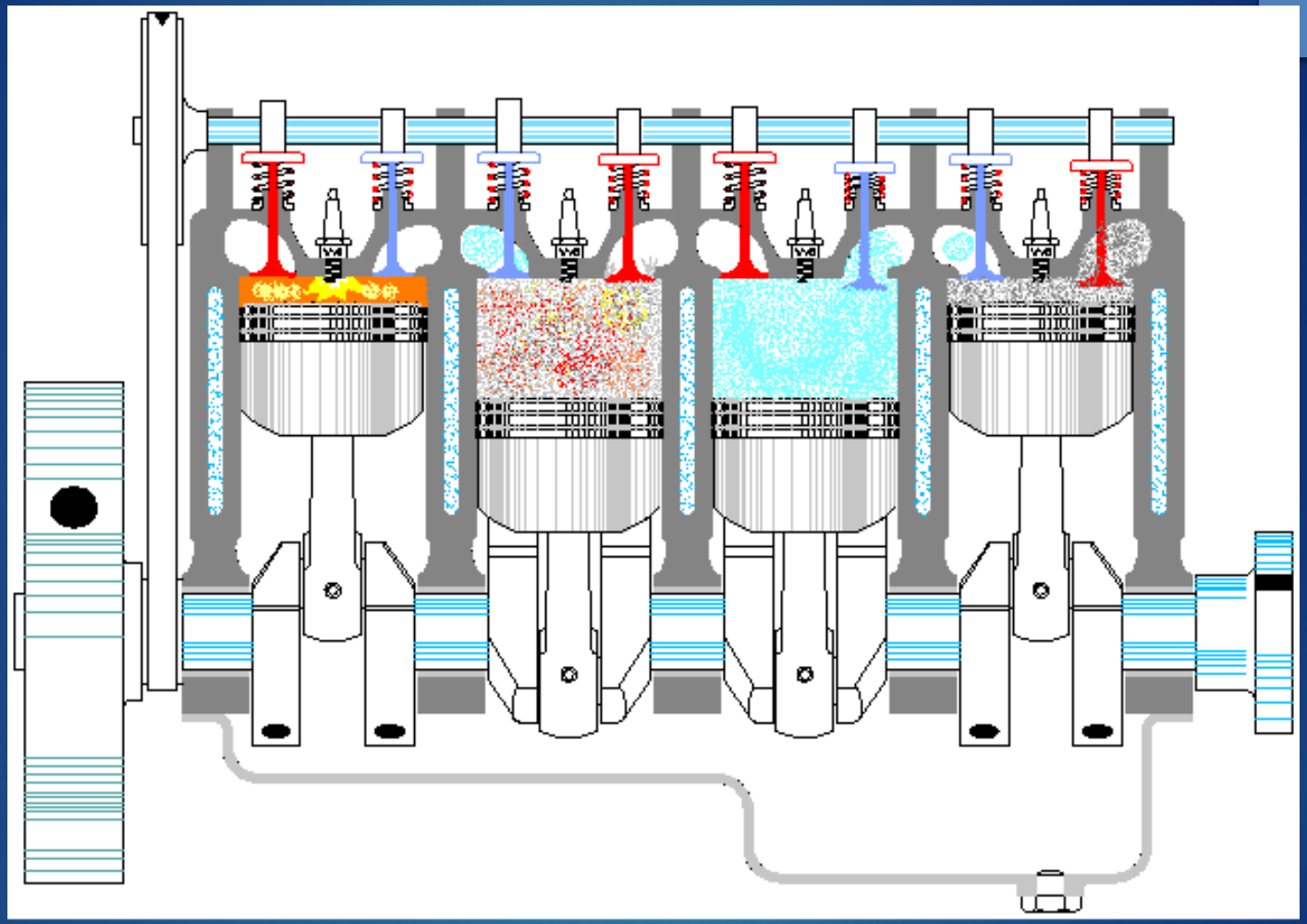
Medium/Heavy Duty Truck Engines, Fuel & Computerized Management Systems,

ENGINE BREATHING



Introduction

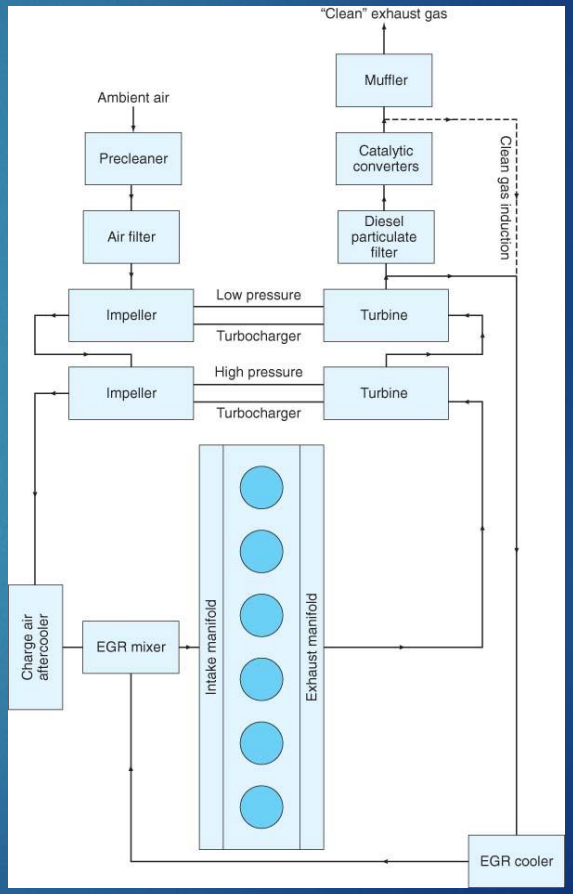
- The intake & exhaust systems on current diesel engines have become more interconnected:
  - Use of turbochargers
  - Exhaust gas recirculation (EGR) systems
- Turbochargers:
  - Boost the intake manifold at pressures above atmospheric
  - Use rejected heat from the exhaust system
- EGR systems reroute exhaust gas back into to the intake circuit

