Combustion Chamber Design

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Topics

- Combustion Chamber Defined
- Design Considerations
- Chamber Shapes
- Fast Combustion
- Volumetric Efficiency
- Heat Transfer
- Low Octane Requirement
- Knock
- Flow Inside A Cylinder
- Turbulence

Combustion Chamber Defined

- The combustion chamber consists of an upper and lower half.
  - Upper half- Made up of cylinder head and cylinder wall.
  - Lower half- Made up of piston head (Crown) and piston rings.

Design Considerations

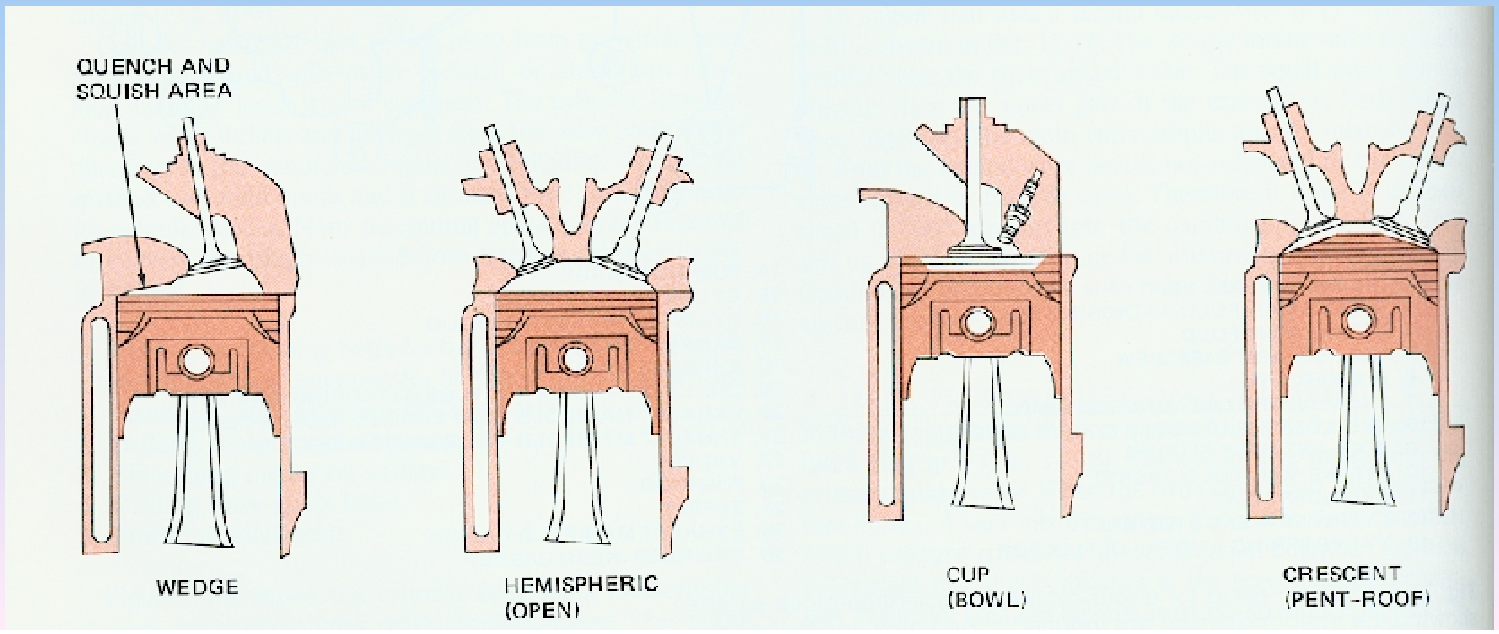
- Minimal flame travel
- The exhaust valve and spark plug should be close together
- Sufficient turbulence

Design Considerations

- A fast combustion, low variability
- High volumetric efficiency at WOT
- Minimum heat loss to combustion walls
- Low fuel octane requirement

