Manifold Tuning

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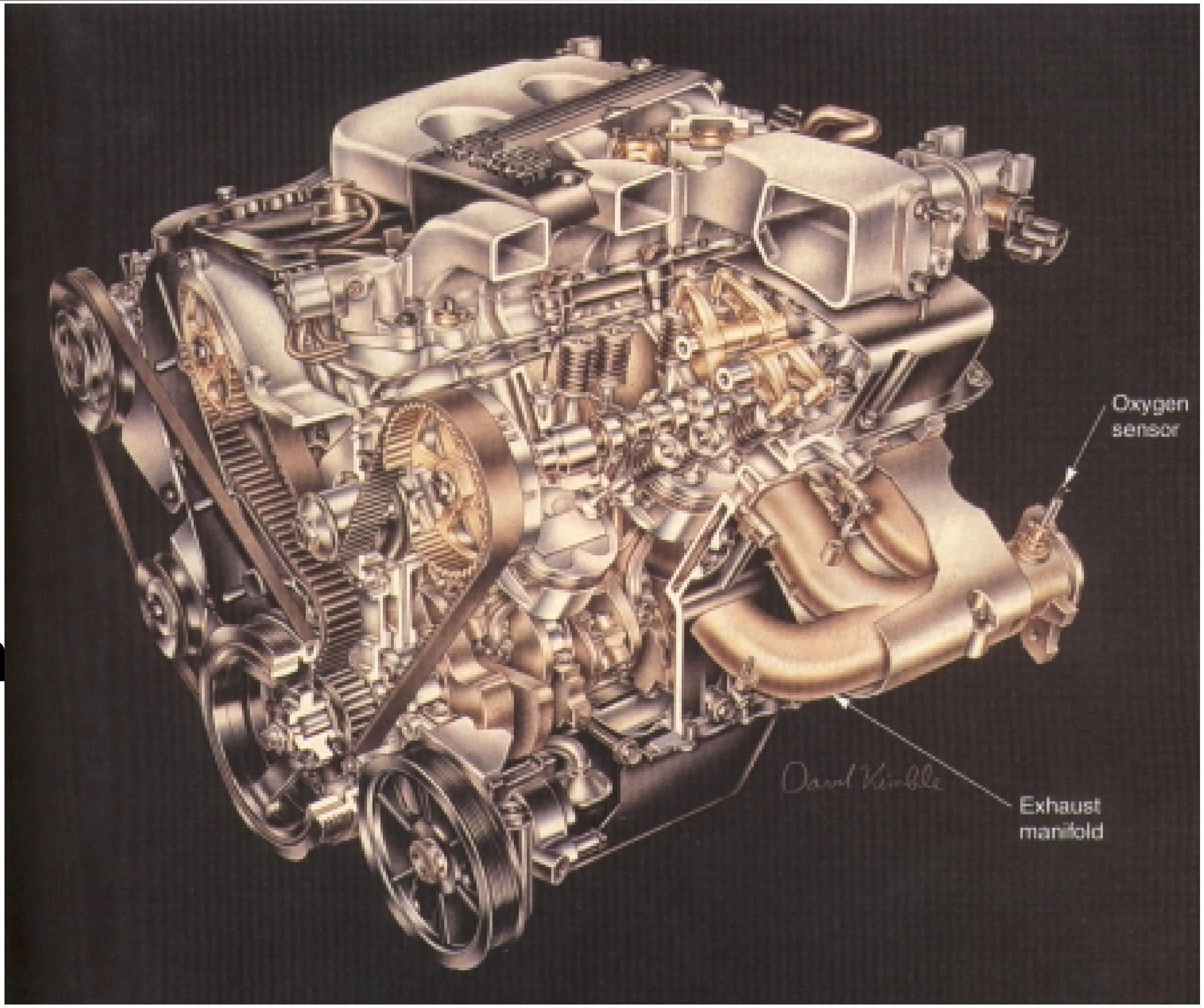
Overview

- Why is Tuning important?
  - Tuning increases the Volumetric Efficiency
    - Increasing this efficiency helps the engine breathe better as well as burn fuel effectively

Overview

- Intake
- Exhaust
- Diesel Vs. Gas
- Carburetor Vs. Injection
- Tuning Evolution

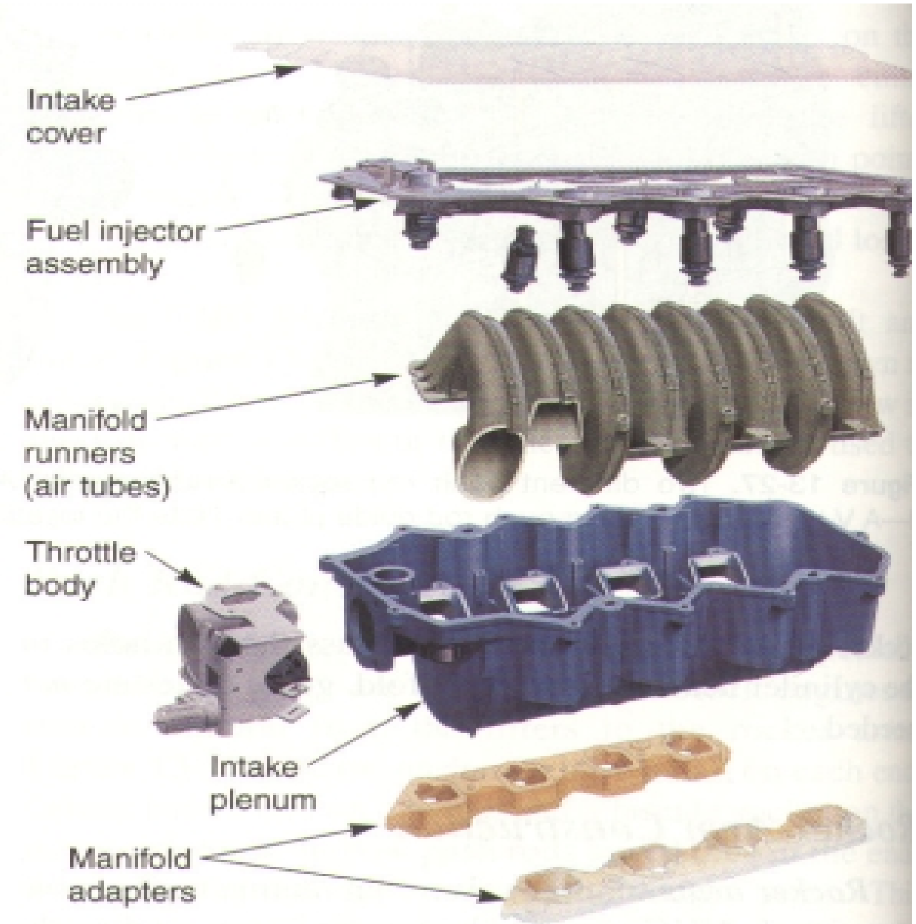


Manifold System Breakdown

- Intake (Induction) And Exhaust
  - System Components
  - Flow Properties
  - Pressure Waves
  - Variations

