UNIT IV

PORTS AND MUFFLER DESIGN

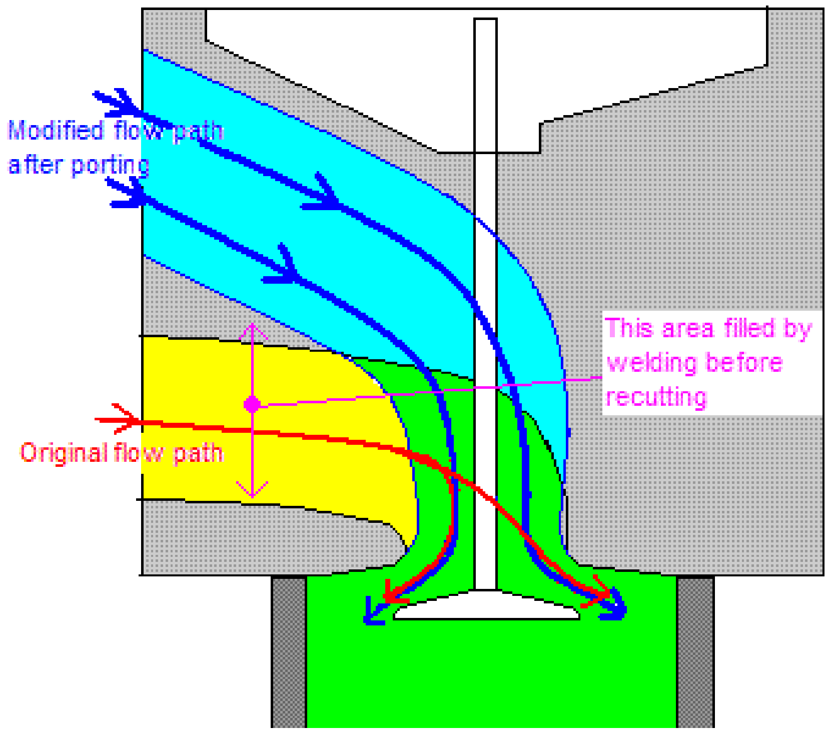
Topics:

- Porting - port flow characteristics - design considerations.
- Design of intake and exhaust systems - Kadenacy system

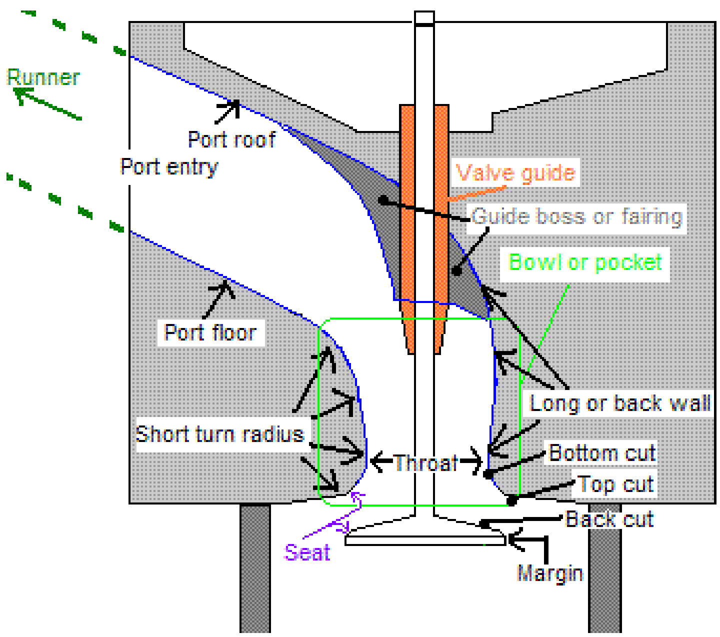
Cylinder head porting refers to the process of modifying the intake and exhaust ports of an internal combustion engine to improve the quality and quantity of the air flow. Cylinder heads, as manufactured, are usually suboptimal due to design and manufacturing constraints.

Porting the heads provides the finely detailed attention required to bring the engine to the highest level of efficiency.