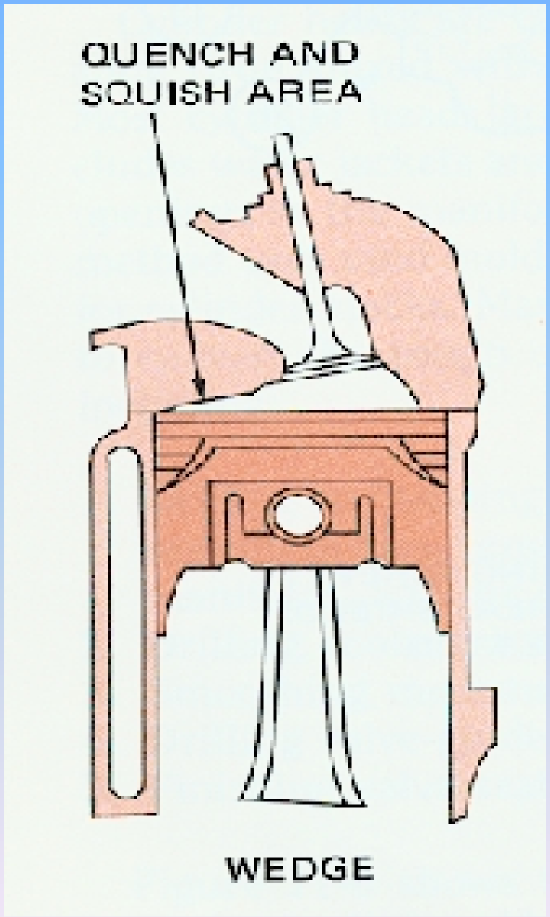
Chamber Shapes

- A basic shapes
  - Wedge
  - Hemispherical
  - Crescent
  - Bowl in Piston



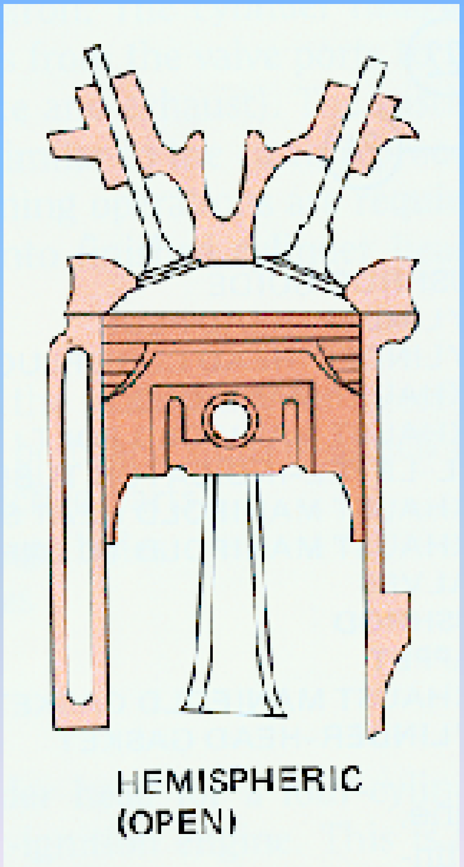
Chamber Shapes

- Wedge
  - Asymmetric design
  - Valves at an angle and off center



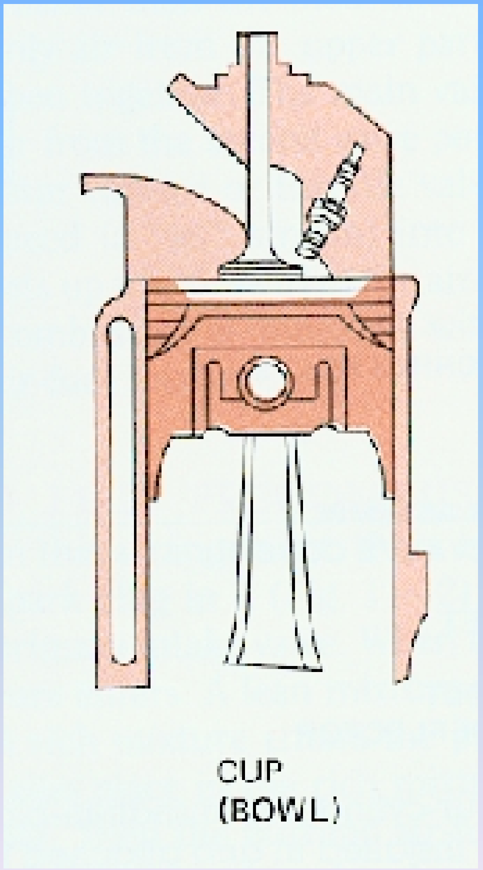
Chamber Shapes

- Hemispherical (Hemi)
  - Symmetric design
  - Valves placed on a arc shaped head



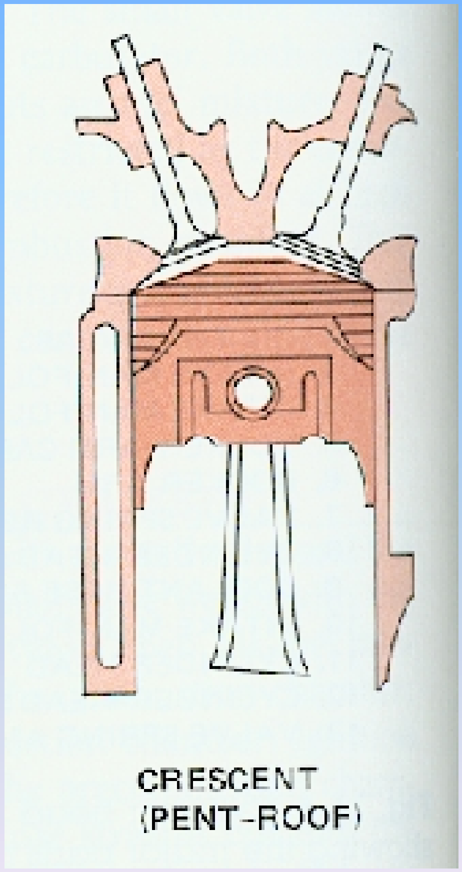
Chamber Shapes

- Bowl-in-Piston
  - Symmetric design
  - Valves are placed perpendicular to head



Chamber Shapes

- Crescent (Pent-Roof)
  - The valves are placed at an angle on flat surfaces of the head