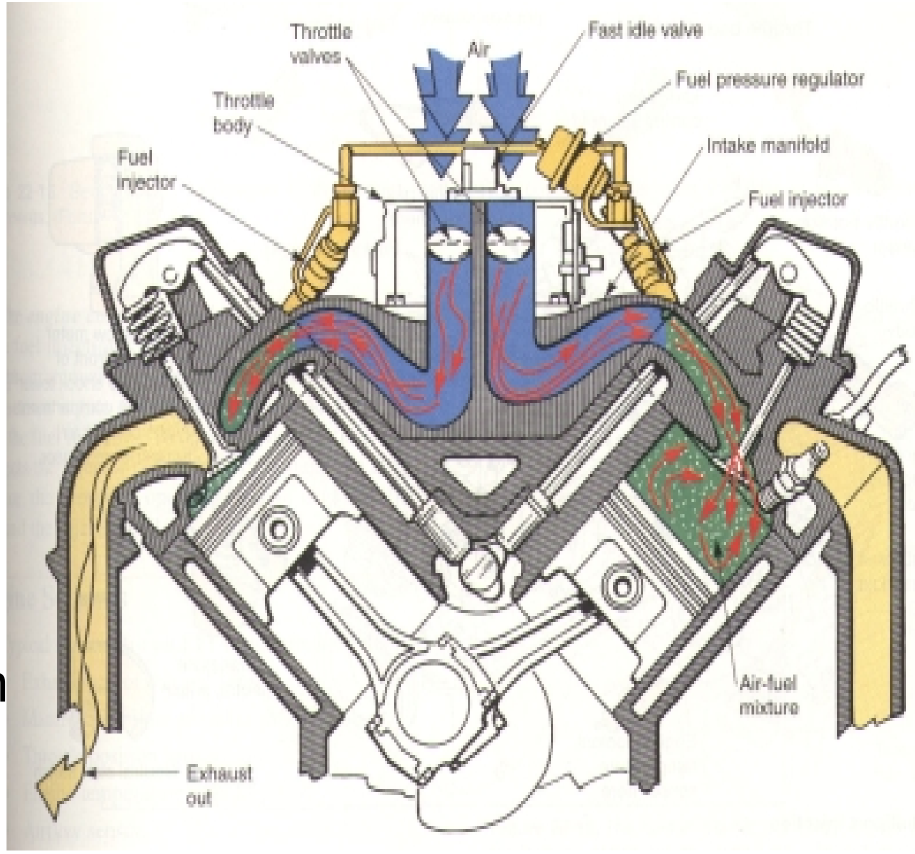
Intake Manifold

- Components
  - Air filter
  - Throttle Body
  - Fuel Injection System
  - Plenum
  - Runners



Desired Intake Flow Characteristics

- Smooth flow when only air present
  - Minimal turns and bends
- Turbulent flow when fuel is present
  - High atomization rate
  - Good fuel/air ratio
  - Proper fuel distribution

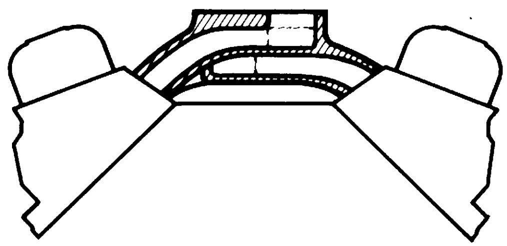


Intake Manifold Types

- Single Plane
- Dual Plane Cross H
- Individual or isolated runner (IR)
- Plenum Chamber

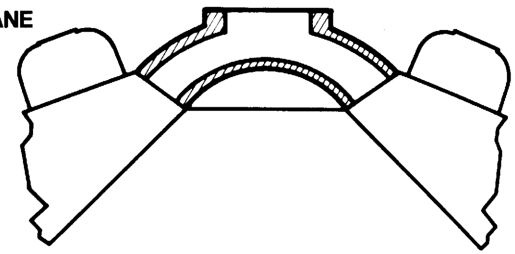
Intake Manifolds (cont…)

CROSS-H



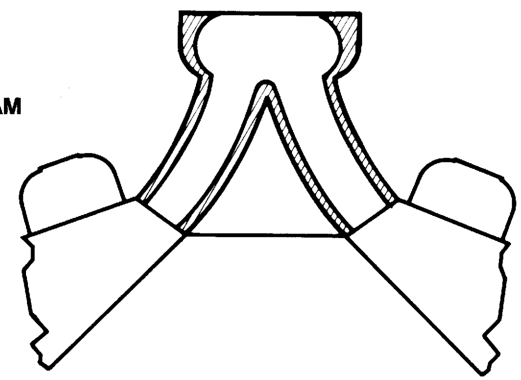
Cross-H or two-level manifold feeds half of cylinders from one side of carburetor—other half from other side of carburetor. Two sides of manifold are not connected.

SINGLE-PLANE



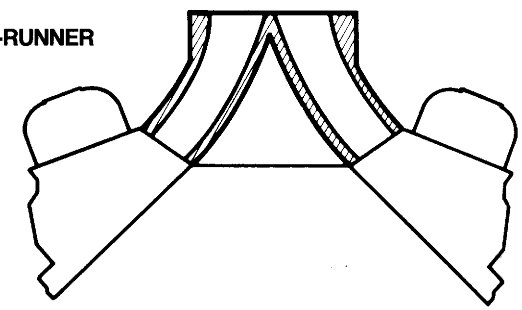
Single-plane manifold has all cylinder intake ports connected to a common chamber fed by the carburetor

PLENUM-RAM



Plenum-ram manifold has a plenum chamber between passages to intake ports and carburetor/s.

ISOLATED-RUNNER



Isolated-runner (IR) manifold uses an individual throttle bore of a carburetor for each cylinder. There is no interconnection between the intake ports or throttle bores.

