COMBUSTION CHAMBERS

COMBUSTION CHAMBERS- SI Engines

The design of combustion chamber has an important influence upon the engine performance and its knock properties. The design of combustion chamber involves the shape of the combustion chamber, the location of the sparking plug and the disposition of inlet and exhaust valves. Because of the importance of combustion chamber design, it has been a subject of considerable amount of research and development in the last fifty years. It has resulted in raising the compression ratio from 4: 1 before the First World War period to 8: 1 to 11:1 in present times with special combustion Chamber designs and suitable anti-knock fuels.

BASIC REQUIREMENTS OF A GOOD COMBUSTION CHAMBER (VTU Jan 2007, July 2006, August 2005, Feb 2006)

The basic requirements of a good combustion chamber are to provide:

- High power output
- High thermal efficiency and low specific fuel consumption
- Smooth engine operation
- Reduced exhaust pollutants.

HIGHER POWER OUTPUT REQUIRES THE FOLLOWING:

- High compression ratio. The compression ratio is limited by the phenomenon of detonation. Detonation depends on the design of combustion chamber and fuel quality. Any change in design that improves the anti-knock characteristics of a combustion chamber permits the use of a higher compression ratio which should result in higher output and efficiency.
- Small or no excess air.
- Complete utilization of the air – no dead pockets.
- An optimum degree of turbulence. Turbulence is induced by inlet flow configuration or ‘squish’. Squish is the rapid ejection of gas trapped between the piston and some flat or corresponding surface in the cylinder head. Turbulence induced by squish is preferable to inlet turbulence since the volumetric efficiency

is not affected.

- High Volumetric Efficiency. This is achieved by having large diameter valves with ample clearance round the valve heads, proper valve timing and straight passage ways by streamlining the combustion chamber so that the flow is with lesser pressure drop. This means more charge per stroke and proportionate increase in the power output. Large valves and straight passageways also increase the speed at which the maximum power is obtained. This further increases the power by increasing the displacement per minute.

(B) HIGH THERMAL EFFICIENCY REQUIRES THE FOLLOWING:

- High compression ratio: Already discussed.
- A small heat loss during combustion. This is achieved by having a compact combustion chamber which provides small surface-volume ratio. The other advantage of compact combustion chamber is reduced flame travel a given turbulence, this reduces the time of combustion and hence combustion time loss
- Good scavenging of the exhaust gases.

(C) SMOOTH ENGINE OPERATION REQUIRES THE FOLLOWING:

- Moderate rate of pressure rise during combustion.
- Absence of detonation which in turn means:
  - Compact combustion chamber, short distance of flame travel from the sparking plug to the farthest point in the combustion space. Pockets in which stagnant gas may collect should be avoided.
  - Proper location of the spark plug and exhaust valve.
  - Satisfactory cooling of the spark plug points (to avoid pre ignition) and of exhaust valve head which is the hottest region of the combustion chamber.

(D) Reduced exhaust pollutants

- Exhaust pollutants can be reduced by designing a combustion chamber that produces a faster burning rate of fuel. A faster burning chamber with its shorter burning time permits operation with substantially higher amounts of Exhaust Gas Recirculation (EGR), which reduces the oxides of nitrogen (NO_X) in the exhaust gas without substantial in crease in the hydrocarbon emissions. It can also burn very lean mixtures within the normal constraints of engine smoothness and response. A faster burning chamber exhibits much less cyclic variations, permitting the normal combustion at part load to have greater dilution of the charge.

DIFFERENT TYPES OF COMBUSTION CHAMBERS

A few representative types of combustion chambers of which there are many more Variations are enumerated and discussed below:

1. T-head combustion chamber.
2. L-head combustion chamber.
3. I-head (or overhead valve) combustion chamber.
4. F-head combustion chamber.

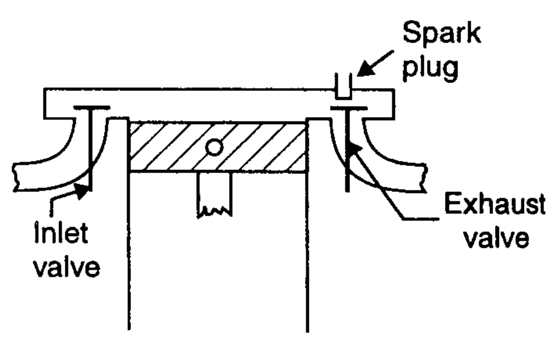
It may be noted that these chambers are designed to obtain the objectives namely:

• A high combustion rate at the start.
• A high surface-to-volume ratio near the end of burning.
• A rather centrally located spark plug.

T Head Type Combustion chambers

This was first introduced by Ford Motor Corporation in 1908. This design has following disadvantages.

- Requires two cam shafts (for actuating the in-let valve and exhaust valve separately) by two cams mounted on the two cam shafts.
- Very prone to detonation. There was violent detonation even at a compression ratio of 4. This is because the average octane number in 1908 was about 40 -50.



L Head Type Combustion chambers (VTU JAN 2007)

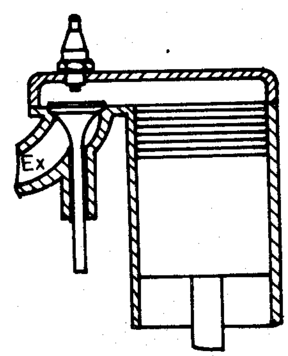
It is a modification of the T-head type of combustion chamber. It provides the two values on the same side of the cylinder, and the valves are operated through tappet by a single camshaft. This was first introduced by Ford motor in 1910-30 and was quite popular for some time. This design has an advantage both from manufacturing and maintenance point of view.

