Lecture-6

Prepared under
QIP-CD Cell Project

Internal Combustion Engines

Valve Timing Diagrams

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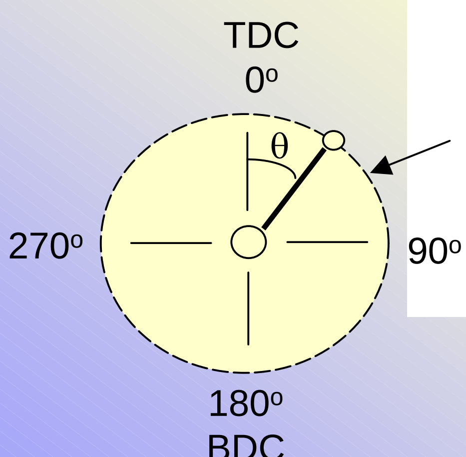
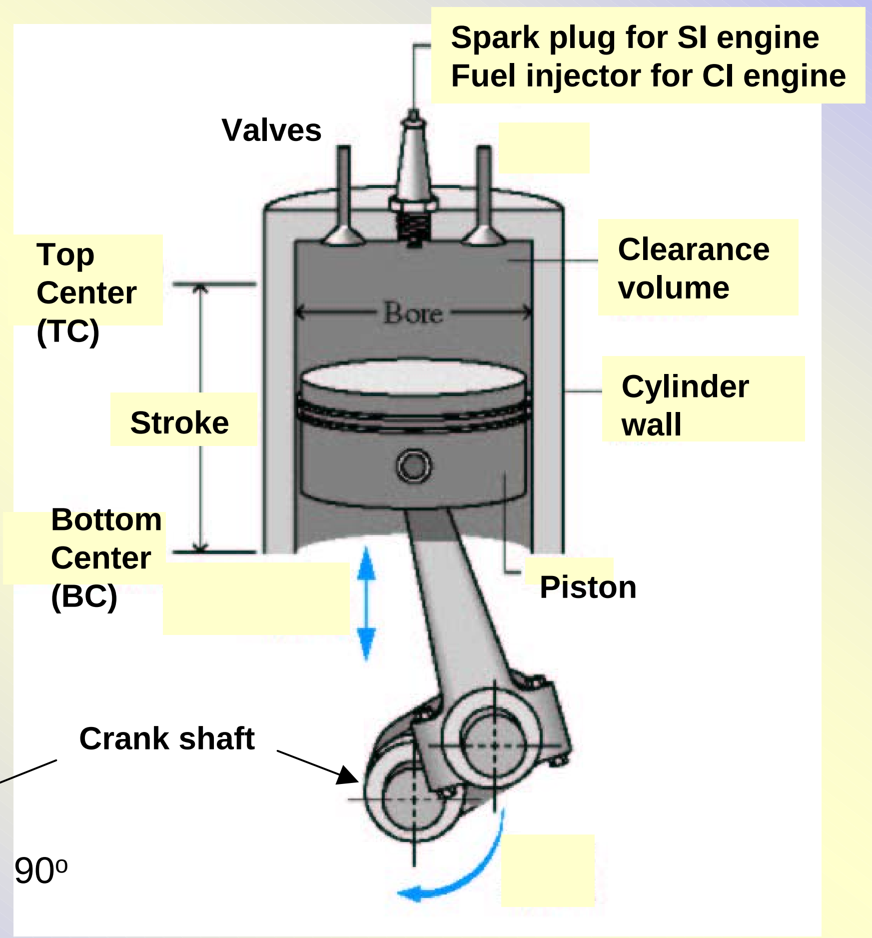
Engine Operating Cycle

$$time = \frac{\text{crank angles}}{\text{crank speed}}$$

$$= CA \cdot \frac{s}{rev} \cdot \frac{1\,rev}{360\,CA}$$





SI and CI Engines

- **Spark ignition (SI):**
  - **combustion is initiated by spark**
  - **air and fuel can be added together**

- **Compression ignition (CI):**
  - **combustion is initiated by auto ignition**
  - **requires fuel injection to control ignition**

Fuel-Air Mixing

- In spark ignition engines, air and fuel are usually mixed prior to entry into the cylinder.

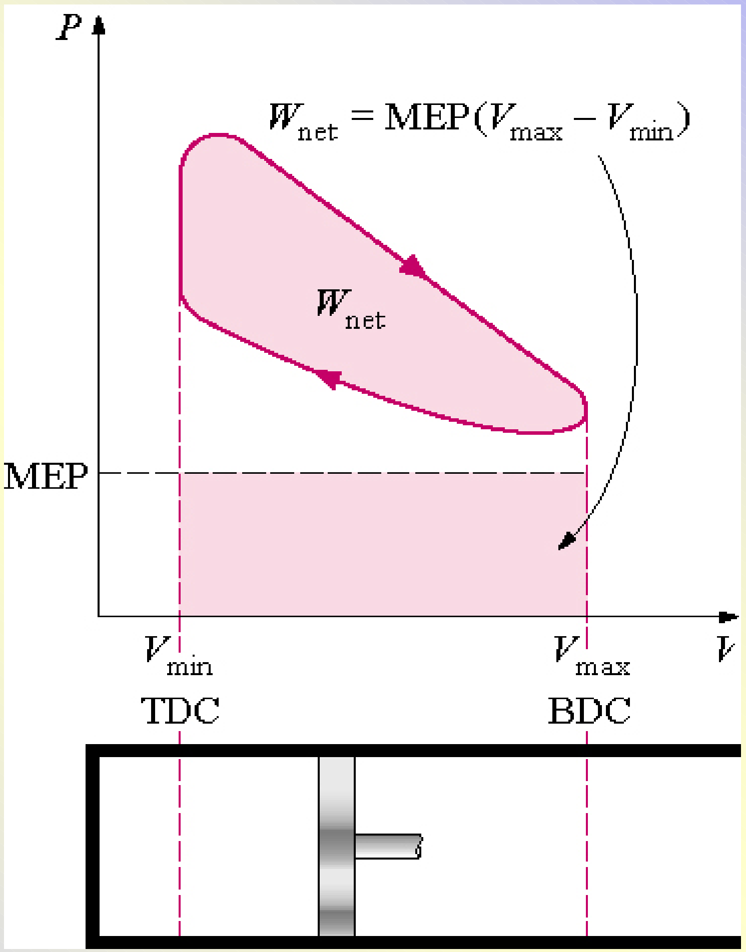
- The ratio of mass flow of air to the mass flow of fuel must be held roughly constant at about 15 for proper combustion.

- Conventionally, a mechanical device known as a carburetor is used to mix fuel and air. Most modern cars use electronic fuel-injection systems.

- With diesel engines, fuel is sprayed directly into the cylinders, and power is varied by metering the amount of fuel added (no throttle).

The Net Work Output of a Cycle

The net work output of a cycle is equivalent to the product of the mean effect pressure and the displacement volume