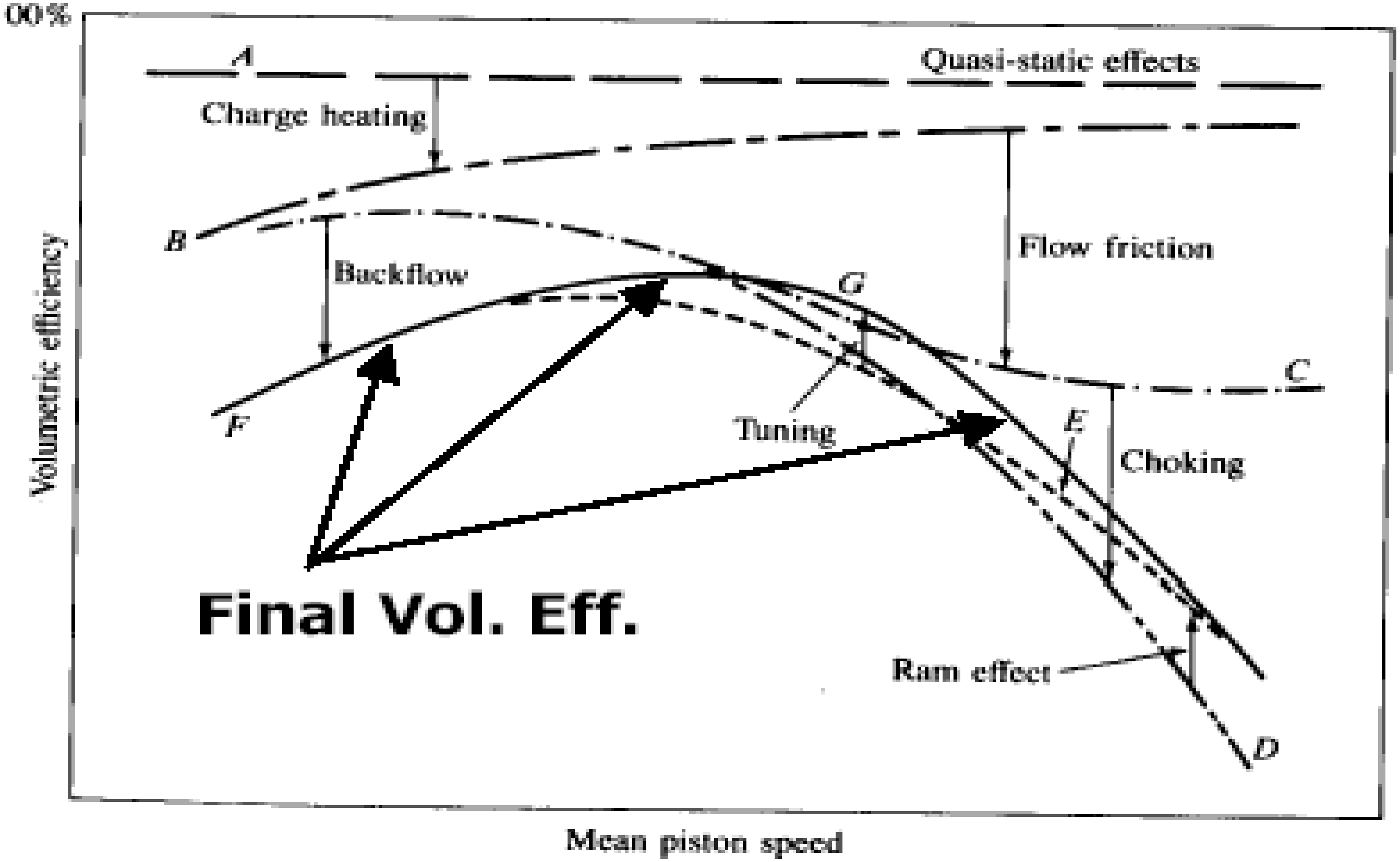
Intake Theory

- Volumetric Efficiency
  - Measure of losses in the intake system
    - Air filter
    - Throttle plate
    - Ports
    - Valves
    - Ducts
  - Actually a mass ratio!
  - Can be greater than 100% for turbocharged engines. Normally between 80% and 90% for NA engines
  - Only meaningful for a 4-stroke cycle (not used to describe 2-stroke cycles)

$$\eta_v = \frac{\text{mass inducted}}{\text{mass at inlet } T \text{ and } P} = \frac{2\dot{m}_a}{\rho_{a,i} V_d N}$$

$$\eta_v = \frac{m_a}{\rho_{a,i} V_d}, \quad m_a \rightarrow \text{Air mass in cylinder}$$

Intake Theory (cont...)



Intake Theory (cont…)

- Volumetric Efficiency Vs. RPM
  - D-type Jaguar Engine
  - Shows that at high RPM Efficiency falls off due to length pipes

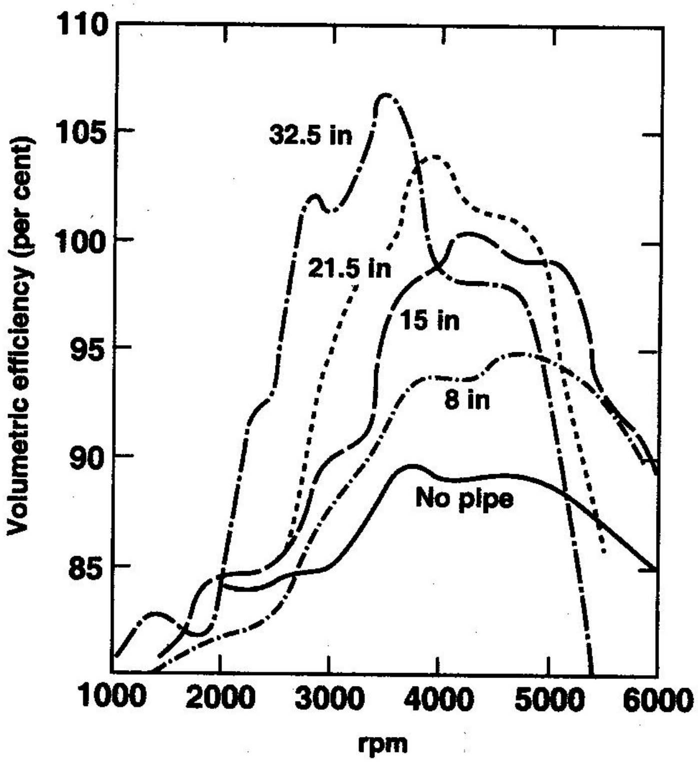
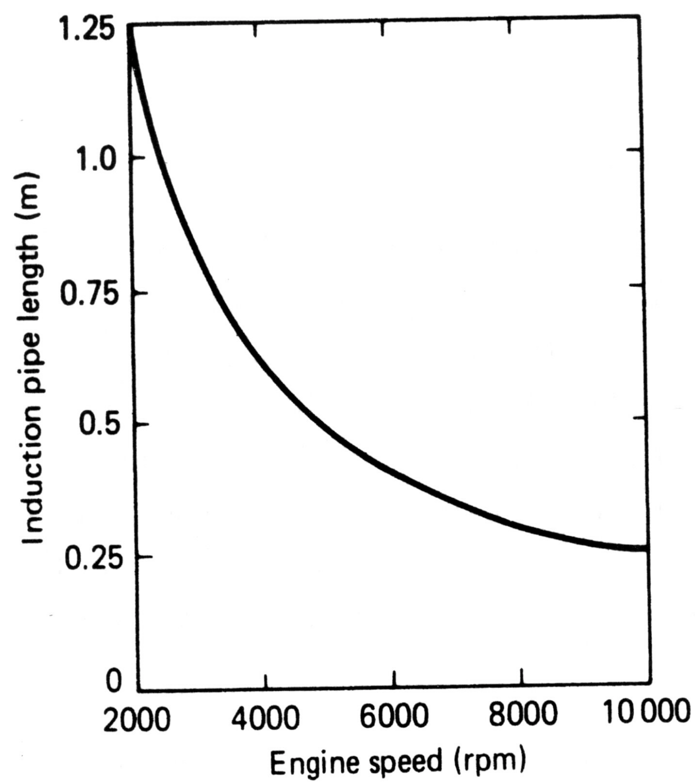