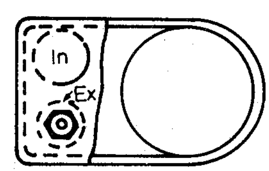
Advantages:

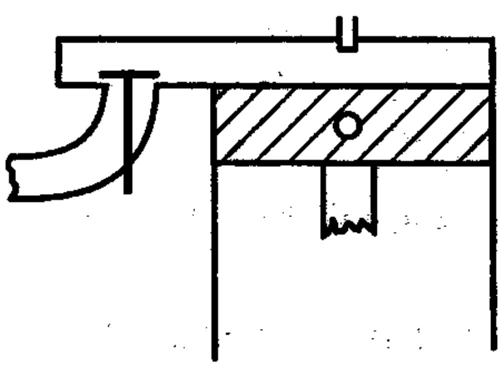
- Valve mechanism is simple and easy to lubricate.
- Detachable head easy to remove for cleaning and decarburizing without disturbing either the valve gear or main pipe work.
- Valves of larger sizes can be provided.

Disadvantages:

- Lack of turbulence as the air had to take two right angle turns to enter the cylinder and in doing so much initial velocity is lost.
- Extremely prone to detonation due to large flame length and slow combustion due to lack of turbulence.
- More surface-to-volume ratio and therefore more heat loss.
- Extremely sensitive to ignition timing due to slow combustion process
- Valve size restricted.
- Thermal failure in cylinder block also. In I-head engine the thermal failure is confined to cylinder head only

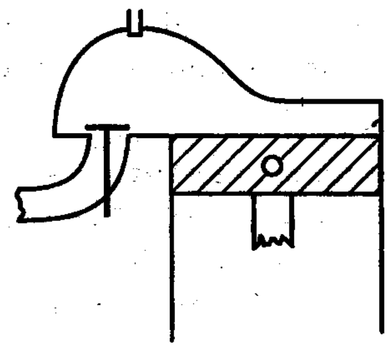






RICARDO'S TURBULENT HEAD– SIDE VALVE COMBUSTION CHAMBER (VTU July 06)

Ricardo developed this head in 1919. His main objective was to obtain fast flame speed and reduce knock in L design. In Ricardo's design the main body of combustion chamber was concentrated over the valves, leaving slightly restricted passage communicating with cylinder.


(b) Ricardo's turbulent head

Advantages:

- Additional turbulence during compression stroke is possible as gases are forced back through the passage.
- By varying throat area of passage designed degree of additional turbulence is possible.
- This design ensures a more homogeneous mixture by scoring away the layer of stagnant gas clinging to chamber wall. Both the above factors increase the flame speed and thus the performance.
- Deign make engine relatively insensitive to timing of spark due to fast combustion
- Higher engine speed is possible due to increased turbulence
- Ricardo's design reduced the tendency to knock by shortening length of effective flame travel by bringing that portion of head which lay over the further side of piston into as close a contact as possible with piston crown.
- This design reduces length of flame travel by placing the spark plug in the centre of effective combustion space.

Disadvantages :

- With compression ratio of 6, normal speed of burning increases and turbulent head tends to become over turbulent and rate of pressure rise becomes too rapid leads to rough running and high heat losses.
- To overcome the above problem, Ricardo decreased the areas of passage at the expense of reducing the clearance volume and restricting the size of valves. This reduced breathing capacity of engine, therefore these types of chambers are not suitable for engine with high compression ratio.

Over head valve or I head combustion chamber (VTU JULY 2007/ August 2005)

The disappearance of the side valve or L-head design was inevitable at high compression ratio of 8 : 1 because of the lack of space in the combustion chamber to accommodate the valves. Diesel engines, with high compression ratios, invariably used overhead valve design.

Since 1950 or so mostly overhead valve combustion chambers are used. This type of combustion chamber has both the inlet valve and the exhaust valve located in the cylinder head. An overhead engine is superior to side valve engine at high compression ratios.

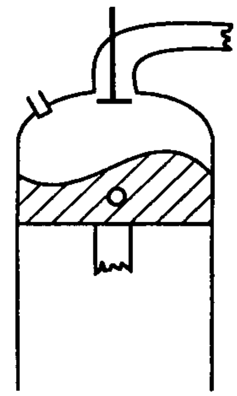


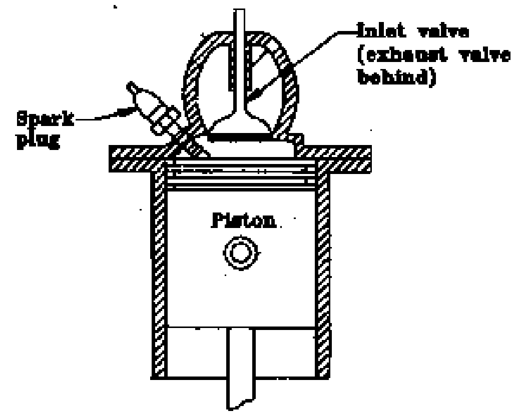
Fig. 5.22. ***I*-head combustion chamber.**

The overhead valve engine is superior to side valve or L-head engine at high compression ratios, for the following reasons:

- Lower pumping losses and higher volumetric efficiency from better breathing of the engine from larger valves or valve lifts and more direct passageways.
- Less distance for the flame to travel and therefore greater freedom from knock, or in other words, lower octane requirements.
- Less force on the head bolts and therefore less possibility of leakage (of compression gases or jacket water). The projected area of a side valve combustion chamber is inevitably greater than that of an overhead valve chamber.
- Removal of the hot exhaust valve from the block to the head, thus confining heat failures to the head. Absence of exhaust valve from block also results in more uniform cooling of cylinder and piston.
- Lower surface-volume ratio and, therefore, less heat loss and less air pollution.
- Easier to cast and hence lower casting cost.

