Lecture 2

Practical Transport Fuels – Composition, Properties, Manufacture, Specifications

Gautam Kalghatgi

(Ch.2. Fuel/Engine Interactions, Richards P. 2014. Automotive Fuels Reference Book, Third Edition, SAE International, Warrendale PA)

Current IC Engines

- Spark Ignition (SI) – fuel/air are mixed and compressed, heat release via expanding flame.
  - Uses gasoline.
  - Light duty.
- Compression Ignition (CI) – air is compressed, heat release via autoignition of fuel as it mixes with air.
  - Uses diesel fuel.
  - Mostly heavy duty.
- CI engines more efficient but more expensive

Current Fuels for IC Engines

- Gasoline and diesel complex mixtures of hydrocarbons
- Primary fuel property is the autoignition quality –
- Gasolines are resistant to autoignition to avoid knock (measured by octane numbers, RON and MON) – used in SI engines
- Diesel fuels are prone to autoignition (measured by Cetane Number) – used in diesel engines
- Diesels are also less volatile, heavier. (Jet fuel is like a lighter diesel)

Jet fuel accounts for around 12% of transport energy and is like a light diesel

Fuels Have Developed along with Engines

Gasoline

- ❑ Start of the 20th Century, only fuels available were lighter fractions from distillation of crude oils and shale oils
- ❑ As engine designers sought improved efficiency, knock became a limiting factor
- ❑Initially fuel quality was improved by adding aromatics produced by distillation of coal tar
- ❑Lead additives discovered in 1921. Great resistance initially because of concerns about toxicity!
- ❑1929 Octane scale and Octane Numbers
- ❑ Continuous improvements in refinery processes and anti-knock quality
- ❑Emissions concerns and fuels to enable after-treatment technologies from the 1970s onwards – removal of lead, reduction in sulphur ...

Fuels Have Developed along with Engines

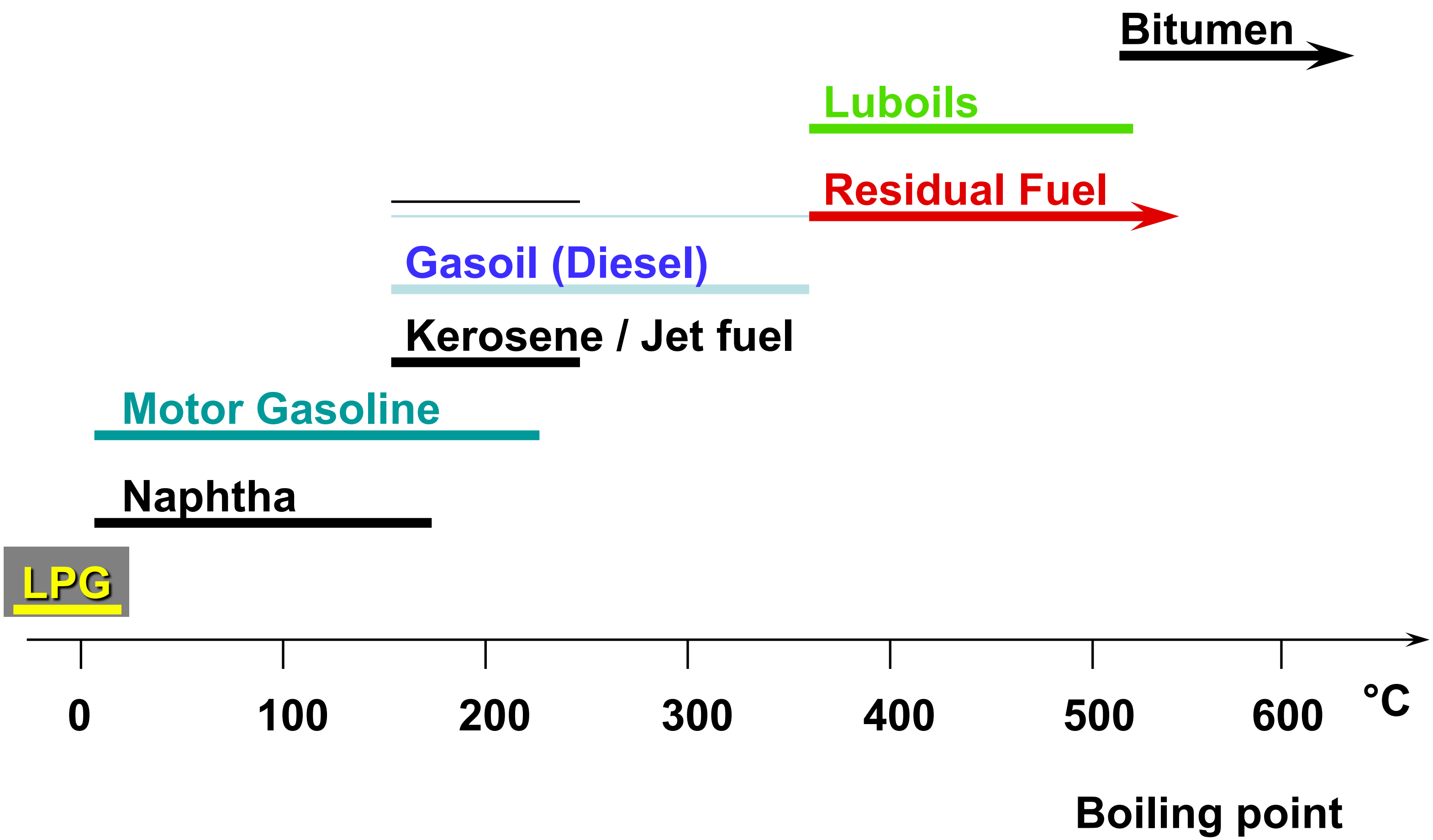
Diesel

- Rudolf diesel had visualised an engine that could be run on different fuels – low grade oil derived from bituminous coal, light crude oil, kerosene, pulverised coal ...
- High viscosities and deposit forming fuels reduced
- Ignition quality improved
- Low temperature performance became important – highlighted in Europe by the extreme winter of 1962-63.
- In recent times sulphur levels reduced

Fuel manufacture in outline

- Most transport fuels made in refineries starting with crude oil
- Initially, petroleum is separated into different boiling ranges (Distillation) – 40%-60% is residue with B.P. > 380˚ C
- Many different processes – cracking, change of composition, redistribution of C/H ratios, removal of contaminants ..
- Fuels are blended from different components + other sources e.g. ethanol, MTBE…
- Refineries also supply feedstocks to the chemical industry