Figure 2.33. Effect of intake pipe length on volumetric efficiency (D Type Jaguar engine) [24]. Courtesy of Bentley Automotive Publishers.

Intake Theory (cont...)

- Induction Length vs. Engine Speed
  - The faster the RPM, the shorter induction pipe length is desired, and vice-versa.
  - Manifold Folding concept



Intake Theory (cont…)

- Manifold Folding
  - Higher engine speeds you want shorter runne to create more horsepower. Lower engine speed longer runners provide more torque
  - With folding, a valve responds to the engine condition, to lengthen c shorten the length of runner the air must travel

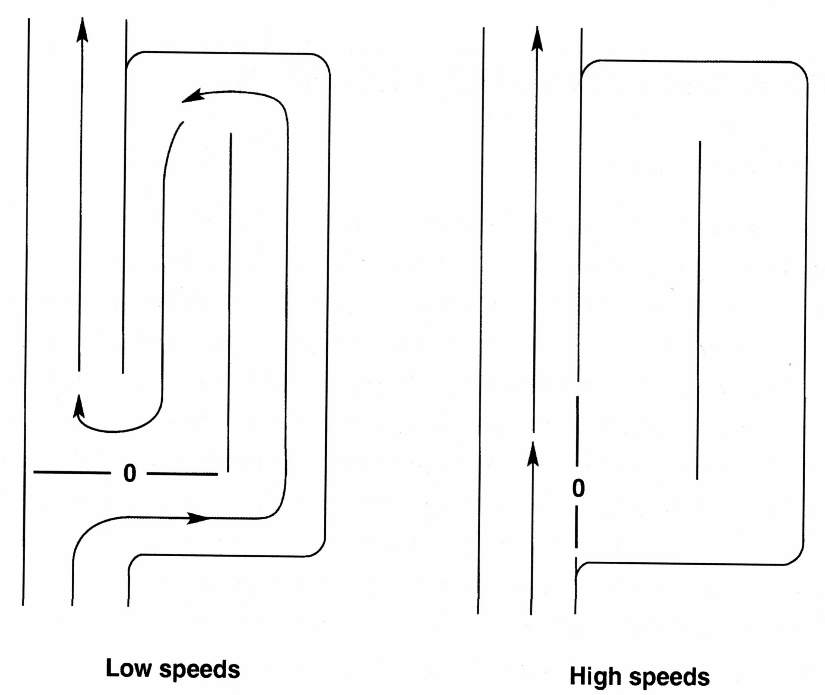
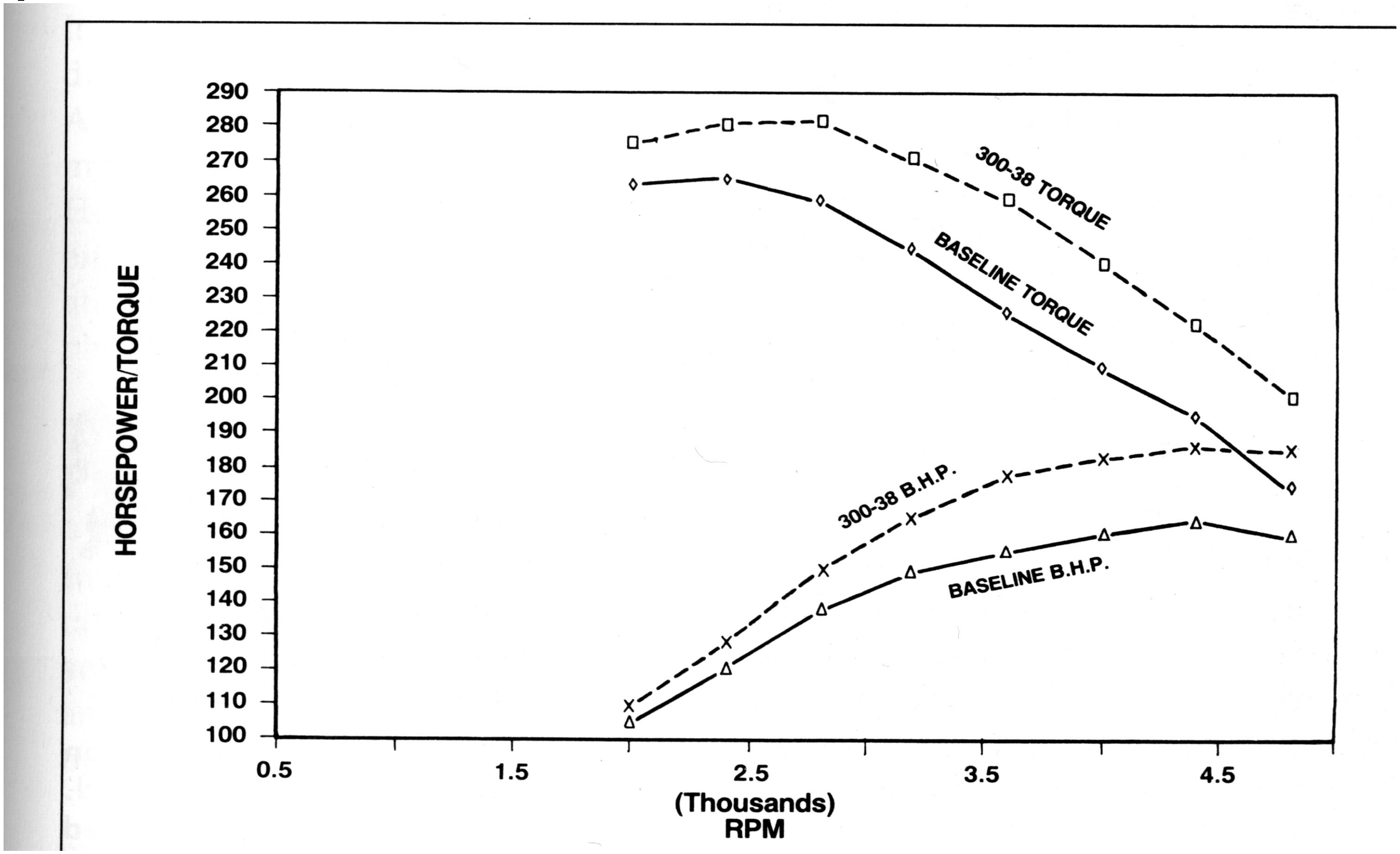