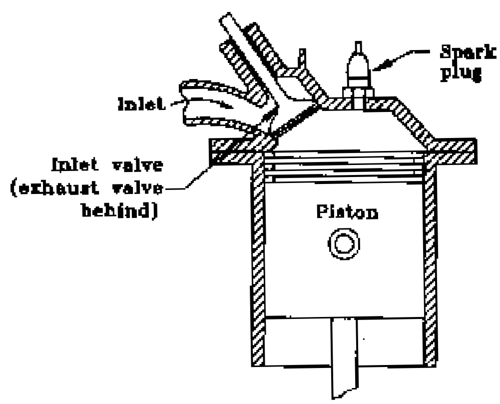
Two important designs of overhead valve combustion chambers are used .

Bath Tub Combustion Chamber. This is simple and mechanically convenient form. This consists of an oval shaped chamber with both valves mounted vertically overhead and with the spark plug at the side. The main draw back of this design is both valves are placed in a single row along the cylinder block. This limits the breathing capacity of engine, unless the overall length is increased. However, modern engine manufactures overcome this problem by using unity ratio for stroke and bore size.



(a)

Wedge Type Combustion Chamber. In this design slightly inclined valves are used. This design also has given very satisfactory performance. A modern wedge type design can be seen in for Plymouth V-8 engine. It has a stoke of 99 mm and bore of 84mm with compression ratio 9:1



F- Head combustion chamber (VTU JULY 2007/ July 2005)

In such a combustion chamber one valve is in head and other in the block. This design is a compromise between L-head and I-head combustion chambers. One of the most F-head engines (wedge type) is the one used by the Rover Company for several years. Another successful design of this type of chamber is that used in Willeys jeeps

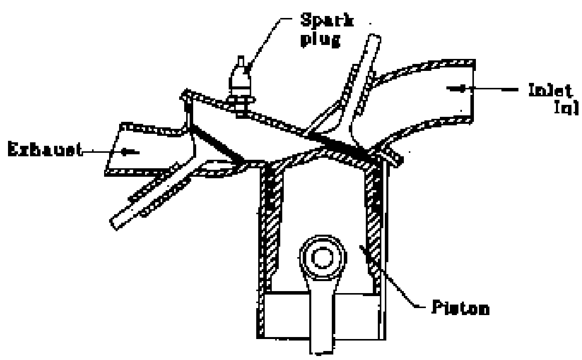
Its advantages are :

- High volumetric efficiency
- Maximum compression ratio for fuel of given octane rating
- High thermal efficiency
- It can operate on leaner air-fuel ratios without misfiring.

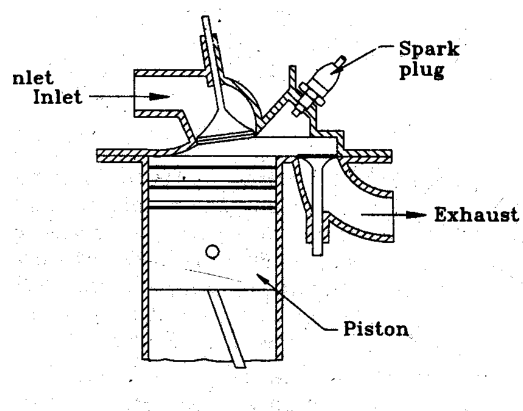
The drawback

- This design is the complex mechanism for operation of valves and expensive special shaped piston.

F- head used by Rover Company



F – head used in Willeys jeep.



Divided Combustion Chamber (VTU July 2006)

In this type of chambers usually with about 80 percent of the clearance volume in the main chamber above the piston and about 20 percent of the volume as a secondary chamber. Main chamber is connected to secondary chamber through a small orifice Combustion is started in the small secondary chamber. As the gases in secondary chambers are consumed by combustion, pressure rises and flaming gas expands back through orifice and act as torch ignition for main chamber.

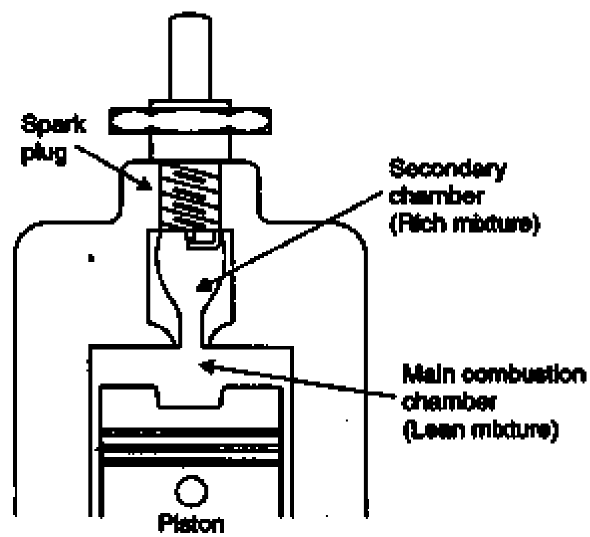


Fig. 5.23. Divided combustion chamber.

Secondary chamber has high swirl and designed to handle rich mixture. The rich mixture with very high swirl in secondary chamber will ignite readily and burn very quickly. The flame gas expands through orifice and ignites the lean mixture in the main chamber. The net result is an engine that has good ignition and combustion and yet operates mostly lean to give good fuel economy.