Boiling Ranges

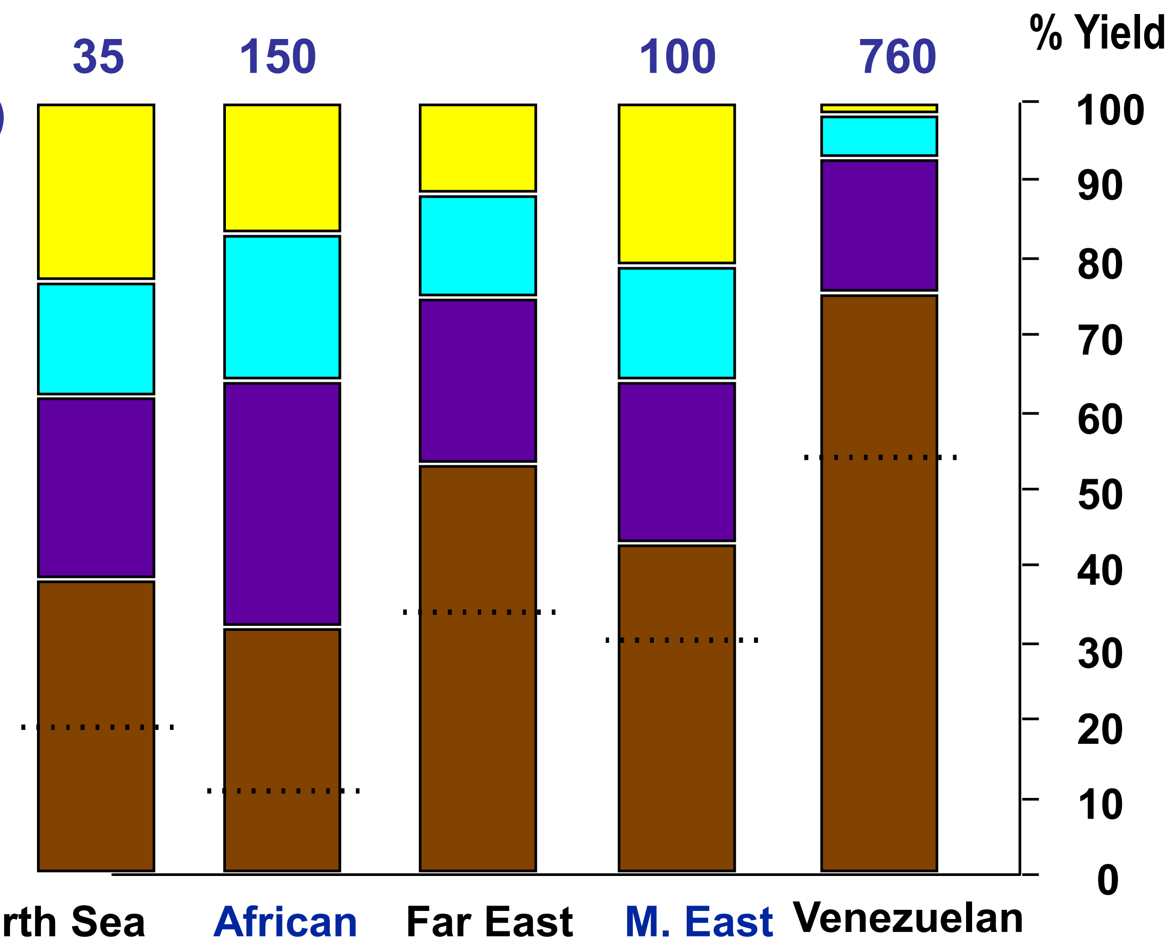


Some differences between Crudes

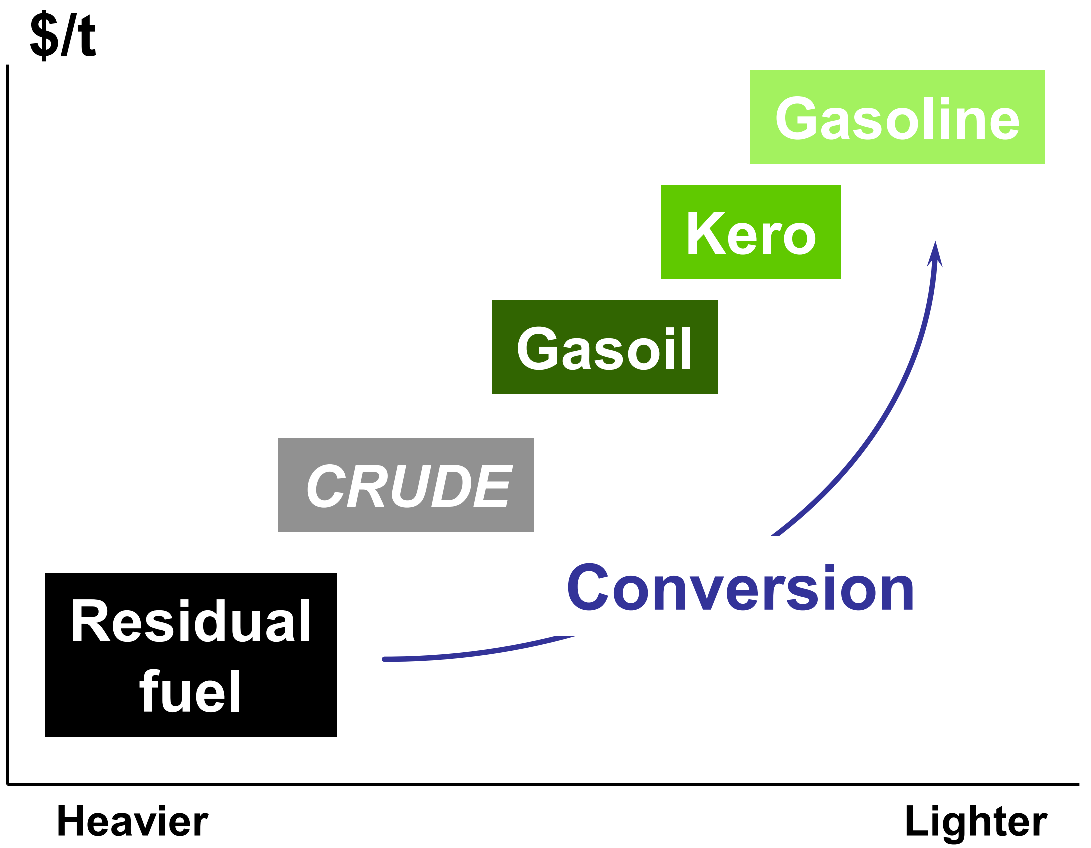
	North Sea	African	Far East	M. East	Venezuelan
API Density	41.8	35.4	34.3	33.9	13.2
Barrels per Tonne	7.71	7.43	7.39	7.36	6.44
Sulphur Content (%)	0.15	0.14	0.08	1.6	2.9
Vanadium + Nickel in Short Residue (ppm)	35	150		100	760