Fast Combustion

- Effect of spark plug location

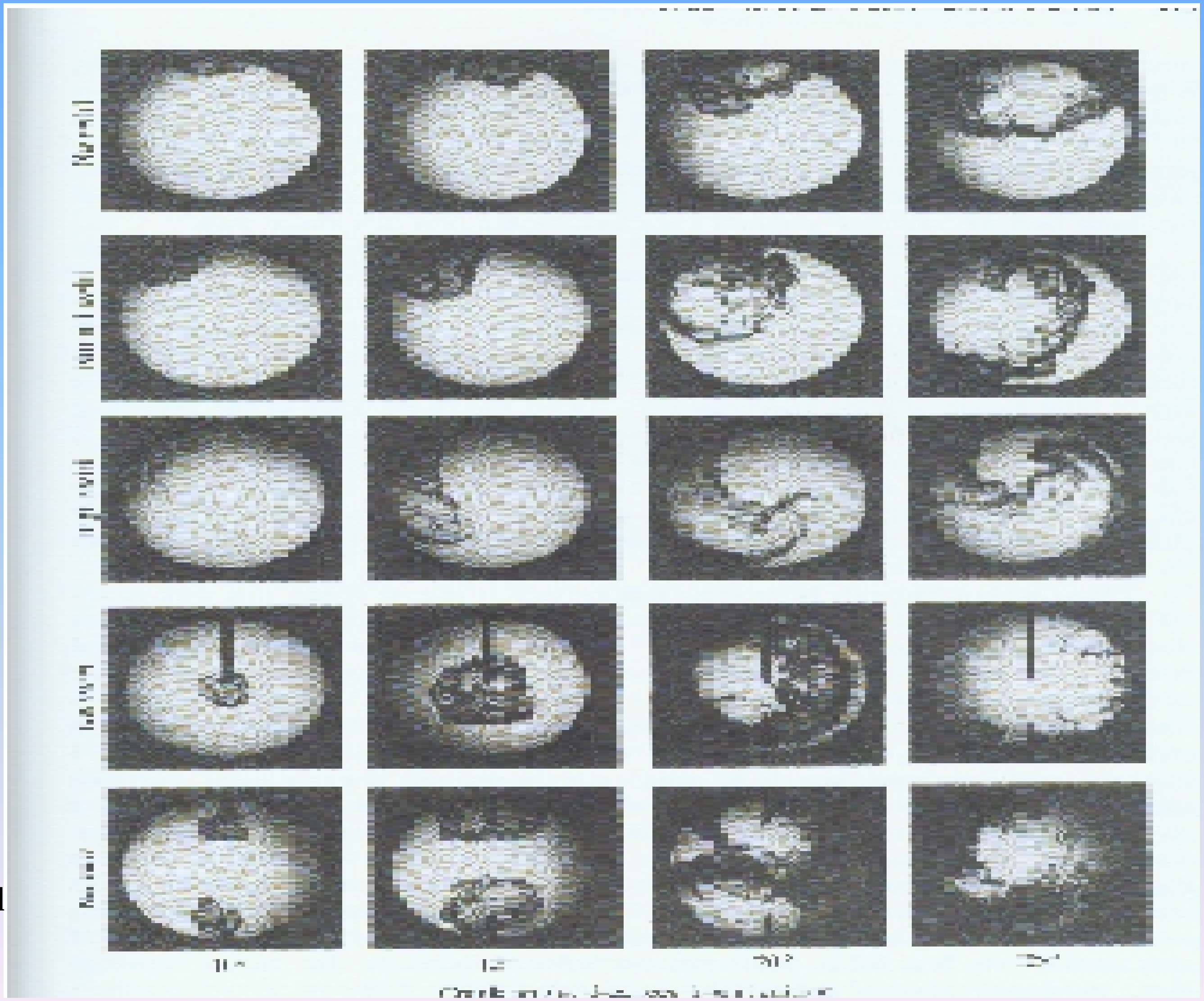
Side plug w/o swirl

Side plug with normal swirl

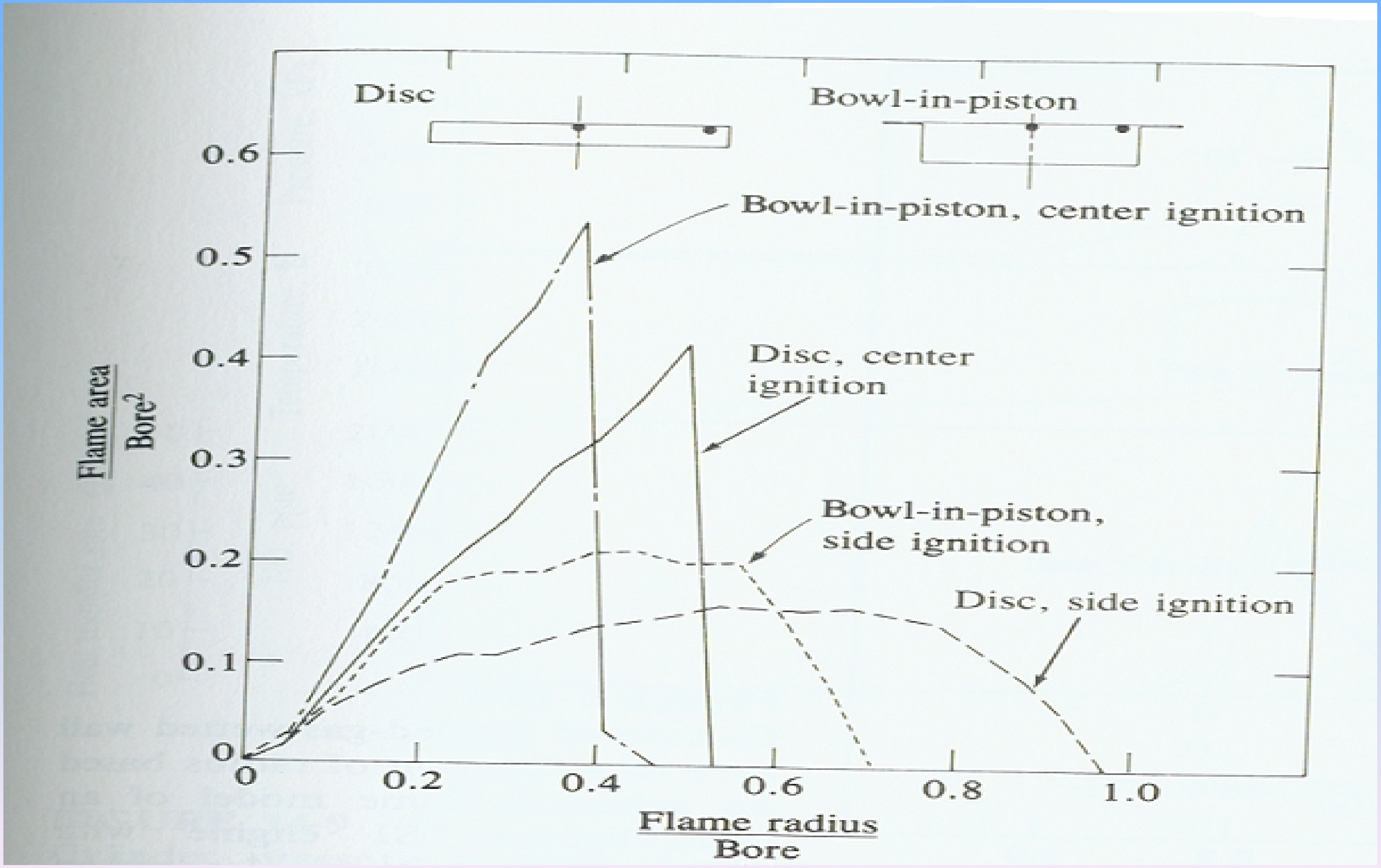
Side plug with high swirl

Central plug w/o swirl

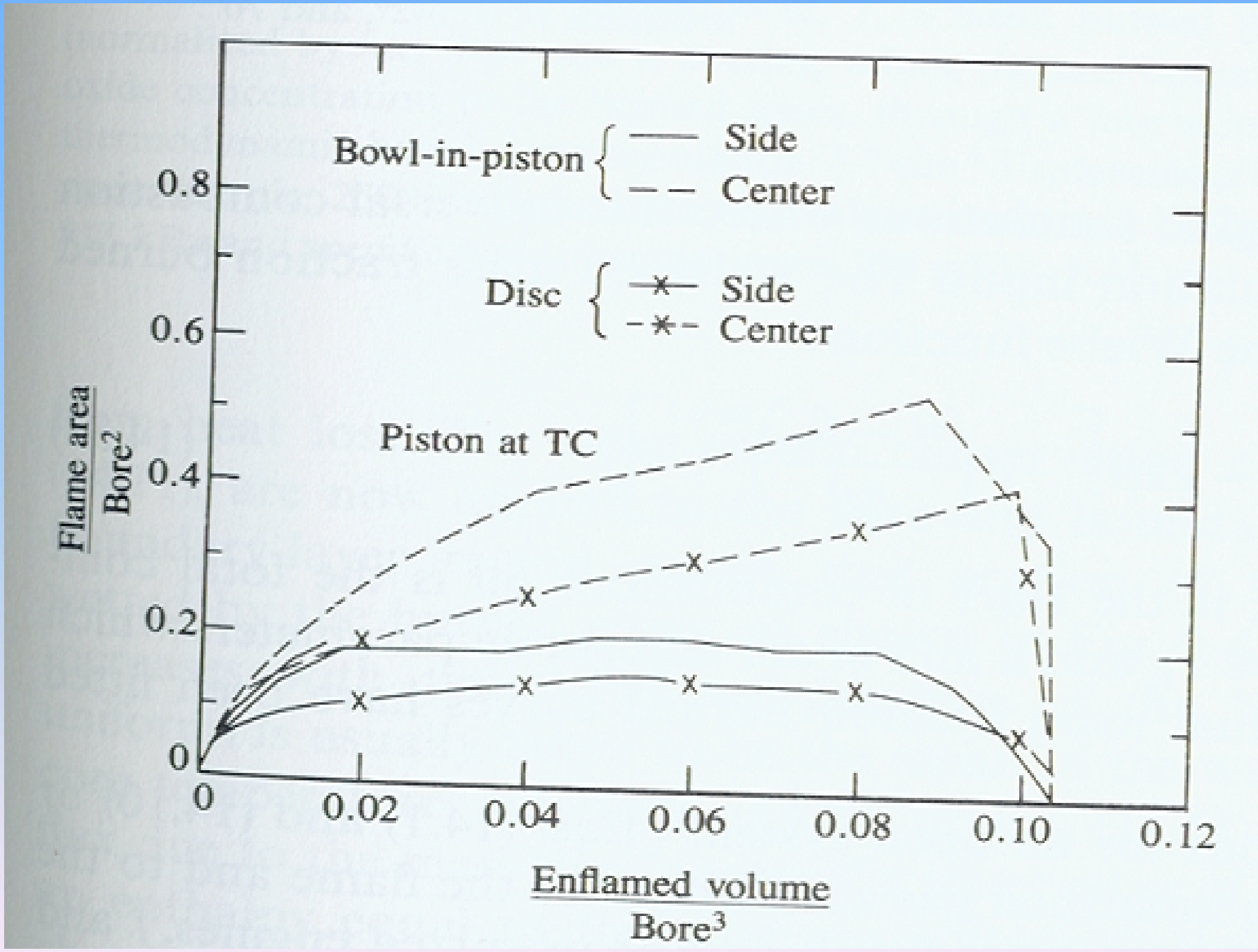
Two plugs w/o swirl



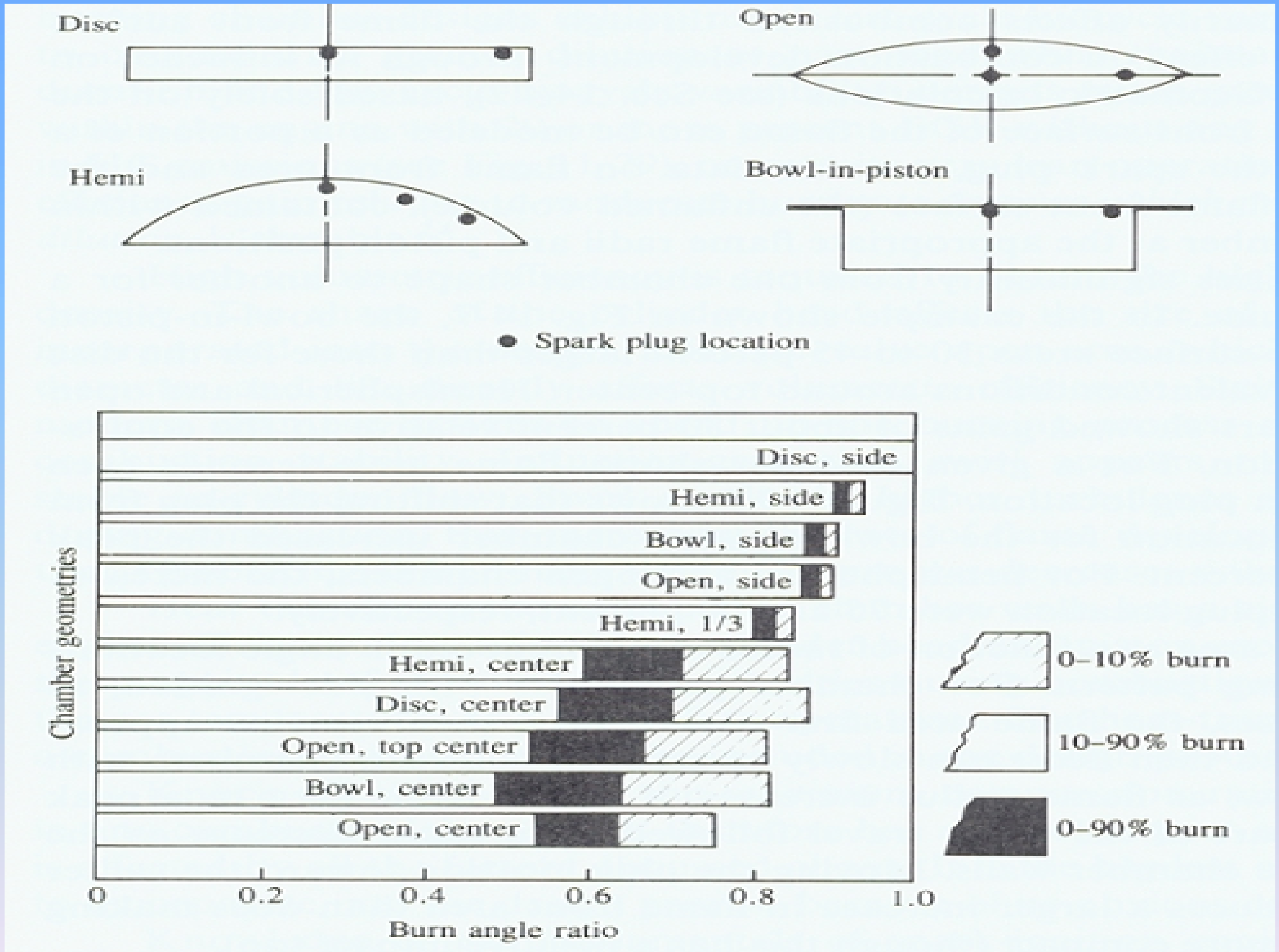
Fast Combustion in Relation to Shape



Fast Combustion in Relation to Shape



Comparison of Burn Angles



Volumetric Efficiency

- Size of valve heads should be as large as possible