COMBUSTION CHAMBERS- CI Engines

Primary Considerations in the Design of Combustion Chambers for C.I Engines

In C engines fuel is injected into the combustion chamber at about 15°C before T.D.C. during the compression stroke. For the best efficiency the combustion must complete within 15° to 20° of crank rotation after T.D.C. in the working stroke. Thus it is clear that injection and combustion both must complete in the short time. For best combustion mixing should be completed in the short time.

• In S.I engine mixing takes place in carburetor; however in C.I engines this has to be done in the combustion chamber. To achieve this requirement in a short period is an extremely difficult job particularly in high speed Cl. engines.

• From combustion phenomenon of C.I. engines it is evident that fuel-air contact must be limited during the delay period in order to limit, the rate of pressure rise in the second stage of combustion. This result can be obtained by shortening the delay to achieve high efficiency and power the combustion must be completed when piston is nearer to T.D.C., it is necessary to have rapid mixing of fuel and air dun the third stage of combustion.

• The design of combustion chamber for C.I. engines must also take consideration of injection system and nozzles to be used.

The considerations can be summarized as follows:

1. High thermal efficiency.
2. Ability to use less expensive fuel (multi-fuel).
3. Ease of starting.
4. Ability to handle variations in speed.

5. Smoothness of operation i.e. avoidance of diesel knock and noise.
6. Low exhaust emission.
7. Nozzle design.
8. High volumetric efficiency.
9. High brake Mean effective pressure.

Role of air swirl in Diesel engine (July 2005)

Most important function of CI engine combustion chamber is to provide proper mixing of fuel and air in short possible time. For this purpose an organized air movement called air swirl is to be produced to produce high relative velocity between the fuel droplets and air.

There are three basic methods of generating swirl in CI engine Combustion Chamber.

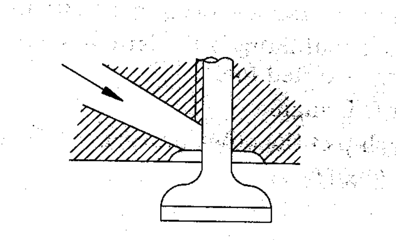
- By directing the flow of air during its entry to the cylinder known as Induction swirl. This method is used in open combustion chamber.
- By forcing air through a tangential passage into a separate swirl chamber during the compression stroke, known as Combustion swirl. This is used in swirl chamber.
- By use of initial pressure rise due to partial combustion to create swirl and turbulence, known as combustion induced swirl. This method is used in pre-combustion chamber and air cell chambers.

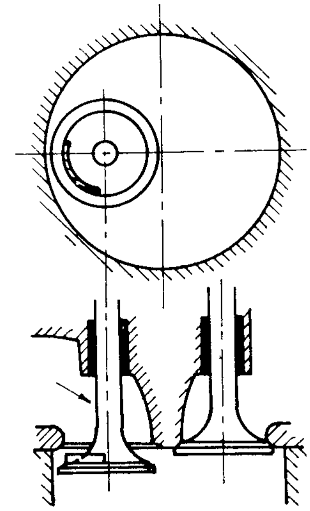
INDUCTION SWIRL (July 2006)

Swirl refers to a rotational flow within the cylinder about its axes.

In a four stroke engine induction swirl can be obtained either by careful formation of air intake passages or masking or shrouding a portion of circumference of inlet valve. The angle of mask is from 90° to 140° of the circumference. In two stroke engine, induction swirl is created by suitable inlet port forms. Induction swirl can be generated using following methods.

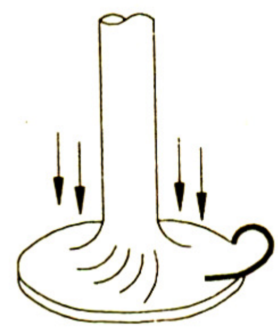
- Swirl is generated by constructing the intake system to give a tangential component to intake flow as it enters the cylinder. This is done by shaping and contouring the intake manifold,





- Swirl can be generated by masking one side of the inlet valve so that air is admitted only around a part of the periphery of the valve and in the desired direction.
- Swirl can also be generated by casting a lip over one side of the inlet valve.

Swirl generated by induction is very weak. Thus single orifice injection cannot provide the desired air fuel mixing. Therefore, with Induction swirl, it is advisable to use a multiple-orifice injector.



(c)

Advantages of Induction swirl.

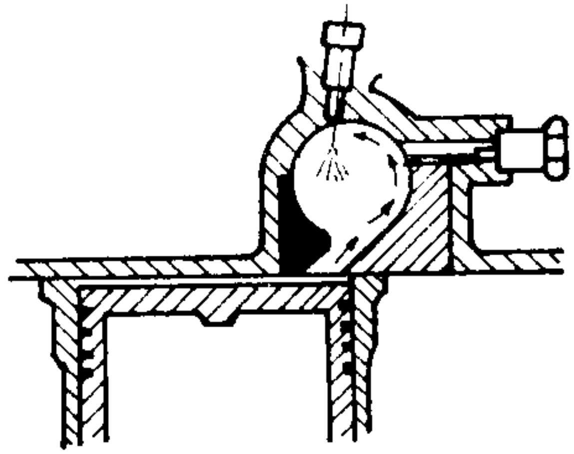
- Easier starting (due to low intensity of swirl).
- High excess air (low temperature), low turbulence (less heat loss), therefore indicated thermal efficiency is high.
- Production of swirl requires no additional work.
- Used with low speeds, therefore low quality of fuel can be used.

Disadvantages of induction swirl:

- Shrouded valves, smaller valves, low volumetric efficiency.
- Weak swirl, low air utilisation (60%), lower M.E.P. and large size (costly) engine.
- Weak swirl, multi-orifice nozzle, high induction pressure; clogging of holes, high maintenance.
- Swirl not proportional to speed; efficiency not maintained at variable speed engine.
- Influence minimum quantity of fuel. Complication at high loads and idling.