Legend

- Naphtha minus
- Kero
- Gasoil
- Long Residue
- SR Yield

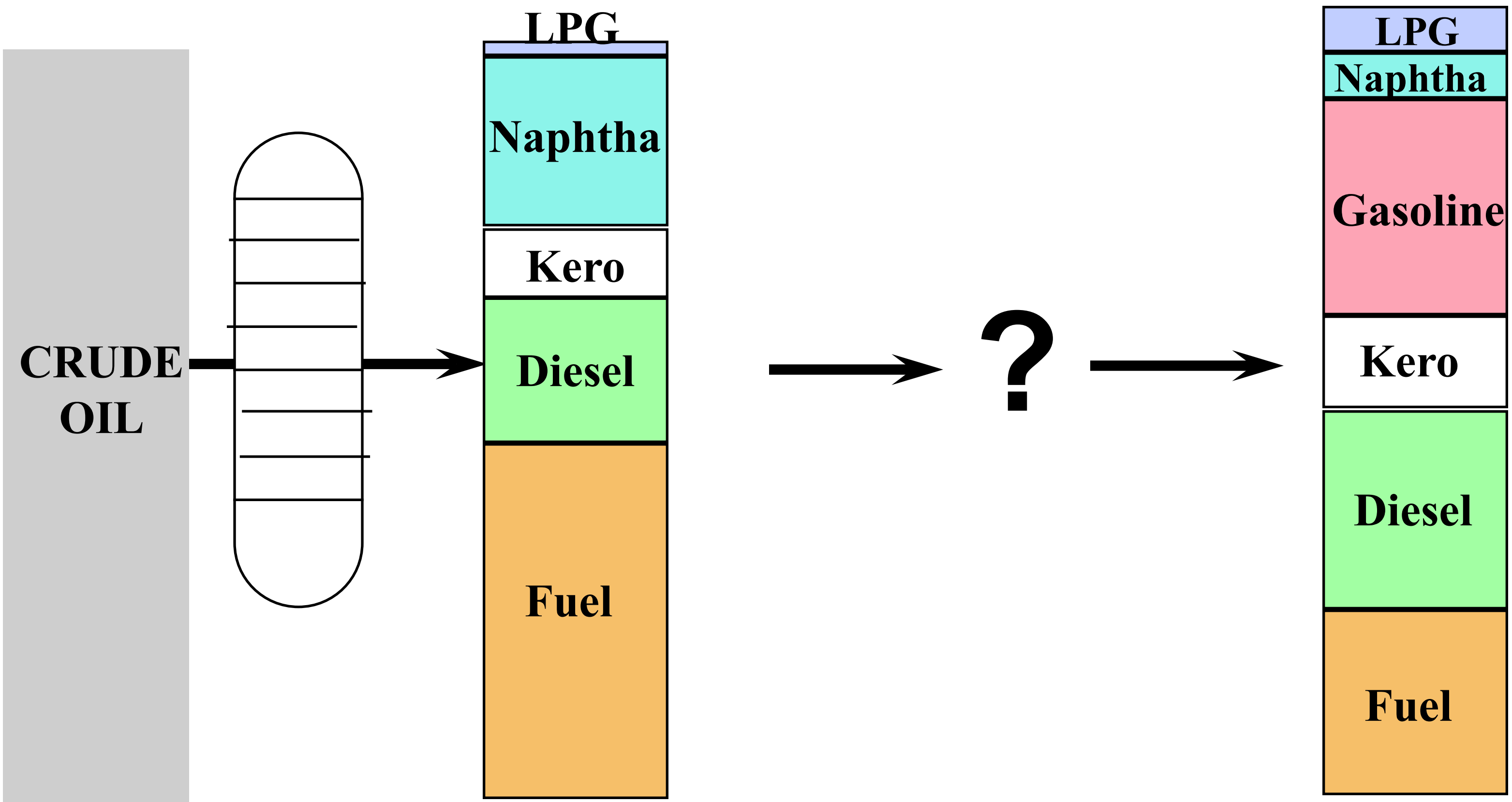


The Price Balance

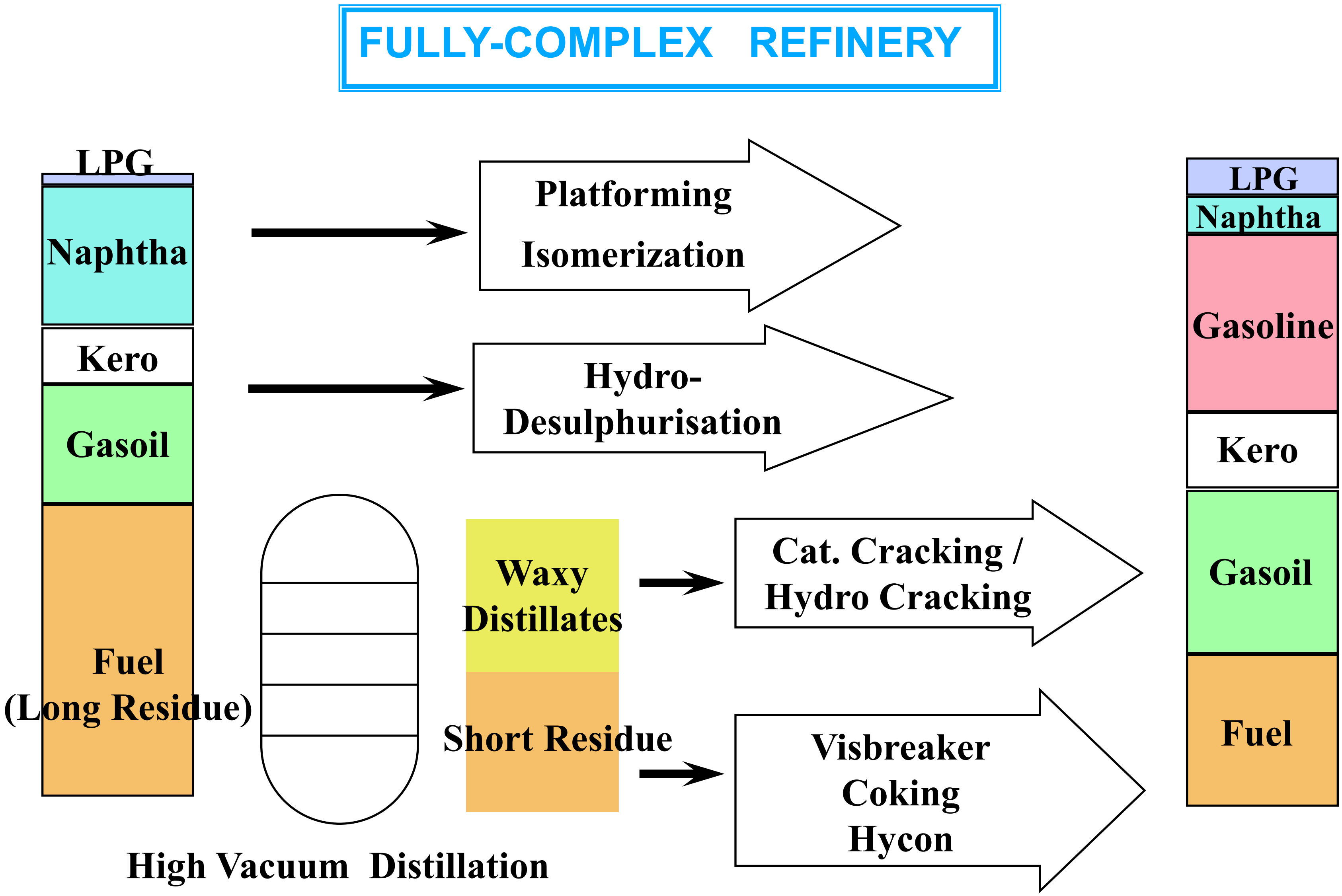


CONVERSION = HIGHER MARGINS

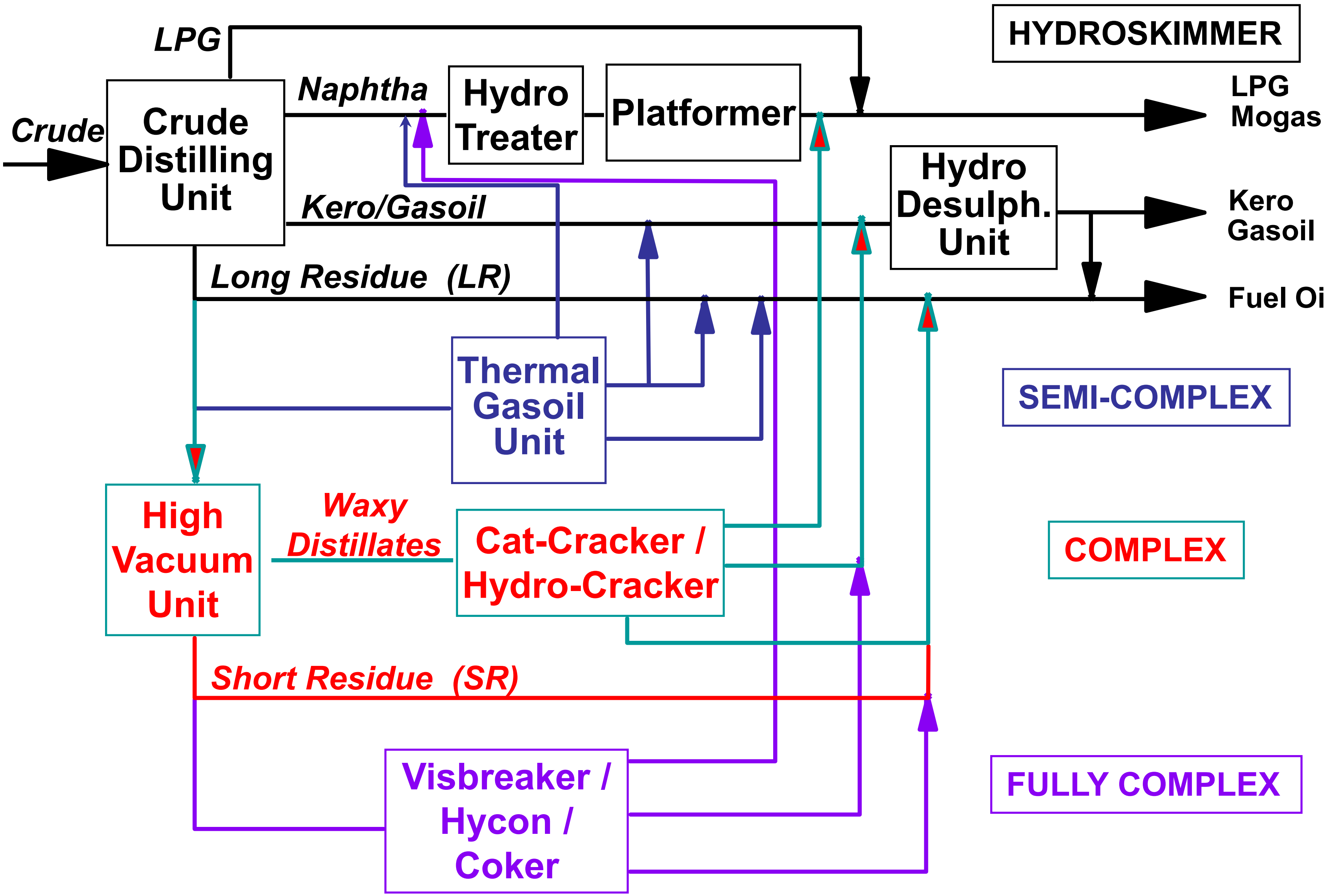
From CRUDE QUALITY.........to MARKET DEMAND