Indicated Power

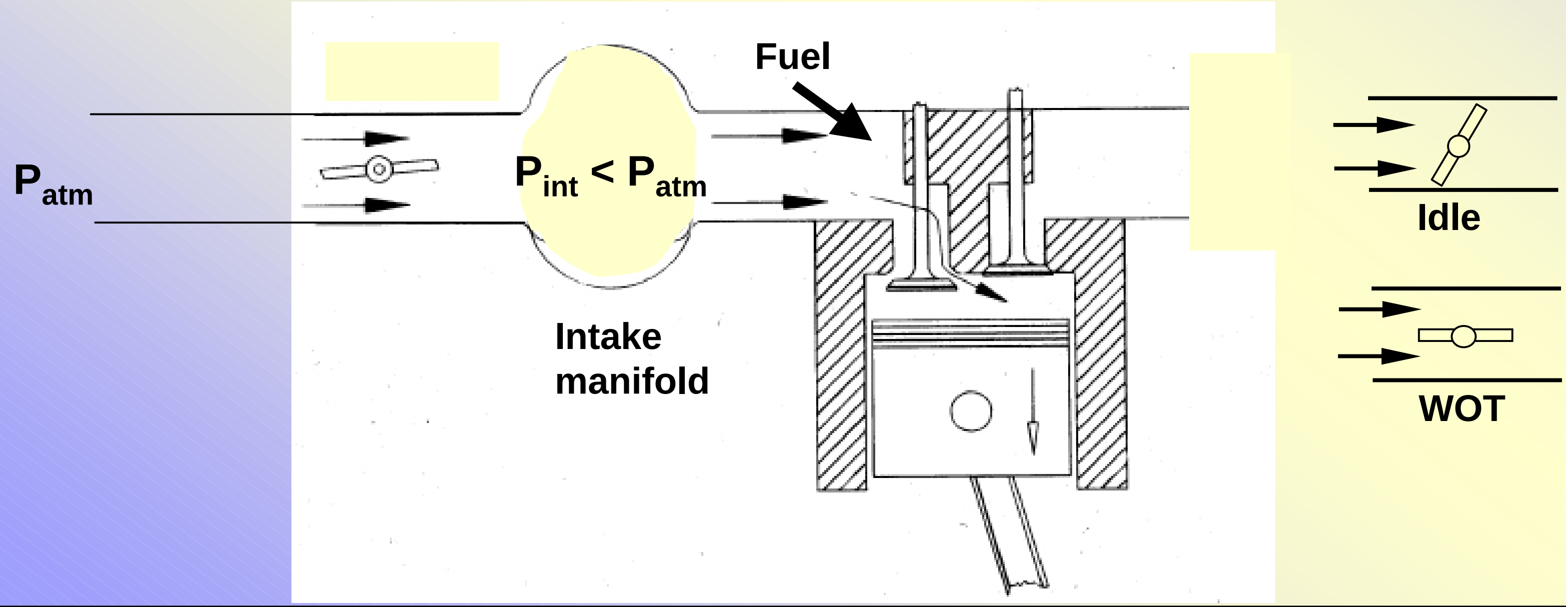
Power can be increased by increasing:

- **the engine size, V_d**
- **compression ratio, r_c**
- **engine speed, N**

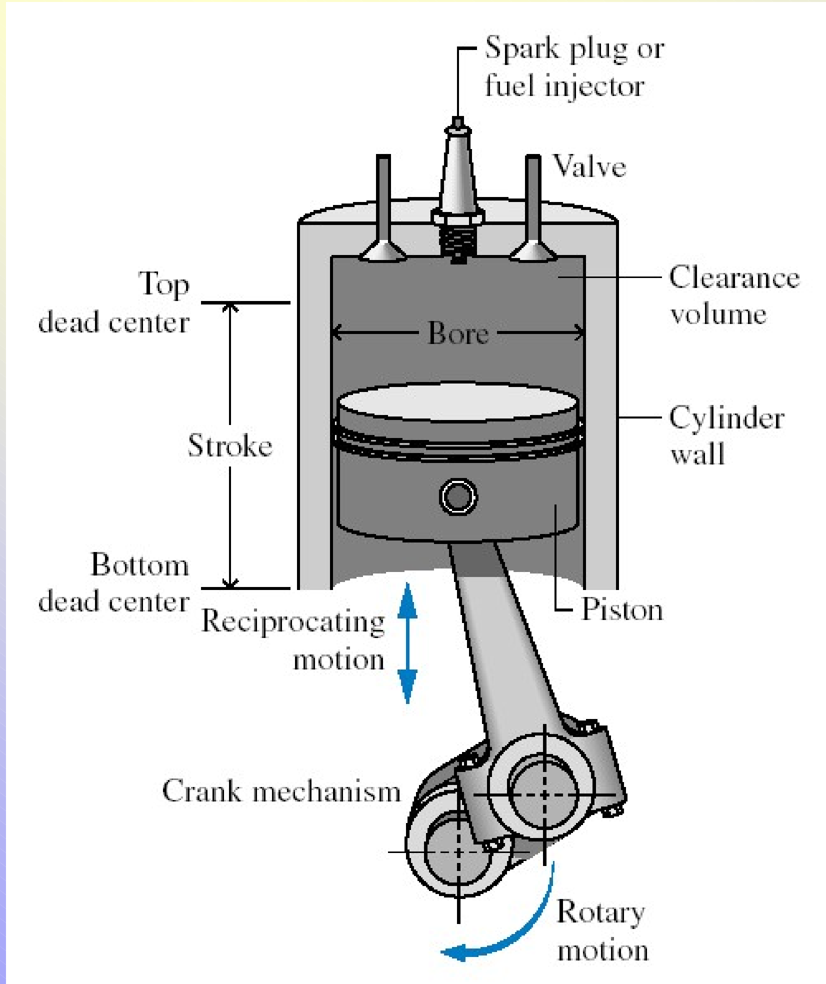
Power Regulation

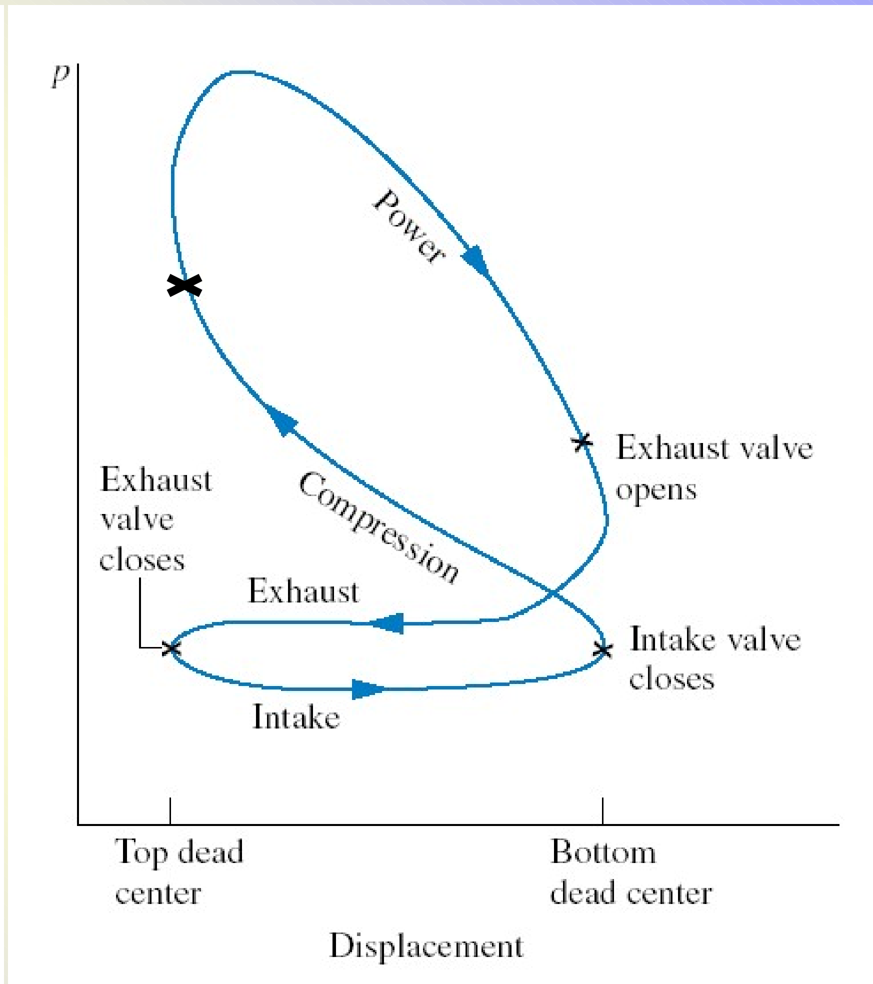
• An IC engine is basically an air engine, the more air you get into the cylinder, the more fuel you can burn, and more the power you get.

• Vary throttle position - Maximum intake pressure (and power) achieved at wide-open-throttle (WOT), and minimum at idle.



