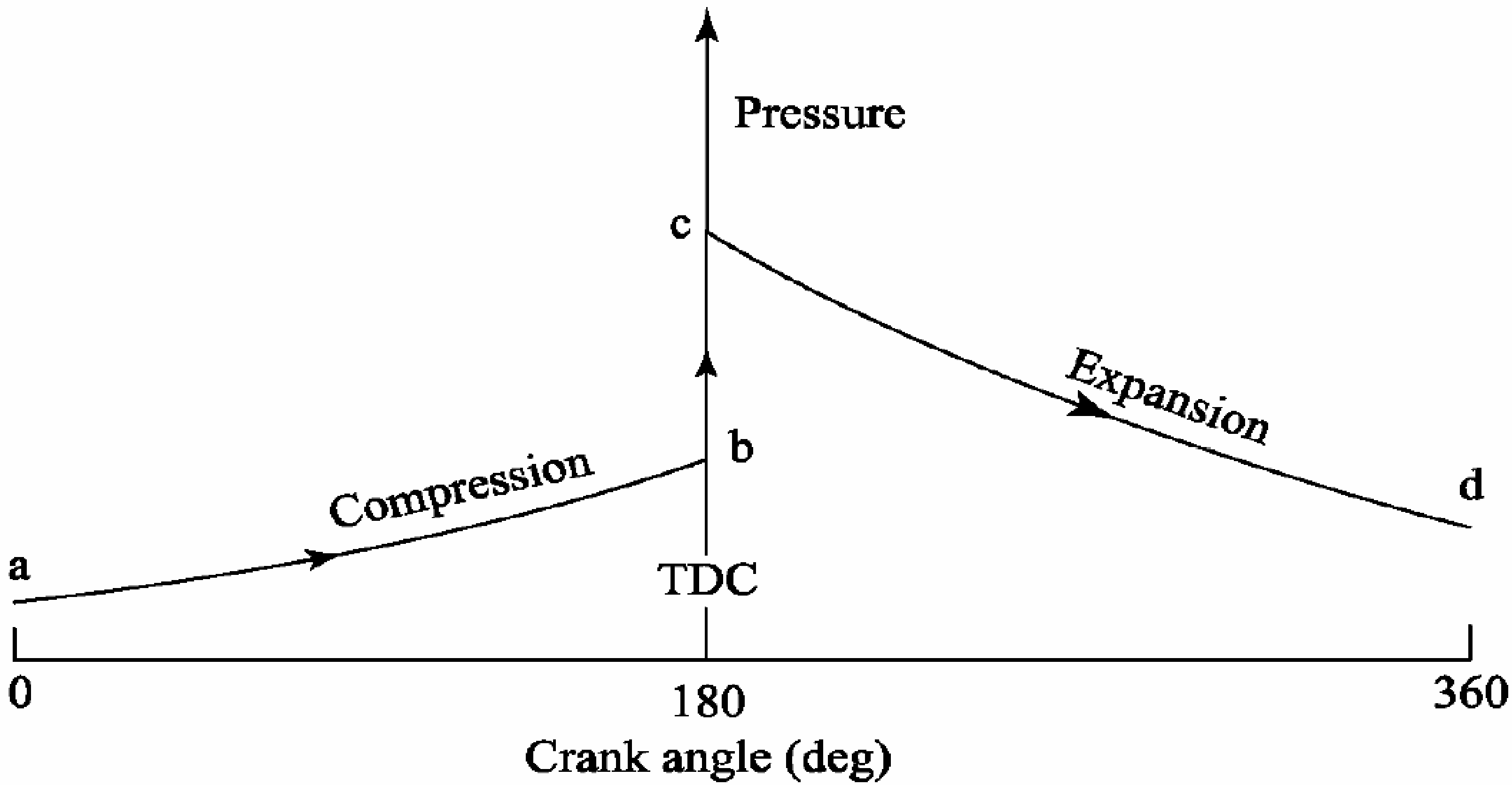
–Reverse of combustion process –Heat is absorbed

- $CO_2 \Leftrightarrow 2CO + O_2$(at 1000 °C)
- $H_2O \Leftrightarrow 2H_2 + O_2$(at 1300 °C)
- Presence of CO and O_2in gases tends to prevent dissociation of CO_2