From CRUDE QUALITY.........to MARKET DEMAND



REFINERY FLOW SCHEME

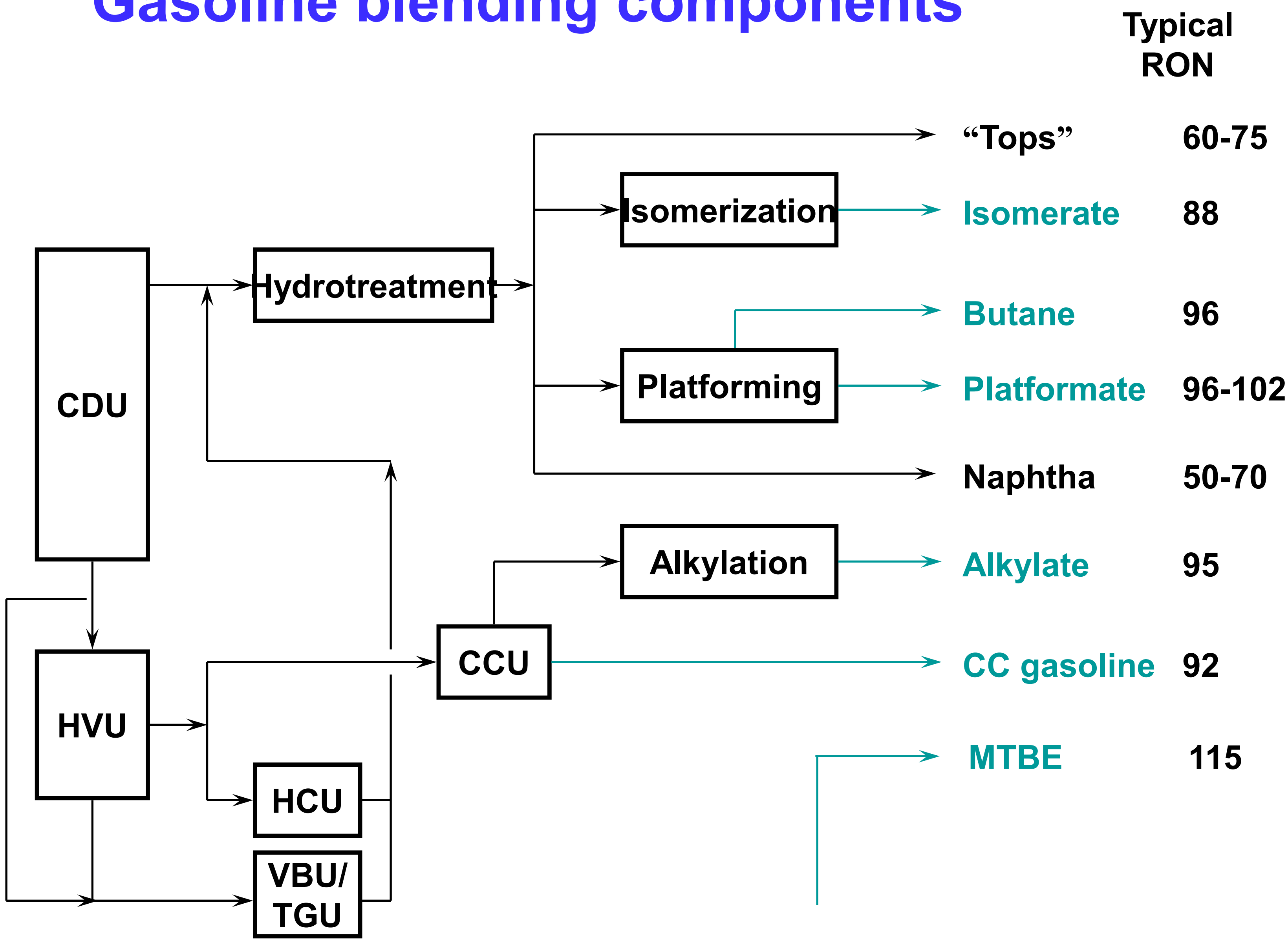


TYPICAL YIELD STRUCTURE

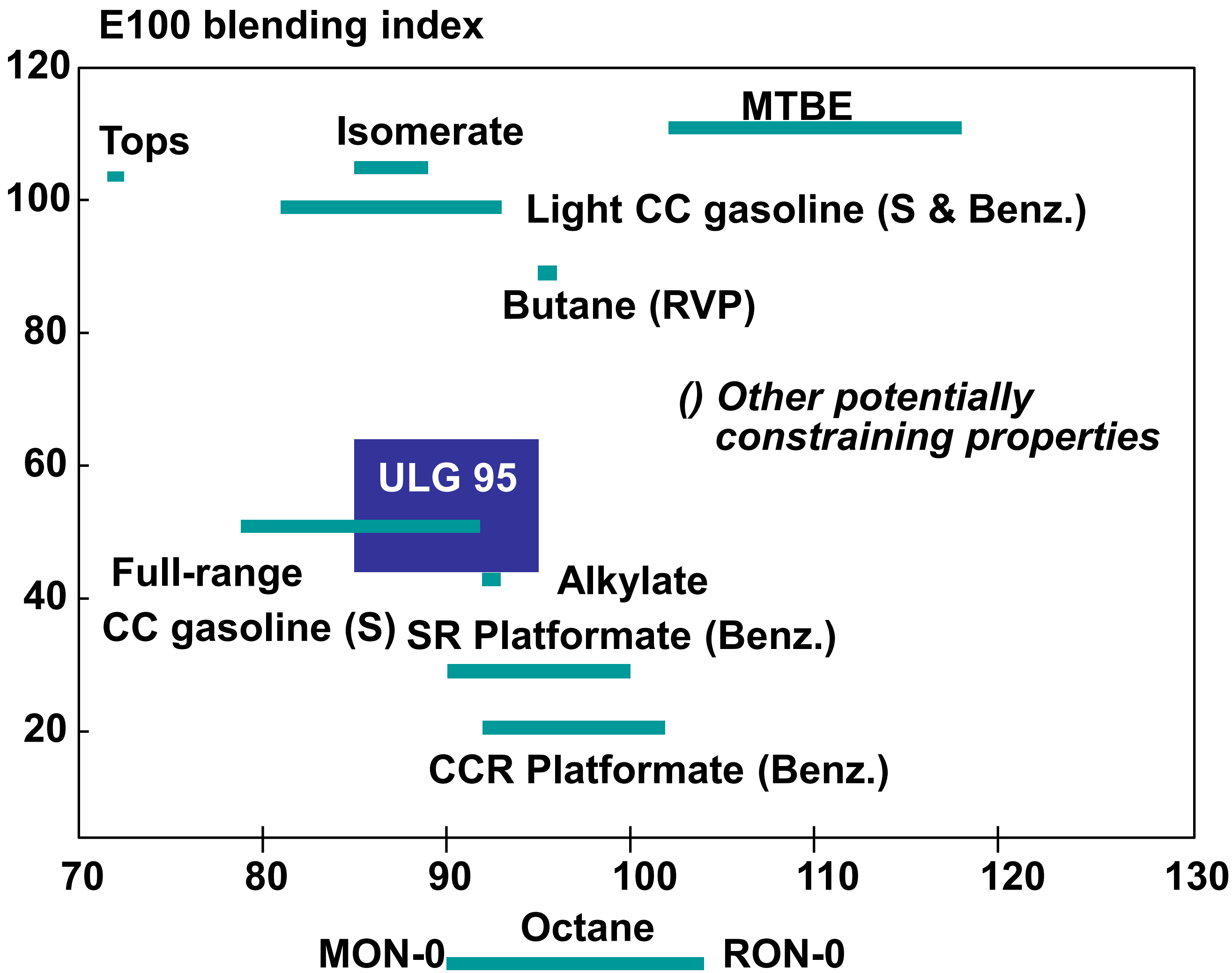
Yield (%moc)	Simple Dist.	Hydro Skimm.	Semi Compl.	Complex (CCU)	(HCU)	Fully Complex (CCU/ VBU)	(HCU\ VBU)
LPG	1.5	1.6	2.2	4.5	2.1	5.0	2.3
Naphtha	23.2	5.7	6.4	6.7	5.9	7.2	6.3
Gasoline	0.0	16.2	18.8	26.2	19.3	28.8	20.4
Kero/Jet	11.0	11.1	11.1	11.1	16.7	11.1	16.7
Diesel	24.8	25.0	31.4	24.6	33.9	27.5	40.0
Fuel oil	37.5	37.8	25.7	21.3	14.9	13.7	6.0
Fuel & Loss	2.0	2.6	3.6	5.6	7.2	6.7	8.3

CRUDE TYPE: BRENT

Gasoline blending components



GASOLINE BLENDING...



...is a SOPHISTICATED PROCESS

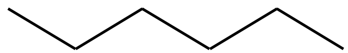
Fuel Properties in outline

What does gasoline & diesel consist of?

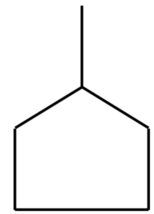
A complex mixture of hydrocarbons

- Paraffins (alkanes)
- Olefins (alkenes)
- Naphthenes (cycloalkanes)
- Aromatics
  - Monoaromatics
  - Polynuclear aromatics (PNA, PAH, Di/Tri+ aromatics)
- Oxygenates (ethers, alcohols, FAME)
- Sulphur Compounds
- Additives (performance, VSRP etc.)

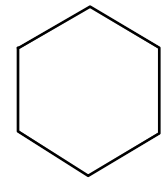
Paraffins, Olefins, Naphthenes & Aromatics



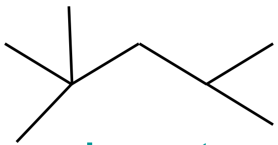
n-hexane



methylcyclopentane

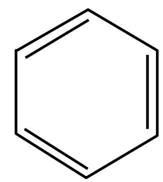


Cyclohexane

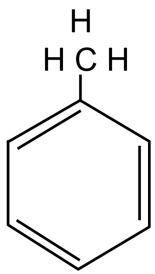


Isooctane

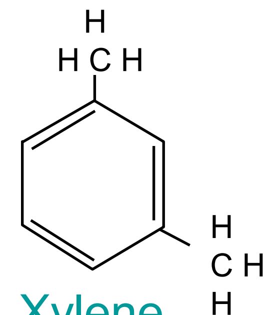
(2,2,4-Trimethylpentane)



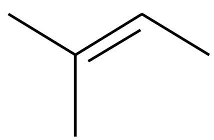
Benzene



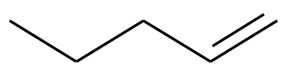
Toluene



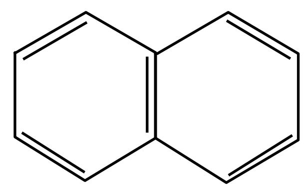
Xylene

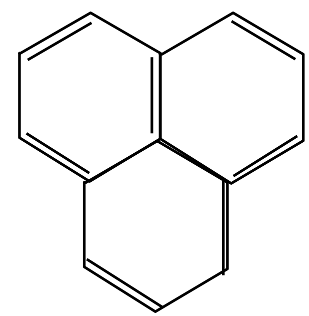


2-Methylbut-2-ene



Pent-1-ene





Polynuclear
Aromatics

Effects of Gasoline Composition

Sulphur – Adverse effect on catalysts in both SI and diesel engines and on-board diagnostic (OBD) sensors.