Figure 2.36. Sketch of a folded manifold with valve.

Intake Theory (cont...)



Intake Theory (cont...)

- When dealing with manifold tuning it is important to consider the pressure wave phenomena
- These Phenomena can be modeled in various ways
  - Organ Pipes
  - Helmholtz Resonator

Intake Theory (cont...)

- Organ Pipes
  - Incident Waves
    - Transmitted
      - Same wave type as incident
    - Reflected
      - Opposite of incident wave type with increasing cross-sectional area
      - Same as incident wave type with decreasing cross-sectional area

Intake Theory (cont…)

- Expansion Waves
  - Associated with decrease in pressure
  - Increases exhausting of gases when prior to valve closing
- Compression Waves
  - Associated with increased pressure
  - Increases air in the cylinder before the valve closes

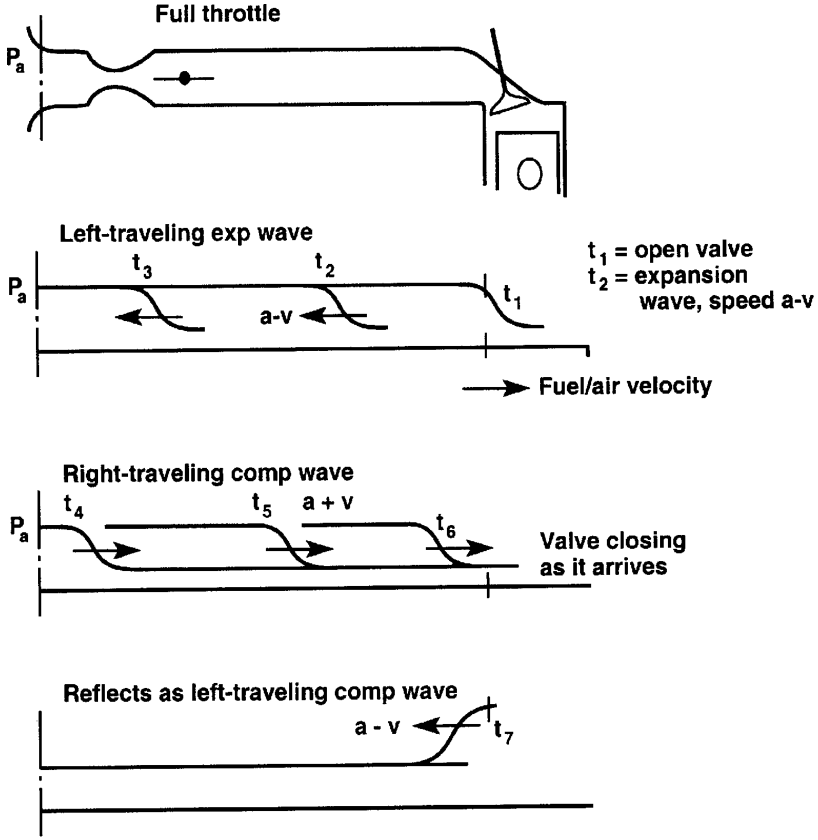


Figure 2.31. Sketch of waves in the inlet manifold of a single cylinder engine.

Method of Characteristics

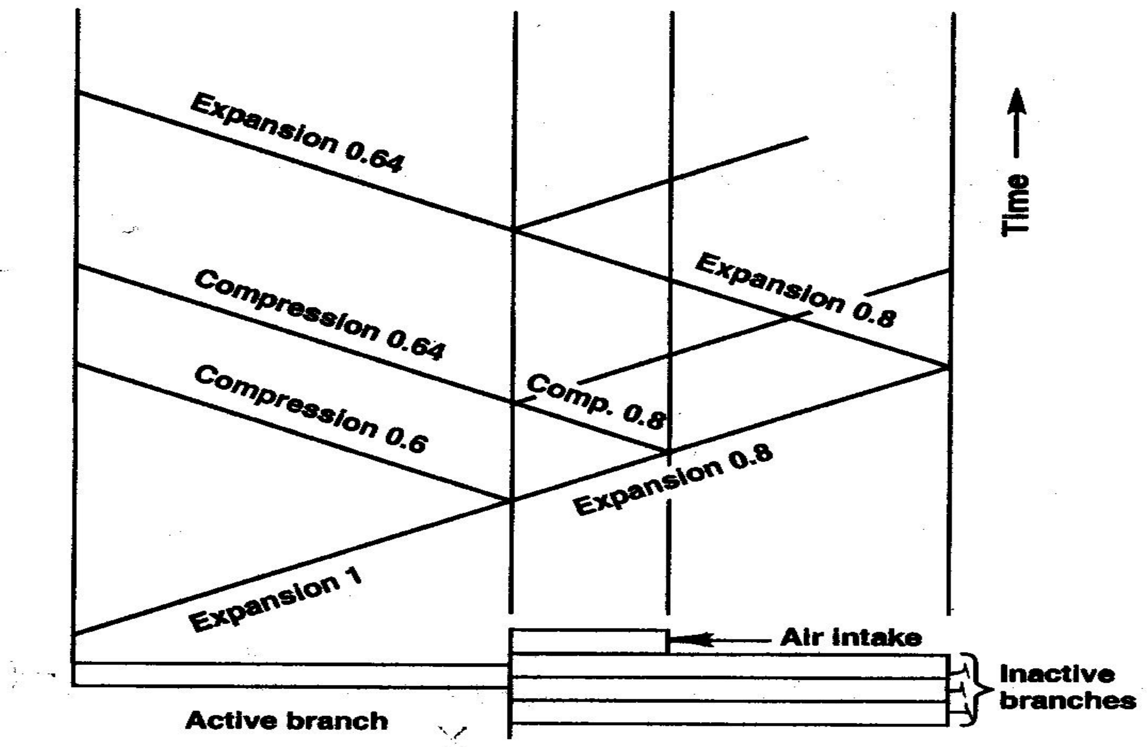


Figure 2.32. $x-t$ diagram of waves in the intake manifold of a four-cylinder engine. The nature and intensity of the waves is indicated on each ray. Only the first three arrivals at the valve are considered. Note that the flow velocity is neglected in this figure. Inclusion of the mean flow speed would change the angle of the lines, and make them not quite straight as the speed varied.