Introduction

- EGR systems play a role in both intake & exhaust systems
- Current exhaust systems contain a complex after-treatment canister to control emissions
- The term “induction circuit” describes naturally aspirated engines
- Engines with a turbo/manifold boost describe the air delivery components as “intake circuit”

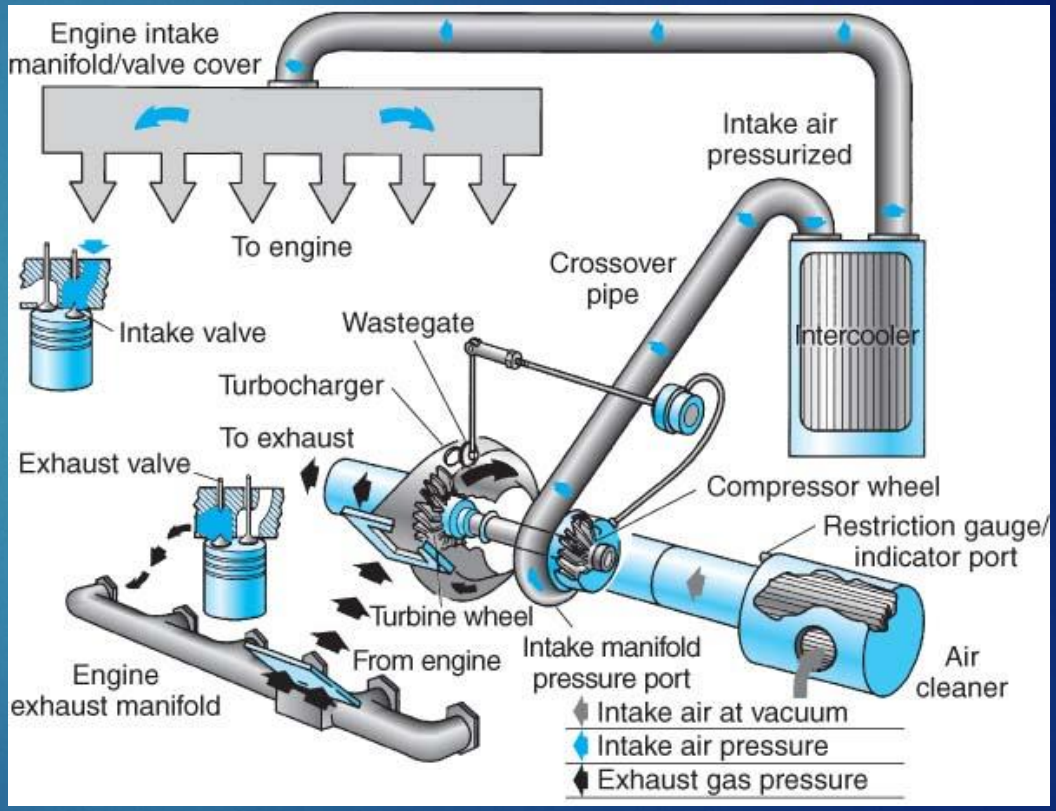
Gas Flow

- Modern gas flow
  - Monitored by ECM
  - Numerous sensors
- Circuits
  - Intake
  - Exhaust
  - Recirculation (EGR)