More than any other single factor, the porting process is responsible for the high power output of modern engines.



Port components



Two-stroke porting

Scavenging quality/purity: The ports are responsible for sweeping as much exhaust out of the cylinder as possible and refilling it with as much fresh mixture as possible without a large amount of the fresh mixture also going out the exhaust. This takes careful and subtle timing and aiming of all the transfer ports.

Power band width: Since two-strokes are very dependent on wave dynamics, their power bands tend to be narrow. While struggling to get maximum power, care must always be taken to ensure that the power profile does not get too sharp and hard to control.

Time area: Two-stroke port duration is often expressed as a function of time/area. This integrates the continually changing open port area with the duration. Wider ports increase time/area without increasing duration while higher ports increase both.

Timing: In addition to time area, the relationship between all the port timings strongly determine the power characteristics of the engine.

Wave Dynamic considerations: Although four-strokes have this problem, two-strokes rely much more heavily on wave action in the intake and exhaust systems. The two-stroke port design has strong effects on the wave timing and strength.

Heat flow: The flow of heat in the engine is heavily dependent on the porting layout. Cooling passages must be routed around ports. Every effort must be made to keep the incoming charge from heating up but at the same time many parts are cooled primarily by that incoming fuel/air mixture. When ports take up too much space on the cylinder wall, the ability of the piston to transfer its heat through the walls to the coolant is hampered. As ports get more radical, some areas of the cylinder get thinner, which can then overheat.

Piston ring durability: A piston ring must ride on the cylinder wall smoothly with good contact to avoid mechanical stress and assist in piston cooling. In radical port designs, the ring has minimal contact in the lower stroke area, which can suffer extra wear. The mechanical shocks induced during the transition from partial to full cylinder contact can shorten the life of the ring considerably. Very wide ports allow the ring to bulge out into the port, exacerbating the problem.

Piston skirt durability: The piston must also contact the wall for cooling purposes but also must transfer the side thrust of the power stroke. Ports must be designed so that the piston can transfer these forces and heat to the cylinder wall while minimizing flex and shock to the piston.

Engine configuration: Engine configuration can be influenced by port design. This is primarily a factor in multi-cylinder engines. Engine width can be excessive for even two cylinder engines of certain designs. Rotary disk valve engines with wide sweeping transfers can be so wide as to be impractical as a parallel twin. The V-twin and fore-and-aft engine designs are used to control overall width.