- Want swirl produced

Heat Transfer

- Want minimum heat transfer to combustion chamber walls
- Open and hemispherical have least heat transfer
- Bowl-in-piston has high heat transfer

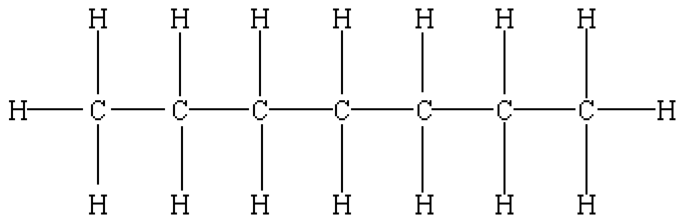
Low Octane

- Octane Requirement related to knock
- Close chambers (bowl-in-piston) have higher knock at high compression ratios than Open chambers (hemispherical and pent-roof)

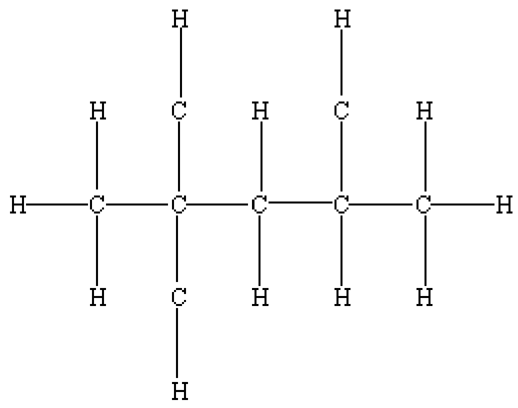
Octane Rating

- Research Octane Number (RON)
- Motor Octane Number (MON)
- Octane is one factor in the combustion process that another group will speak about
- Straight chain C-H bonds such as heptane have weaker C-H bonds than branched chained C-H bonds in branch chained HC such as iso-octane
- Straight bonds are easier to break

Chemical Compositions



n-Heptane



Iso-Octane

Knock

- Surface ignition
  - Caused by mixture igniting as a result of contact with a hot surface, such as an exhaust valve
- Self-Ignition
  - Occurs when temperature and pressure of unburned gas are high enough to cause spontaneous ignition