Aromatics – High anti-knock quality in SI engines. Some effect on benzene formation in the exhaust, combustion chamber deposit formation in SI engines. NOx and particulates in diesel engines (diesel aromatics are heavier), CO2 level

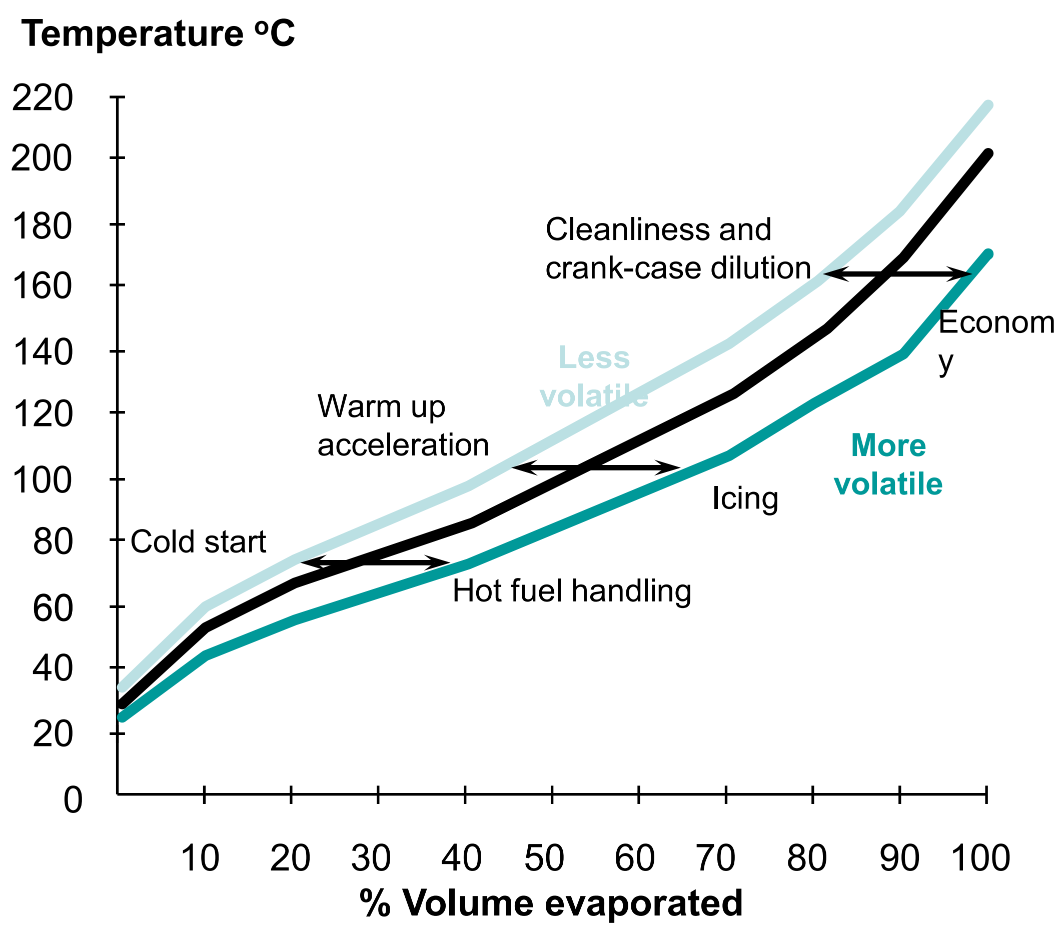
Olefins – High anti-knock quality in SI engines. May lead to gum formation and inlet system deposits, chemically reactive, hence ozone and diene forming potential.

Oxygenates - High anti-knock quality. Lower energy content. Reduction in CO, lower driveability, higher evaporative emissions, degradation of plastics and elastomers

Iron, manganese, silicon, phosphorous – Bad for catalysts and other sensors (e.g. Oxygen sensors)

Gasoline Volatility - 1

Performance factors and gasoline volatility

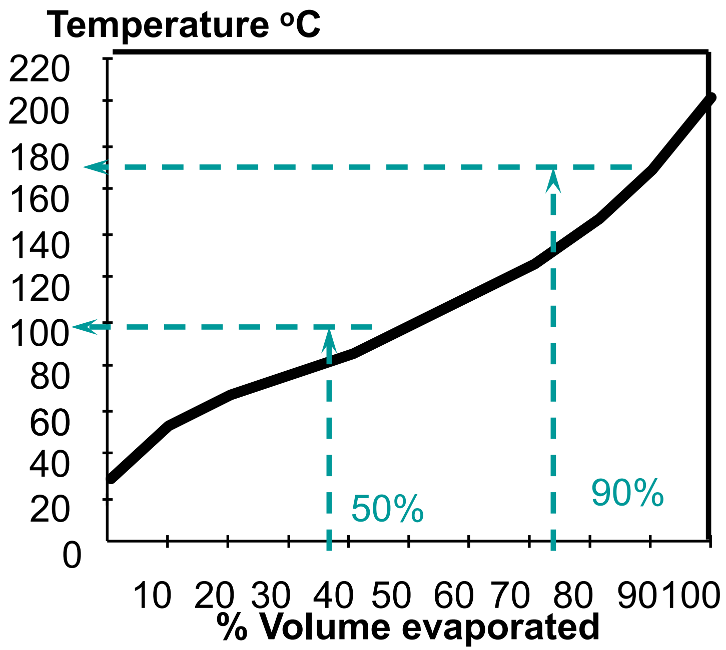


Two ways to express volatility

T numbers

T50%E = 100° C

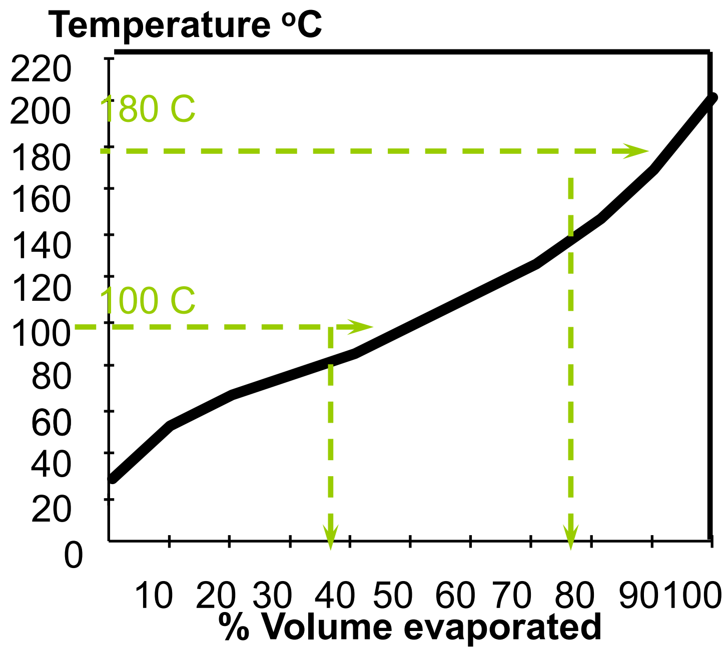
T90%E = 170° C



E numbers

E100 = 50%

E180 = 93%



Vapour Pressure - Gasoline

- The vapour pressure of gasoline should be controlled seasonally to allow for the differing volatility needs of vehicles at different emperatures.
The vapour pressure must be tightly controlled at high temperatures to reduce the possibility of hot fuel handling problems, such as vapour lock or carbon canister overloading. emissions. **Vapour lock** occurs when too much vapour forms in the fuel system and fuel flow decreases to the engine. This can result in loss of power, rough engine operation or engine stalls.
- Control of vapour pressure at high temperatures is also important in the reduction of evaporative emissions.
- At lower temperatures higher vapour pressure is needed to allow ease of starting and good warm-up performance.