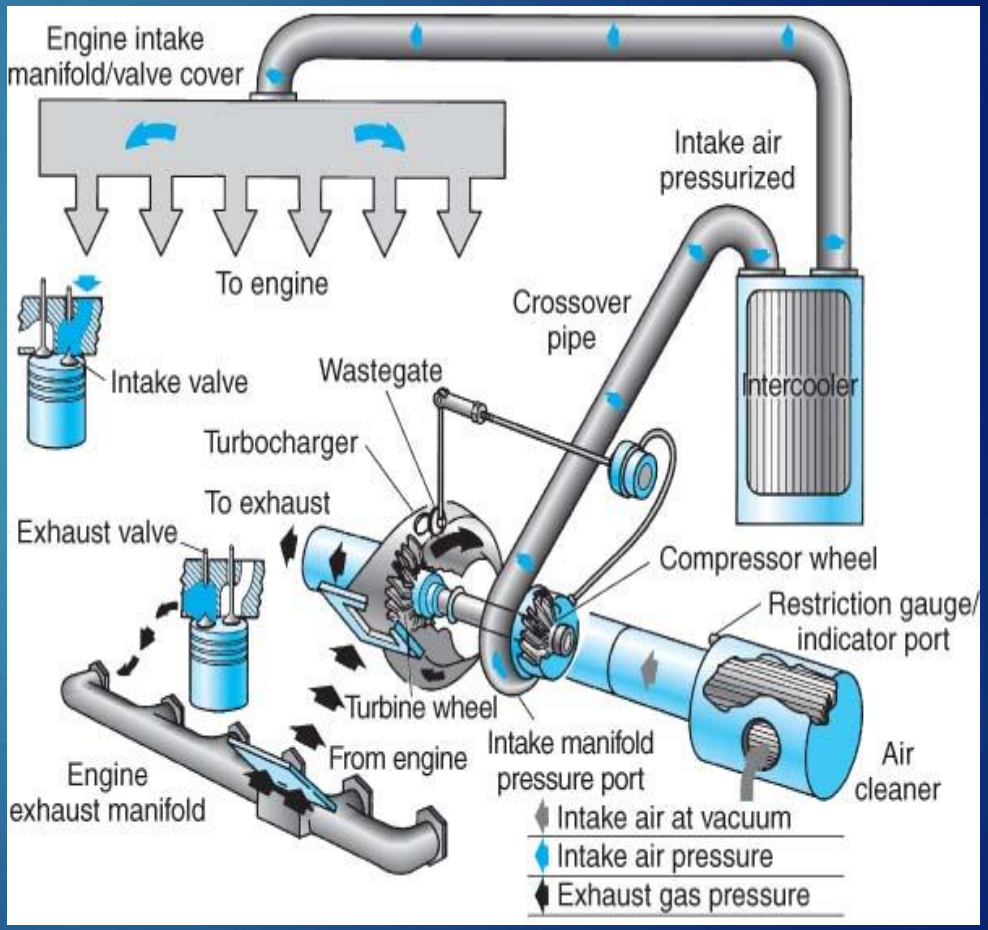
Intake System Role

- Function:
  - Supply air for:
    - Combustion
    - Cooling
    - Scavenging
- System Components
    - Pre-cleaner & Main filter
    - Intake ducting/piping
    - Turbochargers & controls
    - Charge air cooling circuit
    - Intake module for EGR
    - Intake manifold
    - Intake porting & tract design



Exhaust System Role

- Function:
  - Minimize noise
  - Minimize emissions
  - Offer minimum gas flow restriction
- System Components:
  - Valve configuration & tract geometry
  - Exhaust manifold
  - Turbocharger & controls
  - EGR system
  - Exhaust piping
  - Muffler
  - DPF & Catalytic converter
  - Pyrometer

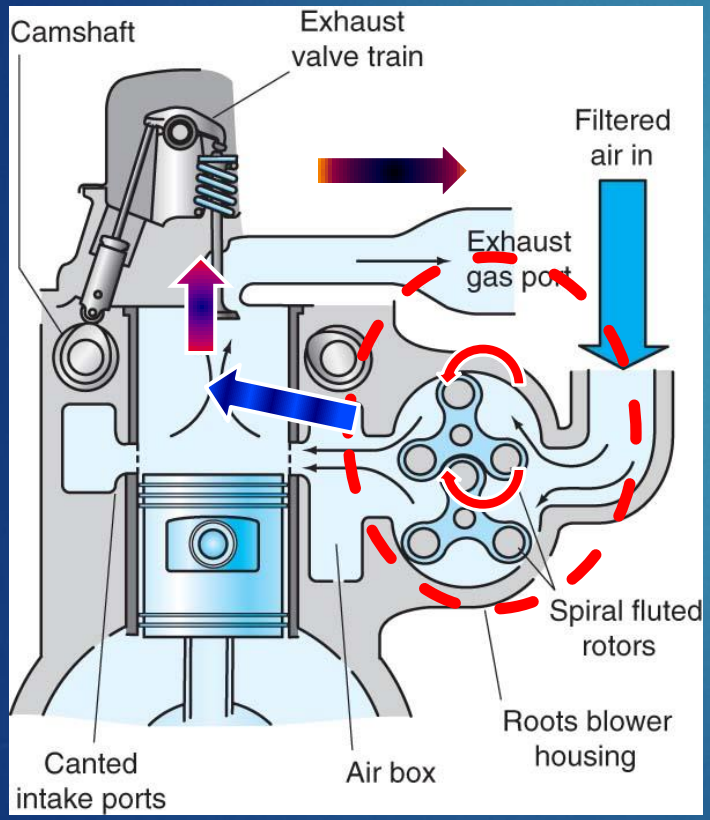


Intake System Components

- Air Cleaners
  - Precleaners
  - Dry positive filters
  - Oil bath filters
  - Inlet restriction gauges
- Servicing air filters
  - Laundering dry elements

- Role:
  - Filter airborne particles from the air that will be delivered to the cylinders
  - Airborne dirt can be highly abrasive & can destroy an engine in a very short period of time

Roots Type Blowers



- Gear driven
- Positive displacement pump
- Used to scavenge engine cylinders on two stroke DDC
- Produces low peak pressures
- Some engines may also use a turbocharger
- Also known as a supercharger

Turbochargers

Center housing separates the exhaust turbine from the compressor housing & provid... method of supplying pressurized engine l...cant to...

Turbocharger rotational speed is affected primarily by the heat of the exhaust & not pressure!

