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PRIFYSGOL FETROPOLITAN ABERTAWE

Advanced Engine Technology

Valves and Air Flow

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Contents

- Introduction
- Measuring Air Flow
- Discharge Coefficient
- Valve flow patterns
- Multi valve cylinder heads
- Case Studies

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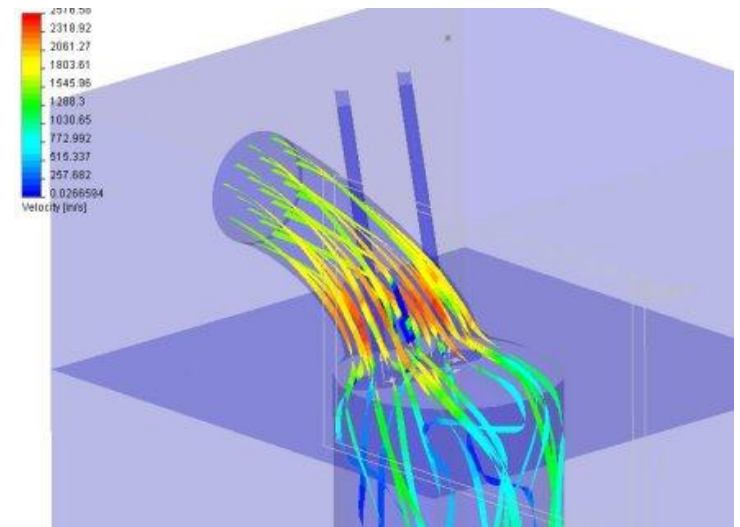
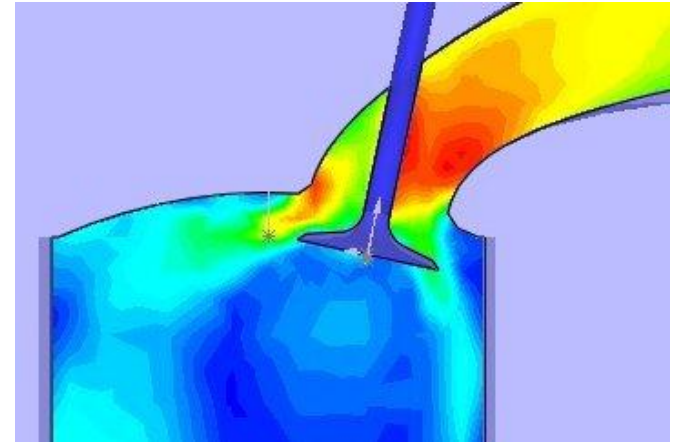
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Introduction

- The valves get in the way of air flow!!!
- We cannot eliminate them
- However we can study and attempt to improve the air flow past a valve
- Inlet and exhaust valves are of the “poppet valve” type
- Here we will consider the basic flow patterns around a poppet valve



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- **Measuring Air Flow**
- Discharge Coefficient
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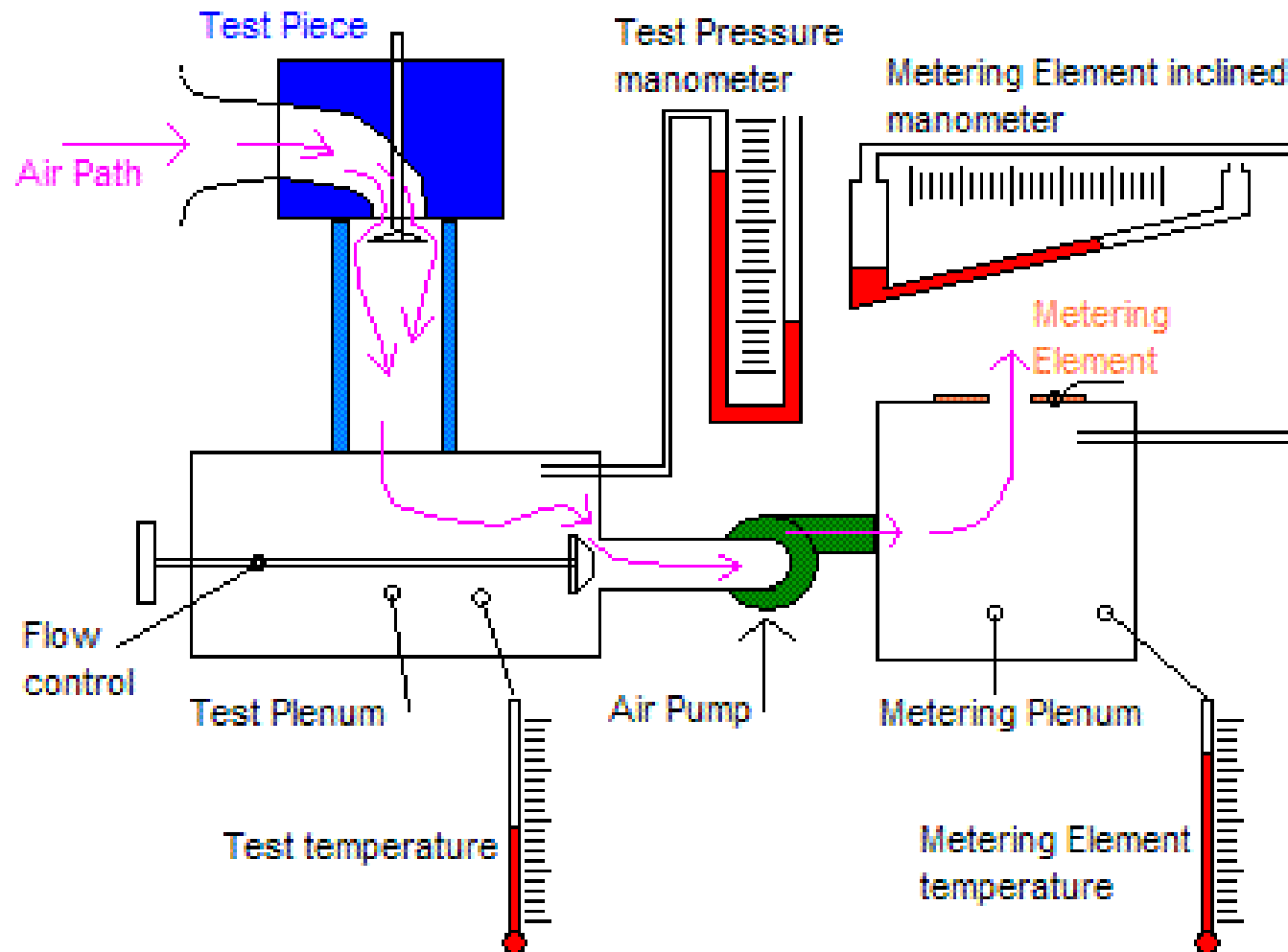
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Measuring Air Flow

- To measure the flow of air through a cylinder head requires a measure of flow at a certain pressure drop, for the range of valve lift
- This is done using a **flow bench**
 - Can be used to test the flow properties of all components (e.g. Air filters, manifolds etc) where gas flows
 - One of the primary tools of engine builders and head porters
 - Allows quantifiable measurements to be made to assess the benefits (or otherwise) of head modifications
 - Also valuable for measuring flow coefficients (see later) for input into engine simulation models

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Measuring Air Flow



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Measuring Air Flow

- Cylinder head is attached to flow bench using a cylinder sleeve to simulate the effects of the cylinder on flow through the valve
- Air is driven through by a pump
- The test pressure manometer measures the pressure drop across the cylinder head
- Flow rate is measured using the metering element
 - This is typically an orifice plate
 - Calibrated plate where the relationship between flow *through* the orifice and pressure drop *across* it is known

