



SWANSEA METROPOLITAN UNIVERSITY

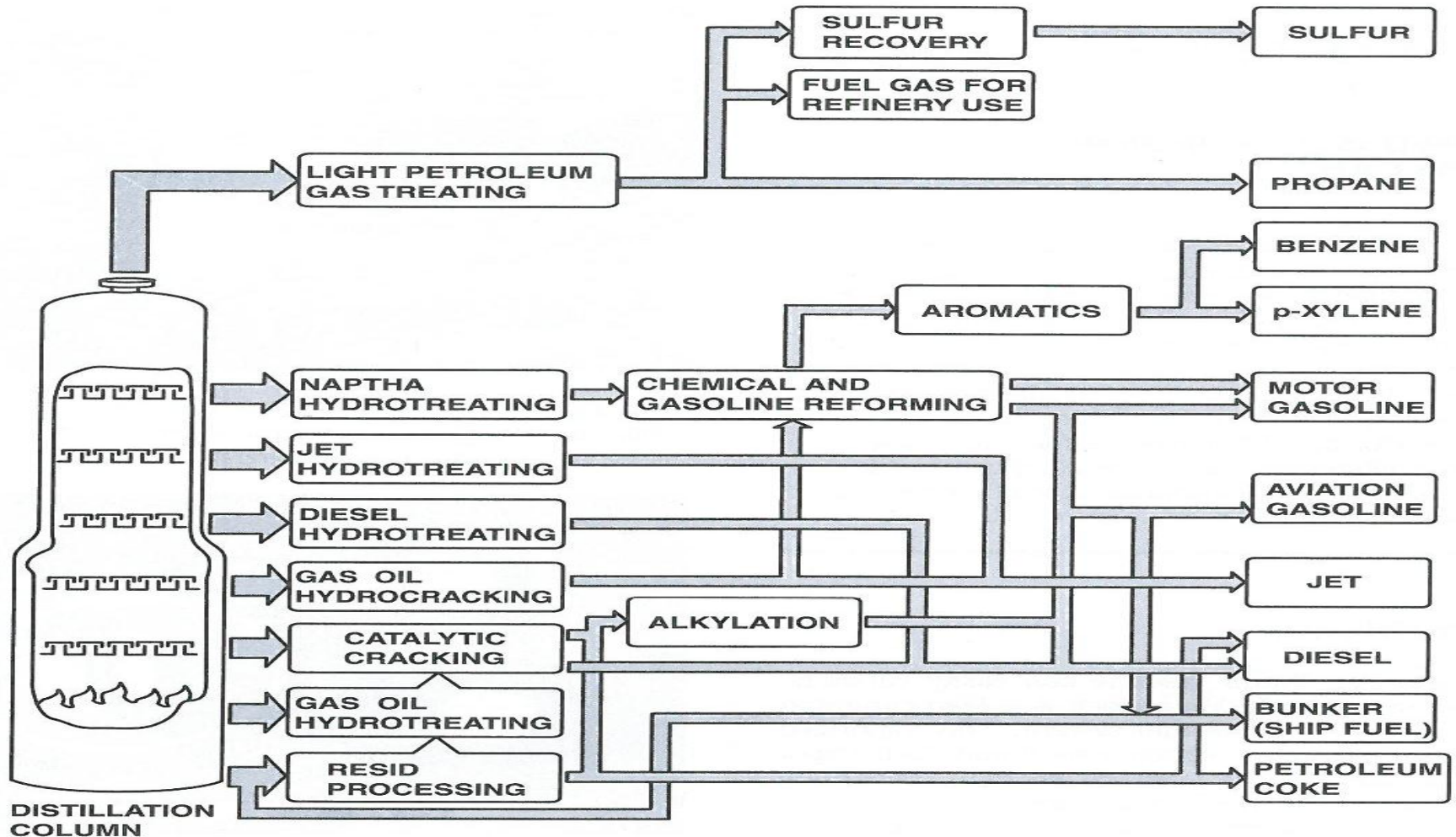
PRIFYSGOL FETROPOLITAN ABERTAWE

Emissions Control and Diagnostics

Gasoline and alternative fuels

- Petroleum comes out of the ground in two forms
 - Thin crude: light coloured (like apple cider) also known as high gravity crude, contains more natural gasoline with less sulphur and nitrogen
 - Thick crude: very thick and dark (like melted tar) and is also known as low gravity crude
- Refining is a series of complex processes to extract a fuel from the crude
 - Distillation is at the centre of the process and a series of by products are obtained
 - Some of the crude does however have very high boiling points not suitable for fuel and cracking. This is nowadays done using a catalyst to break the hydrocarbons. Hydrogen is commonly used for diesel production