Flow

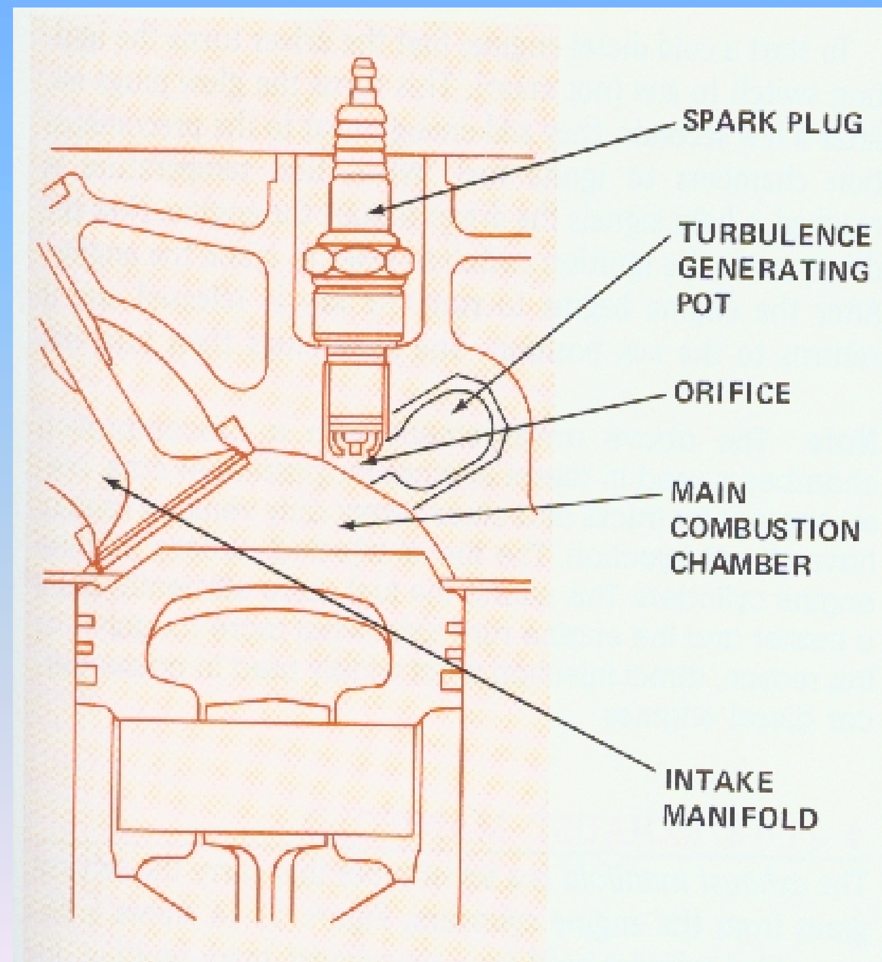
- 2 types of flow
  - Laminar flow
    - Minimal microscopic mixing of adjacent layers
  - Turbulent flow
    - Characterized as a random motion in three-dimensions with vortices (eddies) of varying size superimposed on one another and randomly distributed in the flow

Why Turbulence?

– Decrease burn time
  - Reduces knock
  - Reduces emissions (NO_x)
– Allows for leaner mixture (stratified charge)
  - Reduces emissions (HC)
– Decreases in combustion temperature
  - Reduces knock
  - Reduces emissions (CO)
  - **Reduces power**

Inducing Turbulence

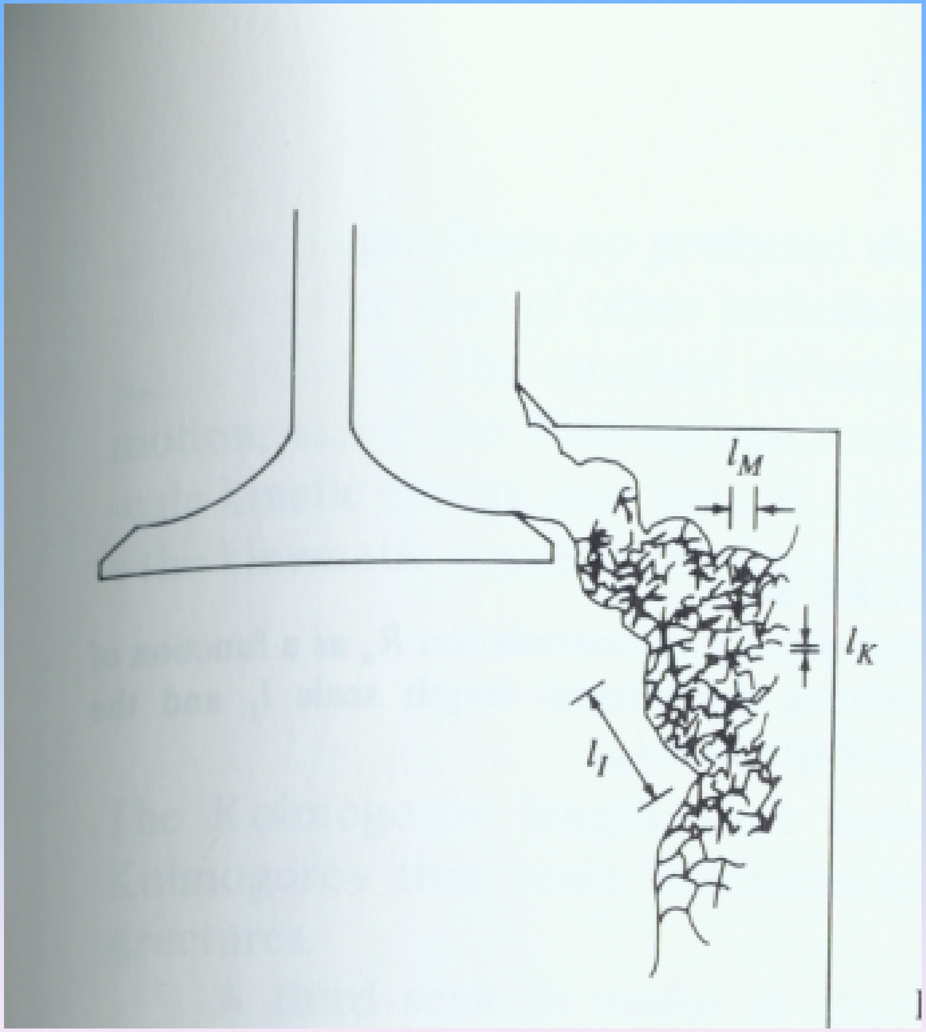
- Valve configuration and valve timing
- Turbulence generation pot



