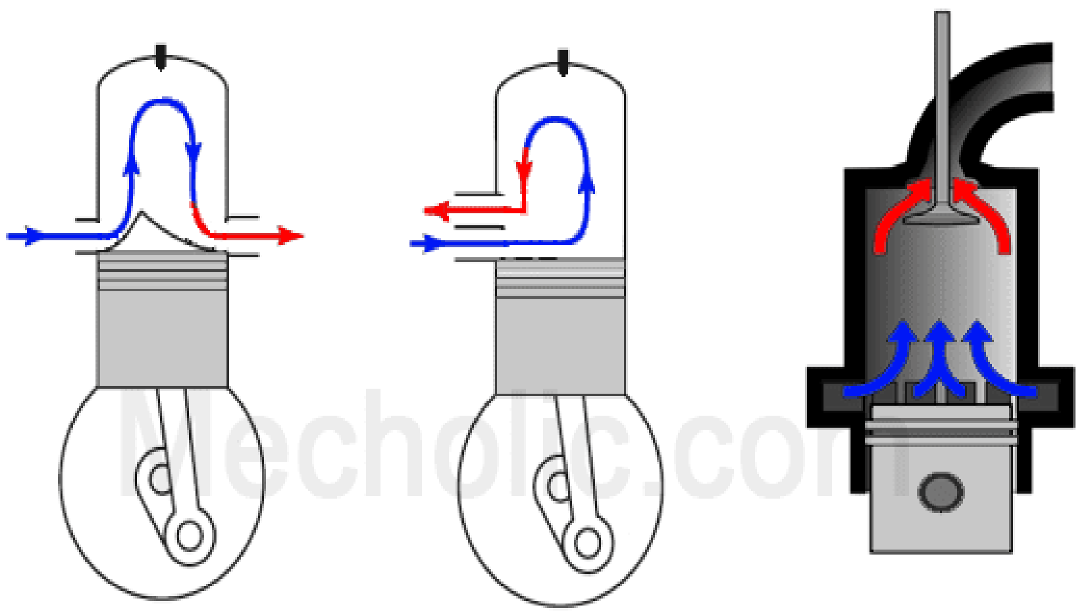
**UNIT-III**

**SCAVENGING OF TWO STROKE ENGINES**

Topics:

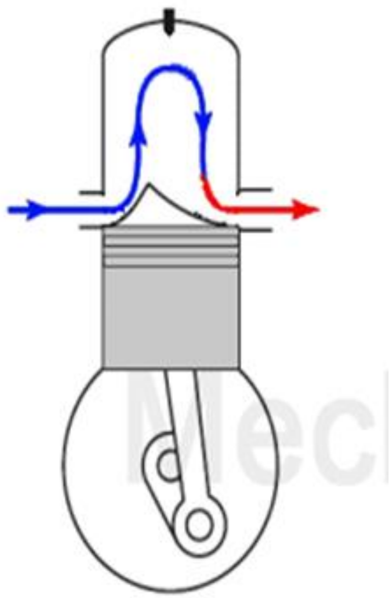
1. Classification of scavenging systems.
2. Charging processes in two stroke engine - Sankey diagram.
3. Scavenging modeling - scavenging models.
4. Mixture control through reed valve induction.

**Classification of scavenging systems:**



(a) Cross flow scavenge (b) Loop scavenge (c) Uniflow scavenge

## Cross flow scavenging



(a) Cross flow scavenge

Cross flow and Revere loop scavenging take place with the help of piston movement. Cross flow scavenging, transfer port (inlet) and exhaust port are situated on the opposite side of the cylinder. The exhaust gas is pushed out by cross flow. The piston head is designed to have a hump shape called deflector. The fresh air enters in the engine cylinder is deflected to the upward by a deflector and pushing exhaust gas down the other side. Before loop scavenging invented, almost all two-stroke engines use this method.