Automotive fuel refining



- Complex mixture of different hydrocarbons used as a fuel in spark ignition engines.
 - Blended to suit specific regional climate and altitudes
- Volatility refers to how easily the gasoline evaporates and is measured as Reid Vapour Pressure (RVP). This is the pressure above the fuel when fuel at 38°
 - Winter blend: at lower temperatures gasoline will not vaporise as well and therefore mix poorly with air. To solve this winter gasolines are blended so that its volatility increases (15psi RVP)
 - Summer blend: the opposite is true for high summer temperatures and the blend now aims at reducing volatility to about 7 psi RVP

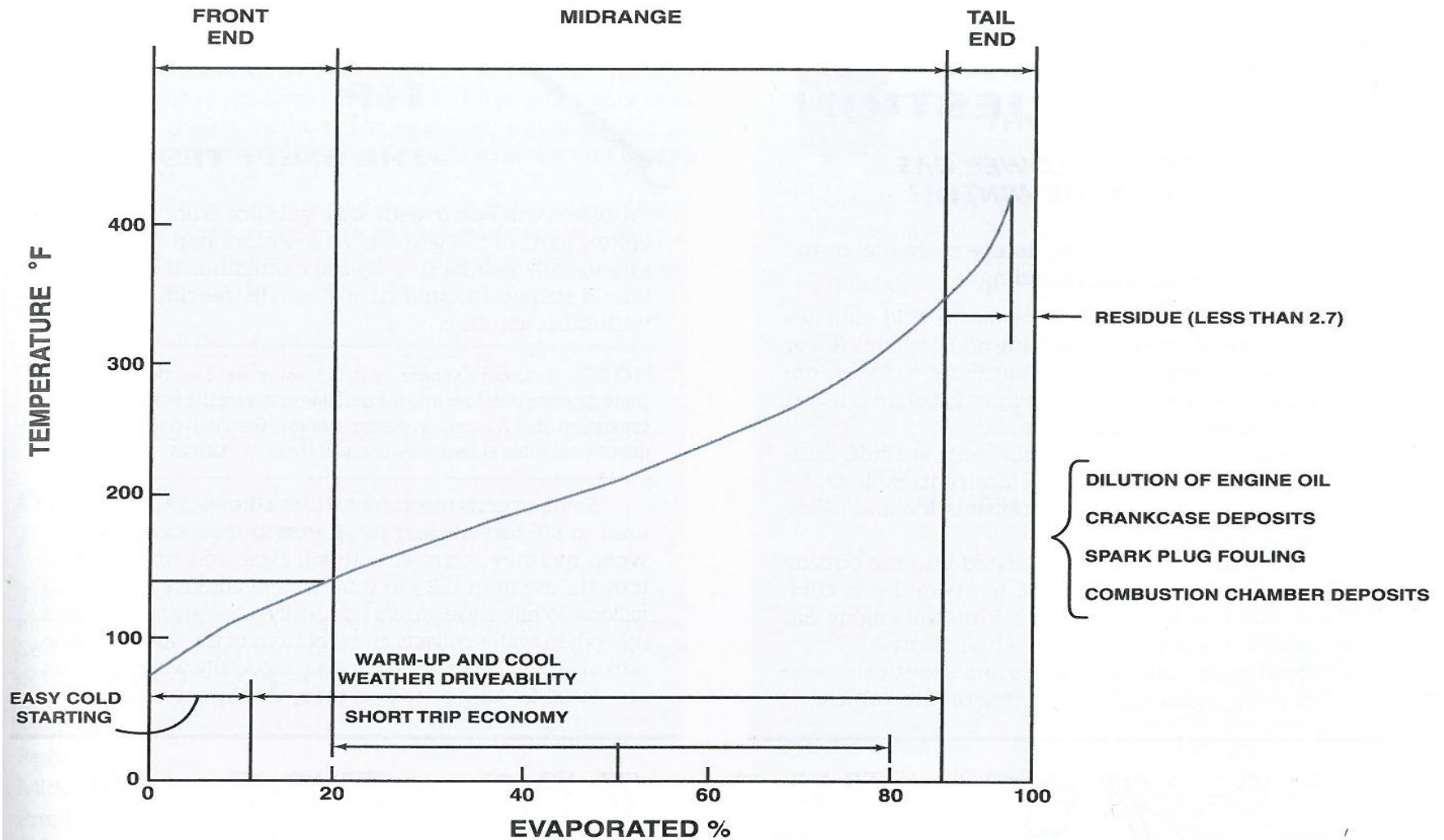
- High temperatures lead to gasoline vapour formation not just in the fuel tank but also in the fuel system
 - This may lead to what is known as vapour lock where vapour takes the place of the liquid fuel that the engine needs to run.
 - It also tends to happen in bends in the fuel systems where the restriction causes the fuel to form bubbles
 - The result is:
 - Rough idle
 - Staling
 - Hesitation on acceleration
 - Surging
 - Distillation curve
 - Another method for classifying gasoline volatility is a distillation curve
 - It shows the temperatures at which various percentages of gasoline evaporate