Characterizing Turbulence

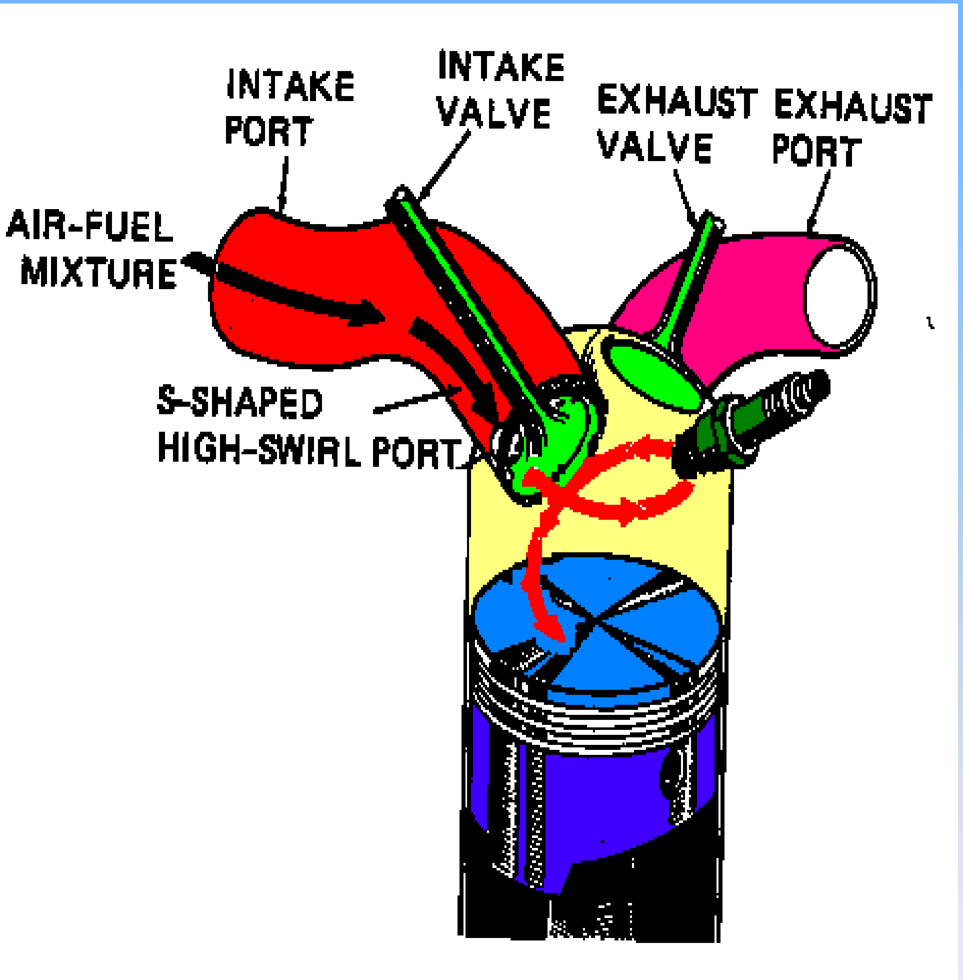
- Eddies are defined by length scales
- The Integral Scale l_I measures the largest eddies of the flow field
- The Kolmogorov scale l_k measures the smallest eddies
- The Taylor microscale l_m relates fluctuating strain rate of flow field to intensity

Characterizing Turbulence



Characterizing Turbulence

- Swirl
  - Axis of rotation is parallel to cylinder
  - Generate swirl about valve axis (inside port)