COMPRESSION SWIRL (July 2006)

Compression swirl is generated using swirl chamber. A swirl chamber is a divided chamber. A divided combustion chamber is defined as one in which the combustion space is divided into two or more compartments. Pressure difference between these chambers is created by restrictions or throats. Very strong swirl can be generated using compression swirl.



Advantage of compression swirl:

- Large valves, high volumetric efficiency.
- Single injector, pintle type (self cleaning), less maintenance.
- Smooth engine operation.
- Greater air utilization due to strong swirl. Smaller (cheaper) engine.
- Swirl proportional to speed, suitable for variable speed operation.

Disadvantage of compression swirl:

- Cold starting trouble due to high loss du to strong swirl, mechanical efficiency l
- Less excess air ; lower indicated efficiency; 5 to 8% more fuel consumption; decreased exhaust valve life
- Cylinder more expensive in construction.
- Work absorbed in producing swirl, mechanical efficiency lower.

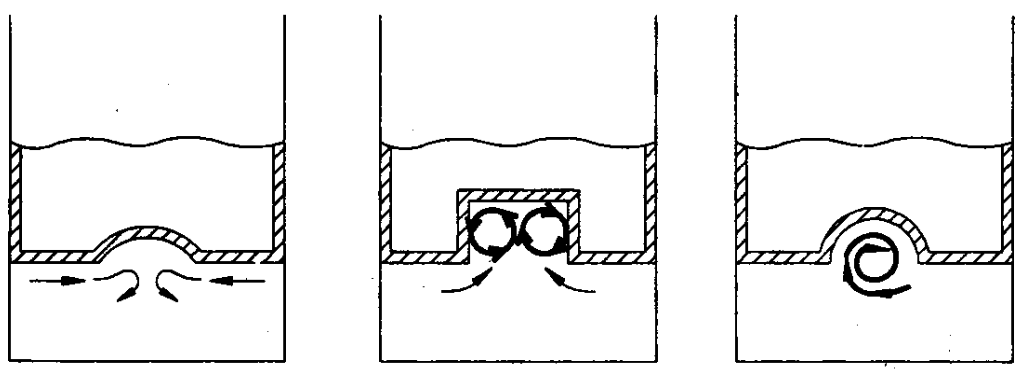


Table 6.3. Comparison of induction and compression swirl.

Induction Swirl	*Compression Swirl*
Advantages	**Disadvantages**
1. High excess air (low temperature), low turbulence (less heat loss). Therefore indicated thermal efficiency high.	1. Less excess air, lower indicated efficiency 5 to 8% more fuel consumption. Decreased exhaust valve life.
2. Due to low intensity of swirl easier starting.	2. Cold starting trouble due to high heat loss due to strong swirl, greater s/v ratio.
3. No additional work for producing swirl. High mechanical efficiency and hence high brake thermal efficiency.	3. Work absorbed in producing compression swirl, mechanical efficiency lower.
4. Used with low speeds. Therefore low quality of fuel can be used.	4. Cylinder more expensive in construction.
Disadvantages	**Advantages**
1. Weak swirl, multiorifice nozzle, high injection pressure, clogging of holes. High maintenance.	1. Single injector, pintle type (self cleaning), less maintenance.
2. Influences minimum quantity of fuel. Complication at high loads and idling.	2. Large valves, higher volumetric efficiency.
3. Shrouded valves, smaller valves, low volumetric efficiency.	3. Greater air utilization due to strong swirl. Smaller (cheaper) engine.
4. Weak swirl, low air utilisation (60%), lower mep, large size (costly) engine.	4. Swirl proportional to speed, suitable for variable speed operation.
5. Swirl not proportional to speed. Efficiency not maintained in a variable speed engine.	5. Smooth engine operation.

COMBUSTION INDUCTION SWIRL (July 2006)

This is created due to partial combustion, therefore known as combustion induced swirl. This method is used only in pre-combustion chamber. In this method, upward movement of piston during compression forces the air tangentially and fuel is injected in pre-combustion , when the combustion of the accumulated fuel during delay periods burns rapidly in pre-combustion chamber as A:F mixture is rich and forces the gases at a very high velocity in the main combustion chamber. This creates a good swirl and provides better combustion.

The requirement of air motion and swirl in a C.I engine combustion chamber is much more stringent than in an S.I. engine.-Justify this statement?

- Air motions are required in both S.I. and C.I. engines. In S.I. engine, we call it turbulence and in C.I. engine, we call it swirl. Turbulence which is required in S.I. engines implies disordered air motion with no general direction of flow, to break up the surface of flame front and to distribute flame throughout an externally prepared combustible mixture. Air swirl which is required in C.I. engines is an orderly movement of whole body of air with a particular direction of flow to bring a continuous supply of fresh air to each burning droplet and sweep away the products of combustion which otherwise would suffocate it.
- If there is no turbulence in S.I. engines, the time occupied by each explosion would be so great as to make high speed internal combustion engines impracticable. Insufficient turbulence lowers the efficiency due to incomplete combustion of fuel. In case of C.I. engines, it is impossible to inject fuel droplets so that they distribute uniformly throughout the combustion space, the fuel air mixture formed in combustion chamber is essentially heterogeneous. Under these conditions, if the air within the cylinder were motionless, only a small portion of fuel would find sufficient oxygen and even burning of this fuel would be slow or even choked. So it is essential to impart swirl to air so that a continuous supply of fresh air is brought to each burning droplet and the products of combustion are swept away.