Intake Theory (cont…)

- Simplified Helmholtz Resonator
  - Large Reservoir is a vacuum and thin tube is high pressure
  - Resonance can be modeled as a second order differential mass damp equation
  - Mass of system is $\Delta m = \rho A \Delta x$

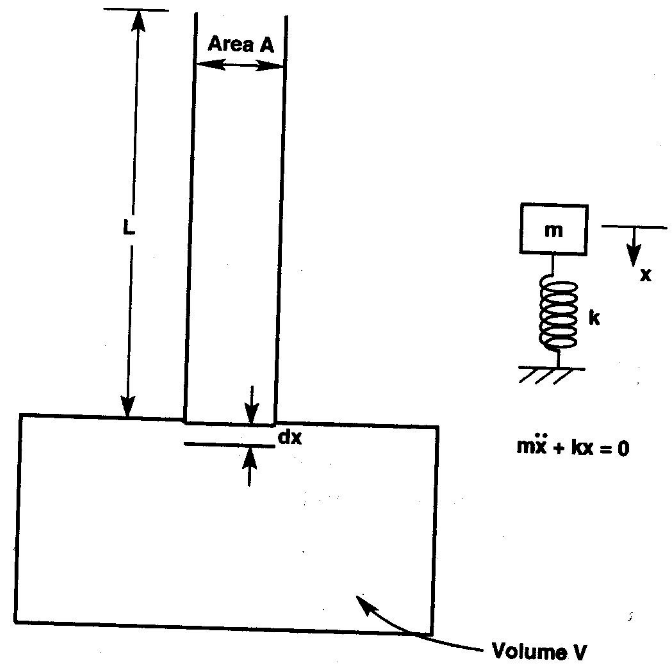


Figure 2.29. Schematic of simple Helmholtz resonator.

Intake Theory (cont…)

- Helmholtz (Cont…)
  - Solution is of the form cos(ωt)
  - Resonant Frequency

$$\omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{a^2 A}{VL}}$$

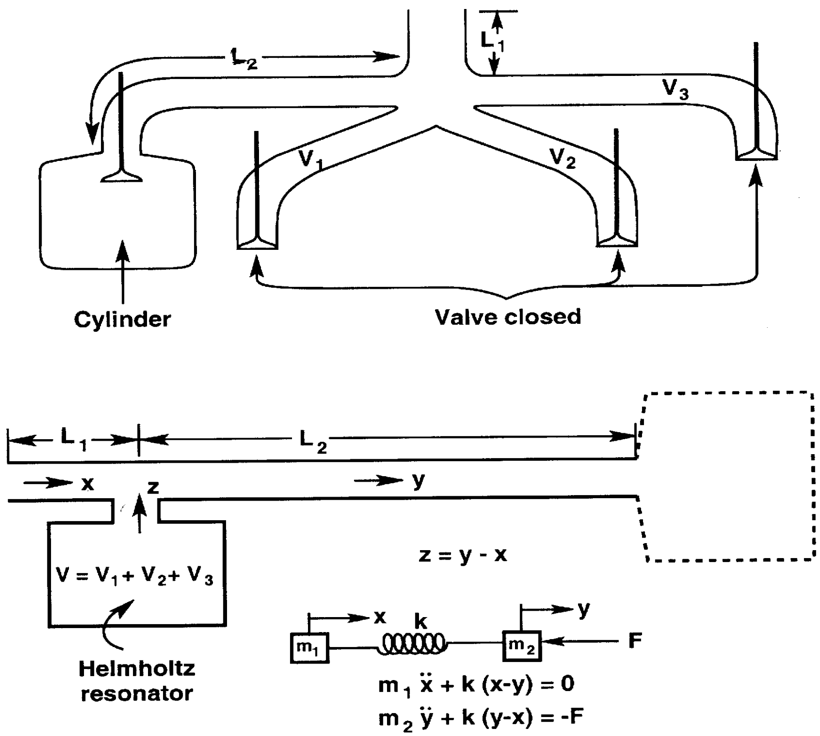
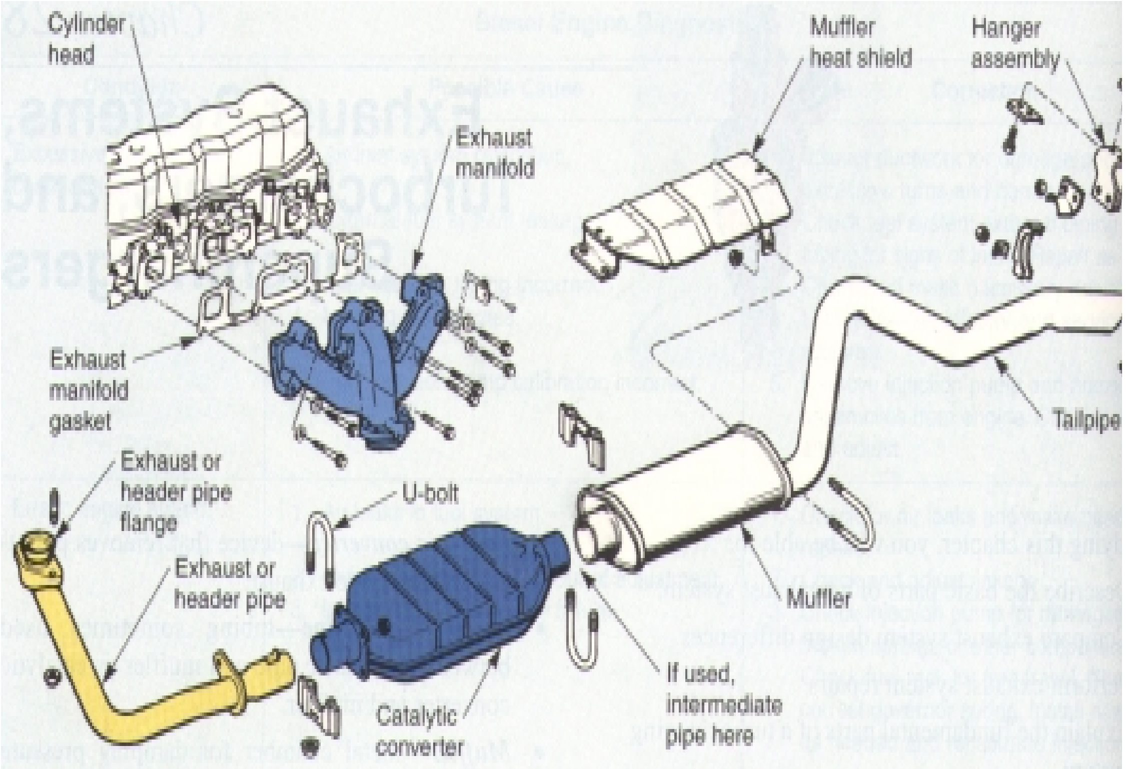


Figure 2.30. Sketch of a manifold, and of a simple Helmholtz resonator model.