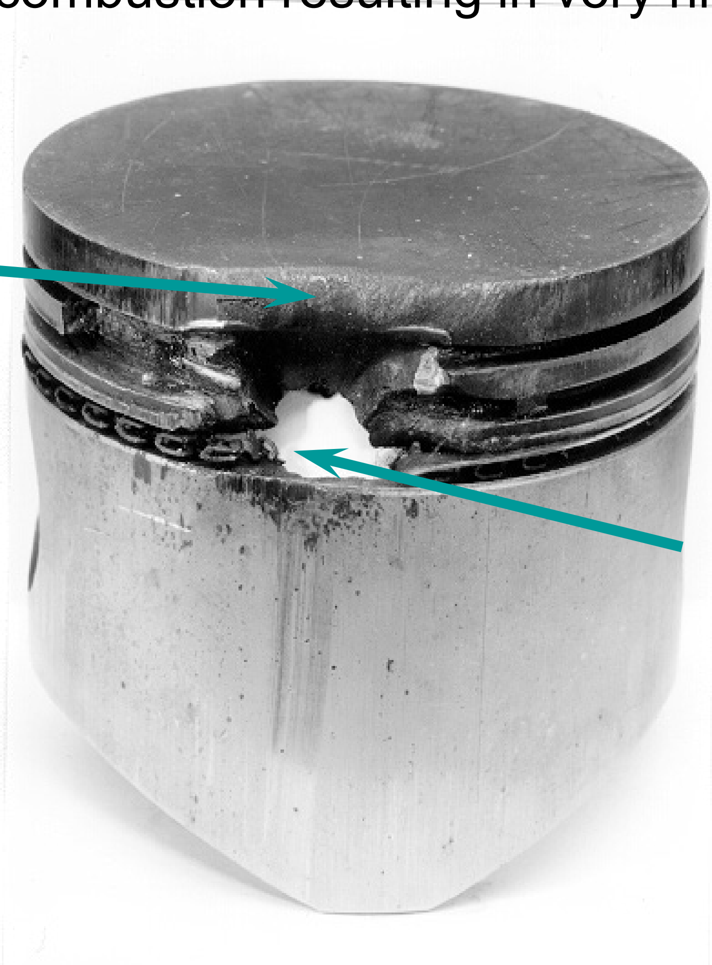
Gasoline Volatility - Warm-up and Cold Driveability

- Driveability describes the smoothness of response to the throttle whilst the engine warms up (easily perceived by drivers), influenced by:
  - Ambient temperature
  - Mid-range volatility
  - Fuel and inlet system design
- Driveability problems are caused by:
  - Incomplete fuel vaporisation - pools of liquid fuel in manifold, fuel hang-up in valve deposits for EFI engines which rely *on hot inlet valves to vaporise fuel*
  - Inability of the liquid to keep up with air flow during acceleration.
  - Maldistribution of this liquid between cylinders for carb/SPI engines.
- The result is:
  - Stalling, hesitation, stumble and even backfire during acceleration
  - Surging during cruise
    - E100 or T50% correlates best with cold driveability

Knock Damage to Piston

Knock is abnormal combustion resulting in very high pressure rise rate

Damage starts at edge of piston furthest from sparkplug, i.e. in the “endgas) causes erosion
and pitting of piston



High heat transfer to the piston can cause local melting and burning
leading to catastrophic engine failure

Anti-knock quality of the fuel is specified by Octane Numbers

Gasoline Octane

Measured with a Cooperative Fuels Research (CFR) engine

Knock limits efficiency and performance in SI engines.

Octane quality is the most important property of gasoline – refining and retailing are driven by Octane

Gasoline Octane Number

- Engine knock intensity of the sample compared with knock intensity of a reference fuel
- Based on a scale with n-heptane = 0; isooctane = 100. Linear blending between these (‘Primary Reference fuels’)
- Octane numbers above 100 compared with leaded isooctane reference fuel.
- Toluene/isooctane/heptane blends used as secondary checks.

Gasoline Octane Number

- Two octane methods:
  - Research Octane Number (RON) (ASTM D2699)
  - Motor Octane Number (MON) (ASTM D2700)
  - MON has higher engine speed and inlet temperature to simulate more severe operating conditions
- RON higher than MON (RON-MON = sensitivity) usually by 10 ON (95/85; 98/88)
- Refinery streams used to blend octane have widely varying sensitivity - one ON usually constraining

The MON test is faster (900rpm) than the RON test (600rpm) and has heated inlet air:
— The temperature, at a given pressure, is higher in the MON test than in the RON test

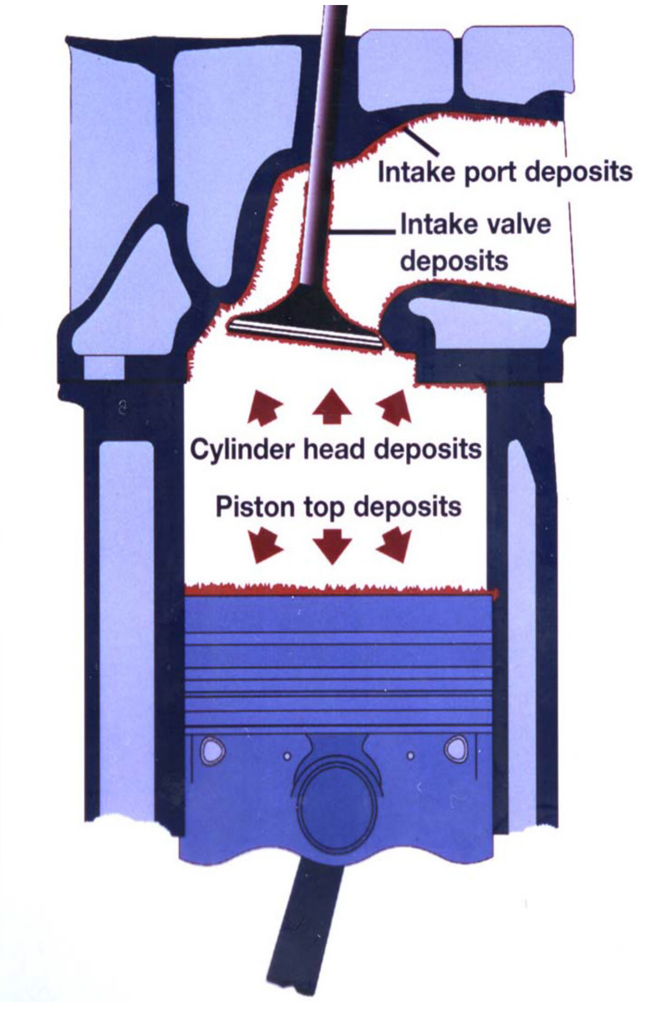
Gasoline Quality Effects on Emissions

- To reduce hydrocarbons:-
  - Reduce RVP (affects evaporative emissions esp. non-cat cars)
  - Reduce aromatics content
  - Add oxygenates (for non-catalyst cars)
  - Increase mid-range to back-end volatility
  - Reduce sulfur (catalyst cars)
- To reduce NOx emissions:-
  - *Reduce aromatics* for non-catalyst cars, but *increase aromatics* for catalyst cars (the NOx/aromatics effect)
  - Reduce sulfur (catalyst cars only)
  - Reduce mid-range to back-end volatility
    - ***fuel effects are relatively small***

SI Engine deposits

Fuel derived deposits form at several places in engine and usually degrade its performance

- Carburettor
- Injector (esp for direct injection)
- Inlet port, inlet valves
- Spark plug
- Combustion chamber head and piston top



Diesel Fuel Properties and Their effects

- Cetane Number CN - Increasing CN makes cold start easier, reduce noise, reduce CO and HC
- Density – Reduced density will reduce particulates and power but increase fuel consumption
- Sulphur – Increased sulphur increases particulates, adversely affects after-treatment systems
- Aromatics – Higher aromatics lead to higher NOx and higher particulates
- Cold Flow Properties - Wax crystals can form as paraffins freeze
- Foaming – Slows filling and risks overflow
- Deposits – Injector deposits reduce power
- Lubricity – High pressure pumps can be ruined without sufficient lubricity

Fuel Specifications

- Fuel quality is defined by selected properties and composition
- Criteria for measuring these are standardised and harmonised
- Specifications require that a given fuel property must fall within a certain range
- To ensure that engines operate smoothly and cleanly with no harm
- Are agreed by oil and auto industries and are legally binding
- Extremely important – affect how fuels are manufactured

Fuel Specifications

- To help understand why certain properties are specified, see World Wide Fuels Charter http://www.acea.be/uploads/publications/Worldwide_Fuel_Charter_5ed_2013.pdf
- Very complex issue – different in different areas

http://transportpolicy.net/index.php?title=Global_Comparison:_Fuels

http://europa.eu.int/comm/environment/air/legis.htm

Examples of some specifications

	Europe EN 228 Gasoline	Saudi Arabia	China Nationwide Gasoline		Europe EN 590 Diesel	Saudi Arabia	China Nationwide Diesel
RON, min	95	95/91	90/93/97	Cetane Number, min	51	45 CI	49/46/45
MON, min	85			Sulphur, max	10 ppm	500	350
Sulphur, max	10 ppm	1000 ppm	150	Polyaromatics, wt% max	11		11
Benzene, vol% max	1	3	1	Density @ 15˚ C, kg/m3	800-845	810-870	790-840
Aromatics, vol% max	35		40	Viscosity @ 40˚ C, cSt	1.2-4.5	1.9-4.1	7-Feb
Olefins, vol% max	18	25	30	T50˚ C,max			300
Oxygen, wt% max	2.7	2.7	2.7	T85˚ C,max	350	350	
Density @ 15˚ C, kg/m3	720-775			T95˚ C,max	360		365
RVP @ 37.8˚ C kPa, summer	45-60	65.5	72 max	Flash Point˚ C, min	55	55	55
RVP @ 37.8˚ C kPa, winter	70-100		88 max	CFPP˚ C, max	5 to -44	-4	2 to -44
E70, vol%	20-50	20-48		Water, vol %	0.02 max		trace
E70, vol%, min	75			Lubricity @ 60˚ C, micron	460 max		460 max
E100, vol%, min	46	46-71					
Full Boiling Point, ˚ C	210	225	205				
Oxidation Stability, minutes, min	360		480				