The induction swirl in a C.I. engine helps in increasing indicated thermal efficiency. Justify this statement.

Induction swirl is used in direct injection type engines, where the entire combustion space is directly above the piston, and hence the surface-to-volume ratio of the combustion chamber is low. Further, the compressed air and the combustion products do not have to pass through a neck narrow connecting passage. Also, the mean combustion temperatures are lower, and there is less turbulence. All these factors result in less heat losses, and thus the indicated thermal efficiency is increased.

TYPES OF COMBUSTION CHAMBERS- CI Engines

The most important function of CI engine combustion chamber is to provide proper mixing of fuel and air in short time. In order to achieve this, an organized air movement called swirl is provided to produce high relative velocity between the fuel droplets and the air.

When the liquid fuel is injected into combustion chamber, the spray cone gets disturbed due to air motion and turbulence inside. The onset of combustion will cause an added turbulence that can be guide d by the shape of the combustion chamber, makes it necessary to study the combustion design in detail.

C I engine combustion chambers are classified into two categories:

1. OPEN INJECTION (DI) TYPE : This type of combustion chamber is also called an Open combustion chamber. In this type the entire volume of combustion chamber is located in the main cylinder and the fuel is injected into this volume.
2. INDIRECT INJECTION (IDI) TYPE: in this type of combustion chambers, the combustion space is divided into two parts, one part in the main cylinder and the other part in the cylinder head. The fuel –injection is effected usually into the part of chamber located in the cylinder head. These chambers are classified further into :
   a) Swirl chamber in which compression swirl is generated
   b) Pre combustion chamber in which combustion swirl is induced
   c) Air cell in which both compression and combustion swirl are induced.

DIRECT INJECTION CHAMBERS – OPEN COMBUSTION CHAMBERS

An open combustion chamber is defined as one in which the combustion space is essentially a single cavity with little restriction from one part of the chamber to the other and hence with no large difference in pressure between parts of the chamber during the combustion process. There are many designs of open chamber some of which are shown below :

In four-stroke engines with open combustion chambers, induction swirl is obtained either by careful formation of the air intake passages or by masking a portion of the circumference of the inlet valve whereas in two-stroke engines it is created by suitable form for the inlet ports.

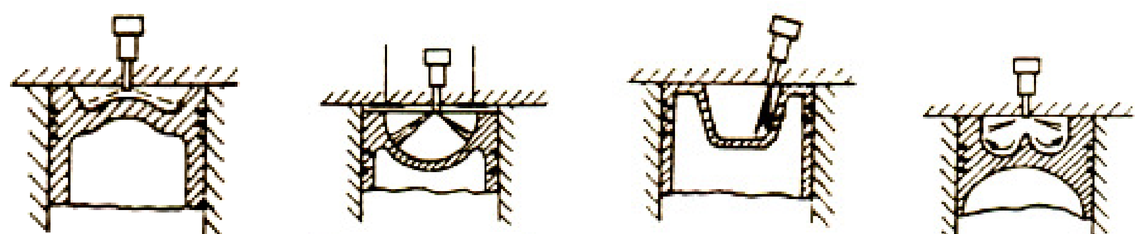
These chambers mainly consist of space formed between a flat cylinder head and a cavity in the piston crown in different shapes. The fuel is injected directly into space. The injection nozzles used for this chamber are generally of multi hole type working at a relatively high pressure (about 200 bar)

The main advantages of this type of chambers are:

- Minimum heat loss during compression because of lower surface area to volume ratio and hence, better efficiency.
- No cold starting problems.
- Fine atomization because of multi hole nozzle.

The drawbacks of these combustion chambers are:

- High fuel-injection pressure required and hence complex design of fuel-injection pump.
- Necessity of accurate metering of fuel by the injection system, particularly for small engines.



| Shallow depth chamber (b) Hemispherical chamber (c) Cylindrical chamber (d) Toroidal chamber

Shallow Depth Chamber: In shallow depth chamber the depth of the cavity provided in the piston is quite small. This chamber is usually adopted for large engines running at low speeds. Since the cavity diameter is very large, the squish is negligible. Hemispherical Chamber: This chamber also gives small squish. However, the depth to diameter ratio for a cylindrical chamber can be varied to give any desired squish to give better performance.

Cylindrical Chamber: This design was attempted in recent diesel engines. This is a modification of the cylindrical chamber in the form of a truncated cone with base angle of 30°. The swirl was produced by masking the valve for nearly 180^0 of circumference. Squish can also be varied by varying the depth.

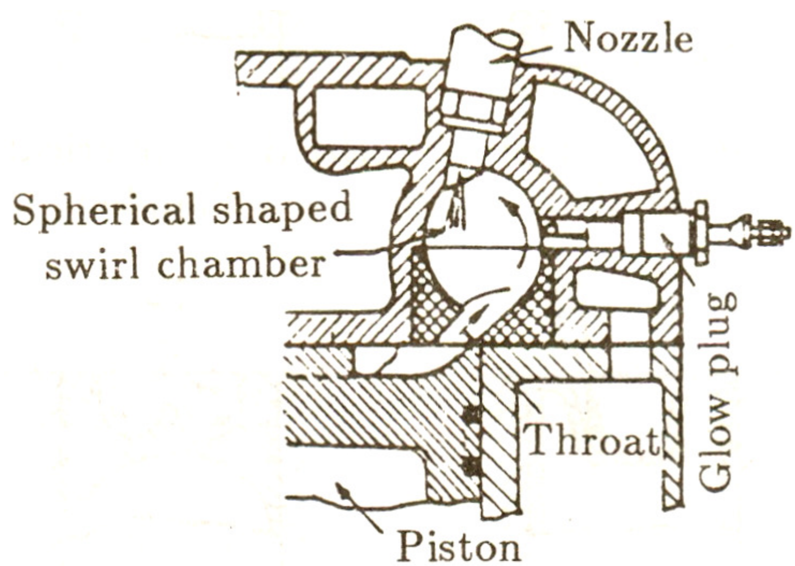
Toroidal Chamber: The idea behind this shape is to provide a powerful squish along with the air movement, similar to that of the familiar smoke ring, within the toroidal chamber. Due to powerful squish the mask needed on inlet valve is small and there is better utilisation of oxygen. The cone angle of spray for this type of chamber is 150° to 160°.