Intake Theory (cont...)

Exhaust system

- Exhaust Manifold (Header)
- Exhaust pipe
- Catalytic Converter
- Muffler
- Tailpipe



Desired Exhaust Flow Characteristics

- Low back pressure
- Large free flowing muffler
- Smooth straight piping system
  - Only need to consider from the exhaust outlet to before the catalytic converter

Exhaust types

- Manifold
  - Cast iron, low grade flow quality
- Header
  - Tuned to engine to maintain the pulse drive of the exhaust to maximize removal of exhaust gases
  - For high performance uses

Exhaust Theory

- Pressure Waves
  - Expansions wave timing is wanted to increase the flow of compressed gases out of the cylinder after combustion
  - The length of the exhaust pipes will affect the timing of the expansion waves

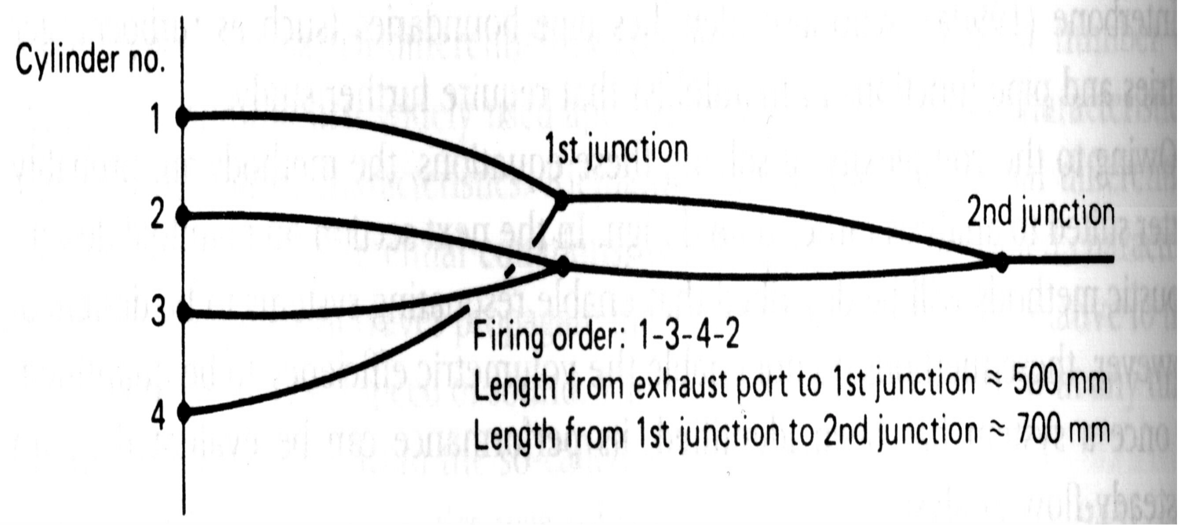
Exhaust theory (cont...)

- Exhaust Pulse
  - Correct timing of the exhaust pulse will increase the removal of hot noxious gases
  - The pulse leaves the exhaust as a compression wave and travels to a junction where it is reflected back as an expansion wave to pull the gases out of the next emptying cylinder

Exhaust theory (cont...)

- An example of this can be seen in a 4-2-1 header. This header takes advantage of the firing order of 1-3-4-2

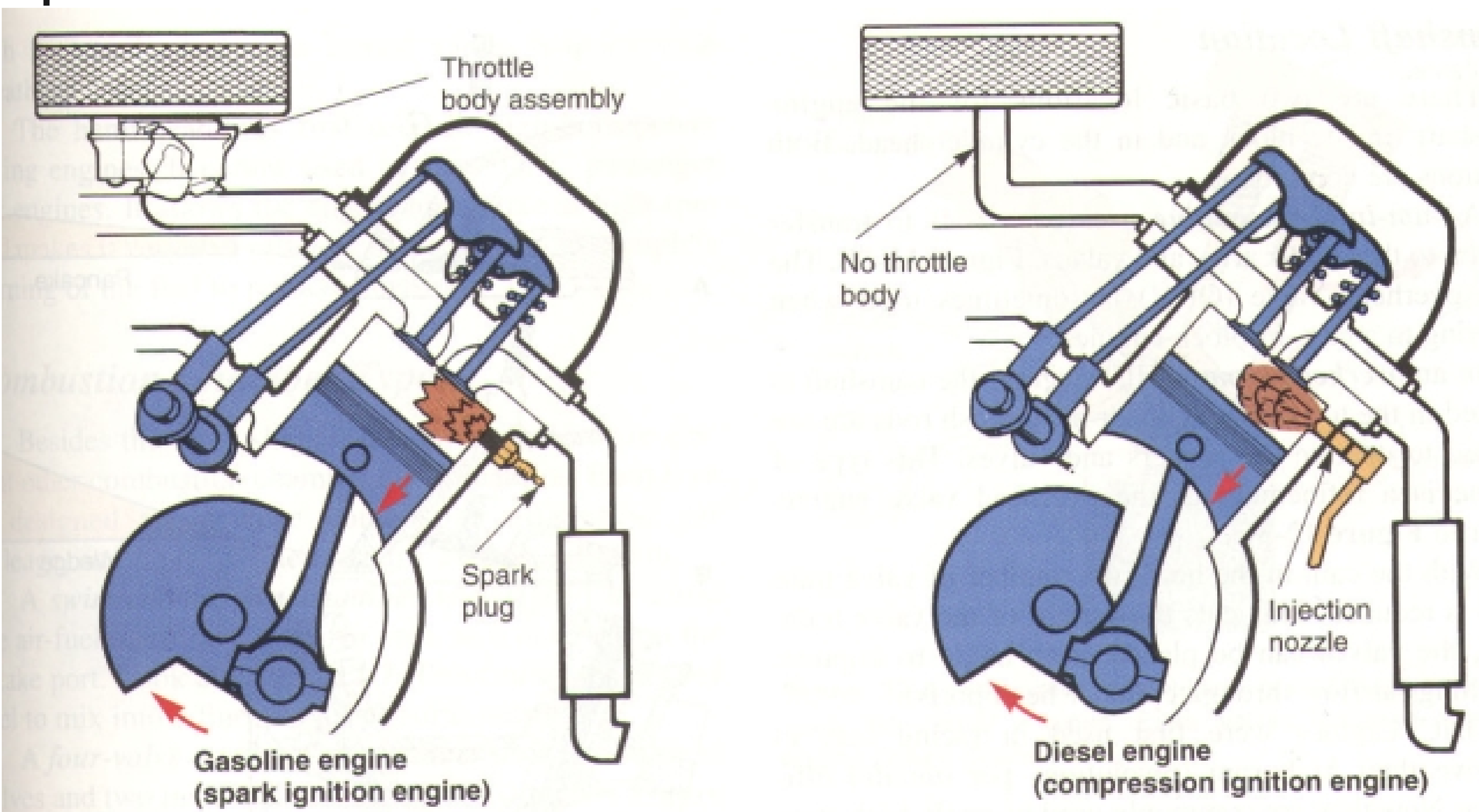
Figure 6.29
Exhaust system for a four-cylinder engine.