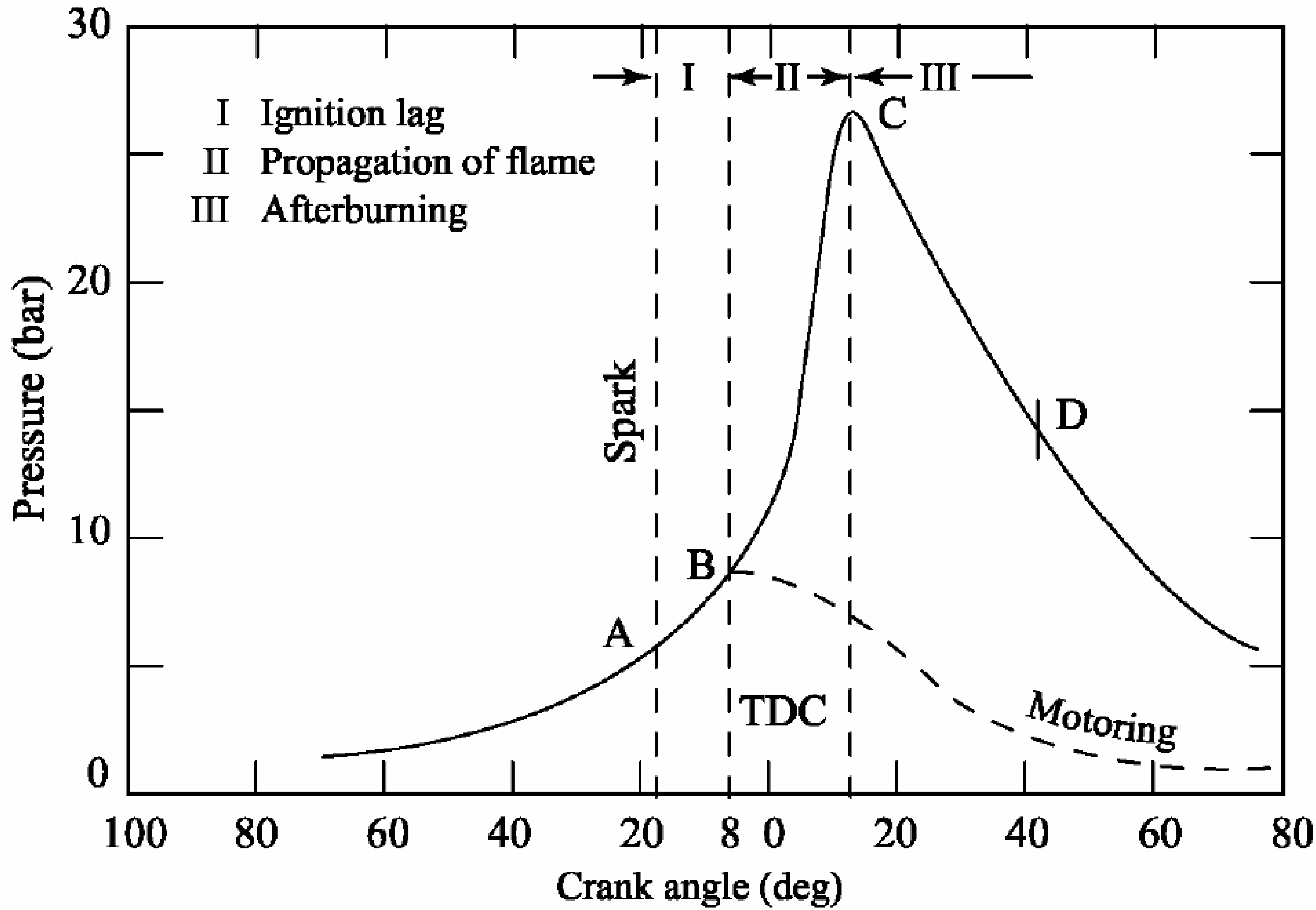
Actual Cycles: Losses

- **Variation of specific heats**
- **Dissociation of combustion products**
- **Progressive combustion**
- **Incomplete combustion of fuel**
- **Heat transfer losses to walls**
- **Blow down at the end of combustion chamber**
- **Working substance –dilution with residual gases**
- **Change in chemical composition of working fluid**

