DUEL FUEL ENGINES

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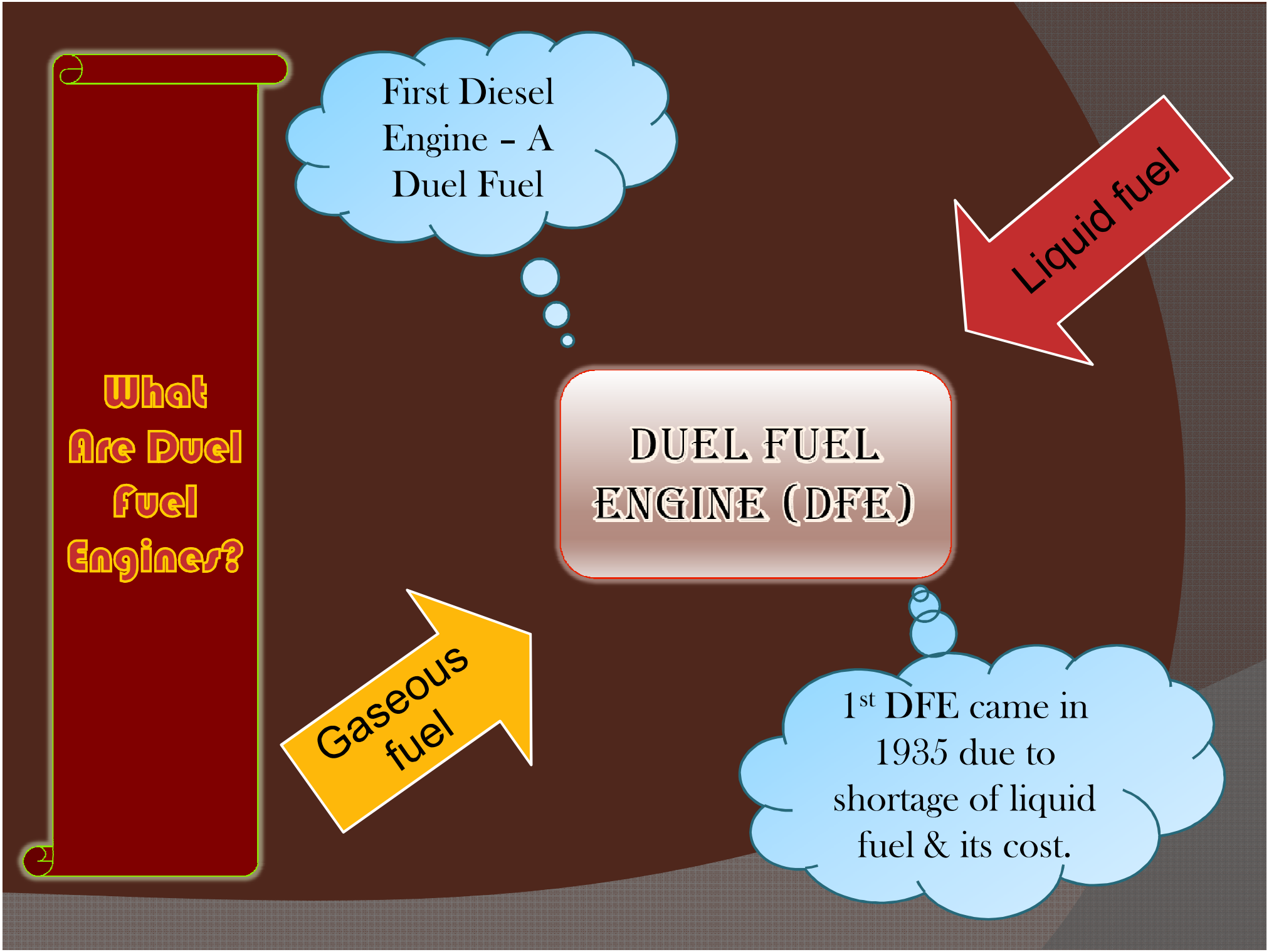
What is DUAL FUEL ENGINE?

- Internal combustion engines operating on gaseous fuel have for long been known. Many large stationary engines use two fuels. Normally of these two fuels, one is gaseous and other is a liquid fuels. The two fuels can be taken widely varying proportion to run engine; such as engine is usually called Duel fuel engine.

Why Dual fuel engine required ?

- The shortage of liquid fuel and the realization that gaseous fuels are far cheaper than liquid fuels have led to attention on dual-fuel engine.
- natural gas available to most of part of the world at rates cheaper than liquid fuels


What Are Duel Fuel Engines?
First Diesel Engine – A Duel Fuel
Liquid fuel
DUEL FUEL ENGINE (DFE)
Gaseous fuel
1st DFE came in 1935 due to shortage of liquid fuel & its cost.

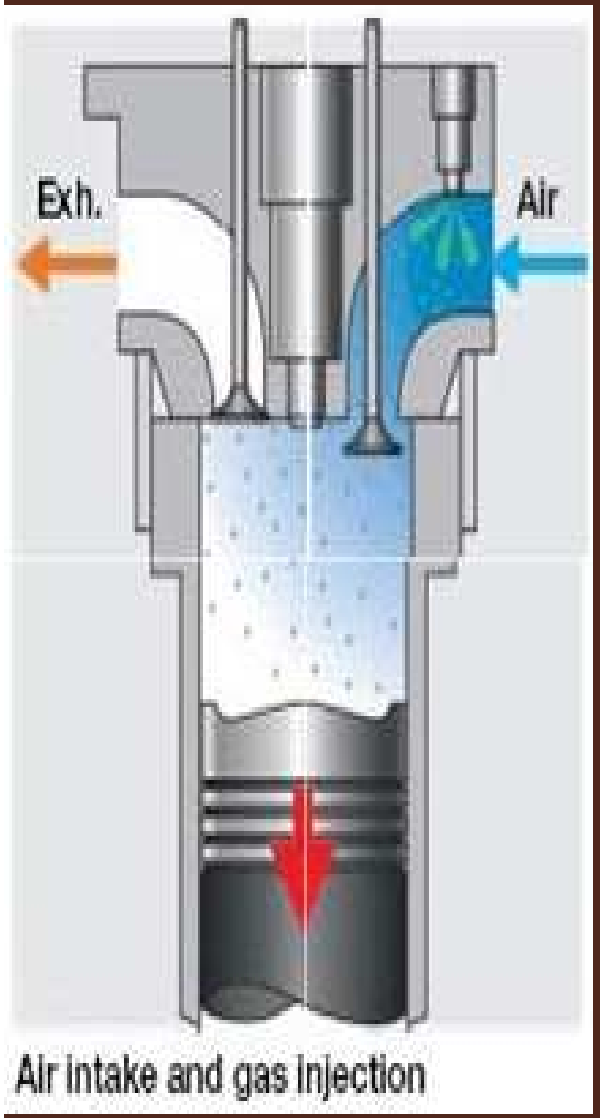
Working principle

- 2 types of fuel
- Gaseous fuel – primary fuel.