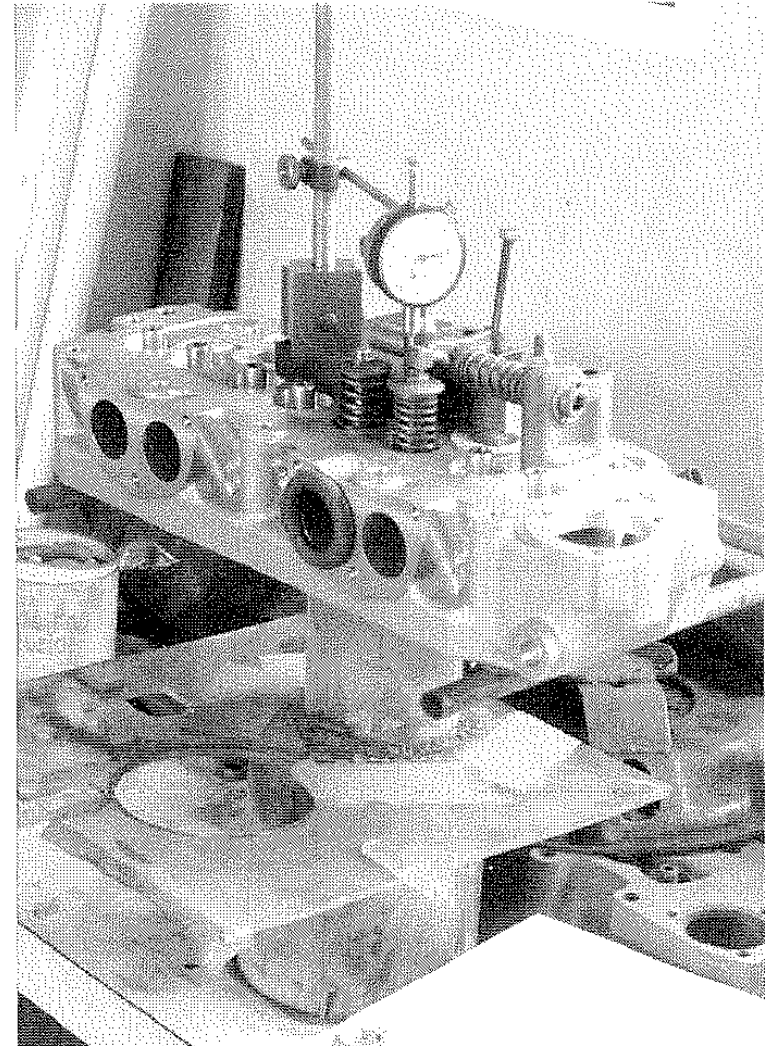
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Measuring Air Flow



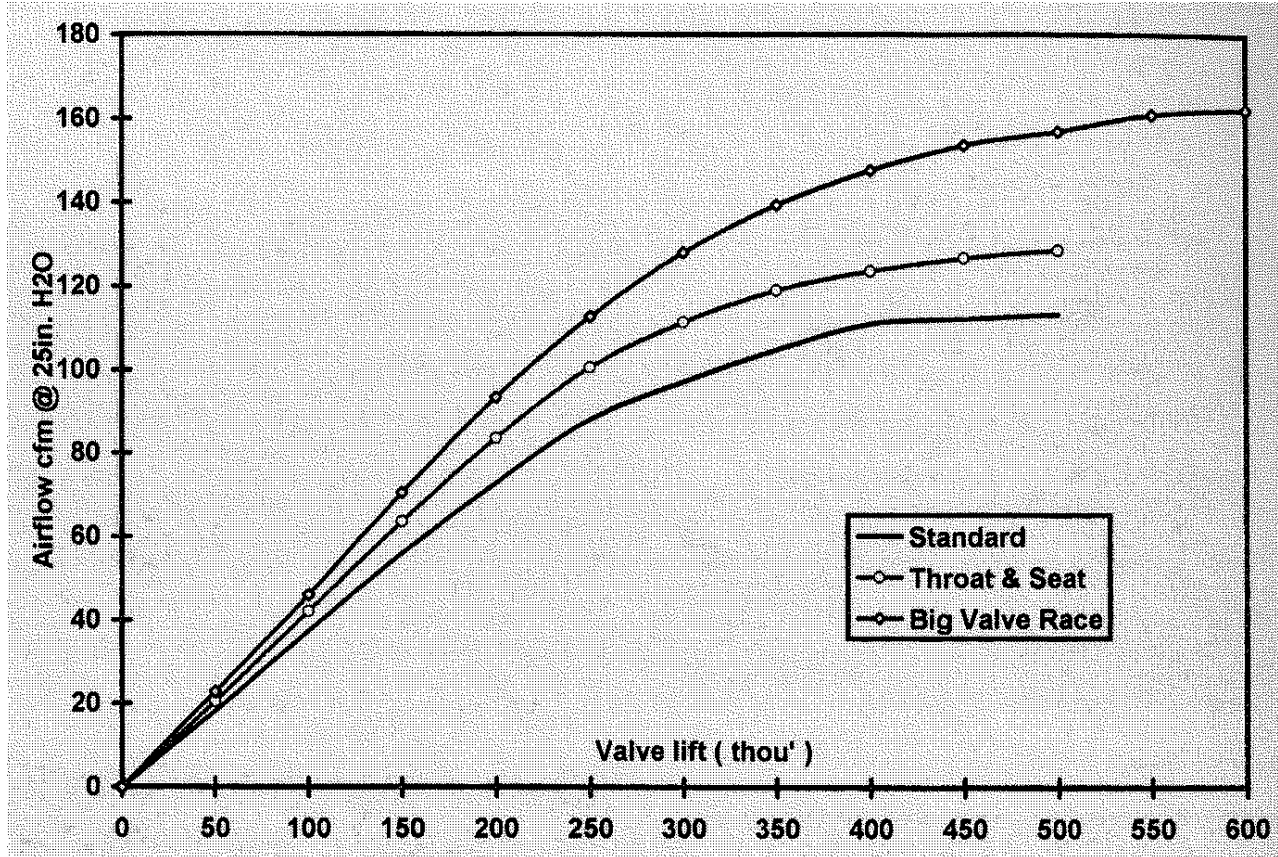
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- Test is performed for the whole range of valve openings, usually in 1.27mm (50 thou) steps
- At each valve opening, Flow rate is adjusted until test manometer shows a pre-determined pressure drop (usually at 25" H₂O)
- Plot of flow rate versus valve lift can now be drawn



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Measuring Air Flow



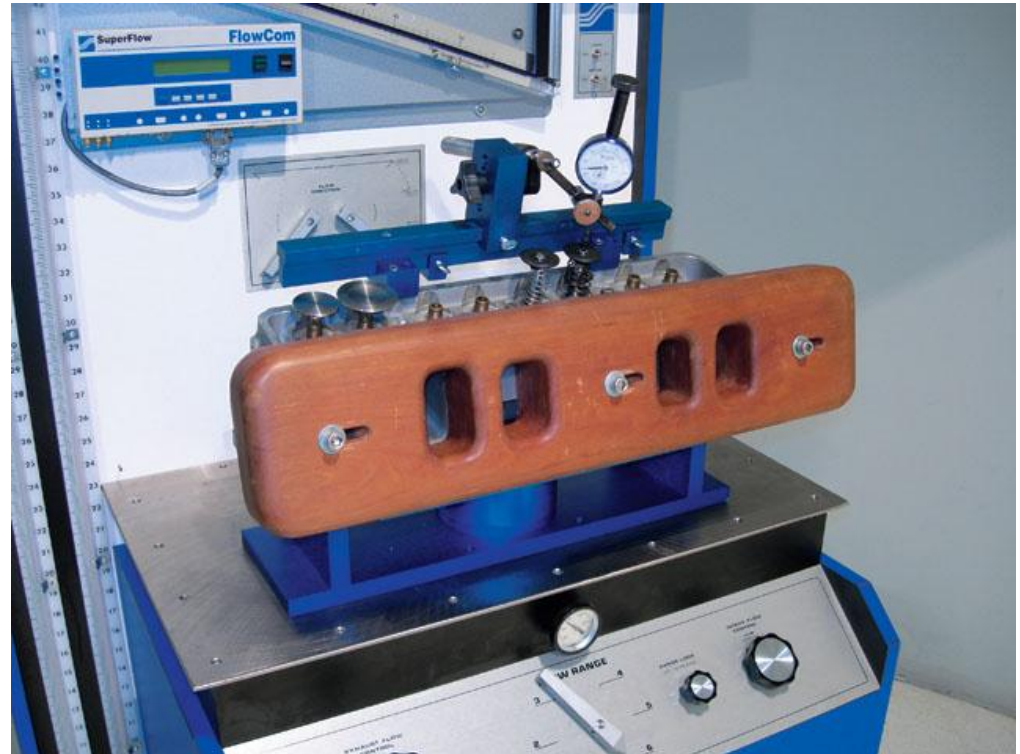
Rover V8 head modifications

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Measuring Air Flow

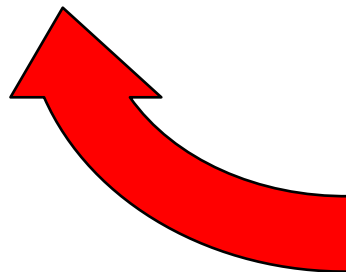
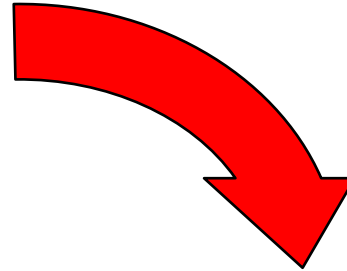


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Measuring Air Flow



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Discharge Coefficients

- Efficiency of flow past valve is important
- Discharge coefficient is a means of measuring this
- Defined as:

$$C_d = \frac{\text{Effective flow area}}{\text{Geometric flow area}}$$

- But why is the effective flow area less??
- And what is the geometric flow area?