Combustion in SI and CI Engine



Theoretical p-θdiagram



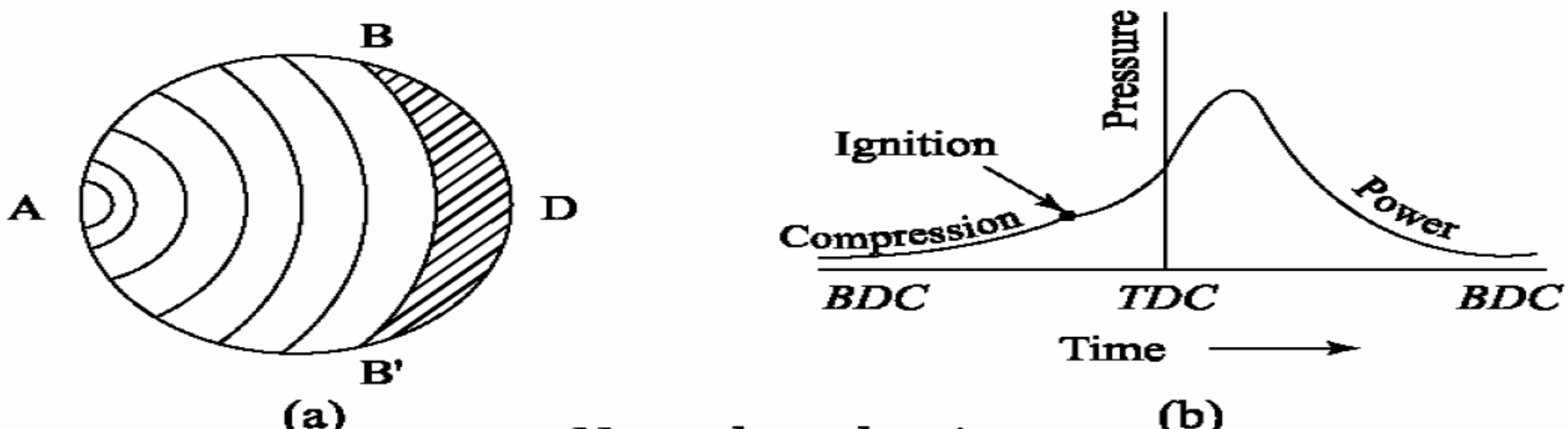
I Ignition lag
II Propagation of flame
III Afterburning
I
II
III
C
D
B
A
Spark
TDC
Motoring
Pressure (bar)
30
20
10
0
100
80
60
40
20
8
0
20
40
60
80
Crank angle (deg)

I-Ignition lag or preparation phase (AB):
-growth and development of a semi propagating nucleus of flame
-chemical process depending upon the nature of the fuel, upon both temperature and pressure, the proportion of the exhaust gas, and also upon the temperature coefficient of the fuel, that is, the relationship of oxidation or burning
-point A shows the passage of spark and point B is the first rise of pressure
-ignition lag is generally expressed in terms of crank angle
-Ignition lag is very small and lies between 0.00015 to 0.0002 seconds
-ignition lag of 0.002 seconds corresponds to 35 deg crank rotation when the engine is running at 3000 RPM
-Angle of advance increase with the speed
II-propagation of flame (BC):
-Period from the point B where the line of combustion departs from the compression line to point C, the maximum rise of pressure in P-θ diagram
-flame propagates at the constant velocity
-Heat transfer to the cylinder wall is low
-rate of heat release depends upon the turbulence intensity and reaction rate
III-After burning (CD):
-After point C, the heat release is due to the fuel injection in reduced flame front after the starts of expansion stroke
-no pressure rise during this period