- Liquid fuel - secondary fuel or pilot fuel.
- charge of diesel fuel is introduced to start the engine until the engine reaches idle state
- Gaseous fuel is introduced as the load increases

Duel fuel operation

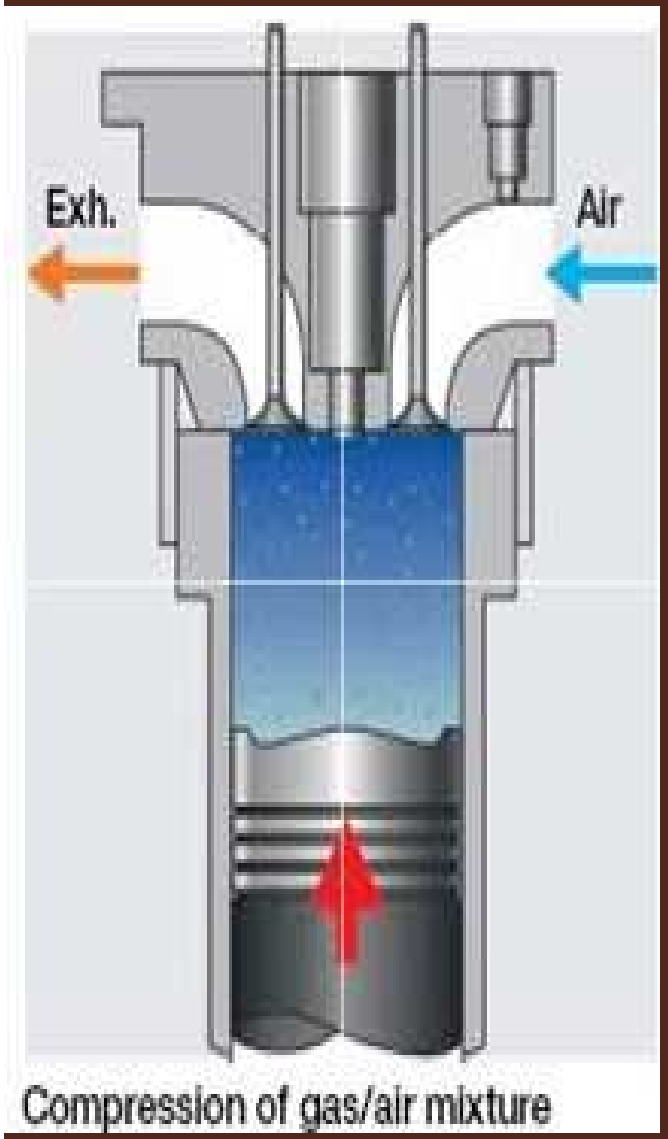
- Dual-fuel operation is achieved by the burning of both a gaseous fuel and diesel at the same time in a CI engine.
- diesel fuel is used as an ignition source.
- power output of the engine is normally controlled by changing the amount of primary gaseous fuel added to the inlet manifold
- 5 to 7 percent of the total heat of the engine at full load released by liquid fuel
- dual fuel engine is capable of running on either gas or diesel oil or a combination of these two



Air intake and gas injection

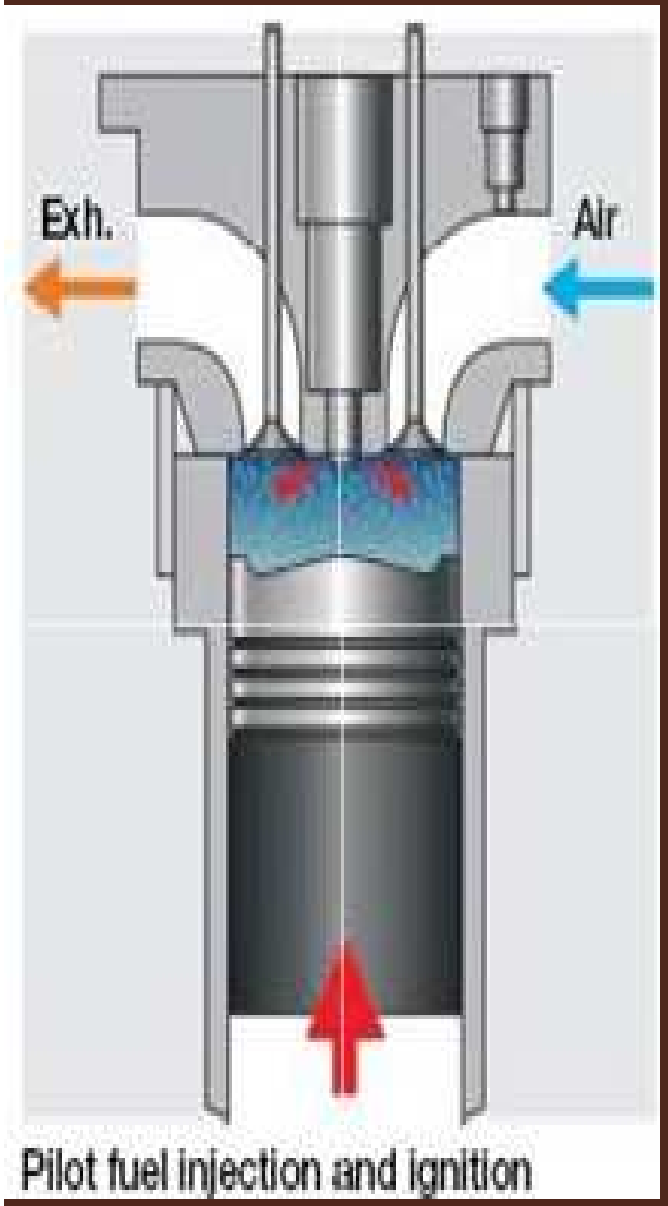
- Gas fuel is added to the air inducted by the engine or supplied by the supercharger at a pressure

  slightly above atmospheric
- homogeneous mixture form between gas and liquid fuel



Compression of gas/air mixture

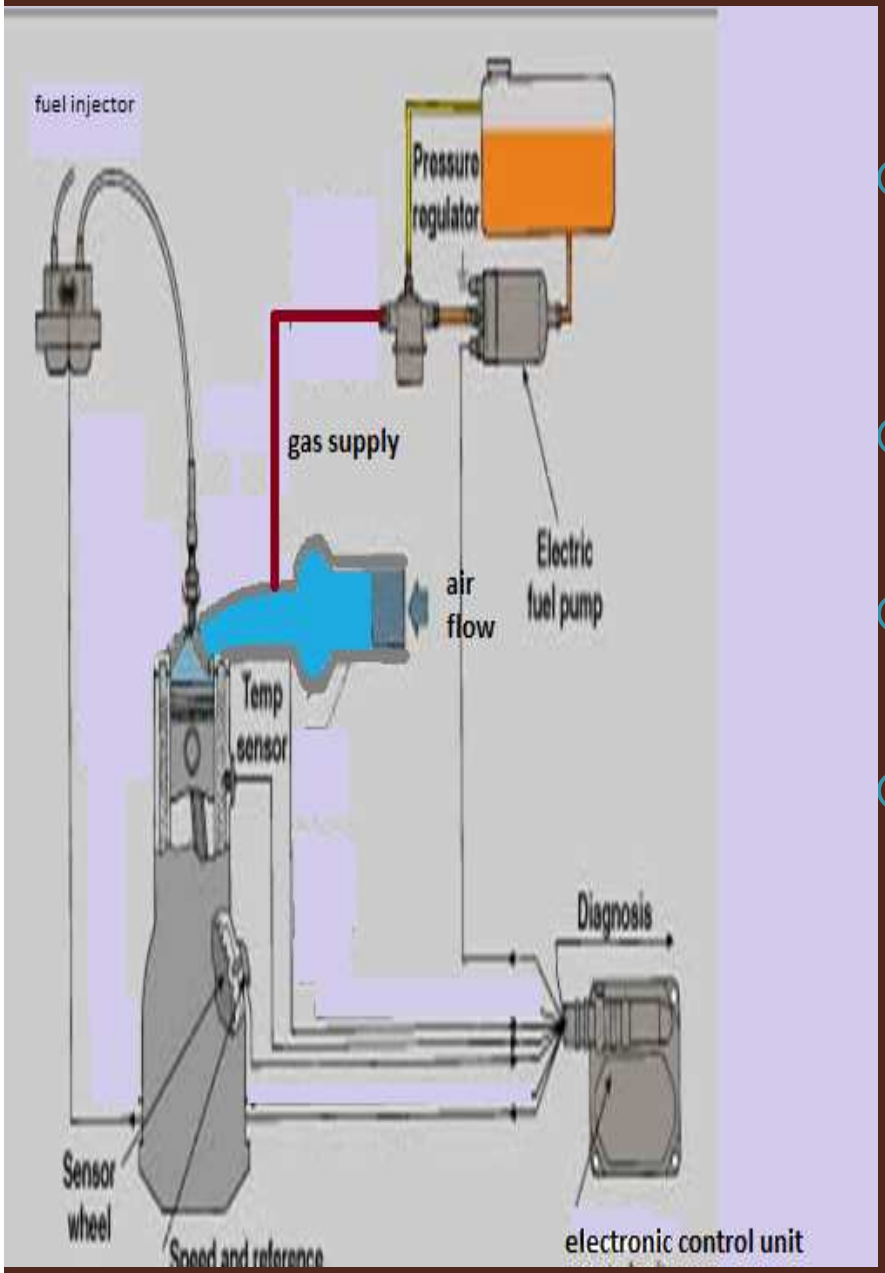
- Gas air mixture is compressed like normal air in diesel engine and its temperature and pressure rises.
- The mixture will not ignite on compression because the gas has a high self ignition temperature than diesel