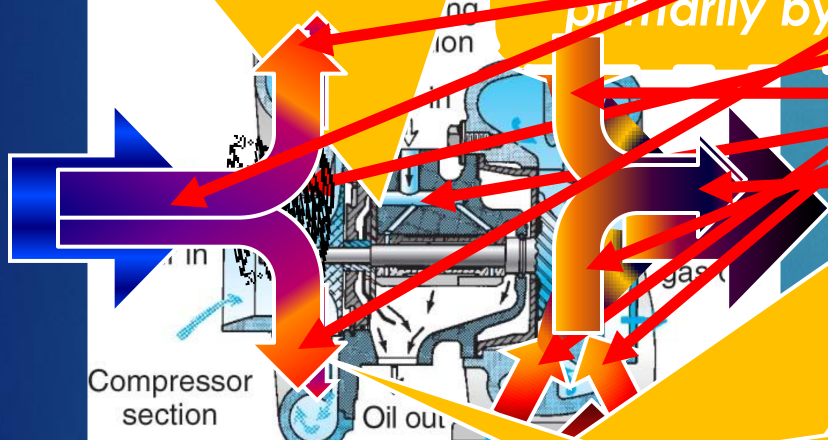
Principles of Operation

Gas Flow Routing

- Compressor Side
  - Impeller driven by shaft
  - Radial outflow
  - Axial inflow
  - Radial out flow turbine
- Turbine Side
  - Air is pulled into
  - Reduces flow restriction
  - Exhaust gas expands
  - Air is accelerated to high velocities
  - acts on turbine
  - Air flows outward to the diffuser
  - Axial

Pressurizes a charge of air to engine cylinder

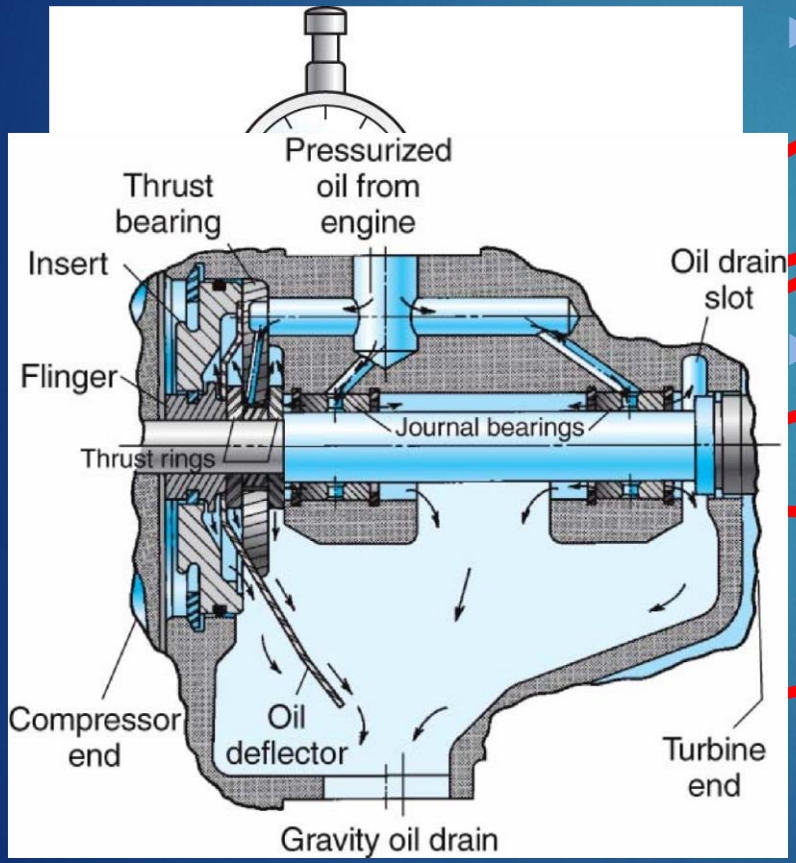
May operate at speeds



Under high engine output heat increases. The high... gas expansion produces ... speeds.

The diffuser may be voluted or a blade type. The blade type is more efficient.

Turbocharger Construction



- Support Operations:
  - Must withstand:
    - High temperatures
    - Centrifugal forces
    - Failure
  - Materials:
    - Compressor
    - Compressor housing
    - Turbine
    - Turbo shaft
    - Turbine housing
    - Bearings

- Pressurized oil supplied to the bearings
- Bearings suspended "hydrodynamically"
- Oil returns via gravity to crankcase
- Pressures sealed by piston style rings on turbo shaft
- Axial & radial play critical dimension