## Advantages and disadvantages of Cross flow scavenging

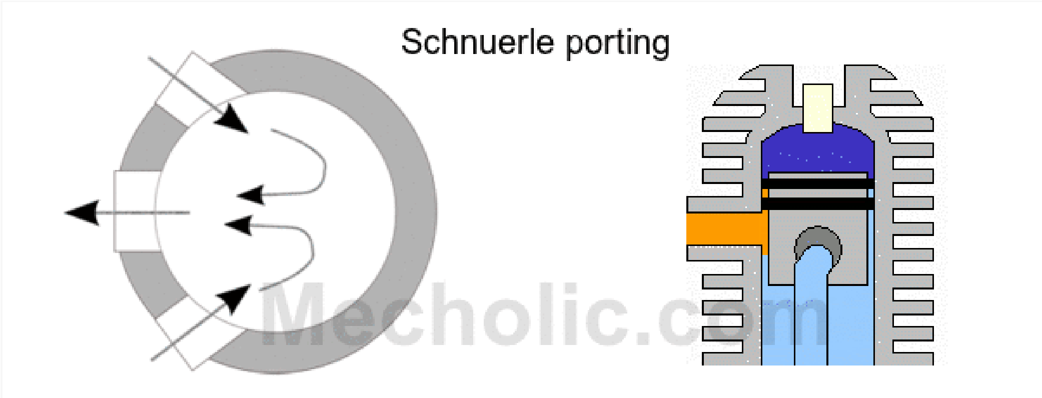
**Advantages:**

- Low manufacturing cost.
- Good scavenging at low speed and part throttle.
- Low engine volume for the multicylinder arrangement.

**Disadvantages:**

- Heavy piston with very high heat absorption.
- High tendency to knock.
- Poor scavenging at high speed and full throttle.
- Compulsory water cooling, difficulty in cooling piston crown.

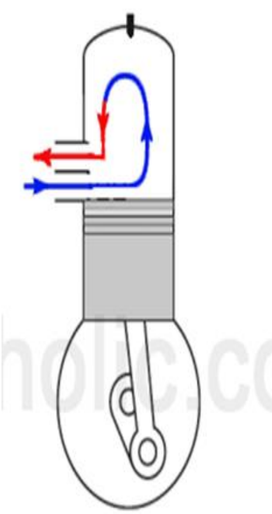
## Loop scavenging




(a) Cylinder and ports, viewed from above (b) Cylinder scavenging, from the side

Similar to the cross flow scavenging, but the inlet ad exhaust port are placed the same side of the engine cylinder. The gases are encouraged to move loops. This type of scavenging used carefully designed transfer port (inlet) to loop fresh air rise towards the cylinder head on one side and pushes the burnt gas down to the exhaust port installed just above the inlet. It has a flat or slightly domed piston crown. This is the most used type of scavenging system.

Example: *Schnuerle porting*



(b) Loop scavenge

# Advantages and disadvantages of Loop scavenging

**Advantages:**

- Low maintenance.
- The low surface area to the volume of the cylinder (hence the heat loss reduced).
- Good scavenging at full throttle.
- Water cooling system not necessary.

**Disadvantages:**

- Poor scavenging at part throttle operation.
- Scavenging time is short.

## Uniflow scavenging

Uniflow scavenging so called because both fresh charge and exhaust gas move in a same upward direction. In this method, fresh air enters from the lower side of the cylinder, and it pushes out exhaust through the exit valve situated at the top of the cylinder. This method is used in large two-stroke diesel engines.

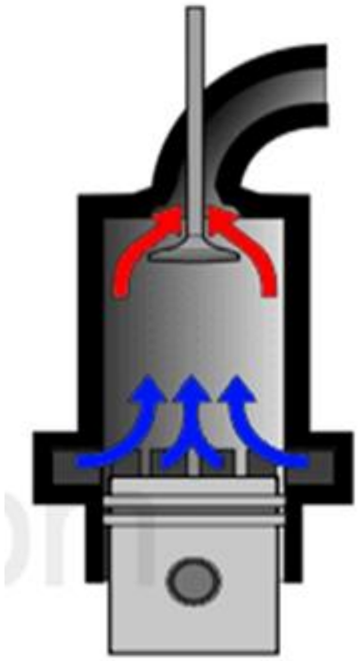
## Advantages and disadvantages of uniflow scavenging

**Advantages:**

- Extended time for valve operation.
- The possibility of mixing is reduced due to uniflow.
- Increase power output.
- Most efficient of all three methods.
- Good scavenging at all speed ranges and throttle position.
- Low fuel consumption compared to other scavenging types.

**Disadvantages:**

- Elaborate and costly construction.
- Difficulty in cooling the piston.



(c) Uniflow scavenge

**Charging processes in two stroke engine:**

**(I)Perfect scavenging.**

Ideally, the fresh fuel-air mixture should remain separated from the residual combustion products with respect to both mass and heat transfer during the scavenging process. Fresh air pumped into the cylinder by the blower through the inlet ports at the lower end of the cylinder pushes the products of combustion ahead of itself and of the cylinder through the exhaust valve at the other end. There is no mixing of air and products. As long as any products remain in the cylinder the flow through the exhaust valves consists of products only. However, as soon as sufficient fresh .air has entered to fill the entire cylinder volume (displacement plus clearance volume) the flow abruptly changes from one of products to one of air. This ideal process would represent perfect scavenging with no short -circuiting loss.