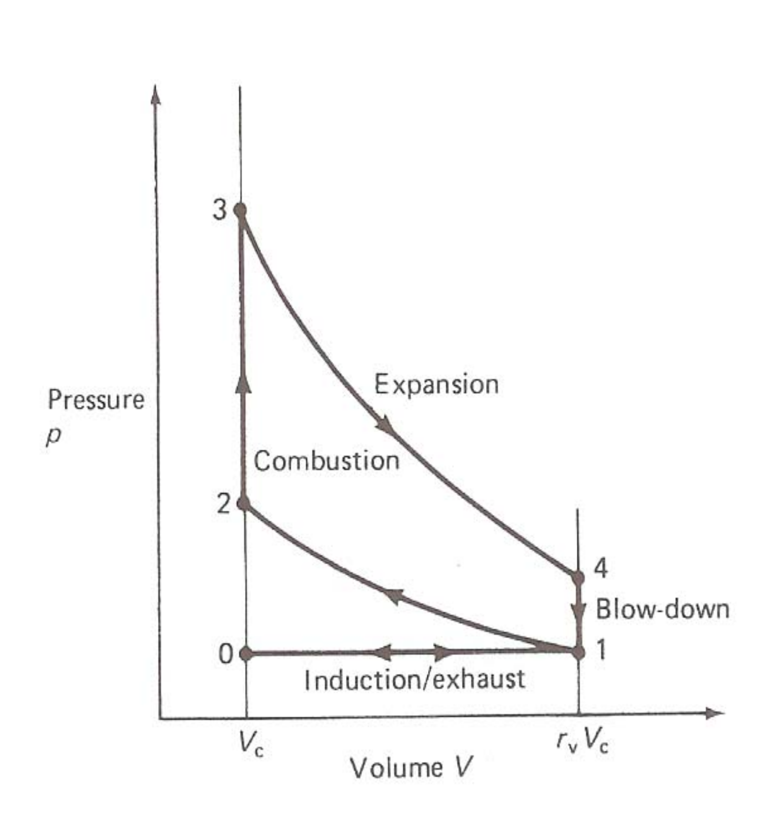
Internal Combustion Engine





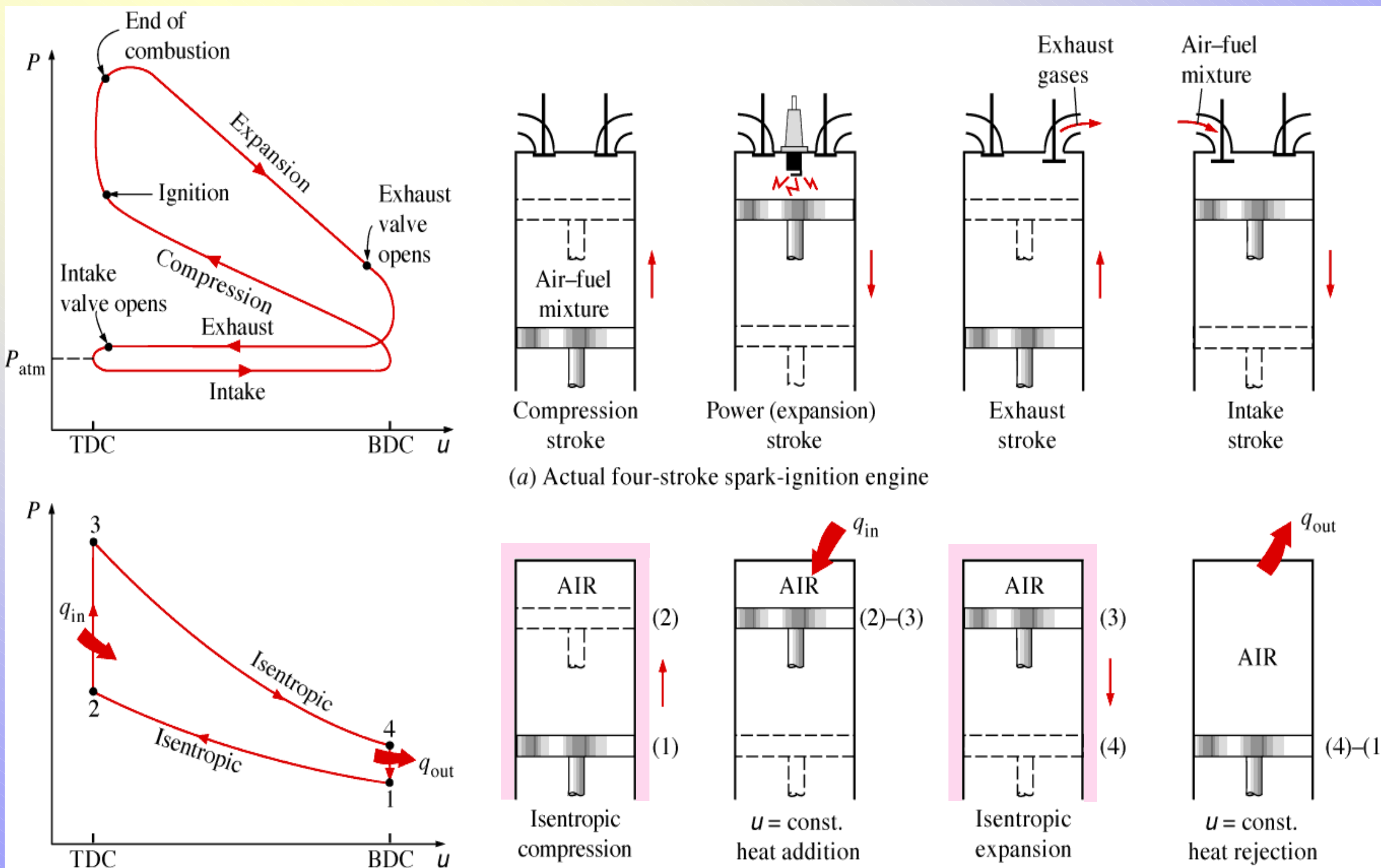
Background on the Otto Cycle

- The Otto Cycle has four basic steps or strokes:
  - An intake stroke that draws a combustible mixture of fuel and air into the cylinder.
  - A compression stroke with the valves closed which raises the temperature of the mixture. A spark ignites the mixture towards the end of this stroke.
  - An expansion or power stroke, resulting from combustion.
  - An Exhaust stroke the pushes the burned contents out of the cylinder.



An idealized representation of the Otto cycle on a PV diagram.

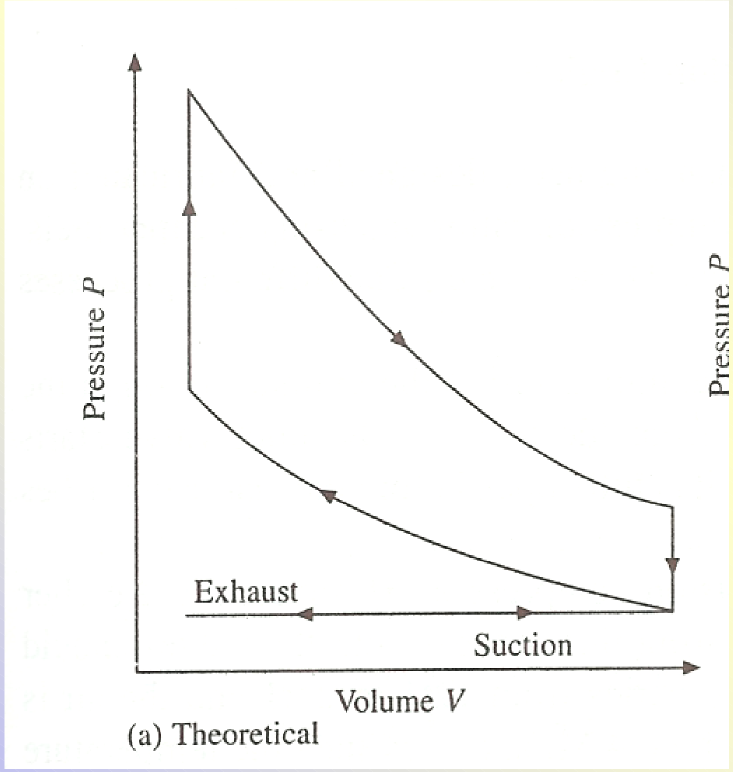
Actual and Ideal Cycles in Spark-Ignition Engines and Their *P*-*v* Diagram