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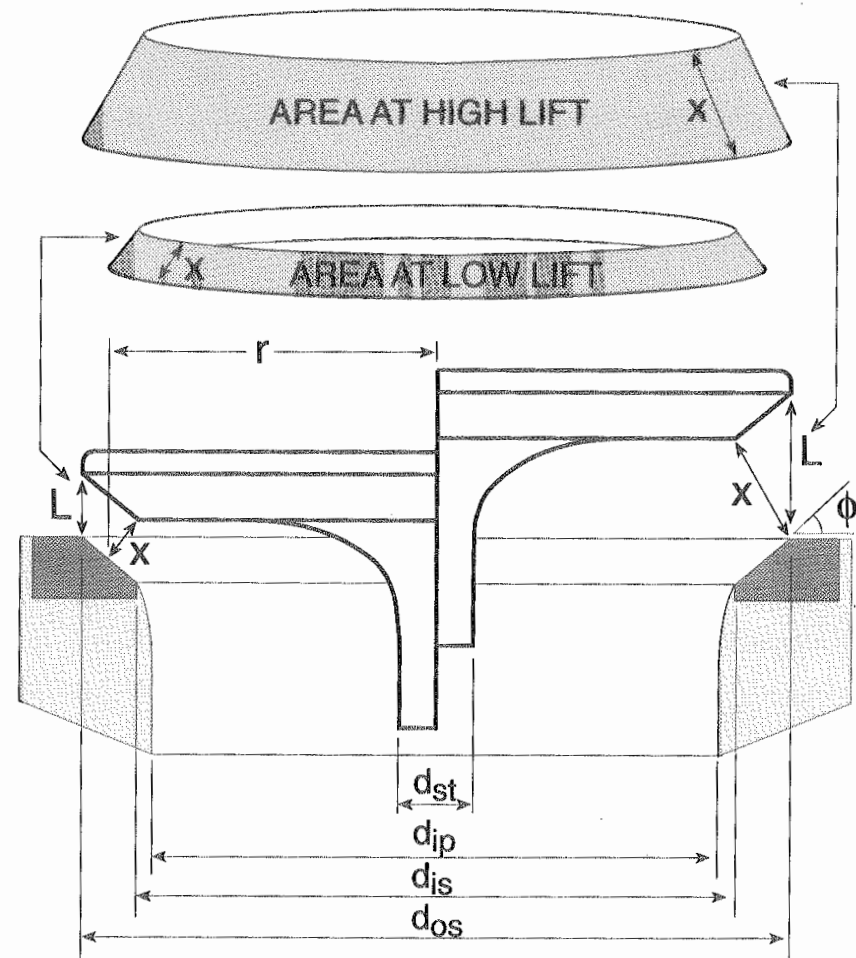
Discharge Coefficients



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- **Geometric Flow Area**

- is the maximum cross sectional area available for air flow
- Commonly called the curtain area
- Is a function of valve lift and valve diameter



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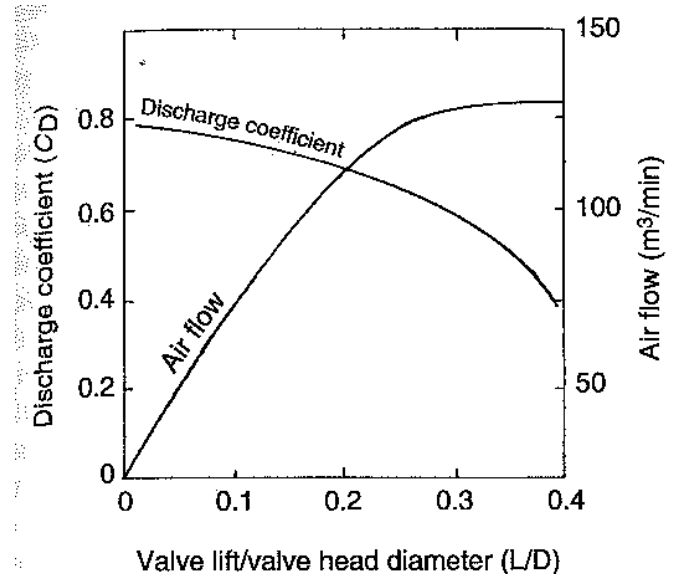
Discharge Coefficients



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- **Effective flow area**

- Is less!!!
- This is because the inertia of the flowing gas moving through the port and over the valve prevents it exactly following the shape of the port and valve seat
- Tendency to “overshoot” as it flows through abrupt changes in geometry
- Flow breaks away from valve head and seat as it flows past these relatively sharp edges
- Forms a “free jet”
- Therefore, flow area is less than geometric (curtain) area



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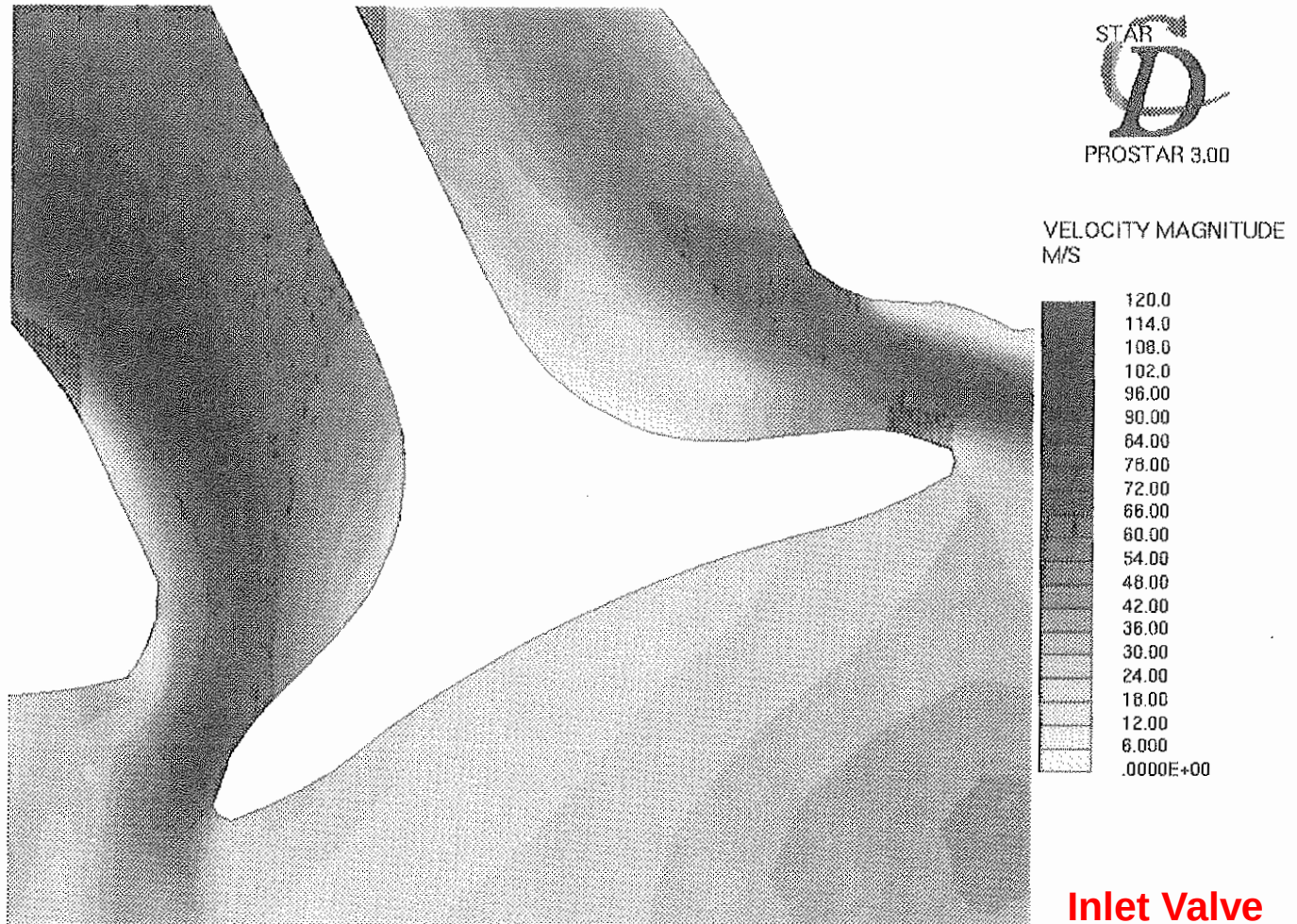
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Flow Patterns