**(ii) Perfect mixing.**

The second theoretical scavenging process is perfect mixing, in which the incoming fresh charge mixes completely and instantaneously with the cylinder contents, and a portion of this mixture passes out of the exhaust ports at a rate equal to that entering the cylinder. This homogeneous mixture consists initially of products of combustion only and then gradually changes to pure air. This mixture flowing through the exhaust ports is identical with that momentarily existing in the cylinder and changes with it. For the case of perfect mixing the scavenging efficiency can be represented by the following equation:

$\eta_{sc} = 1 - e^{-R_{del}}$, where $\eta_{sc}$ and $R_{del}$ are scavenging efficiency and delivery ratio respectively.

This is plotted in Fig. 2.15. The result of this theoretical process closely approximates the results of many actual scavenging processes, and is thus often used as a basis of comparison.

**(iii)Short-circuiting.**

The third type of scavenging process is that of short-circuiting in which the fresh charge coming from the scavenge manifold directly goes out of the exhaust ports without removing any residual gas. This is a dead loss and its occurrence must be avoided. The actual scavenging process is neither one of perfect scavenging nor perfect mixing. It probably consists partially of perfect cavenging, mixing and short-circuiting.

Fig. 2.16shows the delivery ratio and trapping efficiency variation with crankangle for three different scavenging modes., *i.e.*,perfect scavenging (displacement), perfect mixing and intermediate scavenging.

Fig. 2.17shows the scavenging parameters for the intermediate scavenging.

This represents the actual scavenging process. It can be seen from this Fig. that a certain amount of combustion products is initially pushed out of the cylinder without being diluted by fresh air. Gradually,

**The trapping efficiency** - The amount of fresh charge retained in the cylinder is not same as that supplied to the cylinder because some fresh charge is always lost due to short-circuiting. Therefore, an additional term, trapping efficiency, is used to indicate the ability of the cylinder to retain the fresh charge. It is defined as the ratio of the amount of charge retained in the cylinder to the total charge delivered to the engine,

$$\eta_{tr} = \frac{\text{mass of delivered air (or mixture) retained}}{\text{mass of trapped cylinder charge}}.$$

Trapping efficiency indicates what fraction of the air (or mixture) supplied to the cylinder is retained in the cylinder. This is mainly controlled by the geometry of the ports and the overlap time.

**The scavenging efficiency** Scavenging efficiency is the ratio of the mass of scavenge air which remains in the cylinder at the end of the scavenging to the mass of the cylinder itself at the moment when the scavenge and exhaust ports of valves are fully closed. It is given by

$$\eta_{sc} = \frac{\text{mass of delivered air (or mixture) retained}}{\text{mass of trapped cylinder charge}}.$$

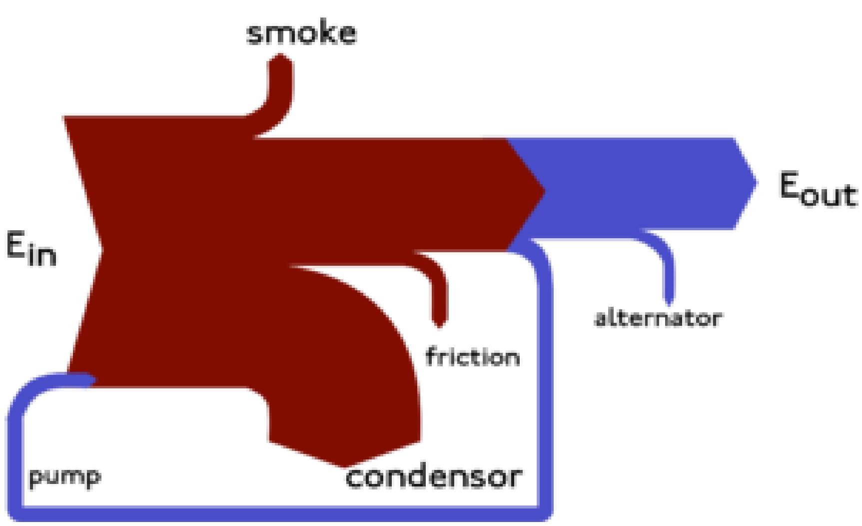
indicates to what extent the residual gases in the cylinder have been replaced with fresh air.
If $=\eta_{sc}$, it means that all gases existing in the cylinder at the beginning of scavenging have been swept out completely.