Distillation curve



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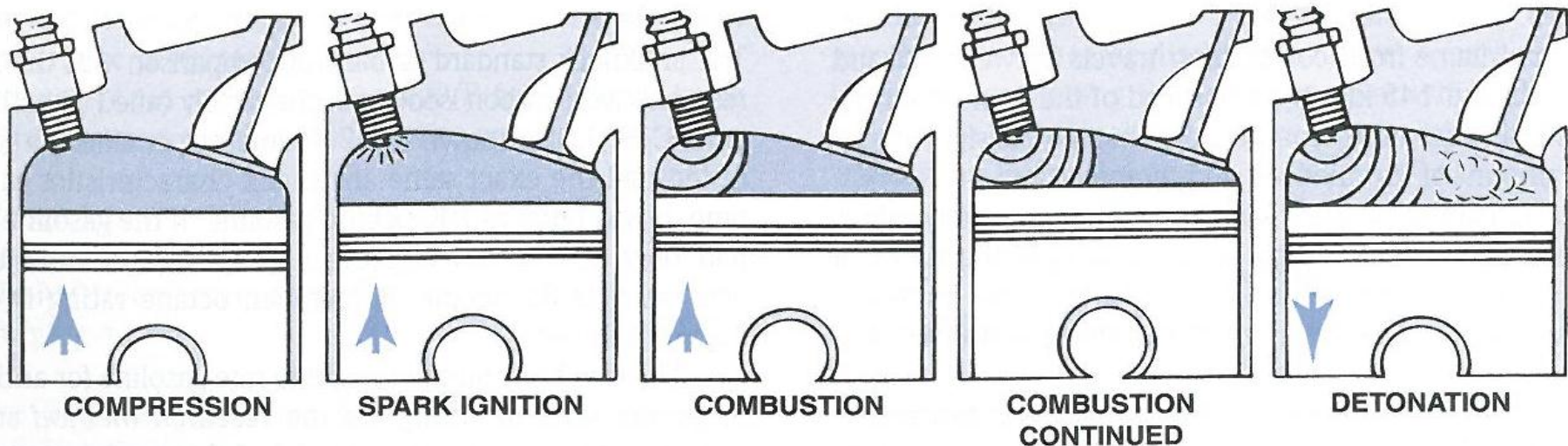
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Octane Rating



- Octane rating measures the anti knock property of a gasoline
 - Engine knock (detonation, spark knock or ping) is a metallic noise engines make as a result of abnormal combustion.



- Normal flame speed between 45 and 90 mph
- During knock it increases up to 10 times: close to speed of sound
 - Higher temperature and pressures that can cause damage

Octane rating

- The anti knock standard is the knock resistance hydrocarbon isooctane called trimethylpentane C_8H_{18}
- If a gasoline showed the same anti knock properties it would be classified as 100-octane. If it had only 85% anti knock compared to isooctane it will be rated at 85 octane.
- Octane rating is therefore a comparative rating
- Two ratings:
 - RON: Research Octane Method
 - MON : Motor Octane Method
 - Both use the same single cylinder engine but at different air temperatures, ignition timing, etc
 - RON values tend to be 6 to 10 points higher than MON

- Up to recent years tetraethyl lead was the preferred booster but was outlawed due to its toxicity leading to unleaded fuel.
- Nowadays they are of the type:
 - Aromatic hydrocarbons (with the benzene ring)
 - Alcohols such as ethanol and methanol
 - Metallic compounds such as MMT – manganese
- Propane and butane are also used but their high volatility may cause hot weather problems – vapour lock
- Oxygenated fuels also help specially at high altitude in order to reduce CO emissions into CO₂