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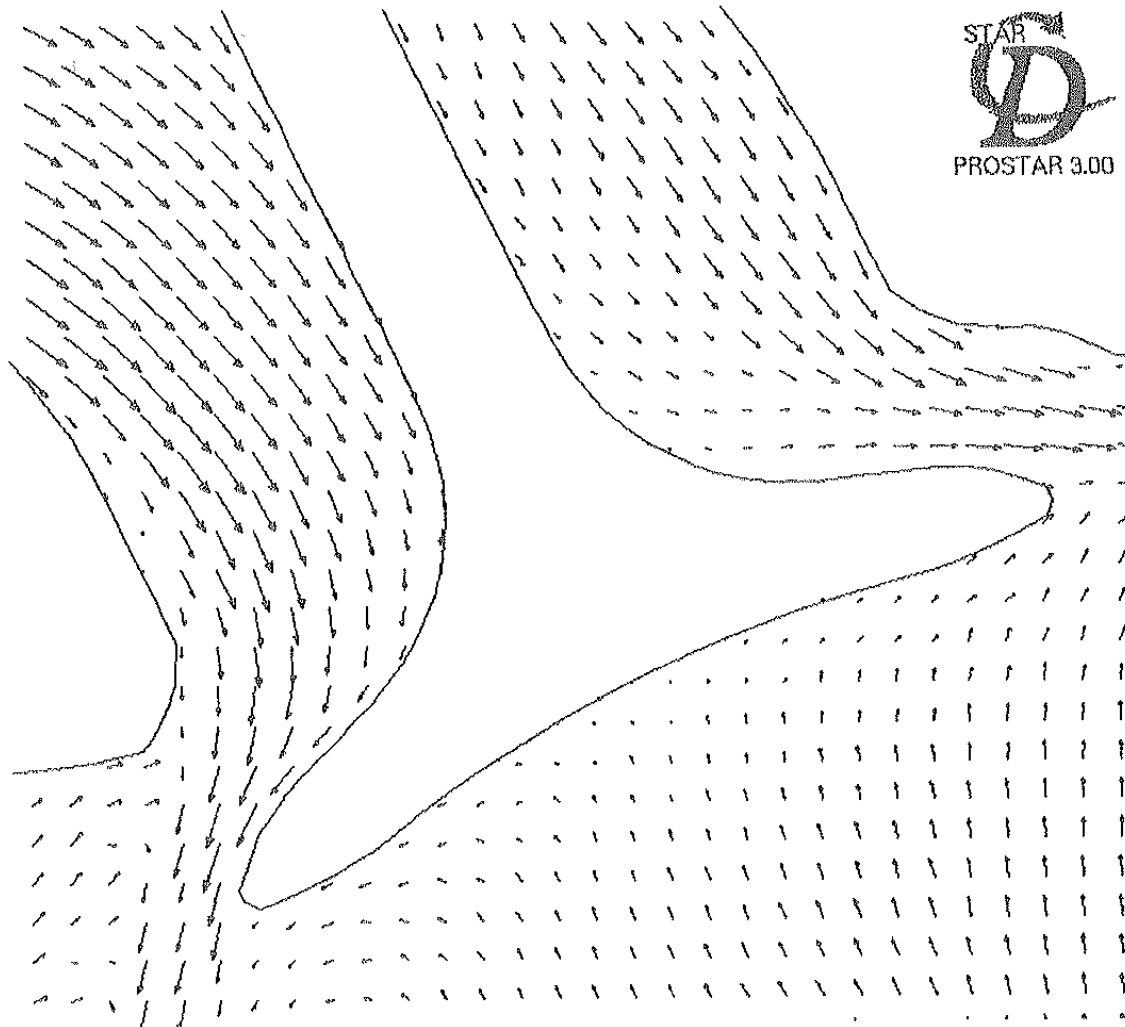


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Flow Patterns



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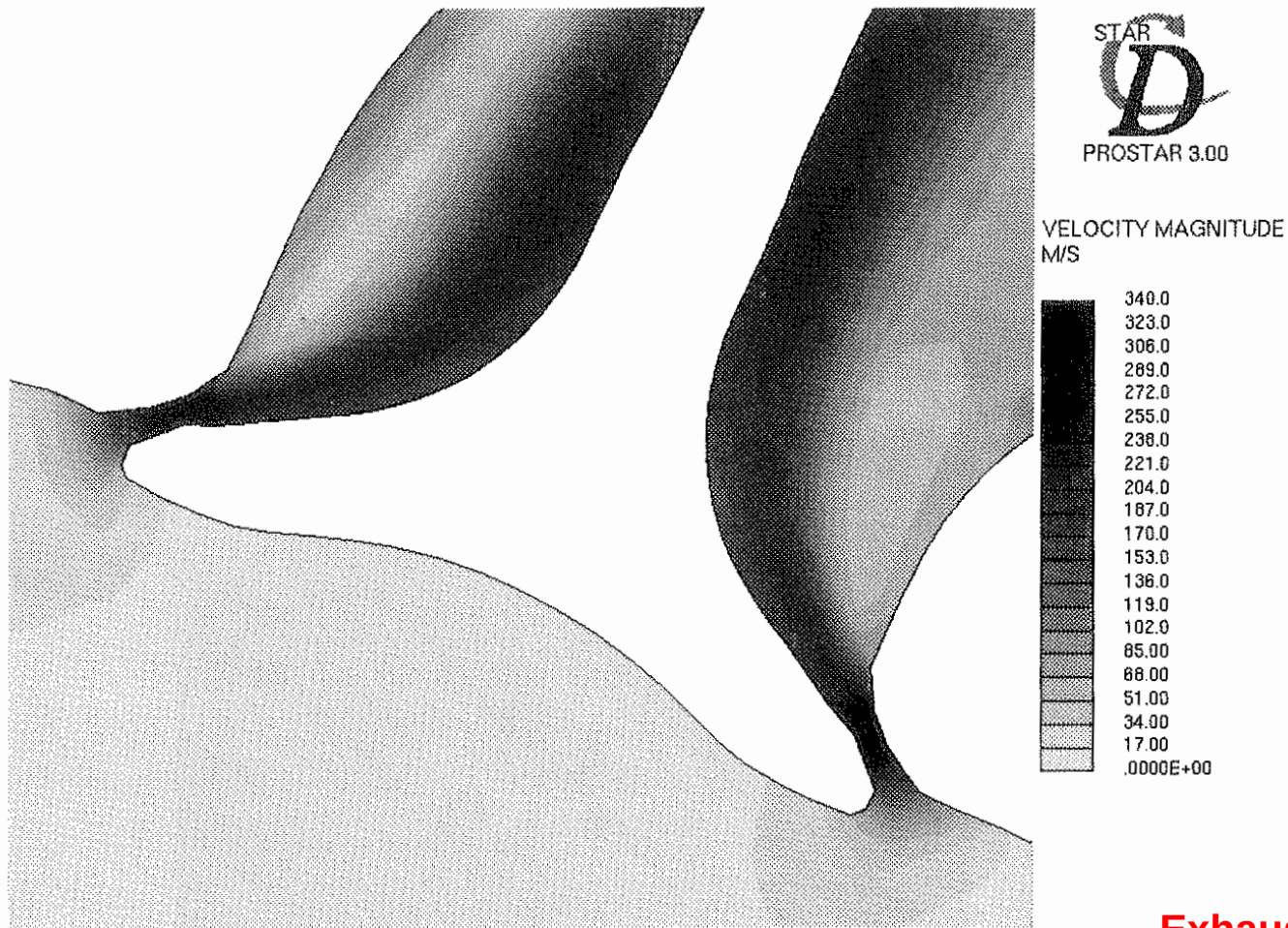
Inlet Valve