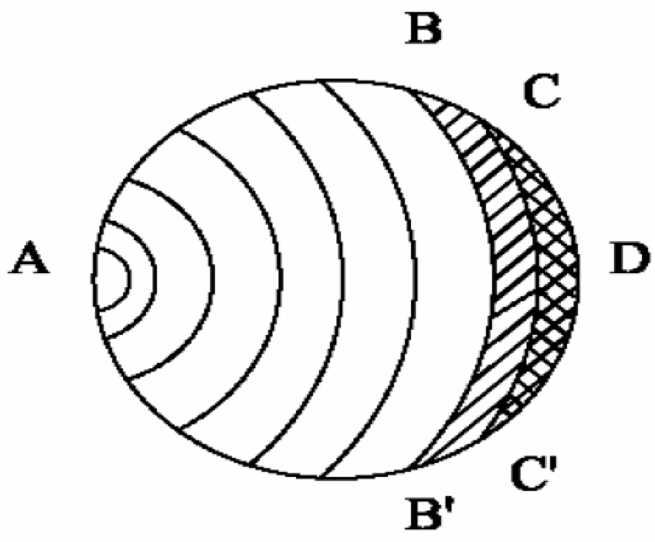
Detonation (Knocking)

Sometimes the Temperature of the unburnt gases continue to rise, reaching maximum at the last end portions

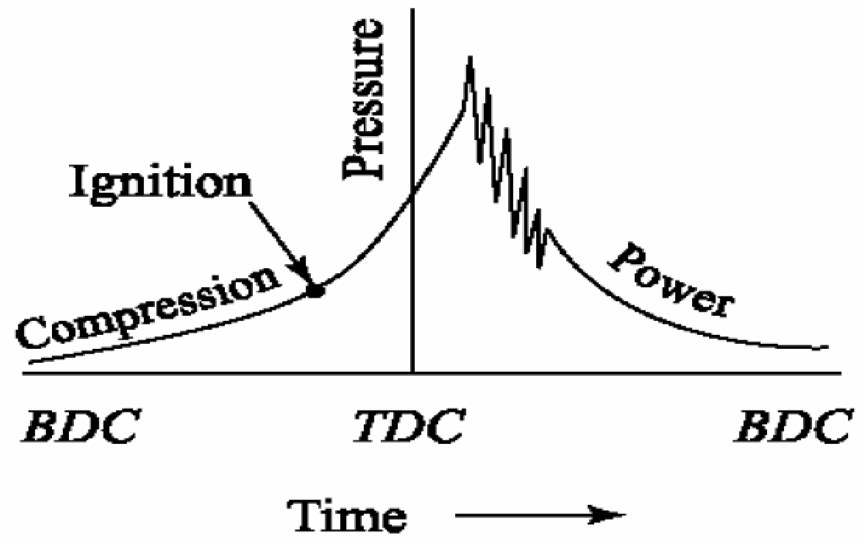
- Temperature exceeds the Self-ignition Temperature
- Leads to Knocking (DETONATION)
- But at the end –only a little mass left, Very small pressure pulses
- In fact: Maximum power is obtained when very slight self ignition & Knock is available at the end
- Knock gives a small pressure boost at the end of the combustion



Normal combustion



(c)



(d)

Combustion with detonation

Knocking

Detonation (SI)

- Auto-ignition of end gas
- Near the end of combustion
- To prevent – auto-ignition of end gas avoided
- Charge homogeneous – Intensity of pressure rise more
- Normal rate of pressure rise for first charge – smaller
-
- Good fuel: High Octane ~ 80-100, low Cetane ~ 20
- Characteristics to reduce Detonation
  - Self ignition temp of fuel – High
  - Ignition delay – long
  - Compression ratio – low
  - Inlet T & P – low
  - Speed – high
  - Cylinder size - small

Knocking (CI)

- Auto-ignition of fresh charge
- At the start of combustion
- To prevent – earliest possible auto-ignition required
- Charge is non-homogeneous – Rate of pressure rise smaller
- Normal rate of pressure rise – higher than SIE (audible knock always)
- Good fuel: low Octane ~ 30, high Cetane ~ 45-65
- Characteristics to reduce Knocking
  - Self ignition temp of fuel – Low
  - Ignition delay – short
  - Compression ratio – high
  - Inlet T & P – high
  - Speed – low
  - Cylinder size - large