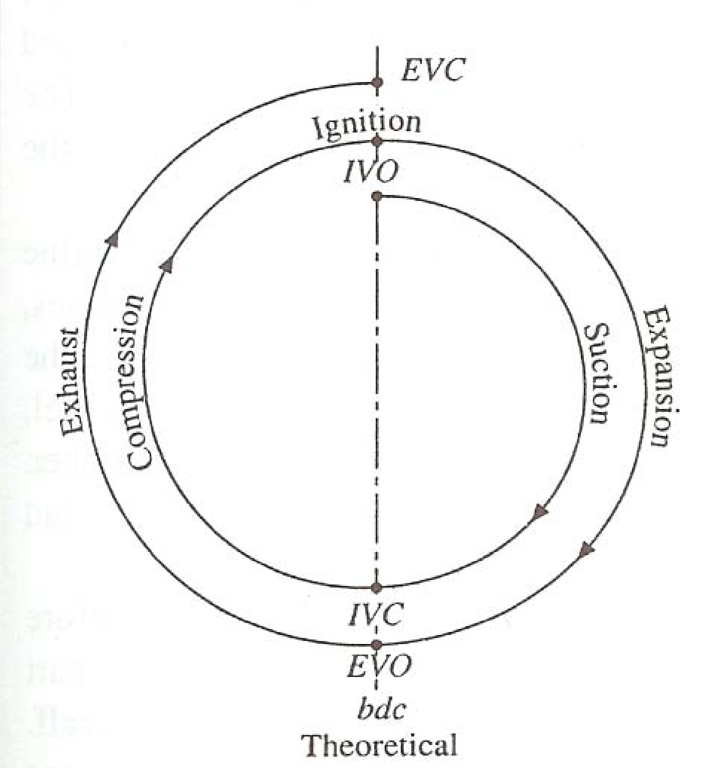


(*a*) Actual four-stroke spark-ignition engine

(*b*) Ideal Otto cycle

Typical Theoretical P-V and Valve Timing Diagrams of a Four-Stroke Spark Ignition Engine





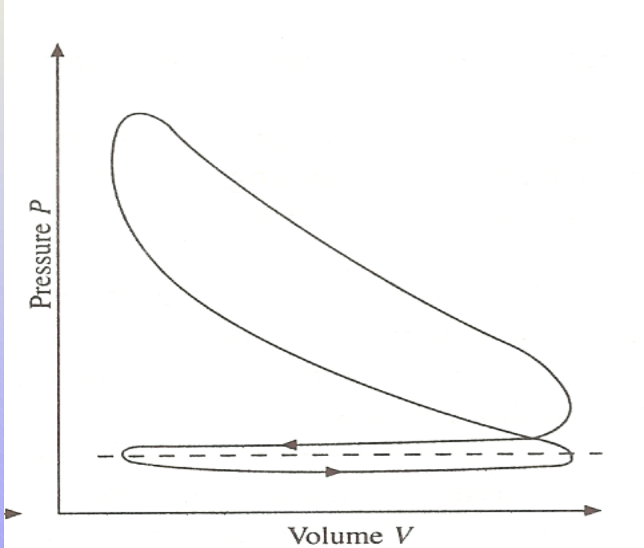
Observations:

- ***P-V diagram shows sharp edges***
  i.e., valves open/close instantaneously at dead centres

Actual Case:

- ❑ ***IV and EV open/close before and after dead centres***
  - ✓ ***Mechanical Factor***
  - ✓ ***Dynamic Factor of Gas Flow***

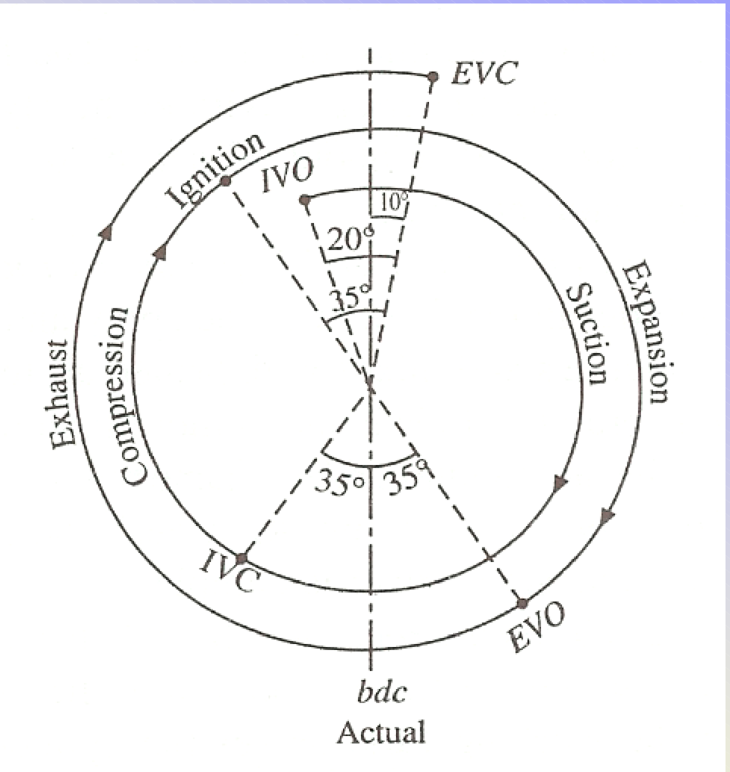
- ✓ ***Valves are opened and closed by cam mechanism***
- ✓ ***Valves will bounce on its seat if closed abruptly***
- ✓ ***Opening/closing of valves spread over a certain crank angle***



(b) Actual

❑ ***Every Corner in the P-V diagram is ROUNDED***

- IV opens 20^0 before TDC.
- IV closes 35^0 after BDC to take the advantage of momentum of rapidly moving gases (Ram Effect).
- Ignition occurs 35^0 before TDC; this is to allow the time delay between the spark and commencement of combustion.
- EV opens at 35^0 before BDC; else pressure will rise enormously, and the work required to expel the gas will increase.
- EV closes at 10^0 after TDC; this is to increase the volumetric efficiency.



Actual Valve Timing Diagram of a Four-Stroke Spark Ignition Engine

Remark

Valve Overlap: ***The time during which both the valves (inlet and exhaust) remain open at the same instant.***

The values quoted in the actual valve timing diagrams are the typical values, and may vary from engine to engine.