Pilot fuel injection and ignition

- As the piston approaches TDC a small amount of diesel (1%) is injected through the pilot nozzle. Ignition of this pilot fuel then ignites the gas air mixture.
- Charge of liquid fuel acts as the source of ignition, gas- air mixture ignites in the vicinity of the injected spray at number of places and number of flame fronts which starts combustion smoothly and rapidly


WORKING



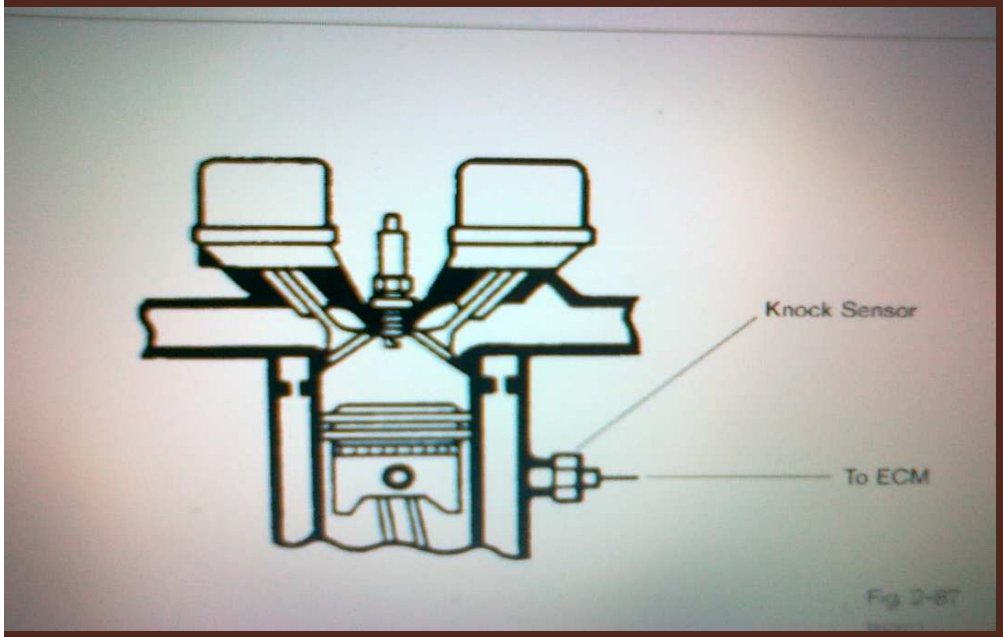
- At full power diesel fuel is 10% of total fuel –and natural gas utilization is around 85%
- Uses a standard electronically-controlled engine
- Maintains electronic control of both gas and diesel injection
- Dual-Fuel ECU controls gas operation and modifies diesel demand for the diesel engine ECU

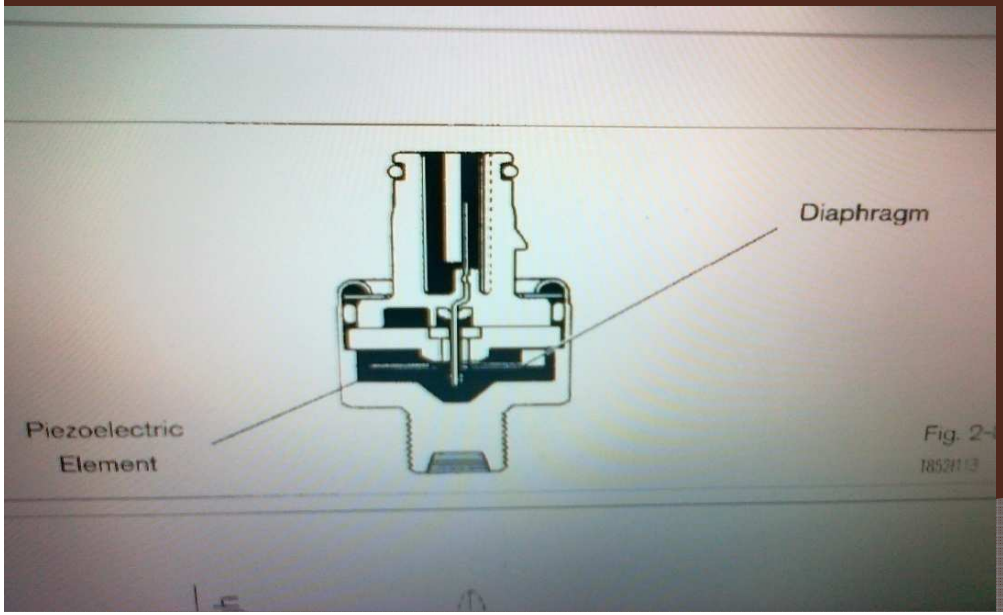
How ECU works??

- *Electronic control unit (ECU)* is a generic term for any embedded system that that determines the amount of fuel, ignition timing and other parameters an internal combustion engine needs to keep running. It does this by reading values from multidimensional performance maps (so called LUTs), using input values (e.g. engine speed) calculated from signals coming from sensor devices monitoring the engine.

  function of Engine Control Unit
- Control of fuel mixture by regulating the supply of gas
- Control of ignition timing
- Control of idle speed

Knock sensor





- Knock sensor detects the engine knock and sends a voltage signal to the ECM. The ECM uses the knock sensor signal to control the timing of injection of gas and hence control the quantity of gas
- Knock sensor located in the cylinder head
- Consists of a piezoelectric element which generates a voltage when pressure or vibration applied to them
- Introduction of knock sensor limits the supply of gas as load increases and reduces the wear and tear of engine

back up fuel

- Duel fuel engine is also equipped with back up fuel
- Injection of back up fuel is similar to normal diesel injection process.
- Supply is regulated by the fuel pump which operates on cam mechanism

BACKUP FUEL

Features

- Less operation cost - main fuel natural gas.

  OPERATION COST - approx. 30% less.
- Environmental friendly - drastic reduction of emissions.

CO_2	30-40% less
SO_X	95% less
NO_X	20% less
Smog producing polutants	60-90% less

On comparing with diesel firing.