There are different specs in Beijing and Shanghai

PROPERTIES UNITS ISO ASTM JIS Other – GASOLINE – TEST METHODS
Research Octane Number - EN 5164 D 2699 K 2280
Motor Octane Number - EN 5163 D 2700 K 2280-96
Oxidation stability minutes 7536 D 525 K 2287
Sulphur content mg/kg 20846 D 2622 K 2541
20884 D 5453
Lead content mg/l D 3237 K 2255 EN 237
Potassium (K) content mg/l NF M 07065
EN 14538
Metal content mg/l ICP (1)
Phosphorus content mg/l D 3231
Manganese content mg/l D 3831
Silicon content mg/kg ICP-AES (Reference in-house methods
with detection limit = 1 mg/kg)
Oxygen content % m/m D 4815 K 2536 EN 13132
Olefins content (2) % v/v 3837 D 1319 K 2536
Aromatics content (2) % v/v 3837 D 1319 K 2536 EN 14517
Benzene content % v/v D 5580 K 2536 EN 238
D 3606 EN 14517
Vapour Pressure kPa D 5191 K 2258 EN 13016/1 DVPE
Distillation: T10/T50/T90, E70/E100/E180, End Point, residue 3405 D 86 K 2254
Vapour/liquid ratio (V/L) °C D 5188
Sediment mg/l D 5452
Unwashed gums mg/100 ml 6246 D 381 K 2261 May be replaced with CCD test
Washed gums mg/100 ml 6246 D 381 K 2261
Density kg/m3 3675 D 4052 K 2249
12185
Copper corrosion merit 2160 D 130 K 2513
Appearance D 4176 Visual inspection
Carburettor cleanliness merit CEC F-03-T
Fuel injector cleanliness, Method 1 % flow loss D 5598
Fuel injector cleanliness, Method 2 % flow loss D 6421
Particulate contamination, code rating 4406
size distribution no of particles/ml 4407 & 11500
Intake-valve sticking pass/fail CEC F-16-T
Intake valve cleanliness I merit CEC F-04-A
Intake valve cleanliness II avg. mg/valve

PROPERTIES UNITS ISO ASTM JIS Other DIESEL FUEL – TEST METHODS

Cetane Number - 5165 D 613 K 2280
Cetane Index - 4264 D 4737 K 2280
Density @ 15°C kg/m3 3675 D 4052 K 2249
12185
Viscosity @ 40°C mm2/s 3104 D 445 K 2283
Sulphur content mg/kg 20846 D 5453 K 2541
20884 D 2622
Total aromatics content % m/m D 5186 EN 12916
PAH content (di+, tri+) % m/m D 2425 EN 12916
T90, T95, FBP °C 3405 D 86 K 2254
Flash point °C 2719 D 93 K 2265
Carbon residue % m/m 10370 D 4530 K 2270
Cold Filter Plugging Point (CFPP) °C D 6371 K 2288 EN 116, IP 309
Low Temperature Flow Test (LTFT) °C D 4539
Cloud Point (CP) °C 3015 D 2500 K 2269
Water content mg/kg 12937 D 6304 K 2275
Oxidation stability, Method 1 g/m3 12205 D 2274
Oxidation stability, Method 2 induction time (1)
Foam volume ml NF M 07-075
Foam vanishing time sec. NF M 07-075
Biological growth - NF M 07 070
FAME content % v/v EN 14078
Ethanol/Methanol content % v/v D 4815 (modified)
Total acid number mg KOH/g 6618 D 664
Ferrous corrosion - D 665 (2)
Copper corrosion merit 2160 D 130 K 2513
Appearance D 4176 Visual inspection
Ash content % m/m 6245 D 482 (3) K 2272
Particulate contamination, total mg/kg D 5452 DIN 51419
EN 12662 (4)
Particulate contamination, size distribution code rating 4406
no of
particles/ml 4407, 11500
Injector cleanliness % air flow loss CEC (PF-023) TBA
Lubricity (HFRR wear scar diameter @ 60°C) micron 12156-1.3 D 6079 CEC F-06-A
Metal content ICP (5)

Fuels and engines

- Engine and fuels are a chicken and egg situation:
  advances in one must use the existing technology of the other.

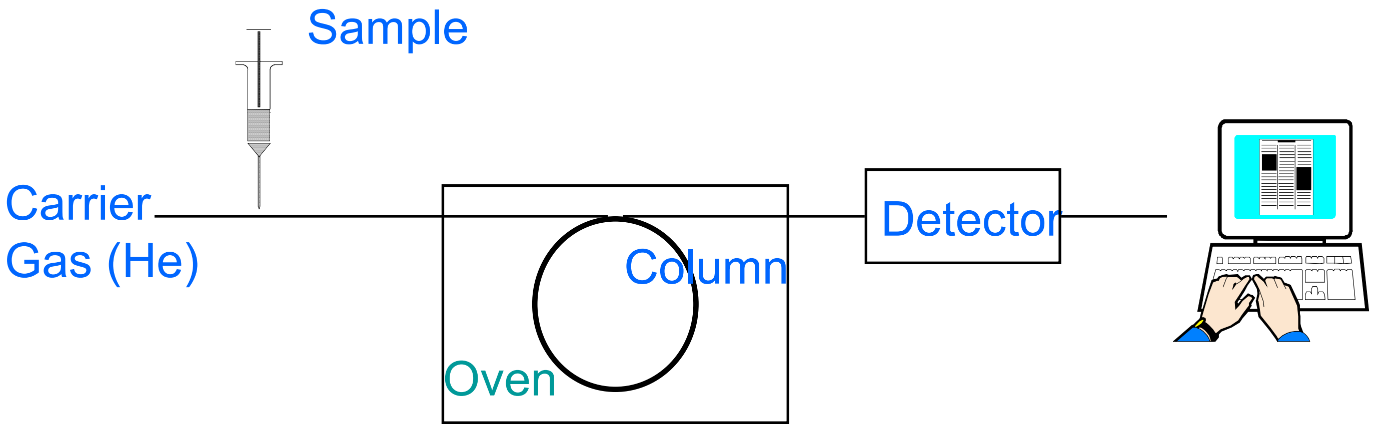
- But the highest performance and efficiency must come from optimisation of the engine and fuel together.

Gasoline HC Composition - Specifications

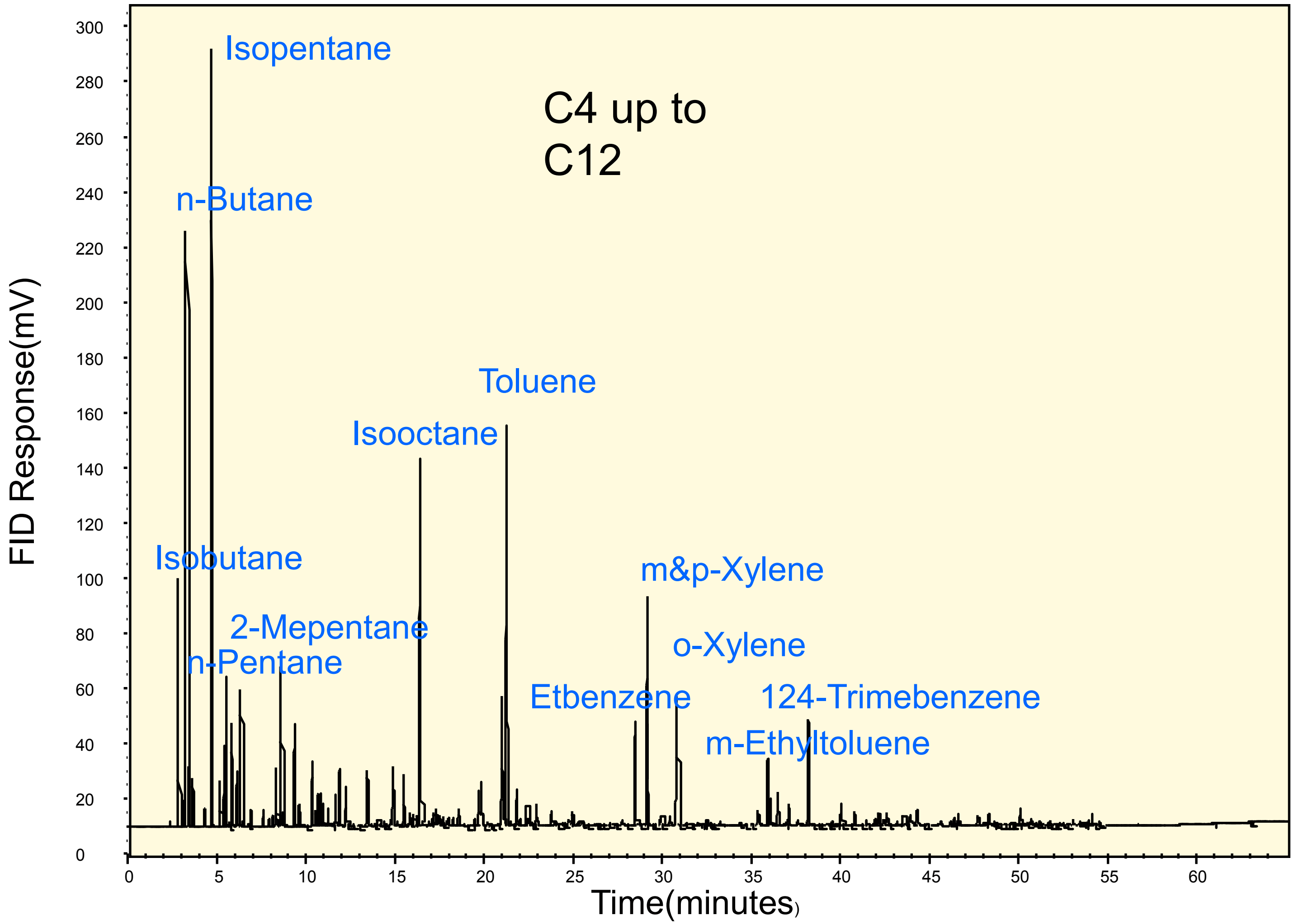
- Currently : Benzene, Total Aromatics and Olefins
- GC or IR method used for benzene (e.g. ASTM D3606)
- Fluorescence Indicator Adsorption (‘FIA’, ASTM D1319) is current method for aromatics/olefins:
  - based on column chromatography
  - for aromatics & olefins
  - Method precision poor (especially for olefins) but can be improved (advice available)