- Ethyl alcohol is drinkable alcohol obtained from grain – yes, beer!
 - Added to gasoline up to 10% raises octane rating in 3 points
 - But also increases volatility in 0.5 PSI
 - A 10% ethanol fuel is known as E10 and has a 3.5% oxygen content
 - E85 therefore means 85% ethanol fuel!
- Methanol is obtained from wood, natural gas or coal
 - POISONOUS!
 - Is more harmful to fuel system materials – conversion required
 - Corrosive to lead, aluminium, magnesium, plastics and rubber
 - Also contains oxygen (2.5%) in a gasoline blend of 5% methanol

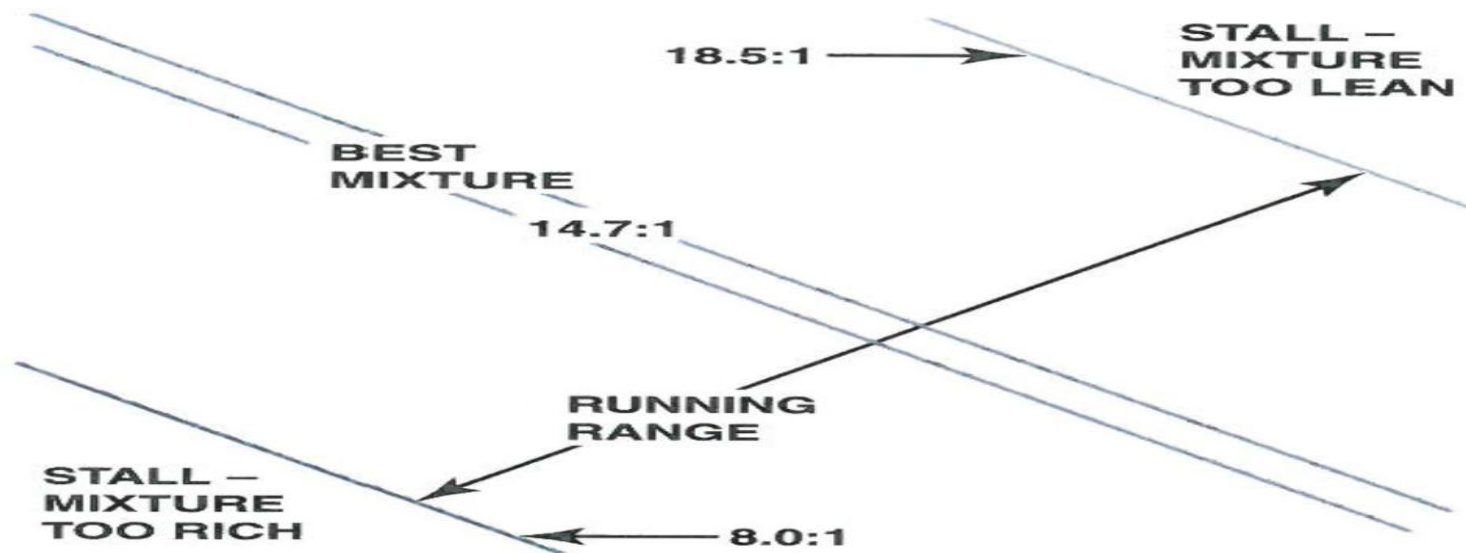
Alcohol additives

Pros and cons

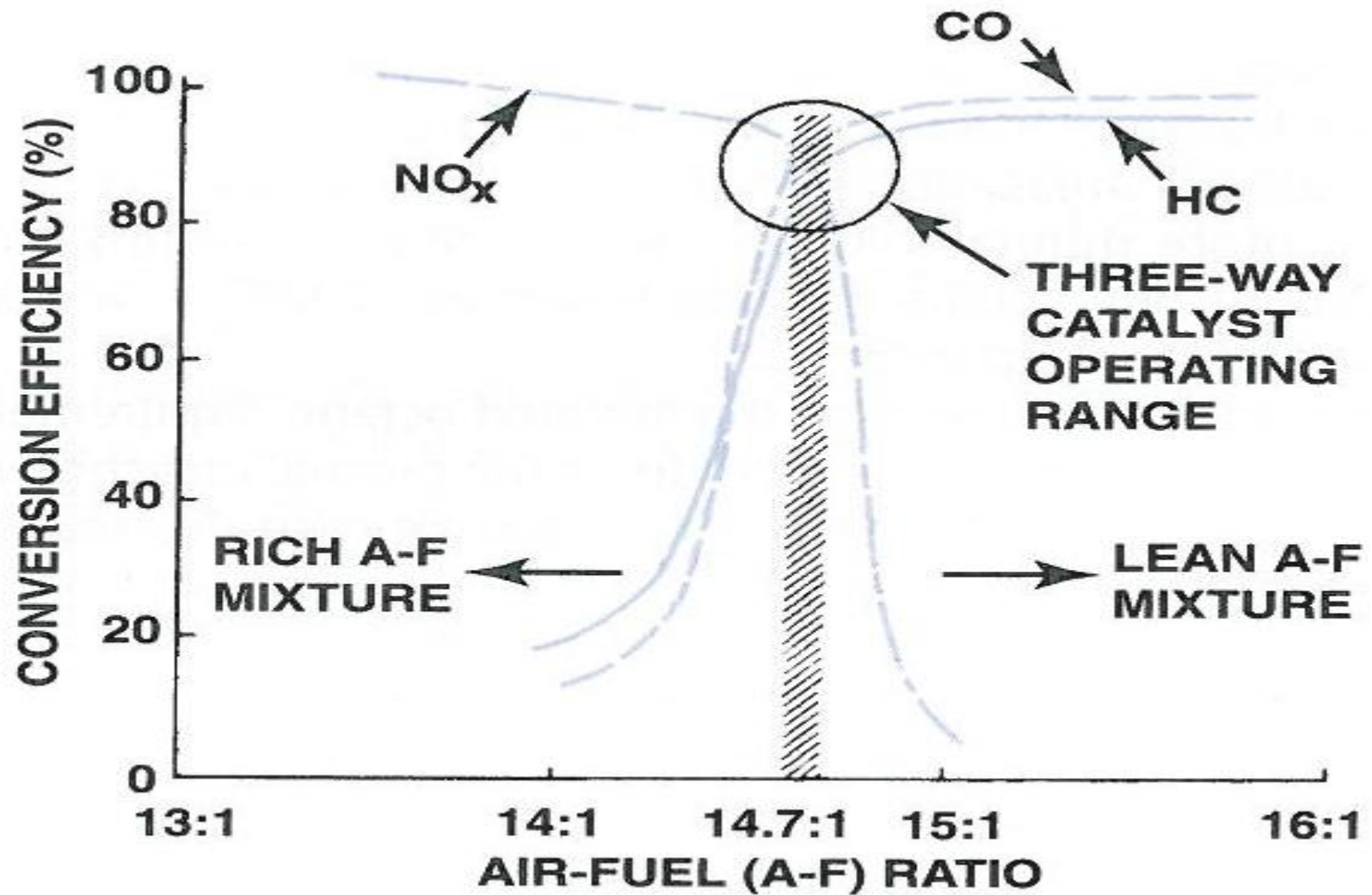
- Pros
 - Absorb moisture in fuel
 - Good improvement of octane rating for small addition of alcohol
 - Cleans the fuel system
 - Reduces CO emission due to the oxygen content
- Cons
 - Cleaned debris lodge and clog up fuel filters
 - Raises the volatility of fuel
 - Alcohol reduces the heat content of the mixed fuel
 - Water absorption can lead to fuel separation in the tank and poor starting

Air/Fuel ratio

- SI engine can run without stalling with A/F ratios from 8:1 up to 18.5 to 1
 - 8 parts of air to 1 part of fuel by weight – richest possible
 - 18.5 parts of air to 1 part fuel by weight – leanest mixture
- The ratio at which all the fuel is burned is called the stoichiometric ratio. In theory this ratio is 14.7 to 1



Air/Fuel ratio



Reformulated gasoline

- RFG is refined in a way that helps reduce emissions by using additives with at least 2% oxygen and reducing Benzene to as little as 1%.
- This is achieved by
 - Reducing light compounds
 - Propane, butane and pentane – high volatile gases responsible for evaporative emissions
 - Reducing heavy compounds
 - Aromatic and olefins that have a very high boiling point and are responsible for HC emissions

- Buy it from busy station – fresher, less water content
- Keep tank over $\frac{1}{4}$ - reduces condensation in tank
- Do not use higher octane rating than necessary
 - Unless the reduction in fuel economy or increase in performance is justifiable.
 - Modern engine are equipped with knock sensors
- Avoid using gasoline with alcohol in hot weather
- Do not buy if the tanker is at the station
 - This stirs up dust, rust and water in the underground tanks
- Do not overfill the tank
 - The excess goes to the charcoal canister and can flood the engine
- When filling canisters have them on the floor to avoid static discharge
- Fill early in the morning to get more fuel molecules per volume