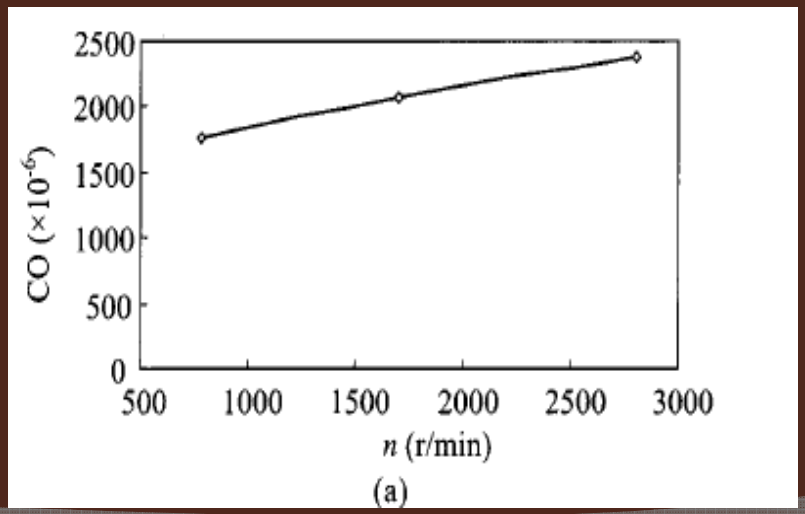
- Clean combustion
- Effective utilization of existing fuel.

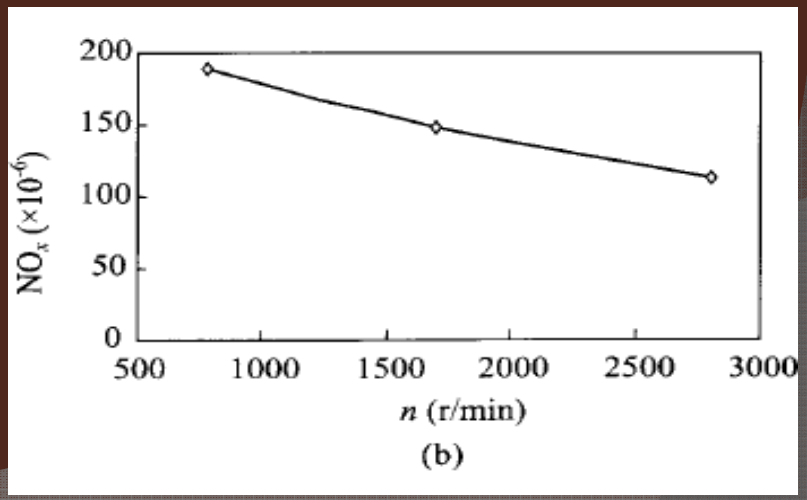
Factors effecting emissions in duel fuel engine

- Effect of speed:

  CO emission increased with increase of rotate speed.

  NOx emission was decreased with increasing rotate speed.

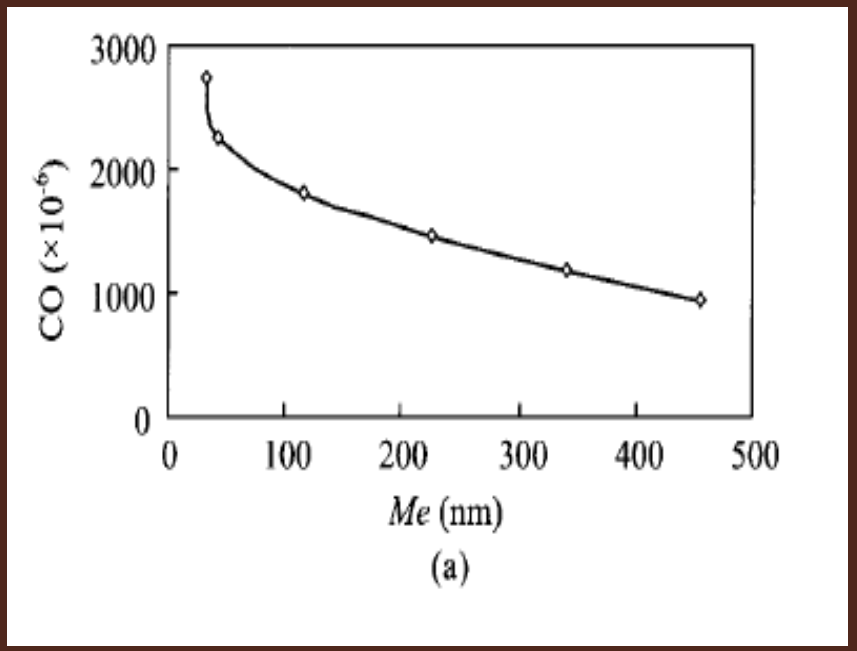


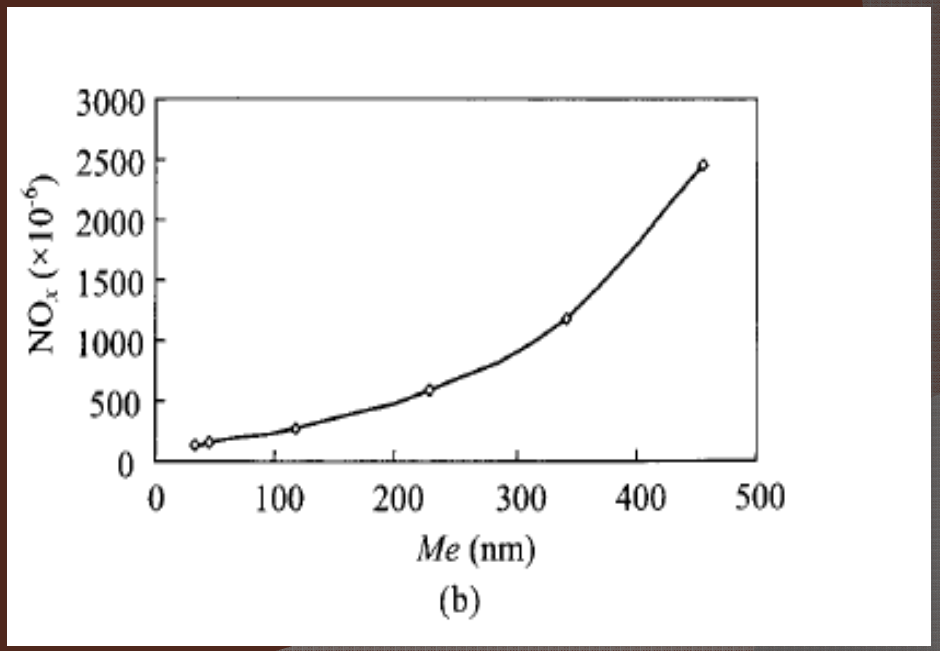


- Effect of quantity of CNG

  CO emissions reduced on Increasing CNG quantity.

  NOx emissions were increased with quantity of CNG due to high load, heat release and temperature are higher





Combustion in duel-fuel engine

- Combustion is broadly divided into 3 stages:

1. Burning of pilot fuel to initiate combustion.
2. Burning of gaseous fuel after initiation of combustion.
3. Burning of gas-diesel mixture which is dispersed inside the cylinder.

- As the gaseous fuel is introduced, the weak gas air mixture comes in contact with the injected spray of the pilot fuel. Only this part of the mixture which is in the combustion zone of the spray gets oxidised.
- The rest of the gas remains unaffected and goes in exhaust. This results in a very low efficiency at part load operation of the engine.

- As the amount of the gaseous fuel is increased,. Flame fronts start travelling from these ignition points and combustion takes place rapidly and almost completely.

- Increased admission of the gaseous fuel results in very fast reaction rates. This produces high rates of pressure rise and combustion becomes uncontrollable. This is the onset of knock.