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Flow Patterns



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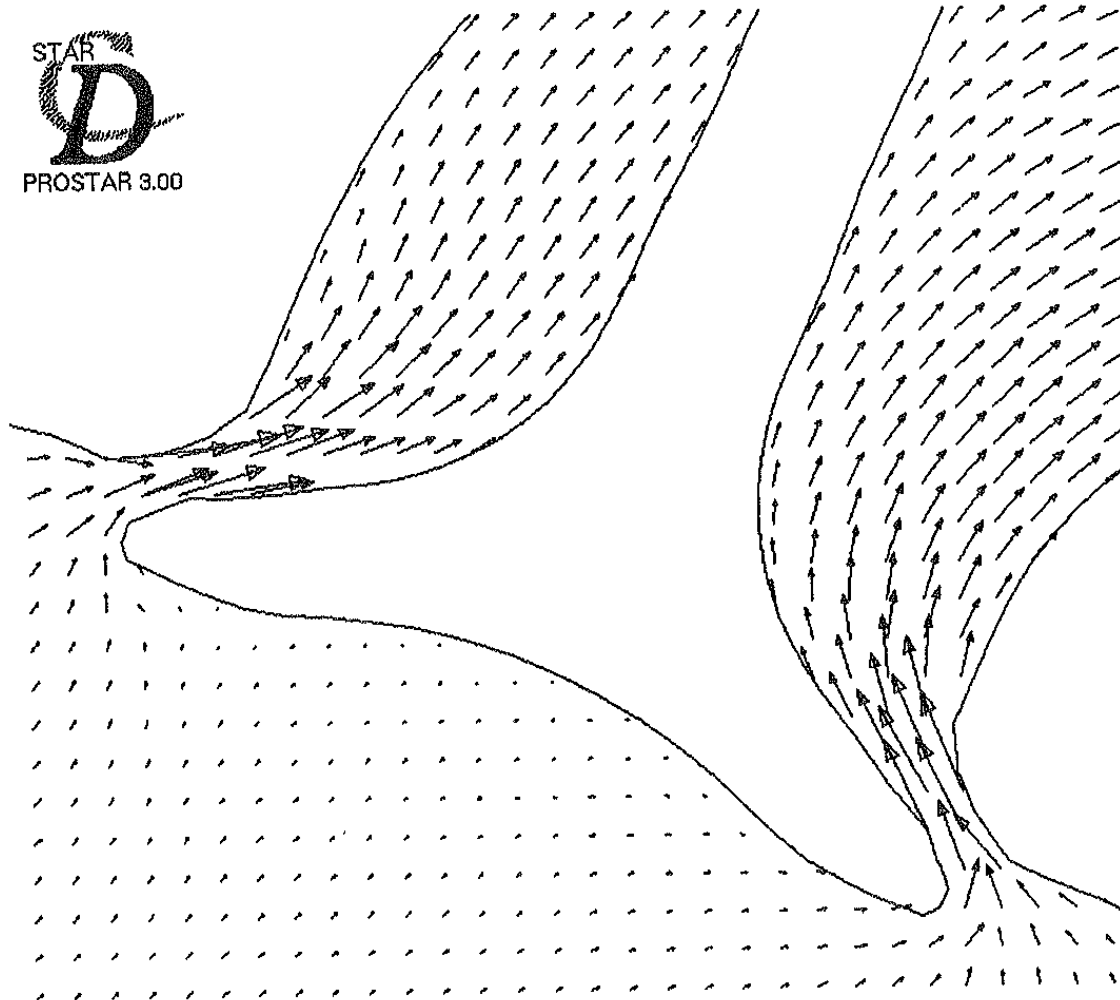
Exhaust Valve

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Flow Patterns



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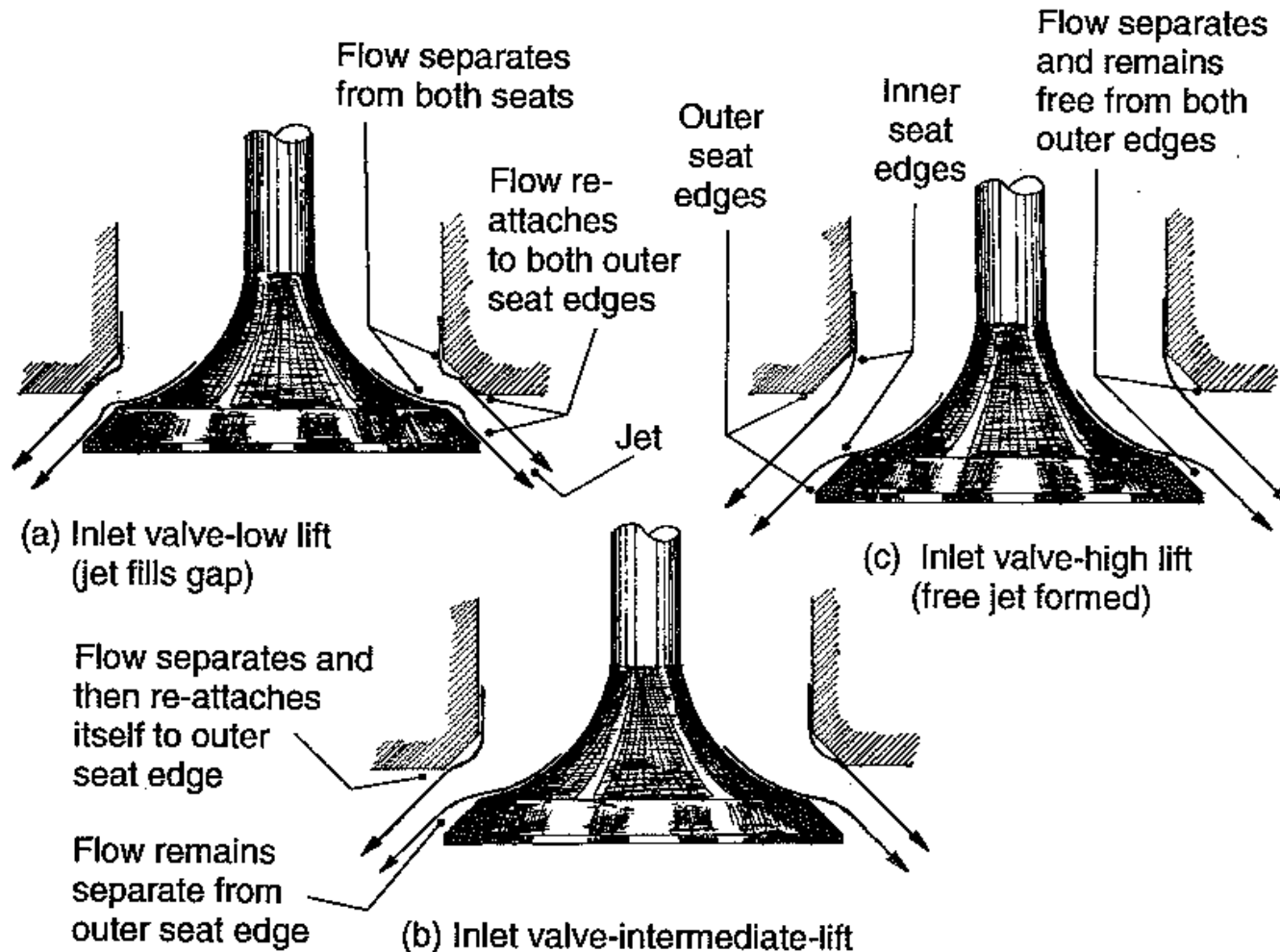
Exhaust Valve

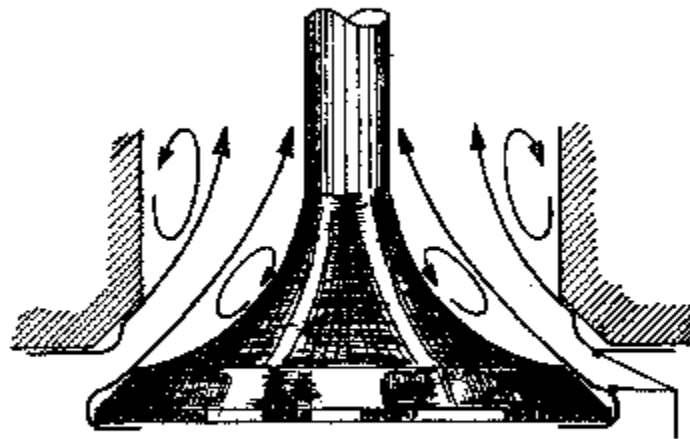
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Flow Patterns



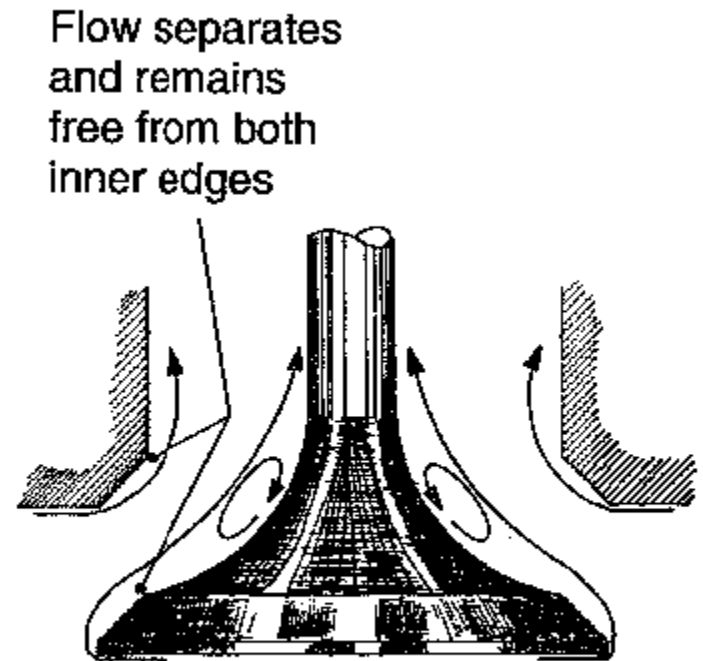
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(d) Exhaust valve-low lift