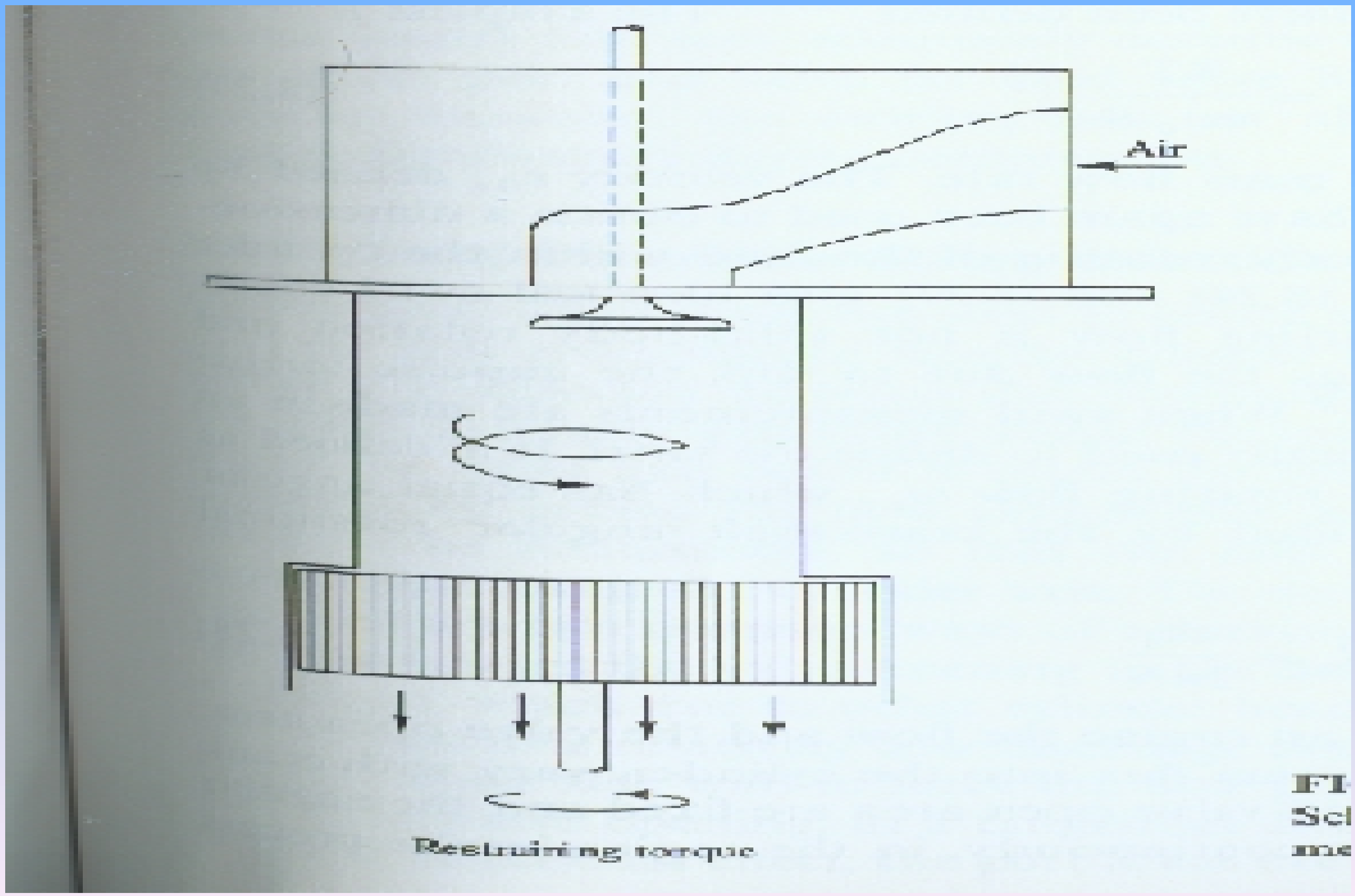
Swirl

- Impulse Swirl Meter
- Honeycomb flow straightener measures total torque exerted by swirling flow.
- A swirling ratio is defined:

$$R_s=\omega_s/2\pi N$$

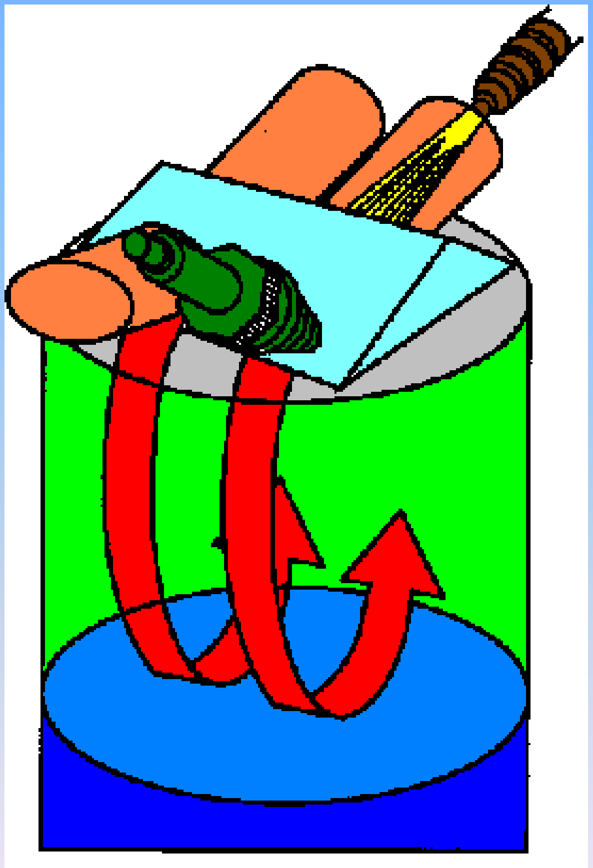
- This ratio is the angular velocity, $\omega_{s,}$ of a solid-body rotating flow (equal to angular momentum of actual flow) divided by the crankshaft angular rotational speed

Swirl



Characterizing Turbulence

- Tumble
  - Axis of rotation is perpendicular to cylinder axis
  - Associated with swirl



Characterizing Turbulence

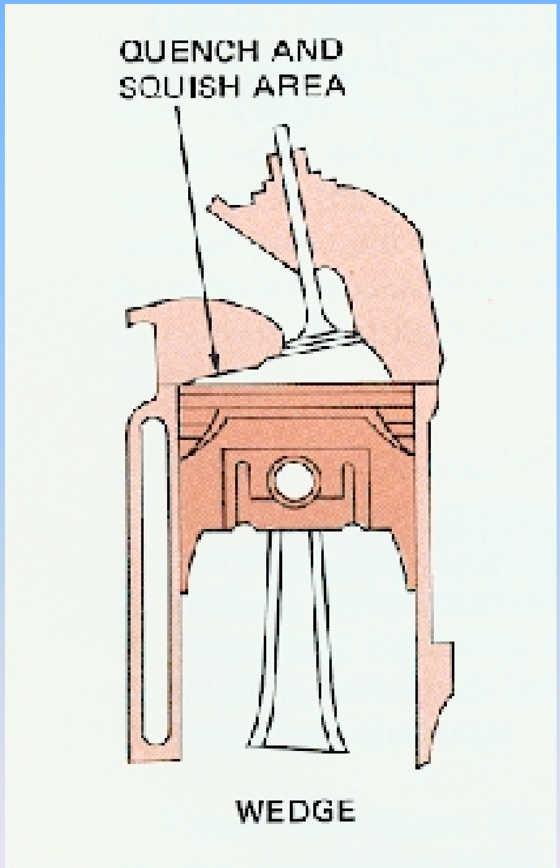
- R_t is the tumble ratio,

$$R_t = \omega_t / 2\pi N$$

- This ratio compares the angular velocity,
- ω_t, of the solid-body rotation with same angular momentum as actual velocity distribution in tumble to angular velocity of the crankshaft (N)

Squish

- Radially inward gas motion that occurs toward end of compression stroke



Conclusion

- Optimum chamber
  - Central spark plug location
  - Minimum heat transfer
  - Low octane requirement
  - High turbulence