Combustion in CI Engines

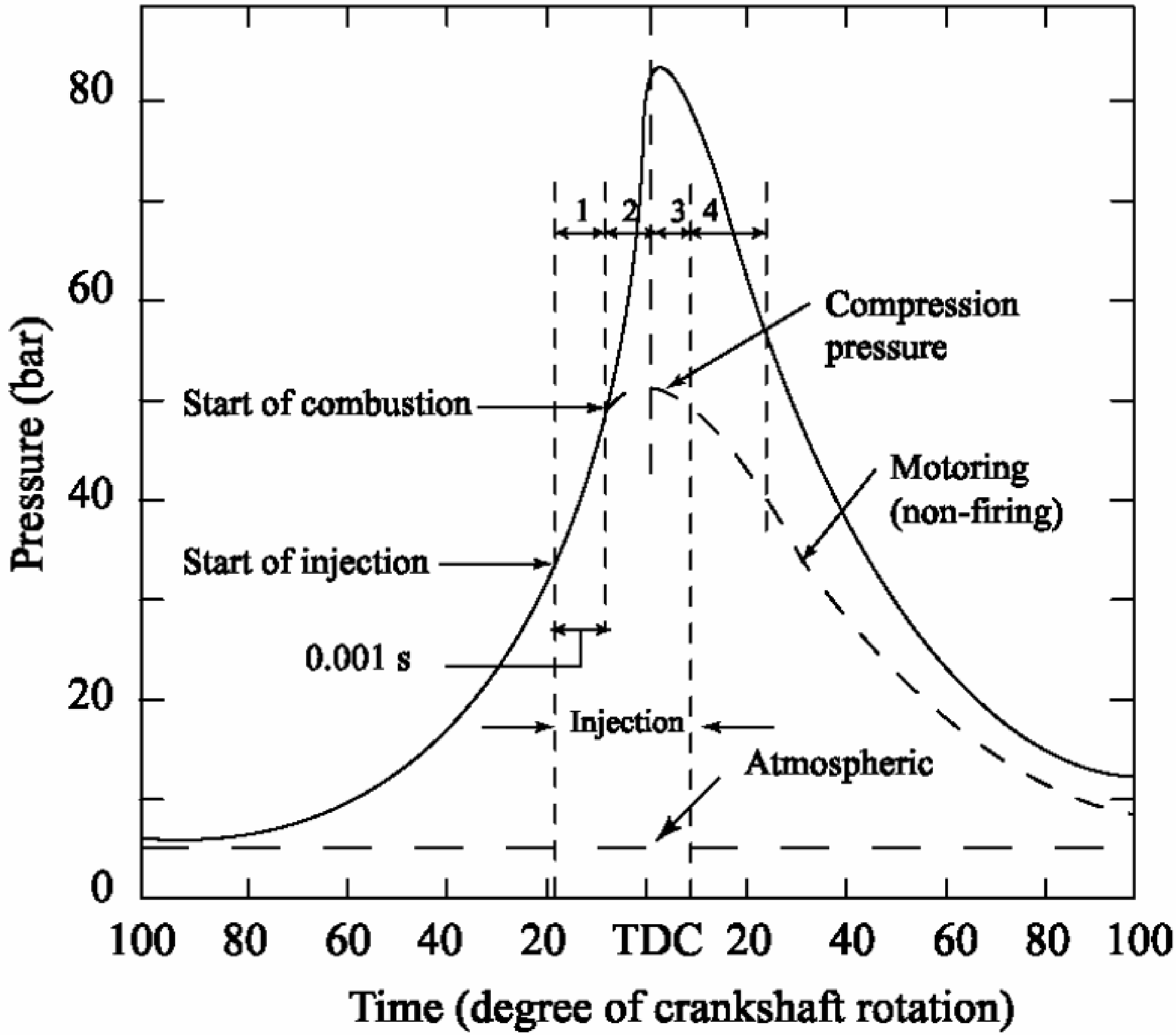
- Injection
- Atomization
- Vaporization
- Mixing
- Self Ignition
- Combustion

I-Ignition delay period
- a. physical delay
- b. chemical delay

II- Un-control Combustion

III- Control Combustion

IV- After burning



80
60
40
20
0
Pressure (bar)
1
2
3
4
Compression pressure
Start of combustion
Motoring (non-firing)
Start of injection
0.001 s
Injection
Atmospheric
100
80
60
40
20
TDC
20
40
60
80
100
Time (degree of crankshaft rotation)