Flow separates
and re-attaches
itself to both seat
inner edges



(e) Exhaust valve-high lift

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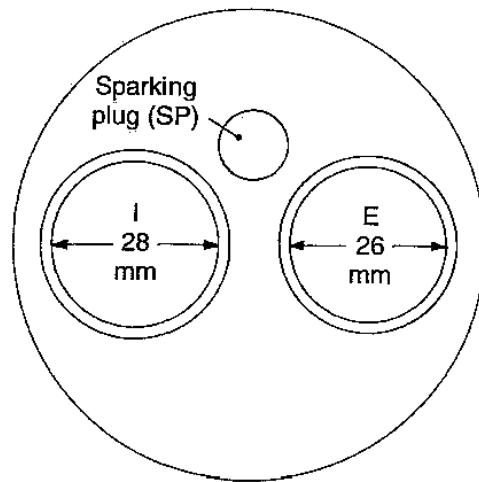
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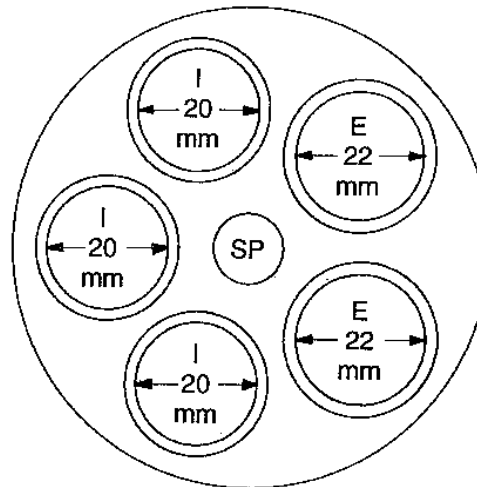
Multi-Valve Heads



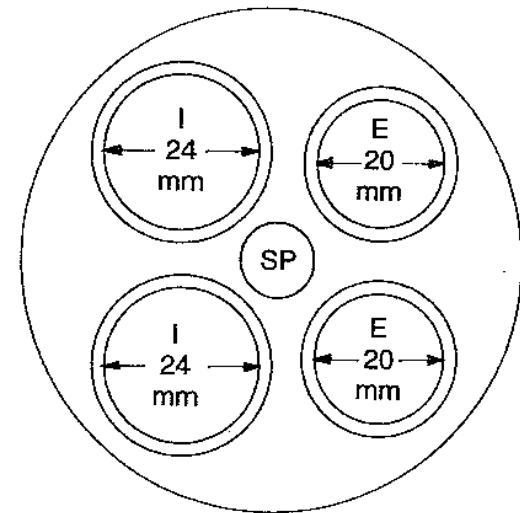
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Single Inlet Valve



Three Inlet Valves



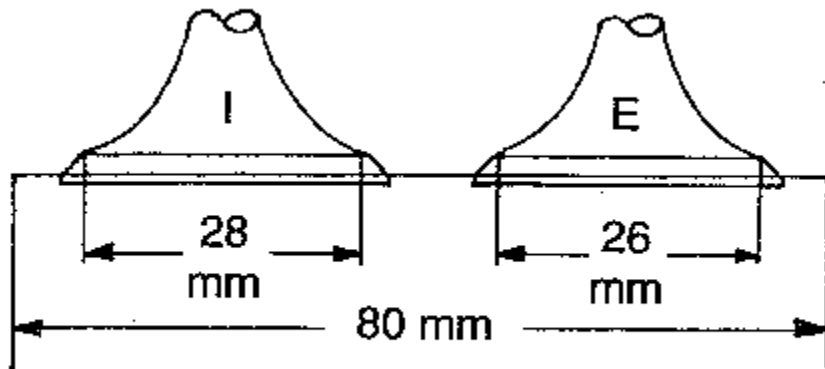
Two Inlet Valves

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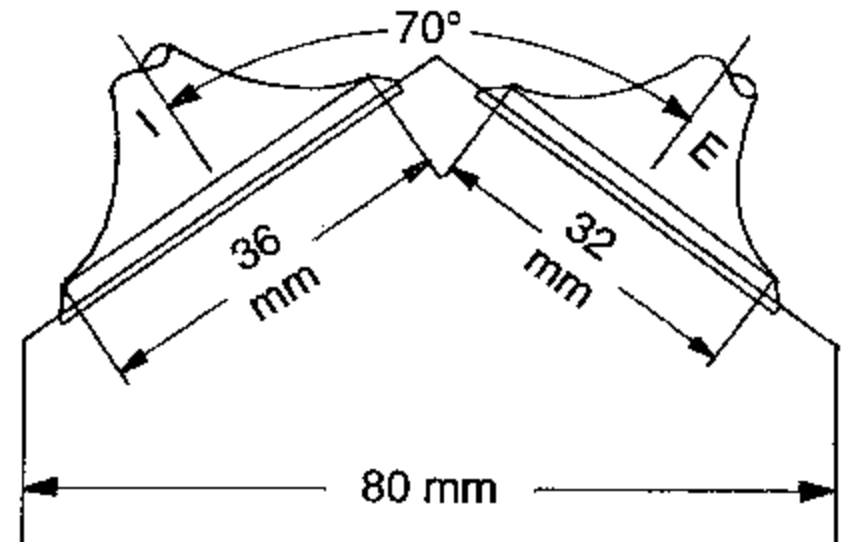
Multi-Valve Heads



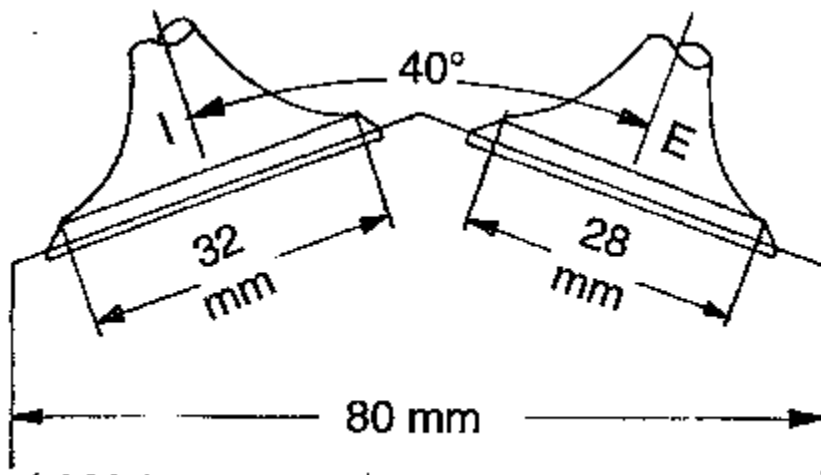
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(b) Valves arranged vertically



(d) Valves inclined 35° from the vertical



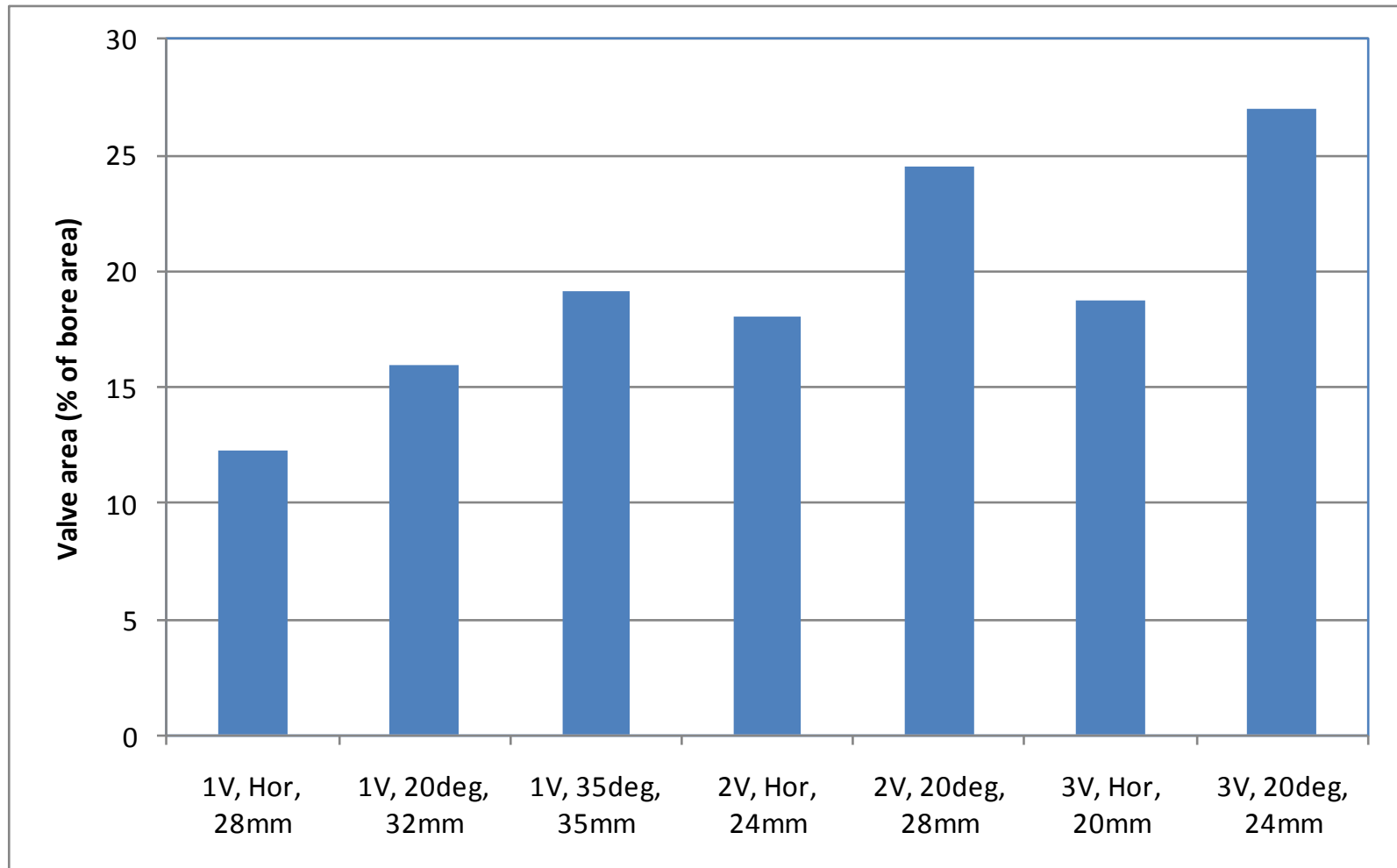
(c) Valves inclined 20° from the vertical