IN DIRECT INJECTION CHAMBERS (VTU Dec 06/Jan 07)

A divided combustion chamber is defined as one in which the combustion space is divided into two or more distinct compartments connected by restricted passages. This creates considerable pressure differences between them during the combustion process.

(VTU Dec 06/Jan 07)

Ricardo's Swirl Chamber: Swirl chamber consists of a spherical-shaped chamber separated from the engine cylinder and located in the cylinder head. Into this chamber, about 50% of the air is transferred during the compression stroke. A throat connects the chamber to the cylinder which enters the chamber in a tangential direction so that the air coming into



this chamber is given a strong rotary movement inside the swirl chamber and after combustion, the products rush back into the cylinder through same throat at much higher velocity. This causes considerable heat loss to walls of the passage which can be reduced by employing a heat insulated passage. This type of combustion chamber finds its application where fuel quality is difficult to control, where reliability under adverse conditions is more important than fuel economy. The use of single hole of larger diameter for the fuel spray nozzle is often important consideration for the choice of swirl chamber engine.

PRE COMBUSTION CHAMBERT

Typical pre-combustion chamber consists of an anti chamber connected to the main chamber through a number of small holes (compared to a relatively large passage in the swirl chamber). The pre-combustion chamber is located in the cylinder head and its volume accounts for about 40% of the total combustion, space. During the compression stroke the piston forces the air into the pre-combustion chamber. The fuel is injected into the pre-chamber and the combustion is initiated. The resulting pressure rise forces the flaming droplets together with some air and their combustion products to rush out into the main cylinder at high velocity through the small holes. Thus it creates both strong secondary turbulence and distributes the flaming fuel droplets throughout the air in the main combustion chamber where bulk of combustion takes place. About 80% of energy is released in main combustion chamber. The rate of pressure rise and the maximum pressure is lower compared to those in open type chamber. The initial shock if combustion is limited to pre-combustion chamber only. The pre-combustion chamber has multi fuel capability without any modification in the injection system because the temperature of pre-chamber. The variation in the optimum injection timing for petrol and diesel operations is only 2 deg. for this chamber compared to 8 to 10 deg in other chamber design.

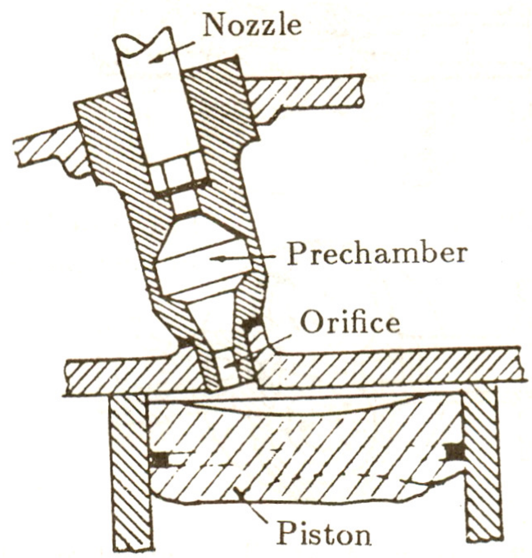


Fig.10.21 Precombustion Chamber

Advantages:

(i) Due to short or practically no delay period for the fuel entering the main combustion space, tendency to knock is minimum, and as such running is smooth.

(ii) The combustion in the third stage is rapid.

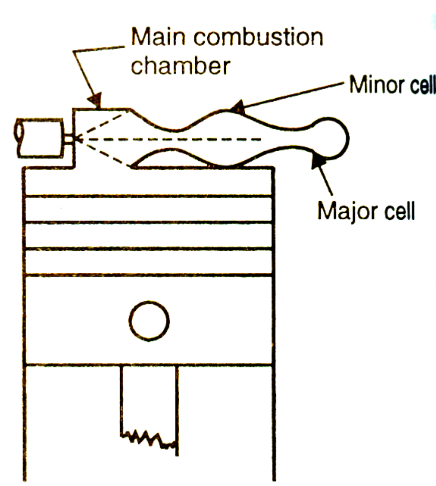
(iii) The fuel injection system design need not be critical. Because the mixing of fuel and air takes place in pre-chamber,

Disadvantages:

(i) The velocity of burning mixture is too high during the passage from pre-chambers, so the heat loss is very high. This causes reduction in the thermal efficiency, which can be offset by increasing the compression ratio.

(ii) Cold starting will be difficult as the air loses heat to chamber walls during compression.