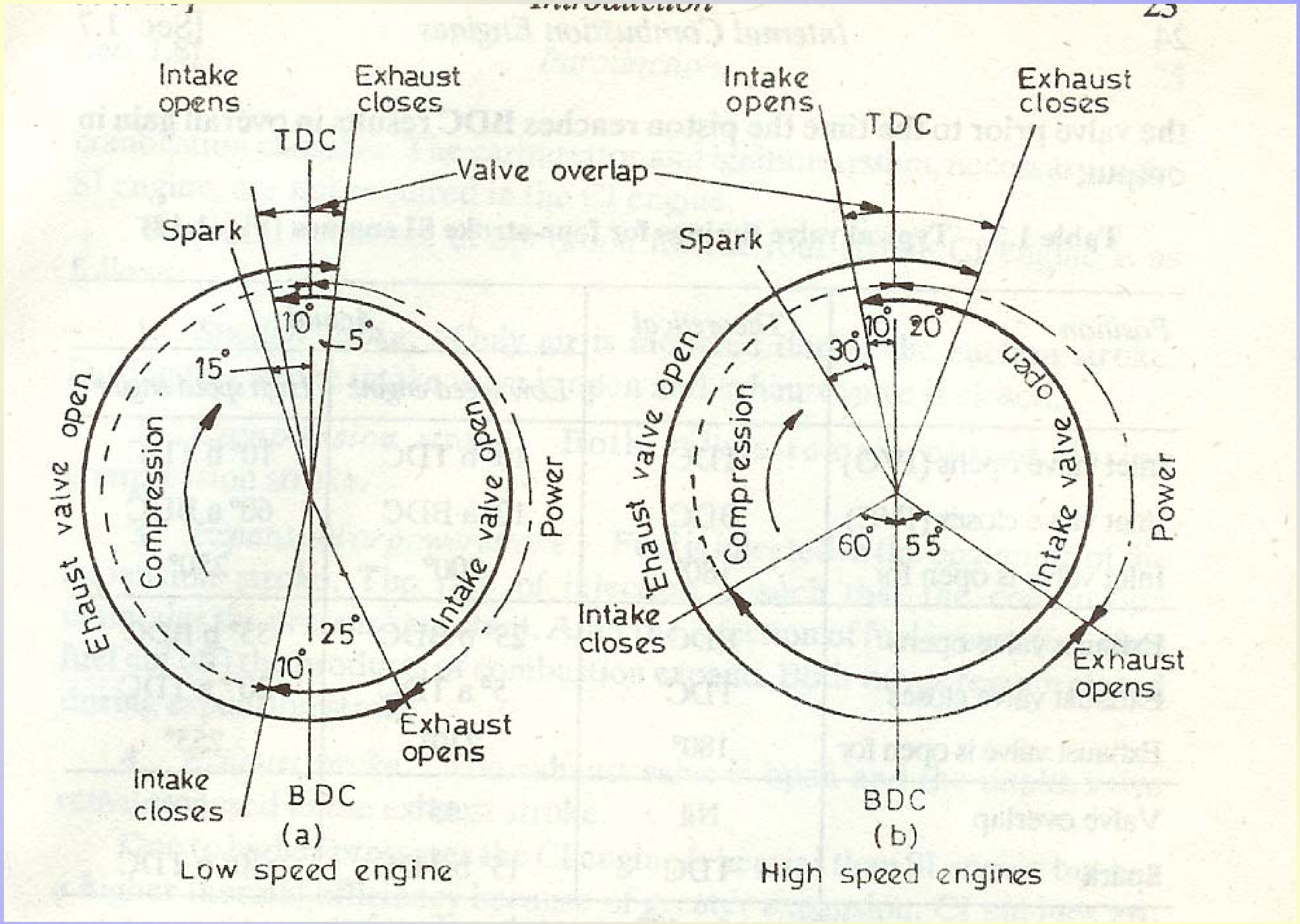
For HIGH SPEED engines, higher values of angles are desirable to take into account the short time interval.

Explanation

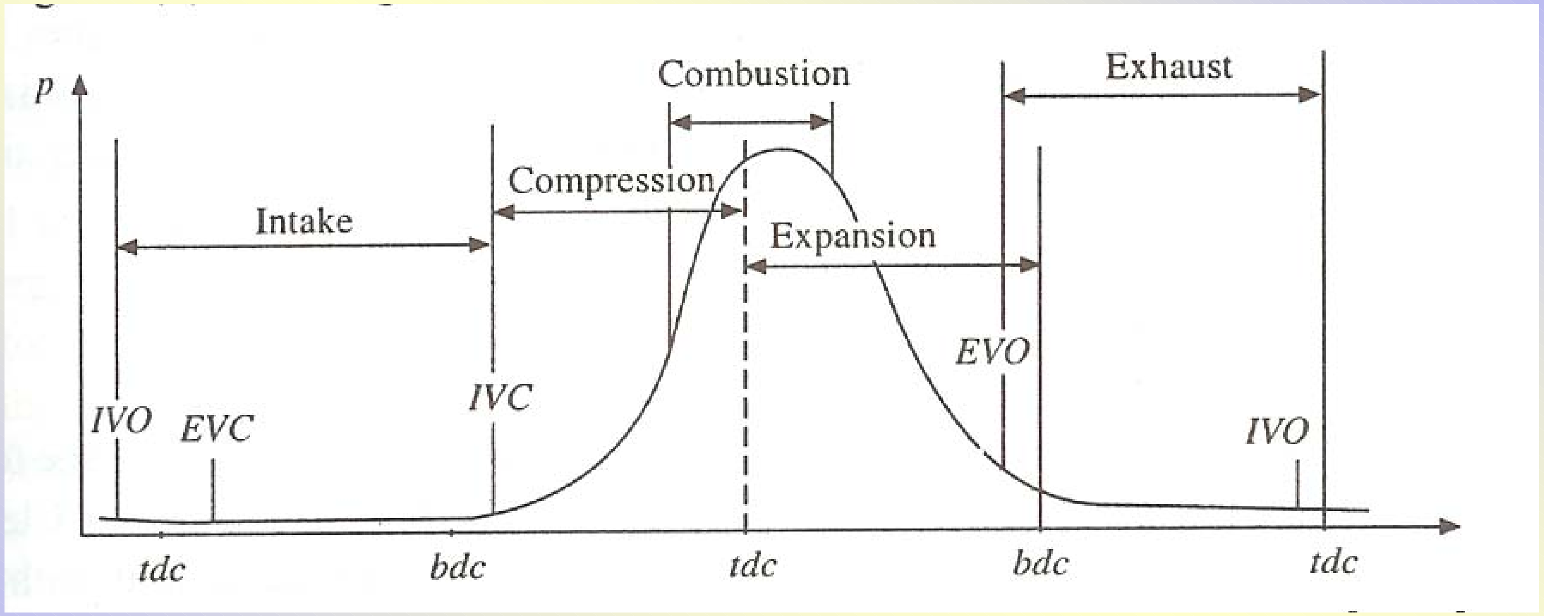
The IV opens before TDC and closes after BDC. This is arranged so as to get maximum charge inside the cylinder. When the IV opens, the charge outside the valve has to be accelerated upto the inlet velocity, and this takes time. In order that maximum inlet velocity occurs at the earliest possible moment during the intake stroke, the IV is opened early. The kinetic energy of the moving charge is used at the end of the intake stroke to produce a ramming effect by closing the IV slightly after BDC. The ramming effect thus increases the volumetric efficiency.

Explanation – Contd.

The EV opens before BDC so as to exhaust the combustion products efficiently. Thus, by virtue of its excess pressure above atmosphere, some exhaust gas leaves the cylinder. This makes the exhaust gas to flow freely from the cylinder by the time piston commences the exhaust stroke. Again, by closing the EV after TDC, the kinetic energy of the exhaust gas can be utilized to assist in maximum exhausting of the gas. In the process, the IV begins to open before the EV closes – and this is called valve overlap.



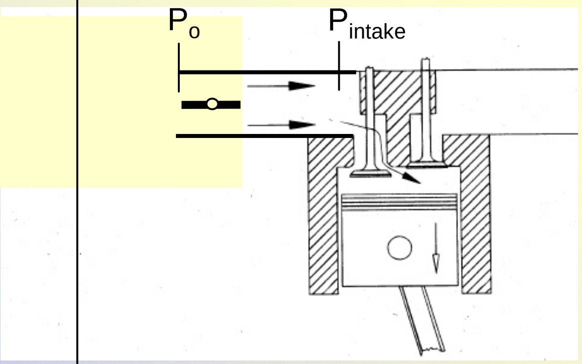
Valve Timing for Low and High Speed Four-Stroke Spark Ignition Engines