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Multi-Valve Heads



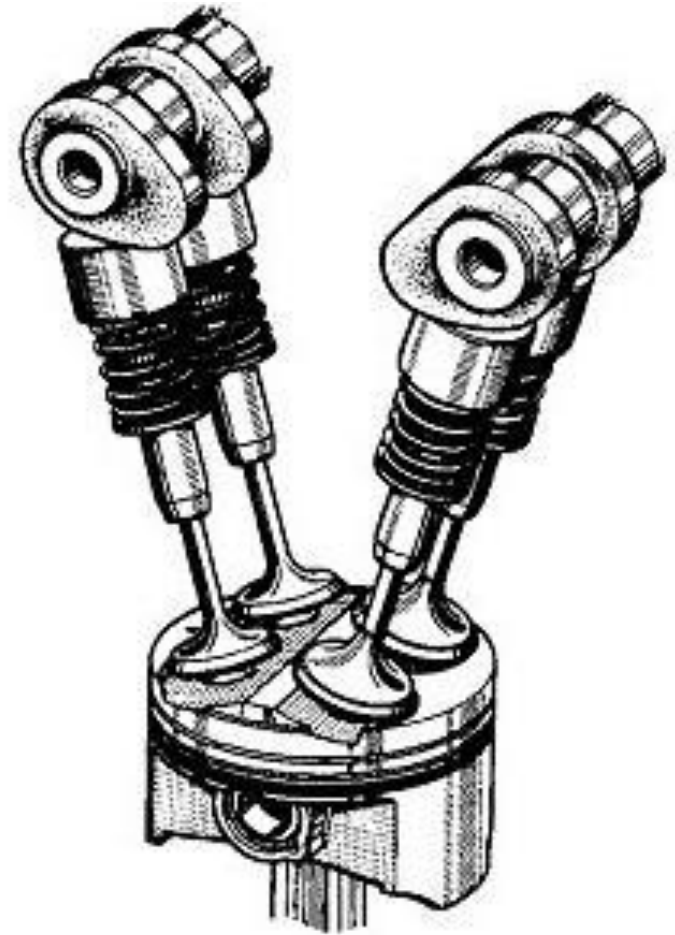
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Multi-Valve Heads

- Engine Speed Advantages
 - Smaller valves have less mass (and hence inertia)
 - This makes them easier to control at high speeds
 - Less tendency for valves to float
 - Smaller valves require less spring pressure, often allowing single valve springs to be used, removing spring harmonics problems
 - Increased flow area – if rest of engine can support higher flow – allows higher rpm



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Multi-Valve Heads

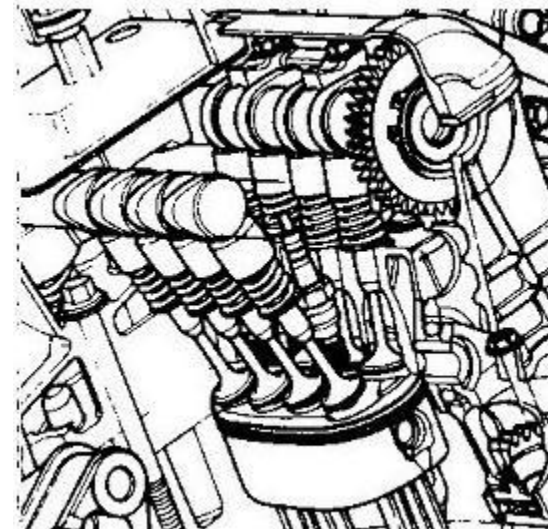
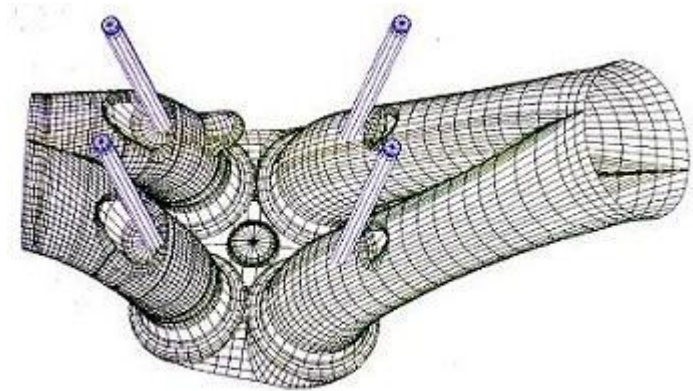
- Combustion Advantages
 - More, smaller valves permits a flat chamber shape
 - This results in a shorter flame distance, requiring less ignition advance
 - Thus the engine is compressing a burning mixture for less time, giving a net power increase
 - Flatter, shorter flame paths allow higher compression without detonation



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Multi-Valve Heads

- Combustion Advantages
 - Increased valve curtain area for a given lift results in more rapid cylinder filling, and hence higher VE
 - Higher port velocities give more homogeneous (better mixed) charge
 - Better combustion, higher cylinder pressures, more torque/power!



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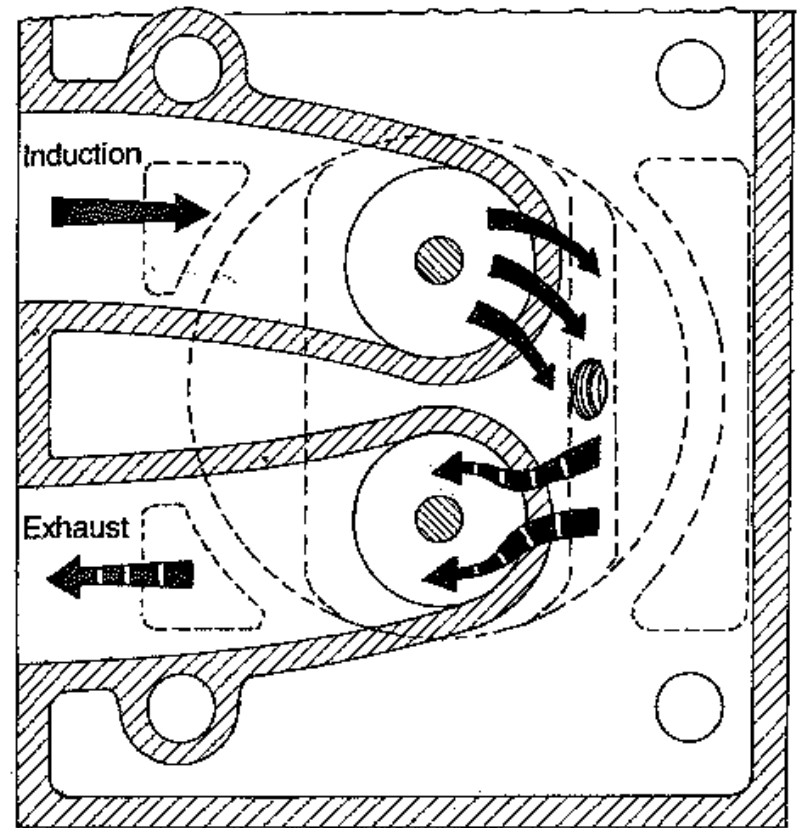
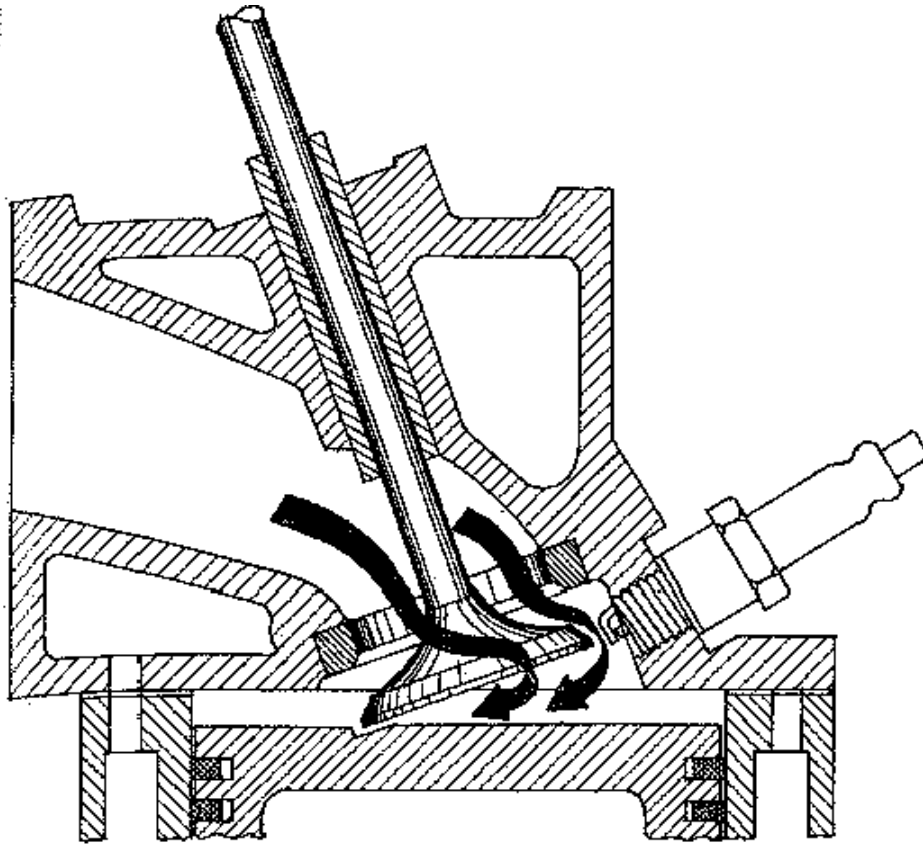
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Case Studies