Diesel Vs. Gasoline

- Diesel
  - Uses Pressure to cause combustion
  - No Throttle Body
  - Operates at Higher Compression ratios therefore more efficient
  - direct fuel injection into the cylinder
- Gasoline
  - Uses Spark to create combustion
  - Throttle Body Controls power output
  - Fuel is injected into the intake manifold

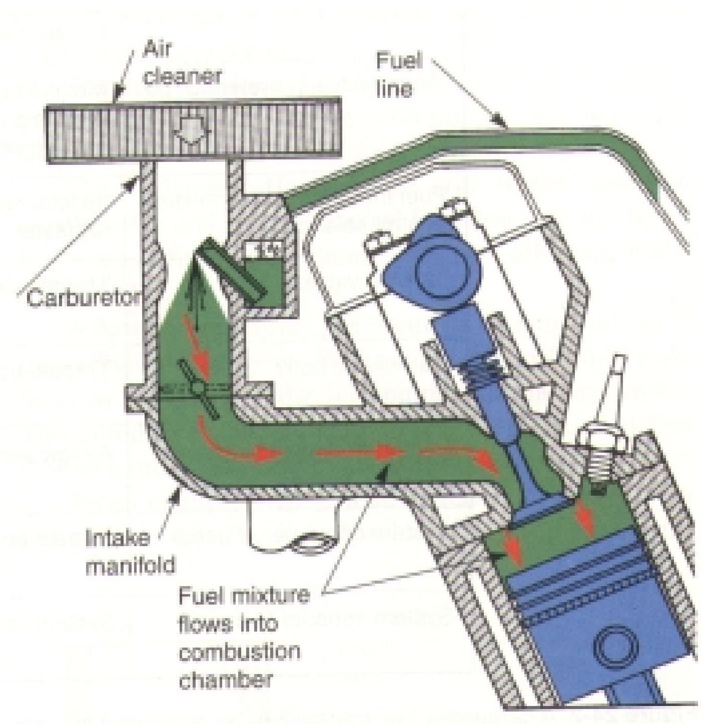
Diesel Vs. Gasoline (cont…)

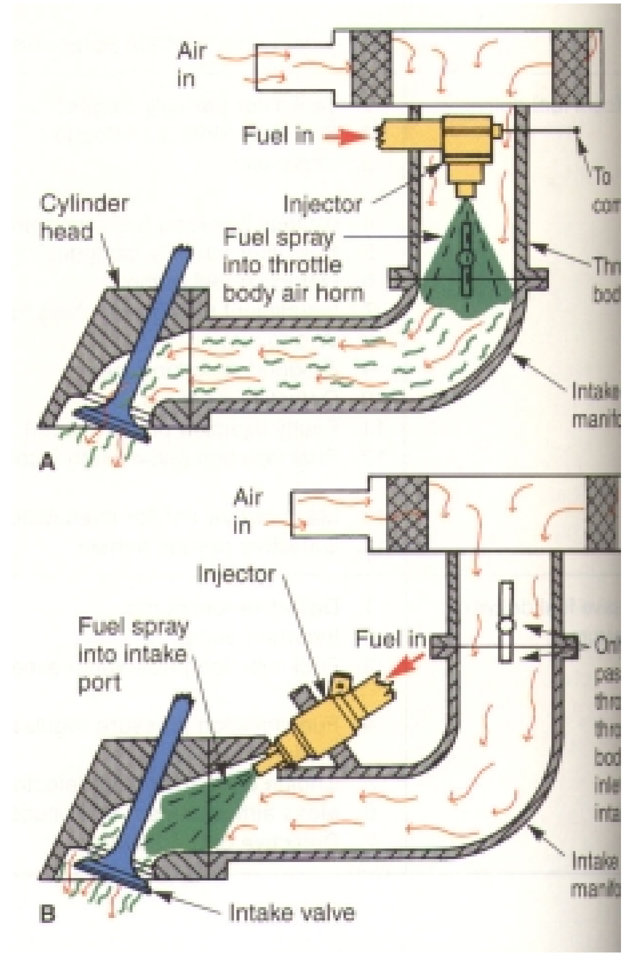


Carburetor Vs. Fuel Injection

- Carburetor
  - Fuel and air are mixed in the intake far upstream of intake valves
  - Can allow residue build up on intake wall
  - Can be tuned by hand
- Fuel Injection
  - Fuel and air are mixed right before the intake valves
  - Fewer losses due to only air present in intake manifold
  - Electronic/ Hydraulic/ Mechanical

Carburetor Vs. Fuel Injection (cont…)





Modern Tuning

- With the modern engines becoming more reliant on computers less tuning is in the hands of the average mechanic
- Complex computer programs monitor engines functions via sensors all over the engine and adjust systems appropriately on the fly
- With the ability to test an engine and see the results on a Dynamometer exact tuning can be done

Summary

- Manifold tuning is a complex process that takes into account a wide variety of thermodynamic and mechanical principles
- Tuning ensures that an engine is able to breathe right and produce an output efficiently
  - Both the intake and exhaust manifolds must compliment each other
- When in tune, the pressure waves created by the intake and exhaust prove to be a constructive and very beneficial by enhancing the flow through the cylinder
- Fuel choice and mixing type also effect the tuning and construction of the manifolds