Types of Turbochargers

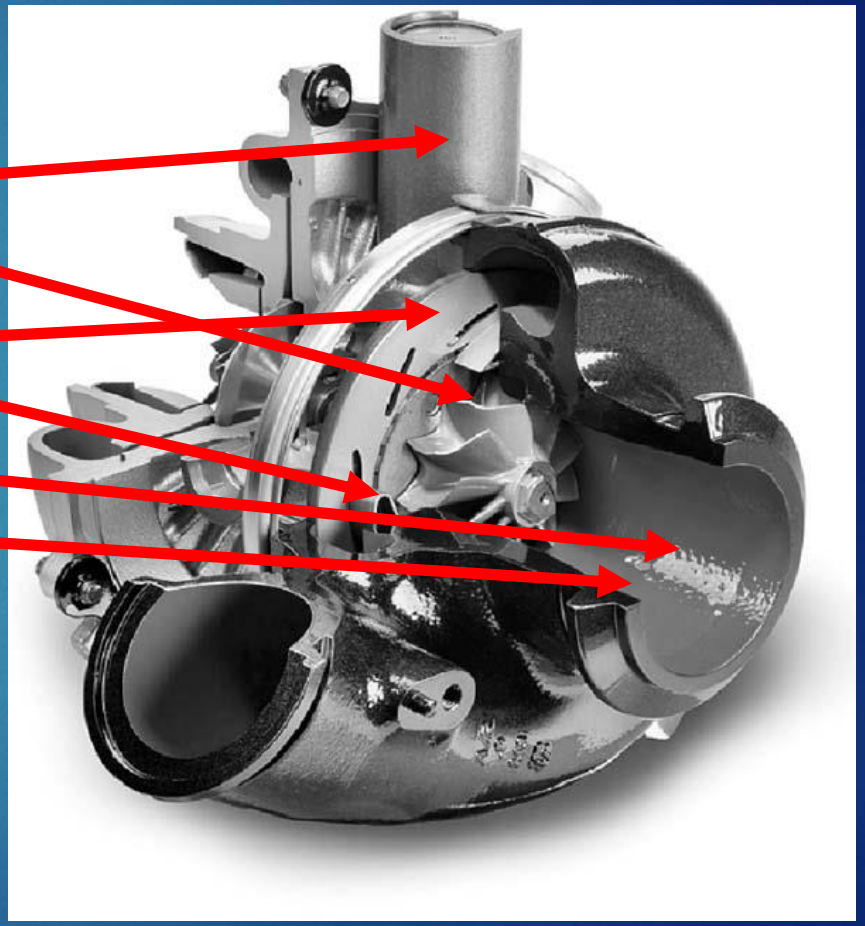
- Constant Geometry (CG)
  - All exhaust gas is routed through the turbine housing
  - Common application until the mid 1990's
  - If used currently, usually one of a series charge pair
- Variable Geometry (VG)
  - Exhaust gas flow areas manipulated
    - A percentage of gas may be allowed to bypass turbine
  - Controls either:
    - Internal
    - External
  - Currently, the most commonly used

Variable Geometry Turbos

- Controls:
  - Wastegate controlled
  - Volute controlled
- Objective:
  - Allow the turbo to act like a small turbocharger when engine loads are light
  - Allow the turbo to act like a large turbocharger when engine loading is high

Variable Nozzle Turbocharger

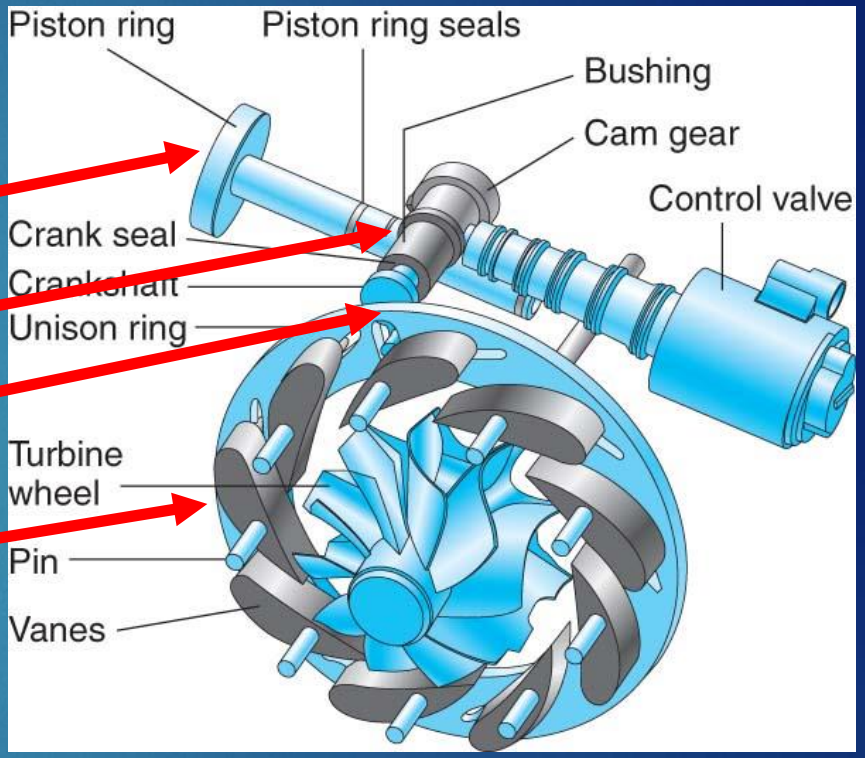
- Construction:
  - Turbine
  - Control Valve
  - Vanes
  - Unison Ring
  - Exhaust inlet
  - Exhaust outlet



The rotational speed of the turbocharger is supplied to the ECM by a shaft speed sensor (using an inductive pulse generator principle) & a trigger consisting of a flat spot on one section of the turbine shaft.