ONE DEEPER LOOK

Features of Dual Fuel Engines

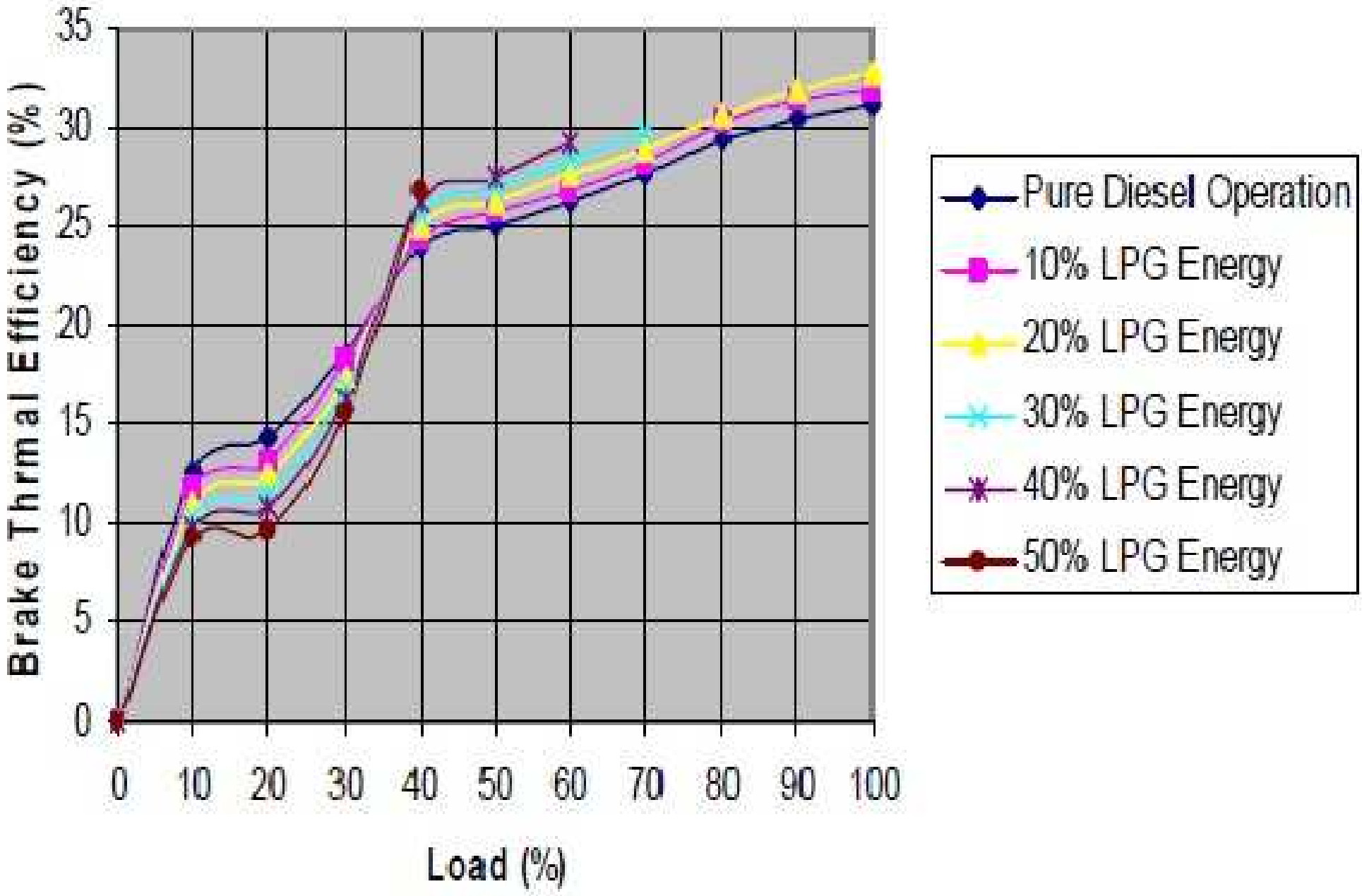
- Capable of producing as much power as diesel engine
- At full load, slightly superior to the diesel engines
- Maximum output of the engine is about the same whether the engine is running on diesel or dual fuel
- The engine operation is smoother and more efficient particularly at high engine loads