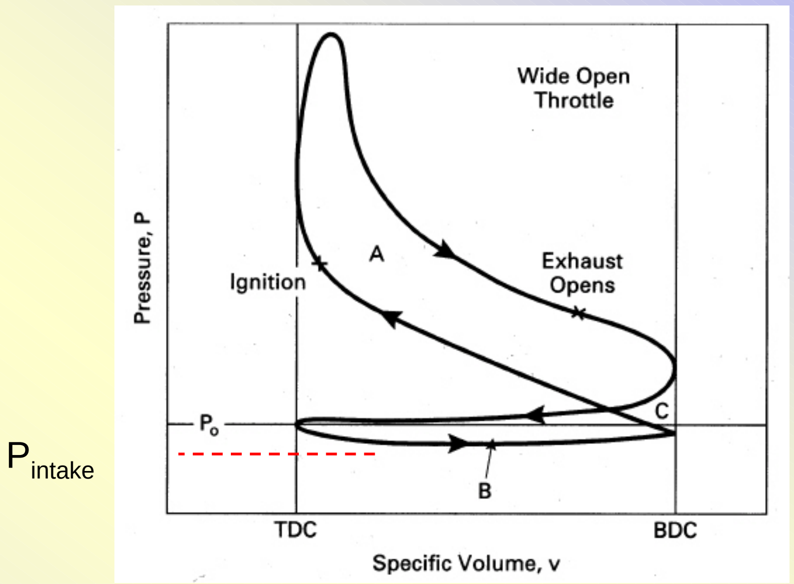


Sequence of Events in a Four-Stroke Spark Ignition Engine – Pressure vs. Crank Angle

p-V diagram of a Four Stroke SI Engine at WOT

The pressure at the intake port is just below atmospheric pressure

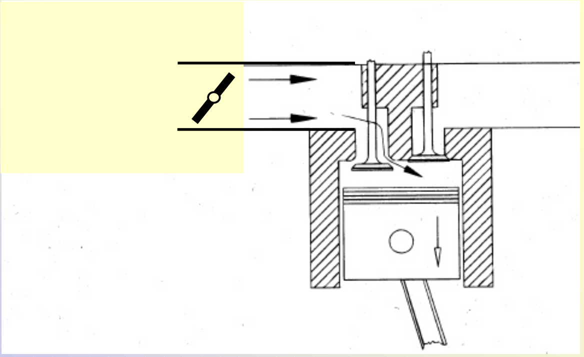


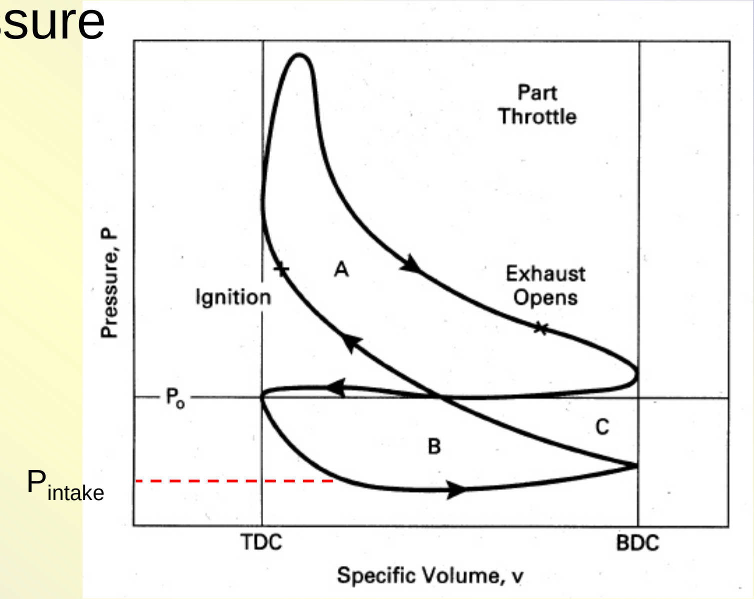


The upper loop consists of compression and power strokes and the area represents positive indicated work. The lower loop indicates negative work of the intake and exhaust stroke. This is called indicated pumping work.

p-V diagram of a Four Stroke SI Engine at Part-Throttle

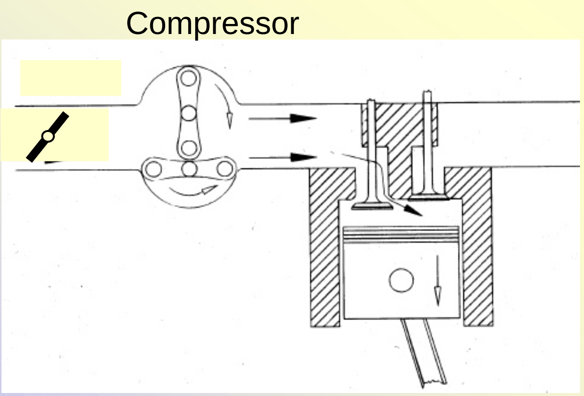
The pressure at the intake port is significantly lower than atmospheric pressure

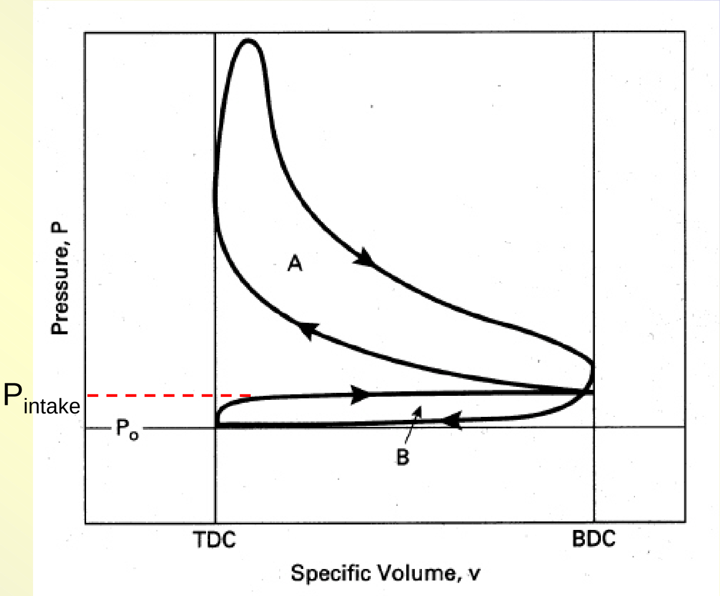




The upper loop consists of compression and power strokes and the area represents positive indicated work. **The lower loop indicates negative work of the intake and exhaust strokes. This is called indicated pumping work.**

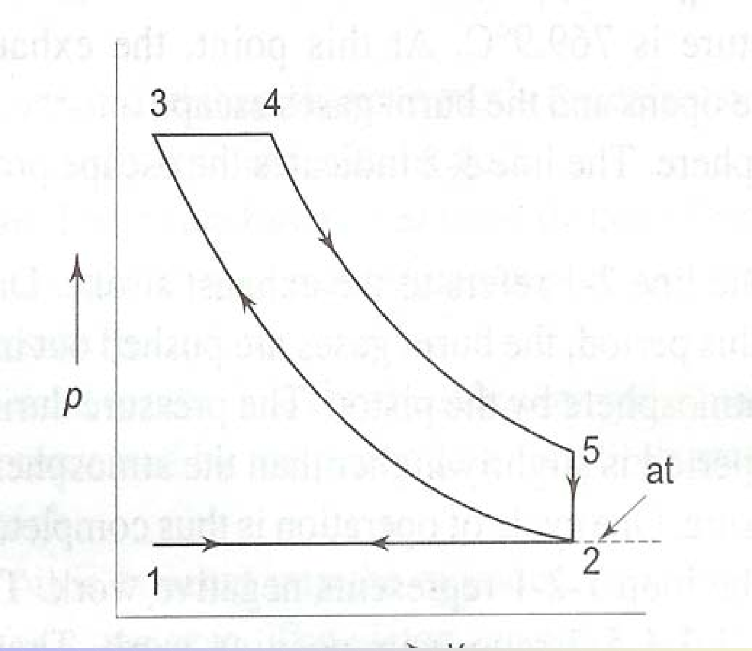
p-V diagram of a Four Stroke SI Engine with Supercharger