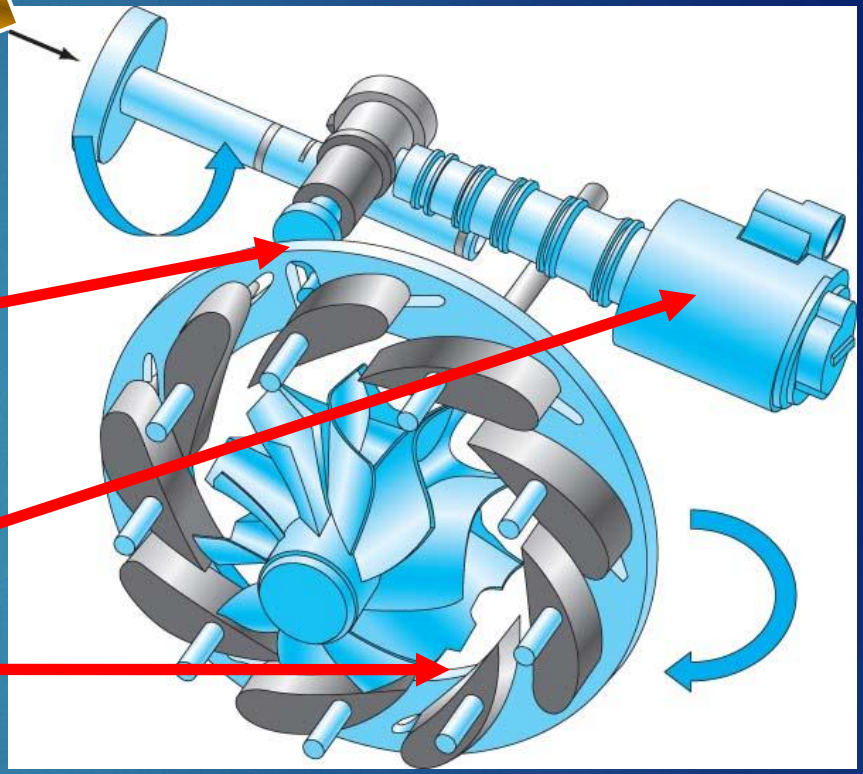
Variable Nozzle Turbocharger

- Basic Operation:
  - Oil pressure acts on piston
  - Piston "tooth meshed" to cam gear & crankshaft
  - Crank turns unison ring
  - Vane angle changes with rotation of unison ring



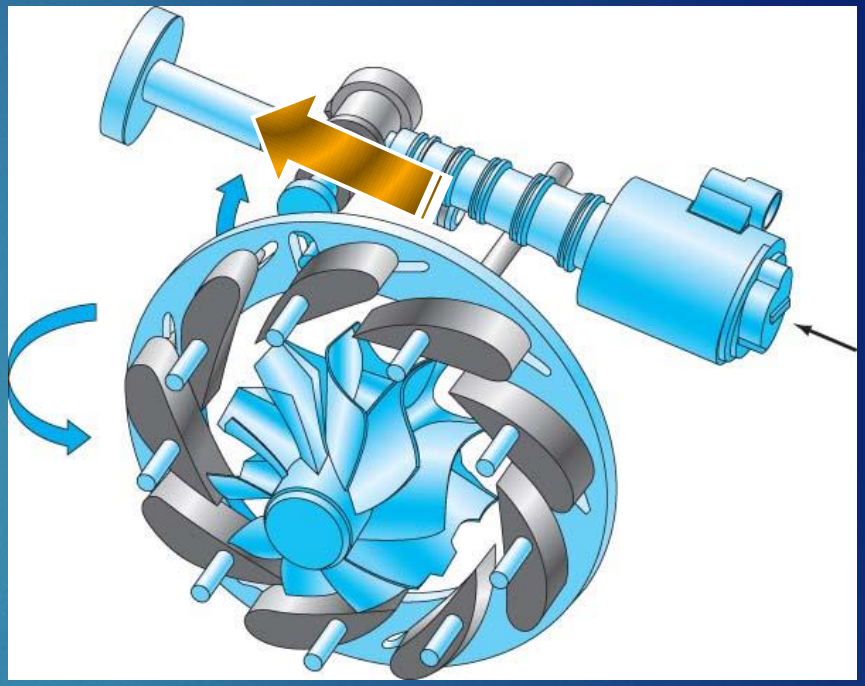
Variable Nozzle Turbocharger

- Reducing Efficiency
  - Oil Pressure actuates cam & crank assembly
  - Unison wheel rotated (clockwise)
  - ECM determines specific piston ring position
  - Vane pitch opened
  - Turbine gas efficiency reduced



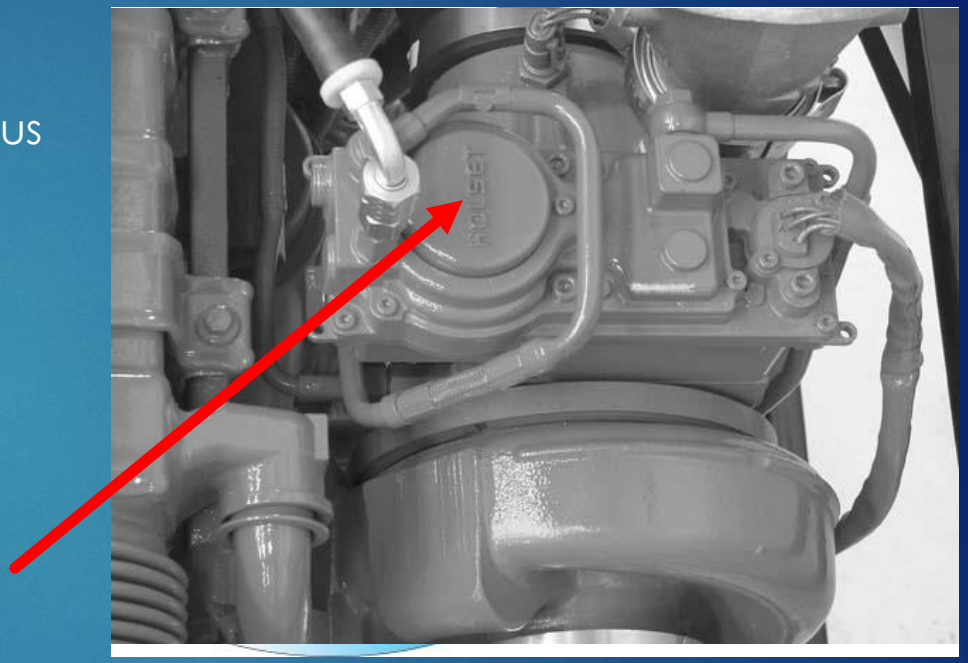
Variable Nozzle Turbocharger

- Maximum Boost
  - Oil Pressure actuates cam & crank assembly
  - Unison wheel rotated (counterclockwise)
  - ECM determines specific piston ring position
  - Vane pitch closed
  - Turbine gas efficiency increased