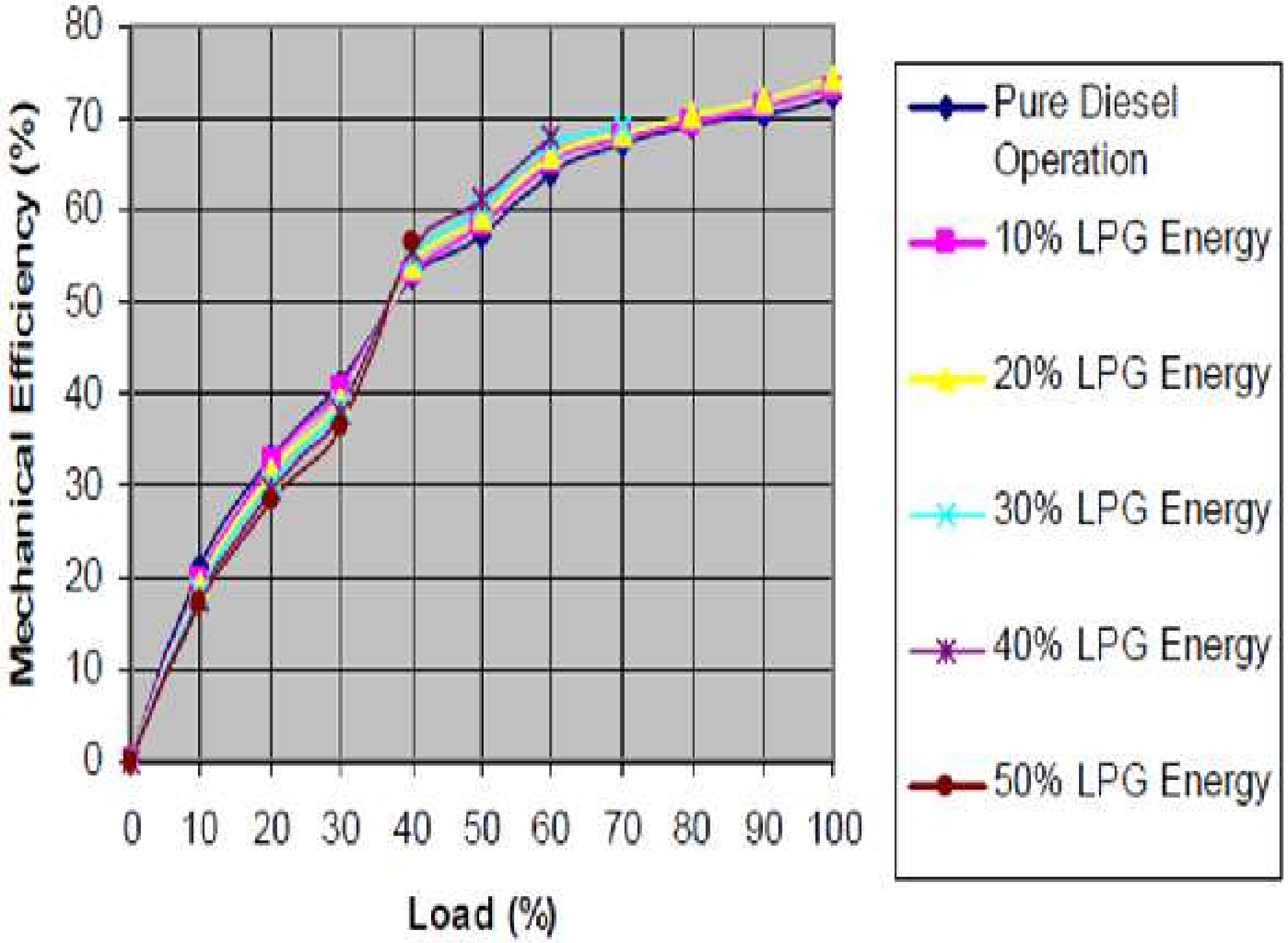
Features of Dual Fuel Engines

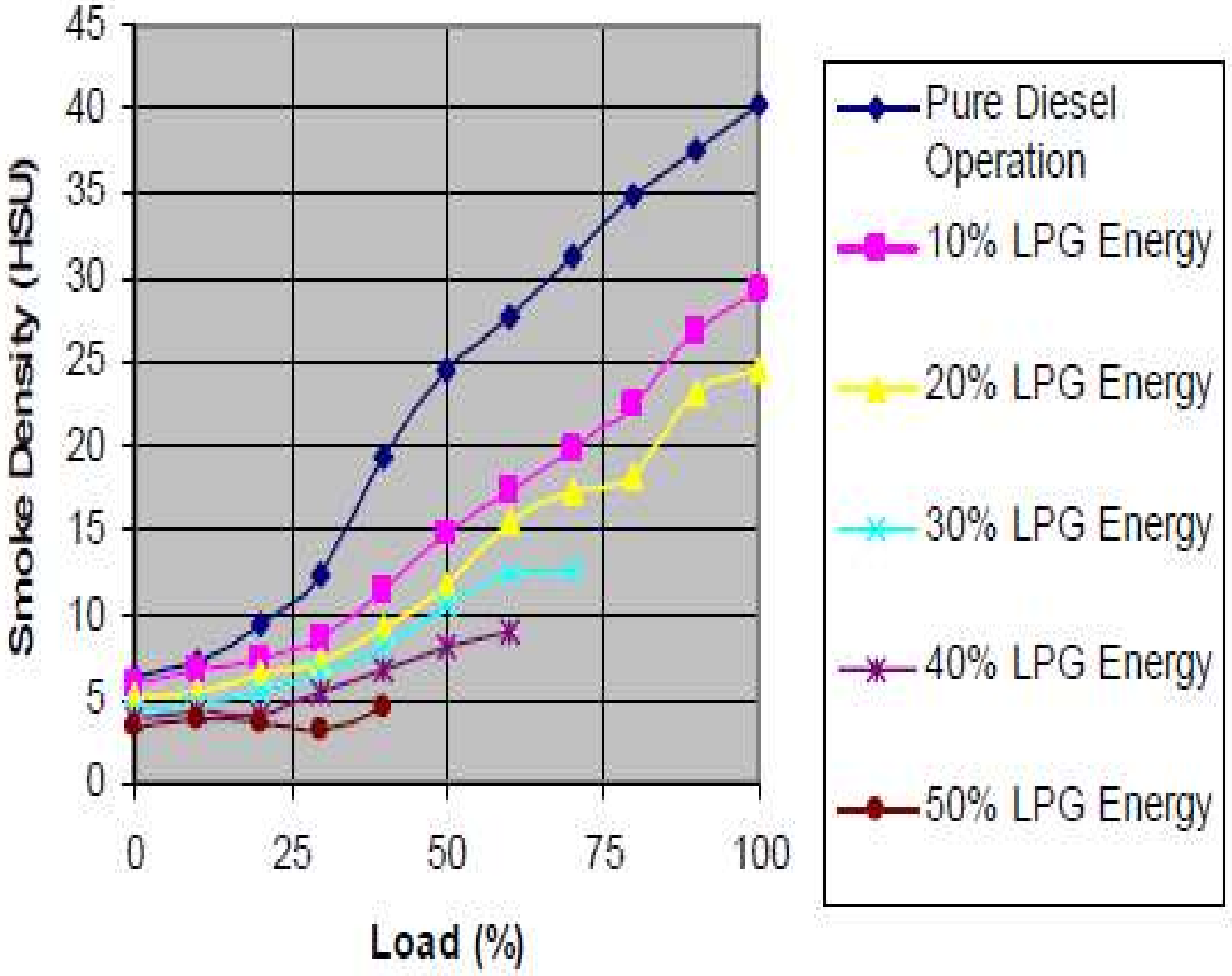
- At lower loads, mechanical, brake thermal efficiencies of the engine are low but reverse is true for higher load
- More economical at higher loads than at lower loads
- The smoke density is negligible on the dual-fuel mode with higher LPG energy substitutions
- Stationary diesel engines can be conveniently operated on the dual-fuel mode at higher loads

Features of Dual Fuel Engines

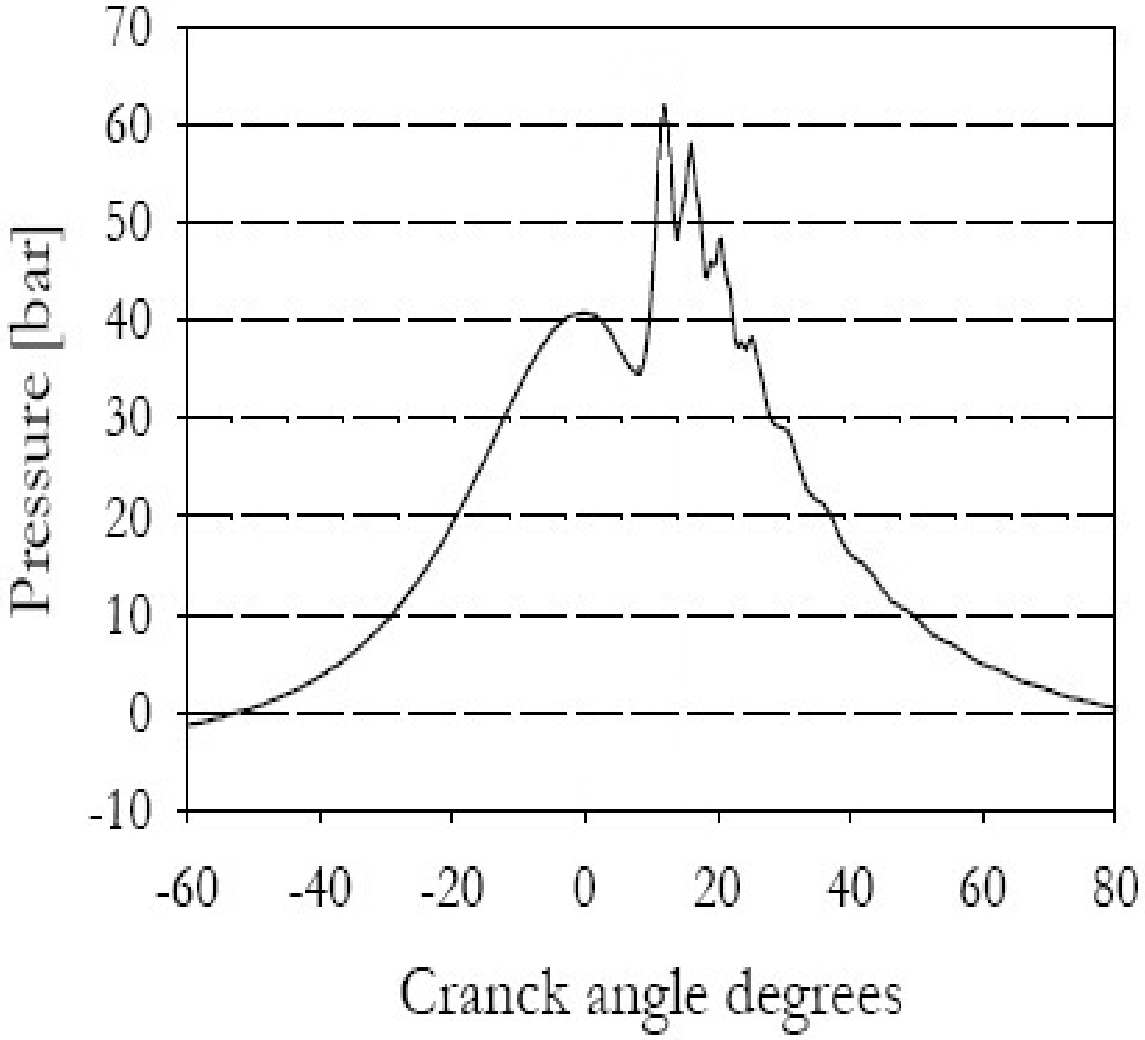
- The ignition delay in gas-fueled diesel engines of the dual-fuel type depends strongly on both the quantity and quality of the pilot fuel used.
- Lower initial cost and lower operating costs than a dedicated natural gas engine
- Dual-fuel engine performance is improved with the employment of high cetane number pilots.
- For stationary application, diesel substitution of 70% is possible by using dual fuel engine which is quite considerable and also economical