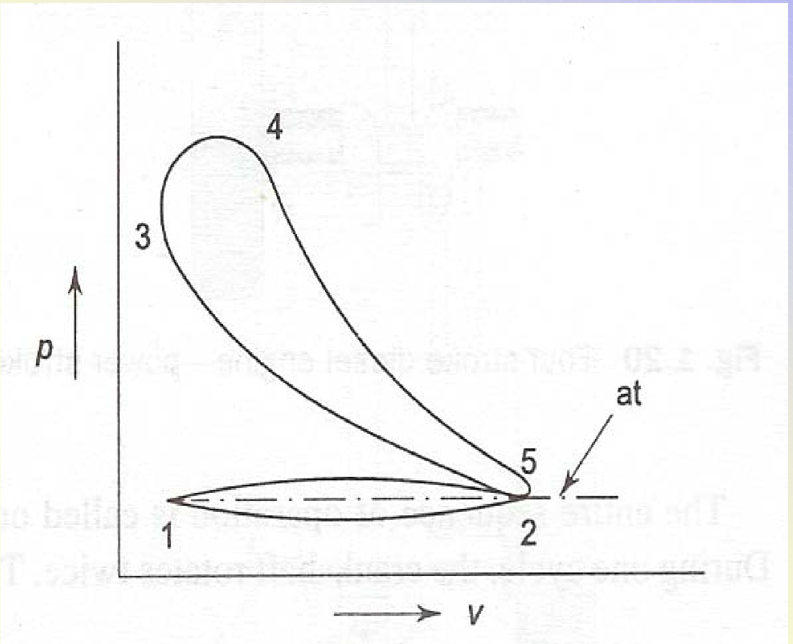




The engines with superchargers or turbochargers have intake pressures greater than the exhaust pressure, yielding a positive pump work.

Typical Theoretical and Actual p-V Diagrams of a Four-Stroke Compression Ignition Engine

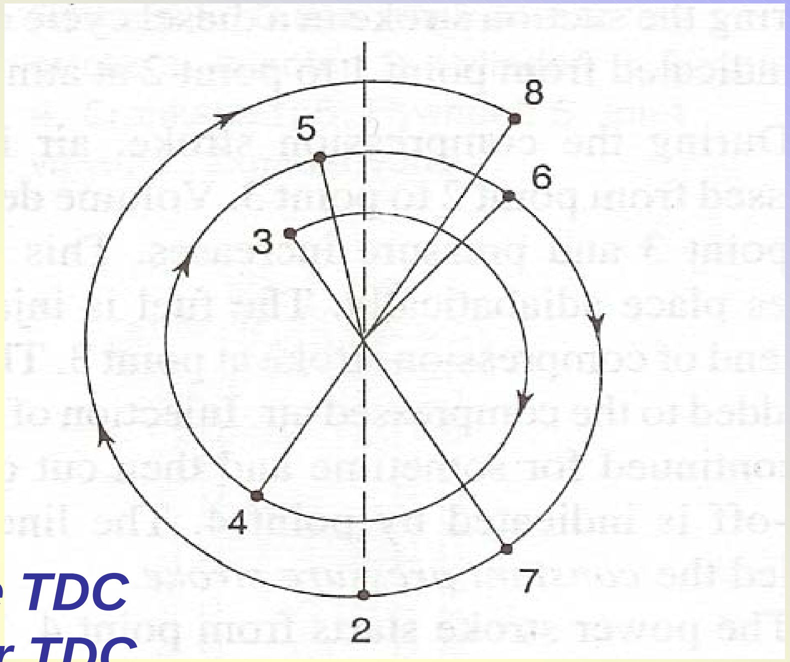




Actual Valve Timing Diagram of a Four-Stroke Compression Ignition Engine

1. TDC
2. BDC

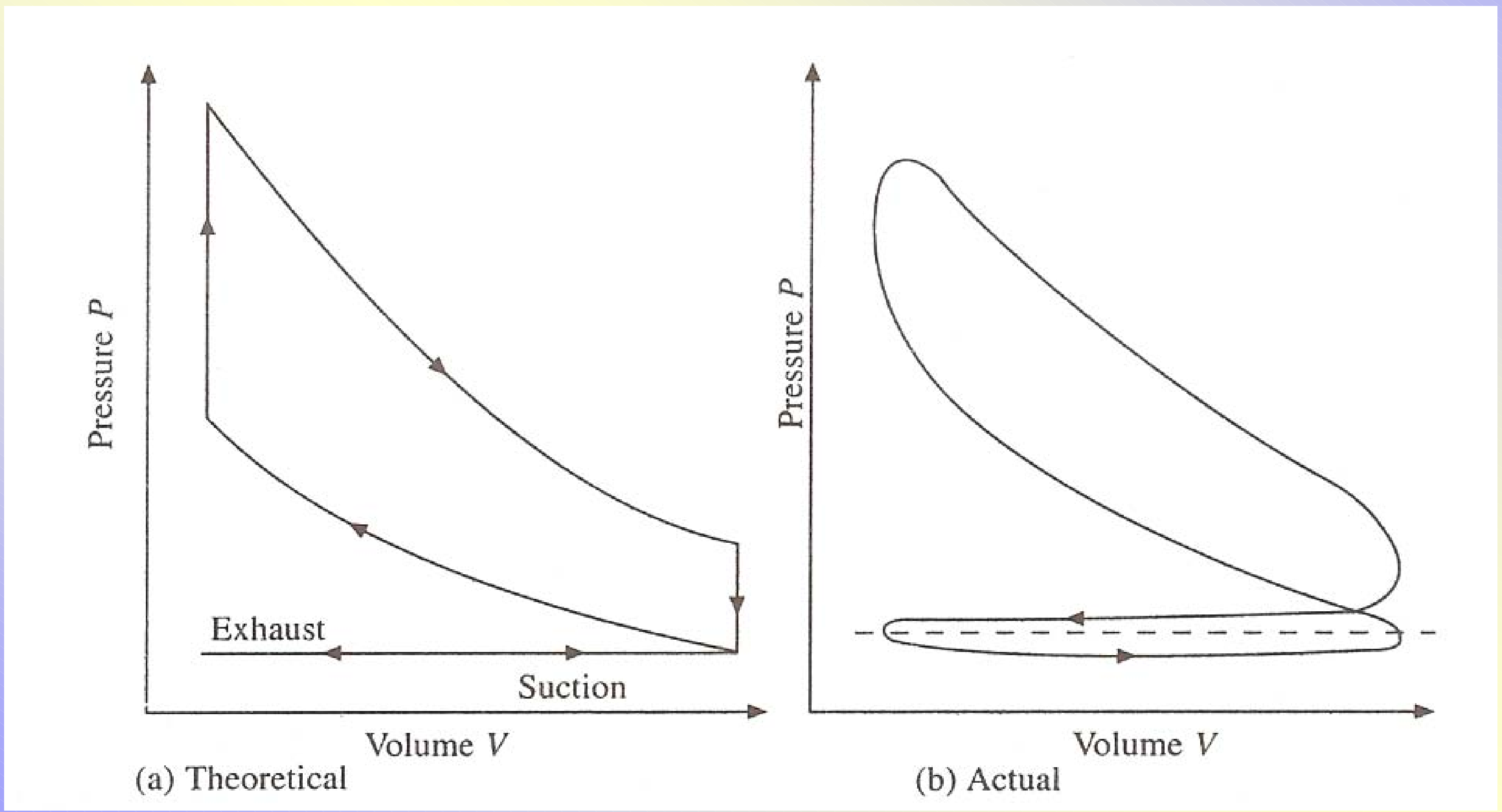
3. IV opens at 25^0 before TDC
4. IV closes at 30^0 after BDC