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- Ford Wedge Type 2 valve chamber

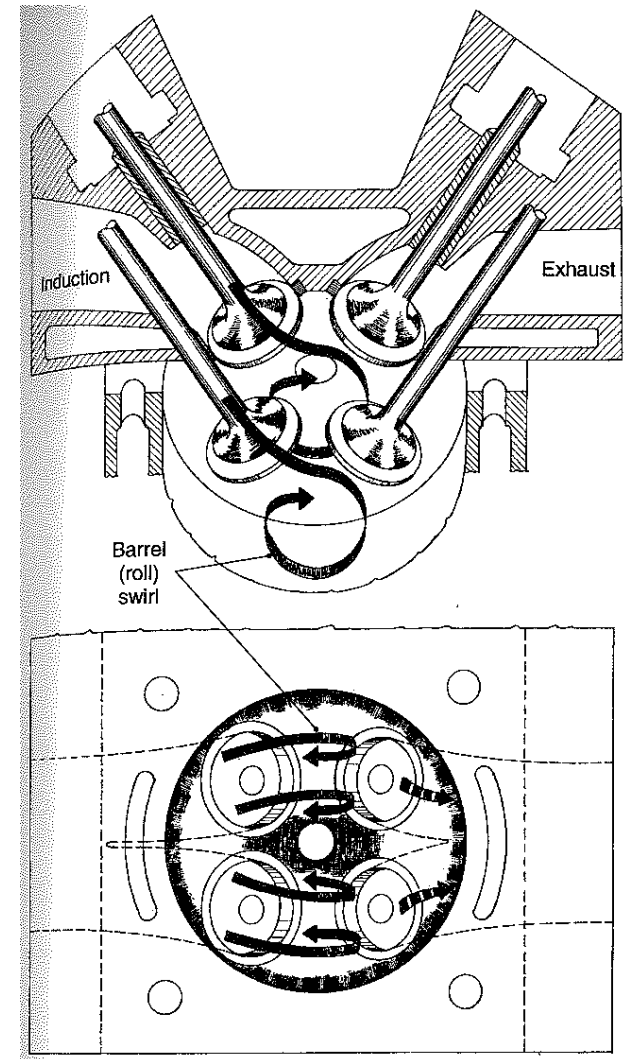


- Single row tilted valves
- Steep end walls partially mask mixture flow – charge is deflected and forced to swirl downwards about cylinder axis
- Towards end of compression stroke, squish area forces mixture rapidly towards thick end of combustion chamber
- Squish zones also quenches end gases, helping to prevent detonation

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Case Studies

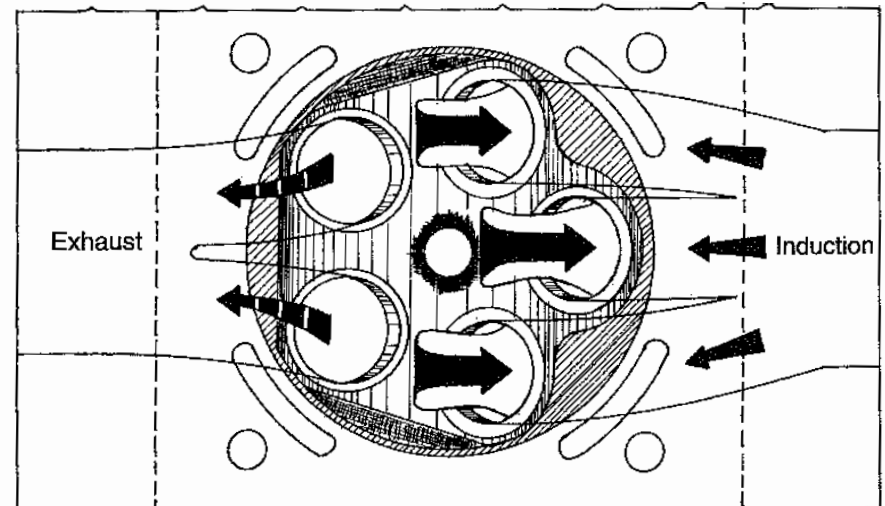
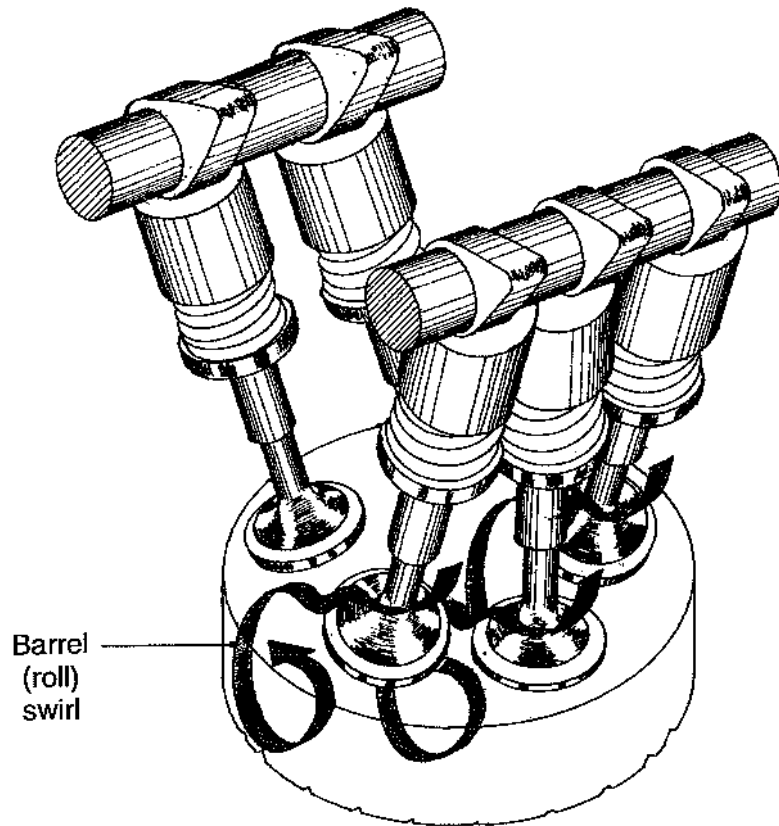
- **Four valve pent-roof chamber (Saab)**
- Twin inlet and exhaust valves with ports arranged in cross-flow manner
- Downturn in ports creates transverse swirl (barrel swirl)
- Towards end of compression stroke, the squish zones increase the turbulence
- This, together with short flame path (due to central spark plug) gives a controlled but high burning rate



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Case Studies

- Yamaha 5 valve chamber



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Case Studies



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- 3 inlet and 2 exhaust valves
- Shallow valve inclinations – central inlet valve more upright than others
- This provides a squish zone – thus high turbulence prior to ignition
- Rapid flame travel
- This head can run to higher than usual compression ratios on 97 RON fuel
- Smaller, lighter valves – higher engine speeds than 4v