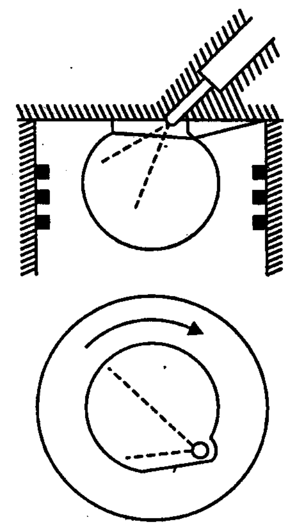
Energy cell :



The 'energy cell' is more complex than the pre-combustion chamber. As the piston moves up on the compression stroke, some of the air is forced into the major and minor chambers of the energy cell. When the fuel is injected through the pintle type nozzle, part of the fuel passes across the main combustion chamber and enters the minor cell, where it is mixed with the entering air. Combustion first commences in the main combustion chamber where the temperature is higher, but the rate of burning is slower in this location, due to insufficient mixing of the fuel and air. The burning in the minor cell is slower at the start, but due to better mixing, progresses at a more rapid rate. The pressure built up in the minor cell , therefore , force the burning gases out into the main chamber, thereby creating added turbulence and producing better combustion in the this chamber. In mean time, pressure is built up in the major cell which then prolongs the action of the jet stream entering the main chamber, thus continuing to induce turbulence in the main chamber.

M COMBUSTION CHAMBER (VTU July 2006)

After twenty years of research in 1954, Dr. Meuner of M.A.N., Germany developed M-process engine which ran without typical diesel combustion noise and hence it was named 'whisper engine'.



The 'M-combustion chamber' is a special type of open combustion chamber, having combustion chamber in the piston cavity. It differs in principle from other open chamber designs in that the fuel spray impinges on and spreads over the surface of a spherical cavity in the piston. Earlier it had usually been assumed that fuel spray impingement was undesirable, though in most diesel engines some impingement always takes place at full load. The fuel is injected tangentially from a multi-hole nozzle on the surface of the chamber in the direction of the air swirl. Injected fuel forms a film, about 0.15 mm thick, on the surface of the chamber. The combustion is initiated by the auto-ignition of a small portion of fuel which is air-borne at the very beginning. The amount of this airborne fuel is controlled by selecting a proper distance between the nozzle tip and the combustion chamber wall. Subsequently the fuel vapours rise from the hot wall and are mixed with the swirling air in successive layers and combustion takes place in a near homogeneous air-fuel mixture at the desired rate. The rate of energy release is thus almost equal to the rate of evaporation of fuel. Thus, even though the engine works on diesel cycle, once the ignition takes place, the combustion characteristics are similar to those of OTTO cycle combustion.

The advantages of 'M-chamber

- Low rates of pressure rise, low peak pressure.
- Low smoke level.
- Ability to operate on a wide range of liquid fuels (multi-fuel capability).
- No combustion noise is reported even for 80-octane petrol.

The disadvantages of M-chamber are:

- Since fuel vaporization depends upon the surface temperature of the combustion chamber, cold starting requires certain aids.
- Some white smoke, diesel odour, and high hydrocarbon emission may occur at starting and idling conditions.
- Volumetric efficiency is low.

The following table gives comparison between Open chamber and divided chamber.

Sl No.	Aspects	Open Combustion Chamber (DIRECT INJECTION)	Divided combustion chamber (INDIRECT INJECTION)
1	Fuel Used	Can consume fuels of good ignition quality. i.e., of shorter ignition delay or higher Cetane Number	Can consume fuels of poor ignition quality i.e. of longer ignition delay or lower Cetane Number
2	Type of injection nozzles used	Requires multiple hole injection nozzles for proper mixing of fuel and air and also higher injection pressures	It is able to use single hole injection nozzles and moderate injection pressures It can also tolerate greater degree of nozzle fouling
3	Sensitivity to fuel	Sensitive	Insensitive
4	Mixing of fuel and air	Mixing of fuel and air is not so efficient and thus high fuel air ratios are not feasible without smoke	Ability to use higher fuel ratio without smoke due to proper mixing and consequent high air utilization factor
5	Cylinder construction	Simple	More expensive cylinder construction
6	Starting	Easy cold starting	Difficult to cold start because of greater heat loss through throat
7	Thermal efficiency	Open combustion chambers are thermally more efficient	Thermal efficiency is lower due to throttling in throat areas leading to pressure losses and heat losses.

COLD STARTING OF CI ENGINES (VTU July 2006)

Easy starting from cold is a very important requirement of a CI engine. To ensure easy cold starting, frequently compression ratios higher than necessary are used. Even so, cold starting may become difficult in

- extreme cold climate like Himalayan region,
- when the cylinder liner is heavily worn, and
- When the valves are leaky.

It is, therefore, sometimes necessary to provide some electrical aid for cold starting. Open chamber direct injection engines are easiest to cold start. The reasons for easy starting of open chamber direct injection engines are as follows

- They have smallest surface to volume (S/V) ratio. Because of this the loss of heat is minimum.
- They have lowest intensity of air swirl. Low intensity of swirl allows stagnant gas film to remain on cylinder walls, which reduces heat transfer.

Many methods have been used in the past to achieve easy cold starting. Few of them are described below:

- Injection of a small quantity of lubricating oil or fuel oil. This ad hoc method helps by temporarily raising the compression ratio and sealing the piston rings and valves.
- Provision of cartridges. These may be self-igniting or requiring lighting before insertion into the combustion chamber.
- Starting as petrol engines. The engine is provided with a sparking plug and carburetor. At starting, compression ratio is reduced by providing an auxiliary chamber and the engine is started as a petrol engine.
- Preheating the engine cylinder by warm water.
- Modifying valve timings for starting.

Modern starting aids of high speed engines. Basically three types of starting aids are used on modern high speed diesel engines:

- Electric glow plugs in. the combustion chamber.
- Manifold heaters which ignite a small feed of fuel.
- The injection into the intake, of controlled amounts of low- ignition temperature liquids, usually ethyl-ether with addition of other fuels.