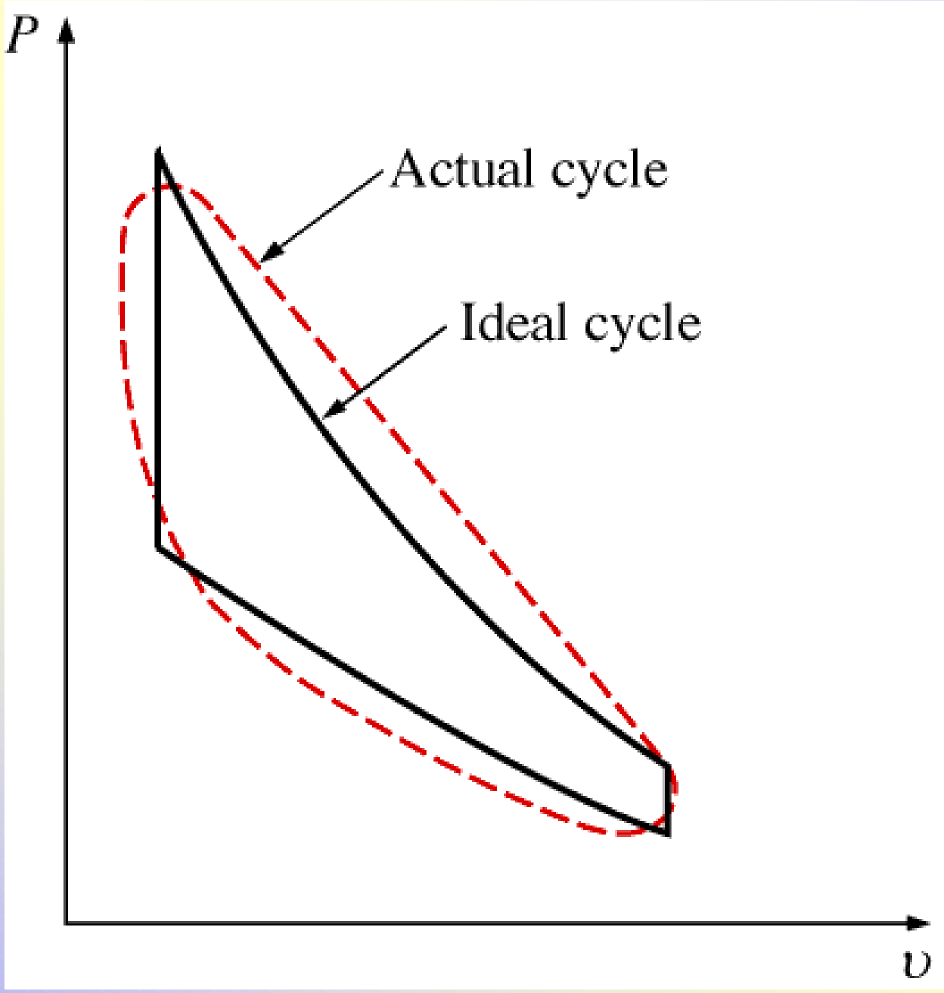
5. Fuel injection starts at 5^0 before TDC
6. Fuel injection closes at 25^0 after TDC

7. EV opens at 45^0 before BDC
8. EV closes at 15^0 after TDC

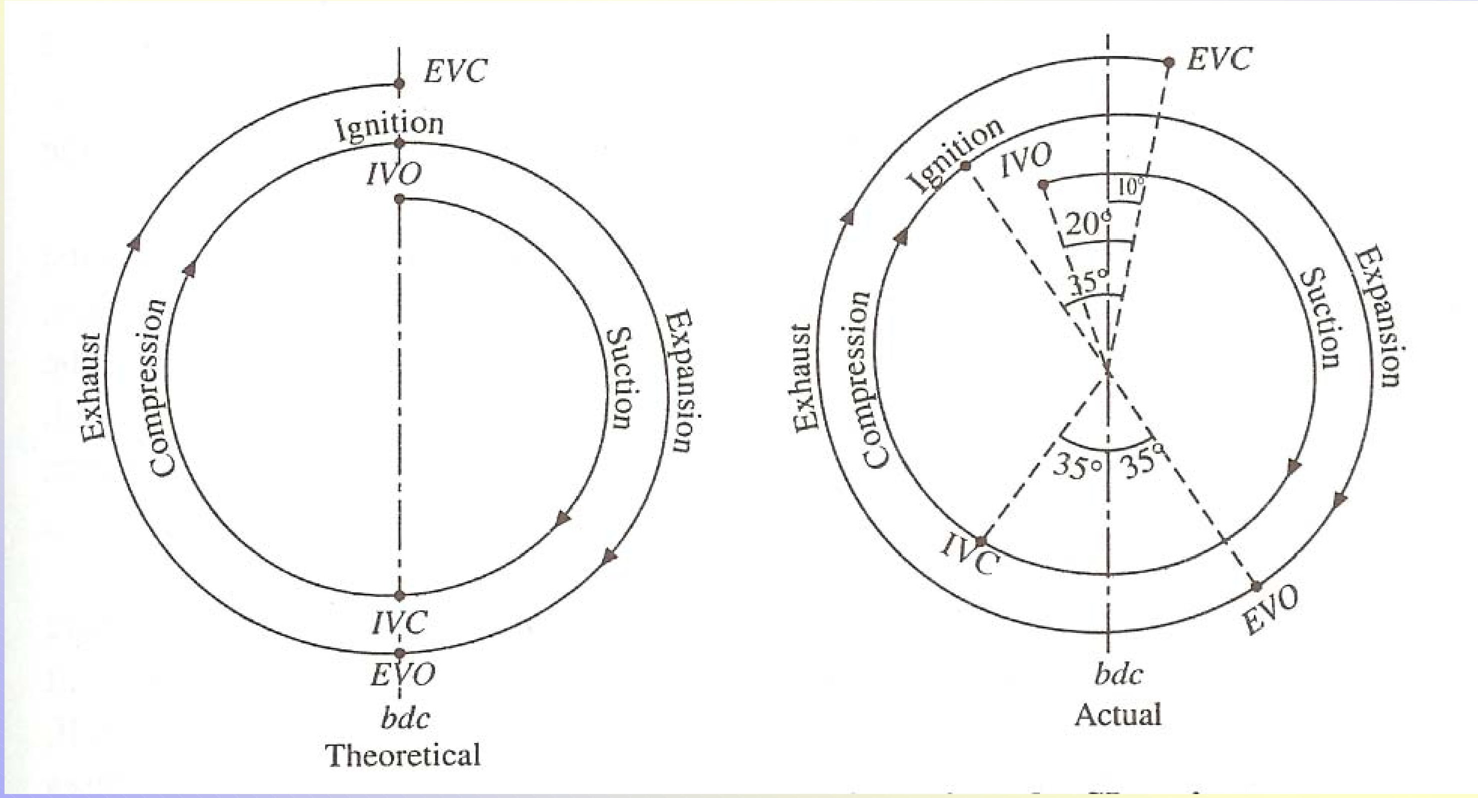
Summary – Ideal and Actual p-V Diagram of a Four Stroke SI Engine



Real vs. Ideal – 4 Stroke SI Engine



Summary – Ideal and Actual Valve Timing Diagram of a Four Stroke SI Engine



Valve Timing – 4 Stroke SI Engine

Valve timing angles:

		Open	Close	Duration
Intake	Conventional	5° before tdc	45° after bdc	230°
	High performance	30° before tdc	75° after bdc	285°
Exhaust	Conventional	45° before bdc	10° after tdc	235°
	High performance	70° before bdc	35° after tdc	285°

Conventional engines operate at low rpms, with idle and part load important
High performance engines operate at high rpms at WOT, with power and volumetric efficiency important

At high engine speeds, less time available for fresh gas intake so need more crank angles to get high volumetric efficiency → large valve overlap

At low engine speed and part throttle valve overlap is minimized by reducing the angle duration for valves staying open.

Variable Valve Timing used to obtain optimum performance over wide range

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Web Resources

1. http://www.mne.psu.edu/simpson/courses
2. http://me.queensu.ca/courses
3. http://www.eng.fsu.edu
4. http://www.personal.utulsa.edu
5. http://www.glenroseffa.org/
6. http://www.howstuffworks.com
7. http://www.me.psu.edu
8. http://www.uic.edu/classes/me/ me429/lecture-air-cyc-web%5B1%5D.ppt
9. http://www.osti.gov/fcvt/HETE2004/Stable.pdf
10. http://www.rmi.org/sitepages/pid457.php
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