**The purity of the charge**: $\text{purity} = \frac{\text{mass of air in trapped cylinder charge}}{\text{mass of trapped cylinder charge}}$, indicates the degree of dilution, with burned gases, of the unburned mixture in the cylinder.

**The charging efficiency** $\eta_{ch} = \frac{\text{mass of delivered air (or mixture) retained}}{\text{displaced volume x ambient density}}$, indicates how effectively the cylinder volume has been filled with fresh air (or mixture)

**Sankey diagram**:

**Sankey diagrams** are a specific type of flow diagram, in which the width of the arrows is shown proportionally to the flow quantity.



**Scavenging modeling - scavenging models**

Perfect Displacement Model:

which is used to estimate the upper bound of the scavenging process, where parameters such as scavenging efficiency and charging efficiency are overestimated. This model is a so called single-phase, two-zone model which refers to a process where the burned gas is displaced by the fresh air charge and no mixing of gasses takes place.

This process consists of two zones, the fresh charge zone and the burned gas zone. For the model calculations it is assumed that the process occurs under a constant cylinder volume and pressure, no heat or mass is allowed to cross the interface between fresh charge and burned gas and the cylinder walls are assumed adiabatic.

**Perfect Mixing Model:**

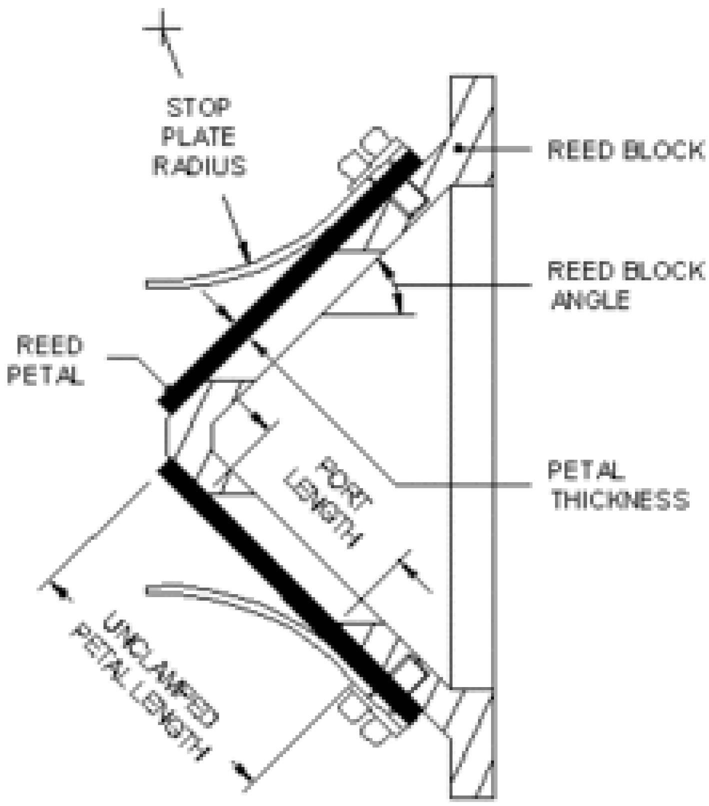
The perfect mixing model is another single-phase model, based on similar assumptions as the perfect displacement model. The perfect mixing model is a single zone model where it is assumed that the fresh air charge mixes instantaneously with the burned gas, forming a homogeneous mixture inside the cylinder volume. The perfect mixing is assumed to occur under constant cylinder pressure and volume and the walls are assumed adiabatic. The two gases involved have to follow the ideal gas law and are assumed to have the same molecular weights and their specific heat is identical and constant.

**Multi-Phase Multi-Zone Models**:

It has been shown by visual observations in motored engines that the scavenging process is not a continuous process that occurs under one-single phase as the simple models introduced. In general the scavenging process is assumed to occur in several distinct phases and in two or more distinct zones. In previous section two phases were used, the displacement and mixing phases. For the extended models an additional phase, the short-circuiting phase, is included in the model calculations. These models often require some empirical model constants that depend on both operating conditions and geometry of the cylinder and scavenging ports. The empirical model constants have been estimated from experimental measurements.