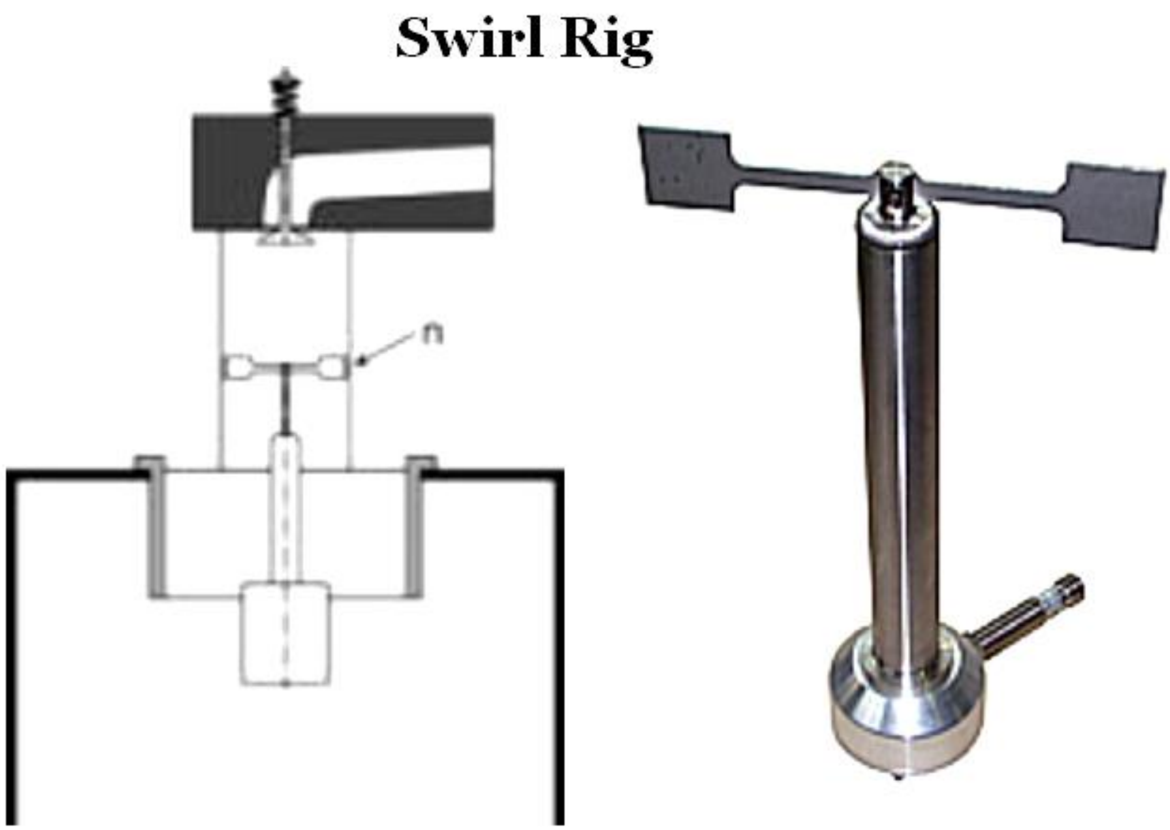
Cylinder distortion: Engine sealing ability, cylinder, piston and piston ring life all depend on reliable contact between cylinder and piston/piston ring so any cylinder distortion reduces power and engine life. This distortion can be caused by uneven heating, local cylinder weakness, or mechanical stresses. Exhaust ports that have long passages in the cylinder casting conduct large amounts of heat to one side of the cylinder while on the other side the cool intake may be cooling the opposite side. The thermal distortion resulting from the uneven expansion reduces both power and durability although careful design can minimize the problem.

Combustion turbulence: The turbulence remaining in the cylinder after transfer persists into the combustion phase to help burning speed. Unfortunately good scavenging flow is slower and less turbulent.

PORT FLOW MEASUREMENT

- Intake port flow characteristics are critical in determining the overall performance of diesel combustion systems. In-cylinder flows created during the intake stroke influence fuel-air mixing, bulk charge motion and turbulence generation.
- The flow capacity of the intake port is also a key factor in determining volumetric efficiency.
- The relationship between intake port geometry and Performance has long been a subject of interest tomany researchers, although as yet a comprehensive understanding remains elusive.
- Swirl is created by bringing the intake flow into the cylinder with an initial angular momentum.

- While some decay in swirl due to friction occurs during the engine cycle, intake generated swirl usually persists through the compression, combustion and expansion processes.
- In engine designs with bowl-in-piston combustion chambers, rotational motion set up during intake is substantially modified during compression.



Design of intake and exhaust systems:

Intake Systems:

The intake system’s job is to regulate the flow of clean, filtered air at the right temperature to the engine and to provide vacuum to operate other devices. Most factory intake systems are designed to generate as little noise as possible. The intake system also pulls crankcase vapours into the intake stream so the engine can burn them. Older carbureted engines do not have much of intake system. Usually just an air filter mounted on top of the carburetor, which is mounted on the intake manifold is enough for those engines. Modern day vehicles have much more intake plumbing to accommodate smaller engine bays which have much technology more packed into them.

Intake Air Source Location:

Most modern intake designs will take air from a location outside the engine bay to get the coolest air possible. It must also be a place that will not be submerged in water or be pugged up with excessive amounts of dirt or debris. One popular design from “back in the good old days,” is the “Ram Air” intake design. This design uses the movement of the vehicle to force more air into the intake system.