- Ethanol C_2H_6O or CH_3-CH_2-OH
- Conventional ethanol
 - From grain such as corn, wheat or soybeans
- cellulose ethanol
 - made from the non food portion of the feedstock
 - Agriculture plant biomass; industrial plant waste (sawdust, paper pulp)
- Generally Ethanol is obtained from
 - Corn, Grain, Sorghum, Wheat, Barley, Potatoes
- Brazil, the largest producer of ethanol is made from sugarcane

- Pure ethanol has an octane rating of 113 whereas E85 which contains 35% oxygen has a rating of 105.
- It has a less heat energy though so that means more of it is required for the same engine output
 - i.e. higher fuel consumption of about 20%
 - But a power increase can be felt due to the higher octane rating – about 5%
- Has the benefit of being considerably cheaper than gasoline and being more environmentally friendly – less CO and CO₂
- Differences are
 - Lower stoichiometric point 9:1 – needs compensation
 - Some manufacturers already equip their vehicles with an ethanol sensor

- Methyl Alcohol CH_3OH is a light, volatile, colourless, tasteless, flammable, poisonous liquid with a very faint odour
- Used as an antifreeze, solvent and fuel
- Also used to denature ethanol due to being poisonous
- Obtained from coal through steaming producing syn gas (synthesis gas)
 - can also be obtained from natural gas or biomass
- Can cause blindness and death and can enter the body by ingestion, inhalation or skin absorption

- Same methanol to gasoline percentage as E85
- Very corrosive so requires completely different fuel system than conventional or E85 engines
 - Stainless steel and alcohol resistant rubber and plastic components
- Heat content of M85 is about 60% that of gasoline

Propane

- Normally a gas it is easily compressed into a liquid and stored easily and cheaply – 300 PSI
- In this form and when sold as a fuel it is also known as liquefied petroleum gas (LPG)
- LPG is propane mixed with 10% of other gases such as butane, propylene butylene and mercaptan to give it smell.
- Its denser than air so any leaks will lay near the floor
 - Reason why in some countries LPG cars are not allowed in underground car parks.
 - Its non toxic but can be an asphixiant as it displaces oxygen
- Very common as a fuel inside warehouses – forklifts – since the emissions are non toxic

Compressed Natural Gas CNG

- Natural Gas has to be compressed at 3,000 PSI so the weight and cost is a major factor in automotive applications.
 - Tanks are usually made of 3mm thick GRP reinforced aluminium
- Octane rating is about 130 and the price is half that of petrol
 - Like the other alternative fuels the heat value is less and therefore more of it is required = poorer fuel economy
 - It is formed by 93% methane and is less dense than air and requires a A/F ratio of 16.5:1
 - This means higher compression ratio and associated engine mods including special injectors to inject a gas and not a liquid
- Hard to re-fill tends to be used in fleets with own refuelling

- Is an alternative fuel developed and Patented by Princeton University
- It's no petroleum based and can be used in any engine ready to run E85
- A blend of
 - Ethanol, MTHF, natural gas liquids (penates) and butane
- Most are obtained from crops
- Production is very limited so not yet an alternative fuel
- What is the issue with using this type of alternative fuels?

- Domestically produced, renewable fuel made from vegetable oils, animal fats or restaurant greases.
- It's a safe, biodegradable fuel, that emits less particles, CO and HC than conventional diesel
- Is sold blended with conventional diesel denoted Bxx – most commonly B20 (20% bio 80% petroleum diesel)
 - This requires no change to engine
 - B100 is possible but engine modifications may be required and winter driving can be problematic
 - Under warranty vehicle using higher than 20% may see its warranty invalidated

- E-Diesel
- The higher the cetane rating the shorter the delays between injection and ignition
- Normal Diesel cetane rating is around 50
- E-Diesel or disohol is a lower grade of diesel that is blended with ethanol
 - Has better cold flow properties but lower heat content
 - 40% less particles, 20% less CO and 5% less No_x

- Obtained from coal, natural gas and other fossil products using the Fisher-Tropsch method
- Coal to liquid or gas to liquid using hydrogen and carbon monoxide to convert into liquid – similar to hydrogenation
- High quality and clean burning fuels
 - No soot or odours
 - Low sulphur and aromatics
 - Virtually no particles
 - HC and CO reductions also expected
- Similar performance to crude oil gasoline and diesel
- At the moment more expensive to produce hence not available at pump

Coal to liquid