Variable Nozzle Turbocharger

- Sliding Ring Volute Turbos
  - Similar operationally to previous illustrations
  - Used on Some Holset turbos found on Cummins engines
  - Actuator moves sliding ring to determine flow area
  - Objectives identical

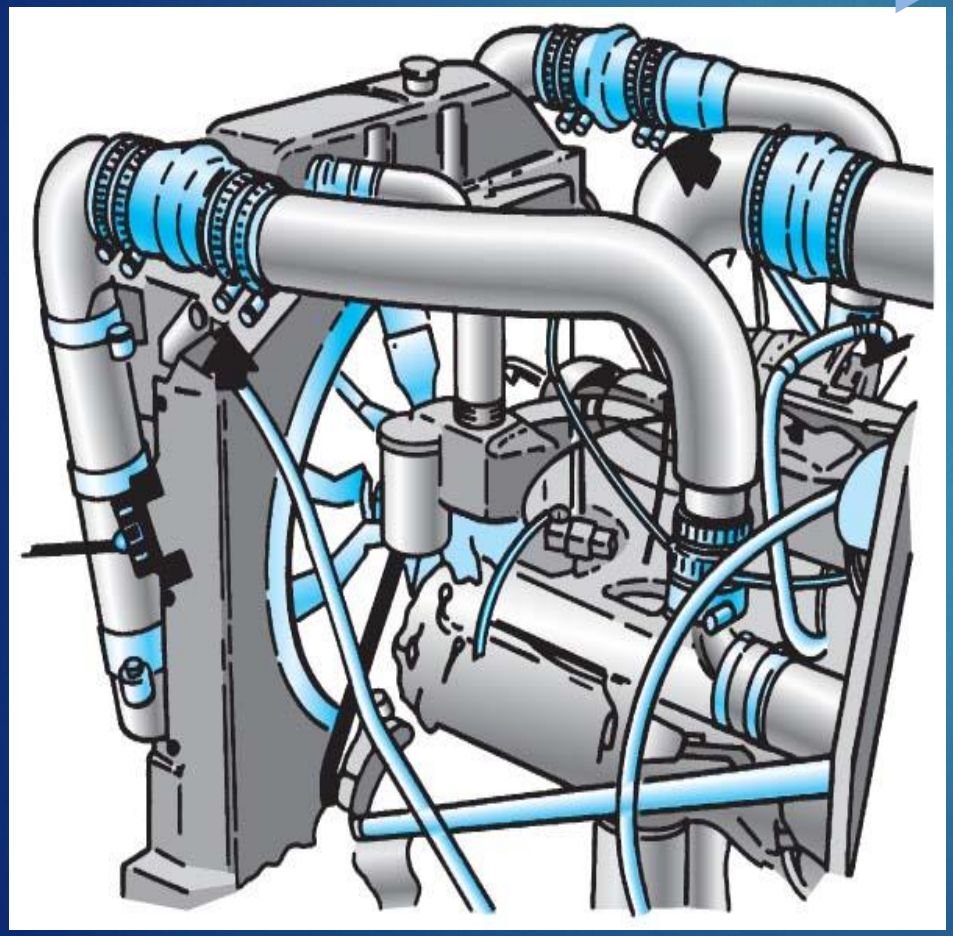


Charge Air Heat Exchangers

- Turbocharging :
  - ✓ Compresses intake air
  - ✓ Compressing increases air temperatures
- Charge Air Coolers (CAC)
  - ✓ A heat exchanger
  - ✓ Objective to cool the turbocharger pressurized air
  - ✓ Maintaining the pressure
  - ✓ Several types in use
  - ✓ Most North American boosted diesel engines use a CAC

As intake air temperature increases, air density diminishes & the oxygen charge in the cylinder is reduced.
This results in lower power & higher cylinder temperatures.

Charge Air Heat Exchangers



- Types
  - Air-to-air:
    - Cooling medium is ram air.
  - Aftercoolers & Intercoolers:
    - Cooling medium is engine coolant
  - Tip turbine:
    - Cooling medium is turbine fanned air & engine coolant

EGR Systems

- EGR systems required 2007
- Principle:
  - NOx is produced when combustion temperatures are high
  - High temperatures are a byproduct of lean burn combustion
  - Dead exhaust gas is "unreactive"
  - Dead gas routed back to engine cylinders
- Issues:
  - Adds wear inducing contaminants
  - Increases engine oil acidity
  - Reduces engine power
  - Reduces fuel economy