Measuring Gasoline HC Composition

Gas Chromatography can be used for obtaining detailed compositional analysis of a gasoline



Detailed GC of a typical Gasoline



Propene	0.01	2,4-Dimethylpentane	0.58	2-Methylheptane	0.27	l,2-Dimethyl-3-ethylbenzene	0.06
Propane	0.06	2,3,3-Trimethylbut-l-ene	0.09	4-Methylheptane	0.15	n-Undecane	0.05
Isobutane	1.87	2,2,3-Trimethylbutane	0.03	3-Methylheptane	0.37	1,2,4,5-Tetramethylbenzene	0.15
Isobutene + But-1-ene	0.55	Benzene + l-Methylcyclopentene	1.16	2,2,5-Trimethylhexane	0.34	1,2,3,5-Tetramethylbenzene	0.21
n-Butane	5.41	3-Methylhex-l-ene	0.04	c1,3-Ethylmethylcyclopentane	0.05	5-Methylindan	0.13
tBut-2-ene	0.93	Cyclohexane	0.15	1,c2,c3-Trimethylcyclopentane	0.14	1-Ethyl-2-n-propylbenzene	0.16
2,2-Dimethylpropane	0.02	2-Methyl-thex-3-ene	0.09	n-Octane	0.28	1,3-Di-isopropylbenzene	0.09
cis But-2-ene	0.25	Unknown Peak	0.03	trans-Oct-2-ene	0.06	Naphthalene	0.28
3-Methylbut-l-ene	0.26	4-Methyl-cis/trans-hex-2-ene	0.13	2,4,4-Trimethylhexane	0.07	Dimethylindan isomer	0.12
Isopentane	11.43	2-Methylhexane + 2,3-dimeC5	1.24	2,3,5-Trimethylhexane	0.03	n-Dodecane	0.05
Pent-l-ene	0.74	Cyclohexene	0.07	n-Propylcyclopentane	0.04	C12 Aromatic	0.08
2-Methylbut-l-ene	1.39	3-Methylhexane	0.74	1,1,4-Trimethylcyclohexane	0.08	C12 Aromatic	0.02
n-Pentane	2.02	3,4-Dimethyl-cis-pent-2-ene	0.04	Ethylbenzene	3.04	Unknown Peak	0.04
2-Methyl-1,3-butadiene	0.09	cis-l,3-Dimethylcyclopentane	0.22	m-Xylene	6.93	Unknown Peak	0.02
trans-Pent-2-ene	1.70	trans-l,3-Dimethylcyclopentane	0.19	p-Xylene	2.58	Unknown Peak	0.05
3,3-Dimethylbut-l-ene	0.02	trans-l,2-Dimethylcyclopentane	0.26	4-Methyloctane	0.08	Unknown Peak	0.06
cis-Pent-2-ene	0.93	Isooctane	4.34	2-Methyloctane	0.13	2-Methylnaphthalene	0.04
2-Methylbut-2-ene	2.30	Hept-l-ene	0.14	3-Methyloctane	0.13	Unknown Peak	0.12
trans-1,3-Pentadiene	0.08	3-Methyl-cis-hex-3-ene	0.02	o-Xylene	4.04	Unknown Peak	0.04
cis-l,3-Pentadiene	0.03	C7 Olefin	0.12	n-Nonane	0.11	Unknown Peak	0.02
2,2-Dimethylbutane	0.21	trans-Hept-3-ene	0.30	Isopropylbenzene	0.16	Unknown Peak	0.03
Cyclopentene	0.30	n-Heptane	0.26	n-Propylbenzene	0.47		
4-Methylpent-l-ene	0.08	cHept-3-ene	0.16	m-Ethyltoluene	1.65		
3-Methylpent-l-ene	0.13	2-Methylhex-2-ene	0.17	p-Ethyltoluene	0.70		
Cyclopentane	0.16	3-Methyl-ttrans-hex-3-ene	0.13	1,3,5-Trimethylbenzene	0.82		
2,3-Dimethylbutane	0.77	trans-Hept-2-ene	0.16	o-Ethyltoluene	0.70		
2,3-Dimethylbut-l-ene	0.13	3-Ethylpent-2-ene	0.06	2-Methylnonane	0.07		
4-Methyl-cpent-2-ene	0.08	3-Methyl-cis-hex-2-ene	0.10	1,2,4-Trimethylbenzene	2.69		
2-Methylpentane	2.07	cis-Hept-2-ene	0.14	n-Decane	0.10		
4-Methyl-tpent-2-ene	0.23	2,3-Dimethylpent-2-ene	0.14	1,2,3-Trimethylbenzene	0.61		
3-Methylpentane	1.31	Methylcyclohexane	0.37	Indan	0.26		
2-Methylpent-1-ene	0.37	Ethylcyclopentane	0.12	C11 Alkane	0.08		
Hex-l-ene	0.24	2,5-Dimethylhexane	0.49	1,3-Diethylbenzene	0.07		
n-Hexane	0.82	2.4-Dimethylhexane	0.57	m-n-Propyltoluene	0.27		
cis + trans-Hex-3-ene	0.62	1,t2,c4-Trimethylcyclopentane	0.07	p-n-Propyltoluene + 1,4-Dietbz	0.16		
trans-Hex-2-ene	0.55	2,3.4-Trimethylpentane	1.30	n-Butylbenzene	0.22		
2-Methylpent-2-ene	0.71	Unknown Peak	0.14	o-n-Propyltoluene	0.04		
3-Methyl-cis-pent-2-ene	0.42	Toluene + 2,3,3-TrimeC5	11.70	4-Methyldecane	0.19		
cis-Hex-2-ene	0.30	2-Methyl-trans-hept-3-ene	0.05	2-Methyldecane	0.16		
3-Methyl-trans-pent-2-ene	0.53	2,3-Dimethylhexane	0.48	1,4-Dimethyl-?-ethylbenzene	0.27		
Methylcyclopentane	0.89	2,5-Dimethylhex-2-ene	0.11	1,2-Dimethyl-4-ethylbenzene	0.39		

Paraffins	9.2
Isoparaffins	30.1
Olefins	16.8
Dienes	0.2
Naphthenes	2.7
Aromatics	40.6
Unknowns	0.6
Total peaks <5%	64.5
RON	98.2
MON	86.2

Table 7.1 Composition (weight %) by gc of a super unleaded gasoline.

Gasoline Specification Summary

Fuel prop	Units	Europe EN 228	EU DIRECTIVE 2000	EU DIRECTIVE 2005	US RFG	Cal. Phase 2/3	Japan
RVP, summer	(kPa) max	70/80	60 (70**)	60	50/56	48.3	72
E100	(%v) min	46/71	46	46		=50	
E150	(%v) min	75	75	75	#	=90	
Olefins	(%v) max		18*	18	#	*6*	
Arom	(%v) max		42	35		*25*	-
Benzene	(%v) max	1.0	1.0	1.0	1.0	1.0/0.8	1.0
Oxygen	(%m) max	2.5/3.7	2.7	2.7	*2.0-2.7*	*1.8-2,2*	7%MTBE
Sulphur	(mg/kg) max	500	150	50 (10)*	# 30	*40/20*	100
Lead	(g/l) max	0.013	0.005	0.005			0

NOTES:

EU ban on sales of leaded gasoline from 2000
* Except for unleaded regular with RON/MON less than 91/81 when limit is 21%v
*** 10 pm S fuel to be available from Jan 2005, all gasoline to be at 10 ppm by Jan 2009**
.
** April - September: may be relaxed to 70kPa May - August for "arctic" climate countries
# No higher than 1990 average, US RFG must meet targets for VOCs and Toxics. **30 ppm from 2004-6**

Gasoline Octane - NIR

- Near infra red (NIR) increasingly used for measuring octane in refineries (for QMI)
- NIR still only a secondary method - calibration of instrument necessary against CFR measurements
- Calibration depends on gasoline composition - most analysers need calibrating for local conditions
- A quick, convenient way of measuring octane