Brake Thrmal Efficiency (%)
35
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
80
90
100
Load (%)
Pure Diesel Operation
10% LPG Energy
20% LPG Energy
30% LPG Energy
40% LPG Energy
50% LPG Energy


Mechanical Efficiency (%)
80
70
60
50
40
30
20
10
0
0 10 20 30 40 50 60 70 80 90 100
Load (%)
Pure Diesel Operation
10% LPG Energy
20% LPG Energy
30% LPG Energy
40% LPG Energy
50% LPG Energy


Smoke Density (HSU)
45
40
35
30
25
20
15
10
5
0
0
25
50
75
100
Load (%)
Pure Diesel Operation
10% LPG Energy
20% LPG Energy
30% LPG Energy
40% LPG Energy
50% LPG Energy

KNOCKING



Increased admission of primary fuel results in very fast reaction rates. This is followed by ignition with very high rates of pressure rise & combustion becomes uncontrollable. This is the onset of knocking.

KNOCKING

- Very high peak pressure results in combustion noise.
- Knocking in dual fuel engine is similar to knocking in S.I. engines.
- Transition from 'normal' to knocking conditions is very sharp i.e. small increase in primary fuel beyond a limit can result in a severe knocking.

Three Types Of Knock

- Diesel knock due to combustion of premixed pilot fuel
- Spark knock due to auto ignition of end gas
- Erratic knock due to secondary ignition of the alternative fuel

KNOCK IN DUAL-FUEL ENGINE IS CONTROLLED BY ANY OF THE FOLLOWING METHODS:-

- Excess supply of air.
- Use of cold combustion air.
- Increased cooling of piston.
- Reducing the pressure of the gaseous fuel.

Dual-Fuel is easier to implement than Spark Ignited Natural Gas Commercial Engines

Dual-Fuel Requirements

- No changes are required to the base engine – a modification is carried out on the induction system only
- Retains diesel FIE (Fuel Injection Equipment) as the ignition source
- Easy to retro-fit, lower cost production

SI Natural Gas Requirements

- New cylinder head, piston, lower compression ratio (CR), turbocharger, modified cooling system & ignition system
- Potentially lower cost ignition system with higher maintenance requirement
- Requires new dedicated gas engine and high production cost

Dual-Fuel Requirements

- Can fall back to 100% diesel
- Neither an air throttle nor spark plugs are required

SI Natural Gas Requirements

- Dedicated to gas, very difficult to retro fit or dealer fit
- Both air throttle and spark plugs are required

Caterpillar 3176B Dual-Fuel CNG 10.3 L Engine

Caterpillar 3176B Dual-Fuel CNG 10.3 L Engine

Performance Data

Operating range (rpm): 1200–2100
Maximum engine rpm: 2120
Maximum hp @ 2100 rpm: 350
Peak torque (lb-ft): 1050
Peak torque (rpm): 1200
Torque rise (%): 20
Altitude capability (ft): 7500

Certification Exhaust Emissions Standards (g/bhp-hr)

Non-methane hydrocarbons: 1.2
Carbon monoxide: 15.5
Oxides of nitrogen: 2.5
Particulates: 0.10

Note: The Caterpillar engine model in this size is now called C-10.

Source: Caterpillar, Inc.

Benefits of Electronically Controlled Dual-Fuel Engine Technology

- Offers similar power to diesel-powered engines
- Lower emissions than diesel equivalent
- Same heat rejection as diesel
- High gas substitution rate
- Attractive operating economics, depending on fleet location and mileage
- Compatible with compression brake installation
- Full use of standard diesel electronic diagnostic and fleet management tools
- Warranty administered through local Caterpillar dealer
- Resale value advantages (versus dedicated gas)
- Full diesel backup (80% power in California)

Source: Caterpillar Engine Division

Engine System Hardware

- **Gas injection system**
  - Electronically controlled gas injectors installed in modified air inlet manifold
- **Turbocharger Air Bypass (TAB)**
  - **Fast and accurate control of air-fuel-ratio**
- **Dual-Fuel Electronic Control Unit (ECU)**
  - **Controls/Integrated with engine OEM's ECU**
  - **New generation Dual-Fuel ECU ready in 2007**

Dual-Fuel Vehicle System Gas Storage

LNG is stored at about temperature of -163 °C
CNG is typically stored at 3,600 psi (248.211263 bar) at 70°F

Dual-Fuel & Bio-Fuels

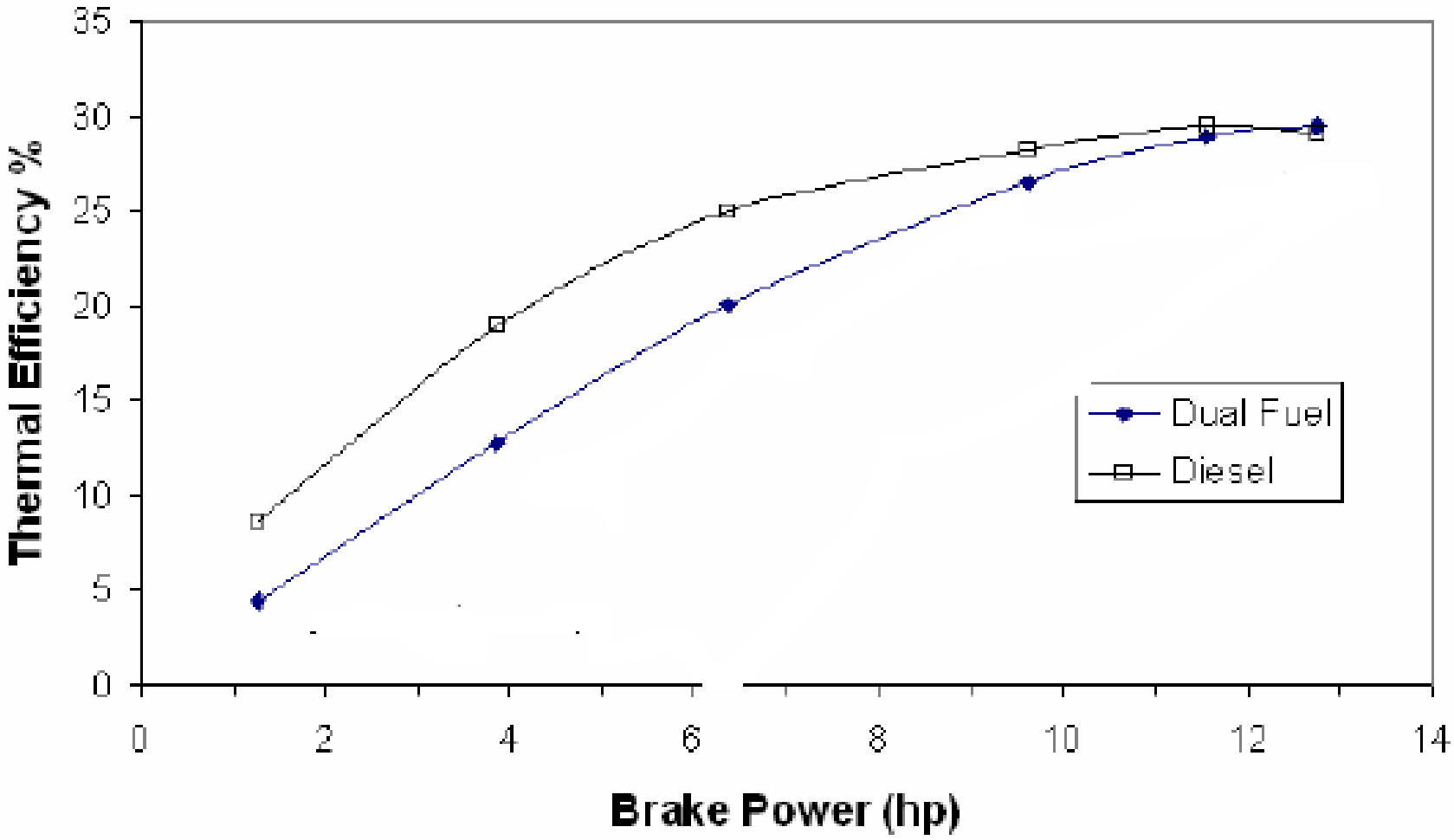
- Dual-Fuel can operate on Bio-Diesel and Bio-Gas
  - Bio-Diesel pilot injection
  - Bio-Gas is methane –usually higher purity than natural gas
- Dual-Fuel enables the practical use of Bio-Fuels
  - Requires much less Bio-Diesel (60-85% less)
  - Efficient combustion of waste-produced Bio-Gas