Airbox and Air Filter:

The airbox houses the air filter. Some airboxes (still) will have a flap in them, which can pull in warm air from near the exhaust manifold when the engine is cold. This improves fuel atomisation on a cold engine and helps the engine get up to temperature faster. The air filter is a folded paper material with a seal around the outside which catches dirt and debris that enters the intake system before it gets to the engine. Allowing dirt into the engine is extremely harmful to the engine and can shorten an engine’s life dramatically. If there are any holes in the filter element or if the outer seal doesn’t seal properly, dirt is being drawn into the engine. An easy way to check if the air filter is clogged is to hold it up at the sun and see if you can see light through it. If you can still see light (without obvious holes), the filter is still good.

Intake Pipes/Hoses:

Intake pipes are much larger than coolant pipes. They allow air to flow from component to component in the air intake system. These must be airtight and have airtight connections to avoid unmetered air and/or dirt and debris from entering the air stream. The pipes must also be flexible or at least have flexible portions to accommodate engine movement. Pipe routing can range from fairly simple on a small 4-cylinder to very complex on a turbocharged engine.

Throttle Body:


The throttle body controls airflow into the engine. They can be controlled by a cable attached to the accelerator pedal or electronically by the PCM.

Intake Manifold:

The intake manifold is the last piece of the intake system that air travels through before the intake port. Its main purpose is to provide equal amounts of air to each cylinder but it also provides a vacuum source for the power brakes and anything else that uses vacuum. Modern intake manifolds are aluminium or plastic to reduce weight. Plastic manifolds are prone to cracking, especially on a turbocharged engine. One important factor in intake manifold design is runner length. Long and/or skinny intake runners increase air speed into the engine which causes the air and fuel to mix better and produce torque at low-mid engine RPM. The the faster an engine runs, the more air it needs. At high engine RPM, air will already be moving very quickly into the engine. Air speed is not as much of a concern as air volume in the high RPM range. To get the best intake air volume and high RPM horsepower, wide and/or short intake runners are best. On a multiport injection system, the fuel injectors are seated in the lower part of the intake manifold but they spray fuel into the intake port. Some intake manifolds have coolant running through them to heat the air entering the engine. This is done to assist in fuel evaporation when the engine is cold.

Exhaust Systems:

The purpose of the exhaust system is to help remove used up exhaust gasses from the cylinder, deliver these gasses to the rear of the vehicle to prevent the occupants from breathing them and also to reduce engine noise in the cabin. The catalytic converter also acts as the vehicles primary emission control device. The gasses that flow through the exhaust system contain many different pollutants that can be harmful if inhaled or even fatal if continuously inhaled. It is important that if you suspect an exhaust leak on your vehicle that you get it looked at as soon as possible for your own health.

Exhaust Manifold:

The exhaust manifold is the first exhaust component the exhaust gasses encounter after the exhaust port. It collects the exhaust gasses from all the cylinders on that bank and directs them to the downpipe, flex-pipe or the catalytic converter.

Catalytic Converter:

The catalytic converter is the primary emission control device for the vehicle.

Flex-Pipe:

Just like the intake system, the exhaust system has to deal with engine movement. To do this, exhaust systems will use a flex-pipe that acts as a pivot point for the exhaust system. Because of the added load, they are a common area for the exhaust system to leak. Flex-pipes can be cut out and a new one welded in on some applications but others will need to be replaced as a unit with the adjoining pipes and components.

Mufflers:

Mufflers are used to reduce engine noise. Most vehicles will have one or two mufflers per exhaust system (duel exhaust). Mufflers tend to be located more to the rear of the vehicle. There are two main types of mufflers, reverse flow mufflers and straight through mufflers. Reverse flow mufflers force exhaust gasses through a series of chambers which cause the gasses to zig-zag through the muffler. This type tends to muffle engine noise much better than a straight through type but will be more restrictive. A straight through muffler will allow exhaust gasses to travel straight through the muffler with holes that expose the exhaust to sound baffling material.

Kadenacy effect

The **Kadenacy effect** is an effect of pressure-waves in gases. The momentum of the exhaust gas leaving the cylinder of an internal combustion engine creates a pressure-drop in the cylinder which assists the flow of a fresh charge of air, or fuel-air mixture, into the cylinder. The effect can be maximized by careful design of the inlet and exhaust passages.

https://www.youtube.com/watch?v=OfabfTUu86A