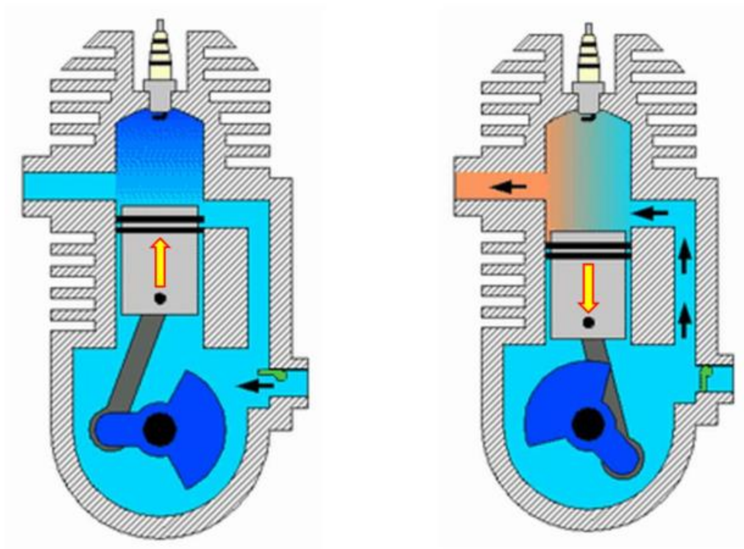
**Mixture control through reed valve induction:**

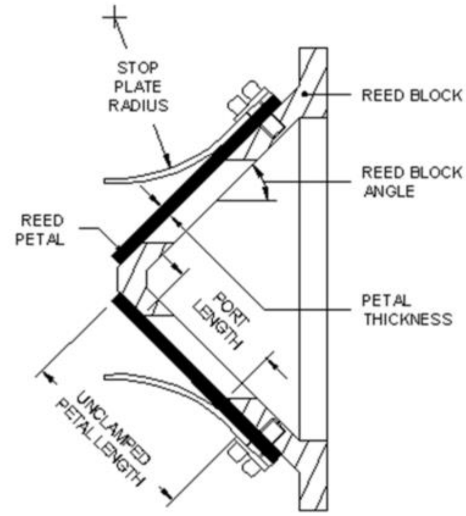
**Reed valves** are a type of check valve which restrict the flow of fluids to a single direction, opening and closing under changing pressure on each face.




- Reed valves are commonly used in high-performance versions of the two-stroke engine, where they control the fuel-air mixture admitted to the cylinder.
- As the piston rises in the cylinder a vacuum is created in the crankcasebeneath the piston. The resulting pressure differential opens the valve and the fuel-air mixture flows into the crankcase.
- As the piston descends, it raises the crankcase pressure causing the valve to close to retain the mixture and pressurize it for its eventual transfer through to the combustion chamber.
- The Swedish motorcycle company Husqvarna produced a two-stroke, 500 cc displacement single cylinder engine with a reed-valve controlled intake, one of the biggest in using this arrangement.
- Reed valves in two-stroke engines have been placed in the intake ports and also in controlling the intake to the crankshaft space.

In a two stroke engine when the piston moves upwards in suction-compression stroke, sudden pressure drop occurs in the chamber below the piston (crankcase). At this moment fresh air-fuel mixture is sucked from the carburetor to the crankcase. Next, when the piston moves downwards in work-exhaust stroke, this fresh mixture is pushed upwards to reload the combustion chamber. In older, less powerful generations of two stroke engines part of the fresh mixture being pushed out from the crankcase was moving back to the carburetor. Nowadays, a one way valve is used between the crankcase and the carburetor. This valve is called a reed valve and is shown on **Pic. 1**. Reed valve allows the mixture to move in only one direction – from the carburetor to the crankcase. It prevents the mixture from moving back to the carburetor. In the effect reed valve improves reloading of the combustion chamber with fresh air-fuel mixture. This improves power output of modern two stroke engines.






Reed valve design is simple (see **Pic. 2**): a valve comprises of the case/support to which reed petals (also called "reeds") are attached. In most, but not all, applications reed petal movement limiter is also used. Due to underpressure created in the crankcase during suction-compression stroke, reeds lift-off allowing fresh air-fuel mixture to pass through. Next, in work-exhaust stroke, reeds close due to its' own resiliency and overpressure occurring in the crankcase. In the effect, since the mixture cannot move back to the carburetor, more of it is loaded to the combustion chamber.

The cycle described  above repeats proportionally to the engine speed usually given in Rotations Per Minute or RPM.

This means that reeds can open & close thousands of times per minute. Each cycle, the total of which must be counted in millions, uses a bit of reed petal „life” since pretty much every material has limited fatigue capability.