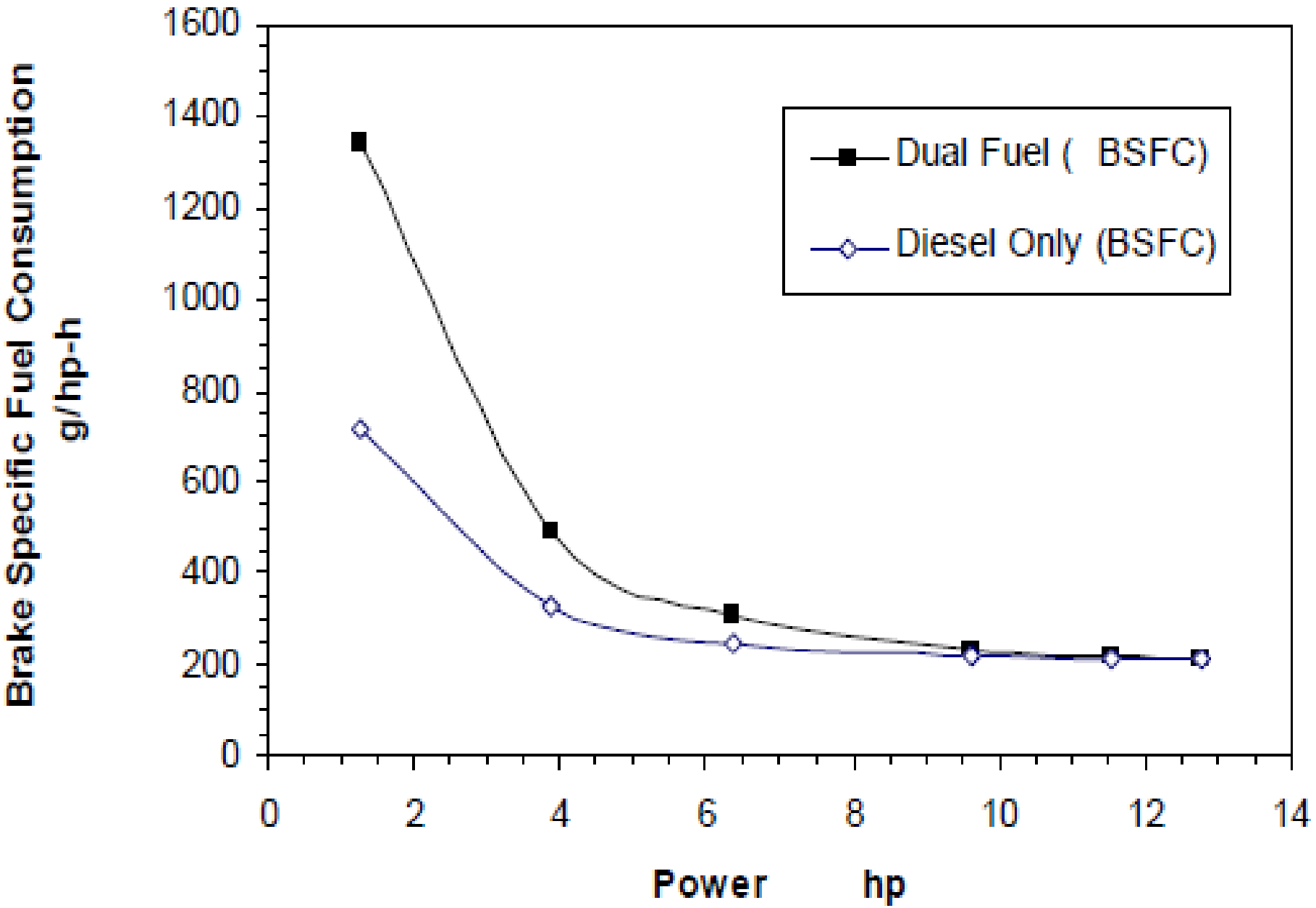
Case Study

The Clean Air Express Commuter Bus Service

- Four buses were used to carry out study(3 equipped with dual fuel engine & 1 with diesel engine)
- Vehicle operation
- Bus driver reported slight reduction in power
- Experienced three break downs(mainly due to water intrusion in computers)
- Engine used 86% of CNG substitution in dual fuel mode (56% was overall substitution)
- Noise and vibration were similar between the two engines

PERFORMANCE OF DUAL FUEL ENGINES




Brake Specific Fuel Consumption
g/hp-h
1600
1400
1200
1000
800
600
400
200
0
0
2
4
6
8
10
12
14
Power hp
Dual Fuel (BSFC)
Diesel Only (BSFC)

- Efficiency at part load is poor because increase in delay period at low mixture strength
- Efficiency can Increase by increase pilot fuel quantity at part load
- Effective compression ratio of dual fuel engine is lesser .
- Pressure of inlet air is increase

ADVANTAGES OF DUAL FUEL ENGINES

- Emissions are very low
- Reduces wear in engine parts
- Lubricating oil consumption decreases
- Instantaneous change over from gas to diesel

- Small amount of liquid fuel uses
- In engines of LPG tanker s gas evaporate during transportation can be use
- Diesel engine can be easily converted into dual engines

Disadvantages of dual fuel engines

- BSFC is slightly higher than diesel engine
- cooling of fuel injector is difficult
- Temperature at the end of compression is lower
- Volumetric efficiency decreases
- Higher compression ratio require

Overall Conclusions

- The ignition delay in gas-fueled diesel engines of the dual-fuel type depends strongly on both the quantity and quality of the pilot fuel used.
- Dual-fuel engine performance is improved with the employment of high cetane number pilots.
- For stationary application, diesel substitution of 70% is possible by using dual fuel engine which is quite considerable and also economical

- The engine operation is smoother and more efficient particularly at high engine loads.
- At higher loads, mechanical and brake thermal efficiency is more than diesel engine.
- The operation is more economical at higher loads.
- Smoke density is negligible.

Queries???