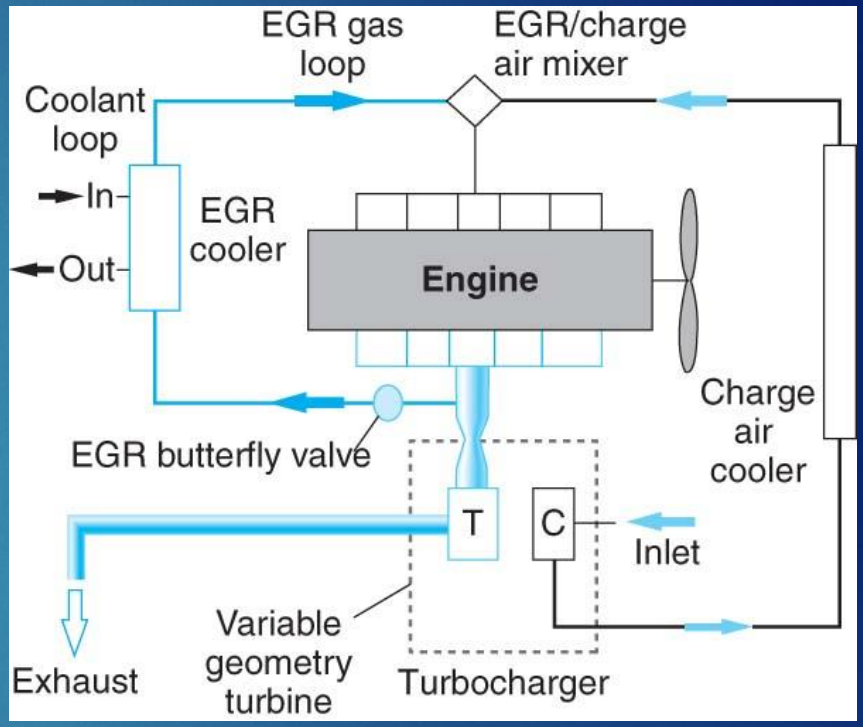
Although all 2007 & onward engines require some form or EGR, some manufacturers do not call theirs by this acronym.

It dilutes the intake charge of oxygen in the cylinder

Both of these factors have the potential to reduce engine longevity

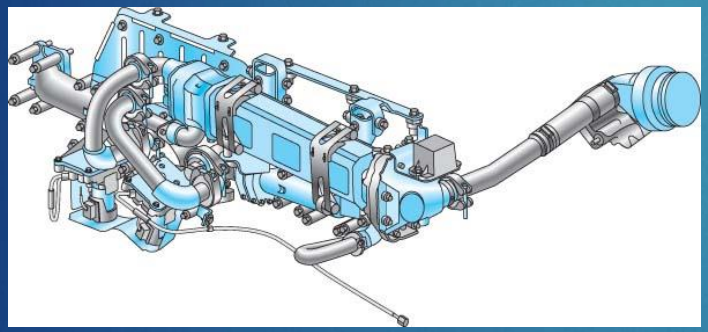
Cooled EGR Systems

- Most diesel EGRs cool the end gas before routing it back into the cylinders
- ECM controls the cycling of EGR gas
- Some OEMs use internal gas recirculation



Cooled EGR Systems

- C-EGR Heat exchanger used on a Volvo D12D Engine



Intake Manifold Design

- Less complex than naturally aspirated SI engines
- Runners of unequal length do not compromise engine breathing
- Tuned manifolds – shape & length of each runner similar
- Types of intake manifolds:
  - Wet – contain coolant ports in addition to air passages
  - Dry – handle intake air only
- Materials:
  - Metallic – aluminum alloy, cast iron
  - Non-metallic – poly-plastics, carbon based fibers

Exhaust System Components

- Functions:
  - Minimize engine noise
  - Assist cylinder scavenging
  - Minimize noxious emissions
  - Route exhaust gases & heat safely to the atmosphere
- Components:
  - Manifold
  - Insulation
  - Pyrometer
  - Piping
  - After-treatment
  - Sonic emissions control

Exhaust Manifold

- Collects cylinder end gases
- Delivers them to the turbocharger
- Constructed of single or multiple sections of cast iron
- Gasketed to cylinder head(s)
- Most diesel manifolds are “tuned”
- “Back pressure” is a factor & a consideration in the design of the exhaust systems

Pyrometer

- A thermocouple
- 1980s & earlier hydromechanical engines:
  - Alerted driver to downshift if temperatures exceeded threshold
  - Located 12" (30cm) downstream of turbo turbine housing
- Current application:
  - Not often used to signal exhaust gas temperature to the driver
  - Used in emissions control components
  - Most diesel particulate filters use several pyrometers to signal temperature conditions to the ECM.
  - Some larger engines locate one pyrometer in the exhaust tract on each engine cylinder to indicate cylinder balance

Exhaust After-Treatment

CAUTION:

It is illegal to tamper with emissions control hardware.
Diesel exhaust after-treatment canisters must be replaced with an OEM-approved equivalent that allows the engine to meet the emissions controls that prevailed in the year of the engine's manufacture!

Redirects DPF heat away from the trailer/ reefer, etc.

Breathing Circuit Sensors

- ✓ Ambient tem
- ✓ Baromet
- ✓ CAC in t
- ✓ CAC out
- ✓ Boost cir
- ✓ Manifold
- ✓ MAF (ho
- ✓ Turbocho
- ✓ Exhaust g
- ✓ DPF in te
- ✓ DPF com
- ✓ DPF out t
- ✓ NOx sens
- ✓ Aftertrea (delta pressure sensor)

Sensors

Intake & exhaust system circuits are comprehensively monitored due to the need to manage emissions within statutory limits.

Many sensors on today's engines are multifunctional, that is they perform more than one task.

This is a sample list of the sensors used.