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## FUEL DATA FOR COMBUSTION WITH AIR

Fuel	Formula (state)	Density [kg/m <sup>3</sup> ]	Theoretical air/fuel ratio	Higher Heating Value [MJ/kg]	Maximum adiabatic combustion temp. K	Flash point &Autoignition temperature <sup>a</sup> [K]	Ignition limits <sup>b</sup>	Maximum laminar deflagration speed [m/s]
Acetylene	C <sub>2</sub> H <sub>2</sub> (g)	1.1	11.9 m <sup>3</sup> /m <sup>3</sup>	48	2500*	<180, 600	2.5..100	1.5
Benzene	C <sub>6</sub> H <sub>6</sub> (l)	880	13.3 kg/kg	42.3	2400	262, 840	1.5..7.5	1.1
Bio-diesel	C <sub>17</sub> H <sub>32</sub> O <sub>2</sub> (l) esters	880	12.4 kg/kg	40	-	420, -		
Bio-petrol	C <sub>6</sub> H <sub>14</sub> O(l) Ethyl Tert. Butyl Ether	750	12.2 kg/kg	36	-	-		
n-Butane	C <sub>4</sub> H <sub>10</sub> (g)	2.4	31 m <sup>3</sup> /m <sup>3</sup>	49.5	2250	210, 670	1.5..9.3	0.45
iso-Butane	C <sub>4</sub> H <sub>10</sub> (g)	2.4	31 m <sup>3</sup> /m <sup>3</sup>	49.5	2250	190, 710	1.6..8.4	0.45
Carbon (graphite)	C(s)	2250	11.5 kg/kg	33		600, 670		
Carbon monoxide	CO(g)	1.2	2.4 m <sup>3</sup> /m <sup>3</sup>	10	2400	-, 900	12..75	0.20
Coal (dry, mean)	85% C 5% H 5% O 5% M(s) <sup>c</sup>	1300..1400	10 kg/kg	31	2200	550, 600		
Diesel or Gas-oil	87% C 13% H(l) <sup>d</sup>	820..860	15 kg/kg	47		330, 480	0.6..8	
DME	C <sub>2</sub> H <sub>6</sub> O(g) (dimethyl ether)	1.8	14.3 m <sup>3</sup> /m <sup>3</sup>	30		232, 600	3.4..20	0.40
ETBE	C <sub>6</sub> H <sub>14</sub> O(l) (ethyl tert-butyl ether)	770	12.2 kg/kg	43		248, 580	1.4..10	
Ethane	C <sub>2</sub> H <sub>6</sub> (g)	1.2	16.7 m <sup>3</sup> /m <sup>3</sup>	51.9	2100	140, 800	3.0..15	0.40
Ethanol	C <sub>2</sub> H <sub>6</sub> O(l)	790	9.0 kg/kg	29.7	2200	285, 630	3.3..21	0.80
Ether	C <sub>4</sub> H <sub>10</sub> O(l) (diethyl ether)	715	11.2 kg/kg	37.2		230, 440	1.8..37	
Fuel-oil	84% C 10% H 3% S 1% N 2% H <sub>2</sub> O(l) <sup>e</sup>	850..990	15 kg/kg	44	2200	320, 480	0.7..5	
Gasoline	85% C 15% H(l) <sup>f</sup>	730..760	14.7 kg/kg	48	2200	230, 650	1.3..8	0.35
n-Hexadecane	C <sub>16</sub> H <sub>34</sub> (l)	773	14.9 kg/kg	47.3	2200	400, 475	0.5..4.7	
n-Heptane	C <sub>7</sub> H <sub>16</sub> (l)	685	15.2 kg/kg	48.1	2200	269, 560	1.1..6.7	0.40

Hydrogen	H <sub>2</sub> (g)	0.08	2.4 m <sup>3</sup> /m <sup>3</sup>	142	2400	-, 850	4.0..75	3.5
Kerosene Jet A-1	85% C 15% H(l) <sup>g</sup>	780..840	15 kg/kg	47	2300	330, 500	0.7..6	0.20
Methane	CH <sub>4</sub> (g)	0.67	9.5 m <sup>3</sup> /m <sup>3</sup>	55.5	2200	85, 850	4.5..16	0.45
Methanol	CH <sub>4</sub> O(l)	790	6.5 kg/kg	22.7	2150	285, 680	6.0..37	0.50
Natural gas	CH <sub>4</sub> (g) <sup>h</sup>	0.68..0.70	9.5 m <sup>3</sup> /m <sup>3</sup>	54	2250	-, 850	5.3..15	0.45
n-Octane	C <sub>8</sub> H <sub>18</sub> (l)	703	15 kg/kg	47.9	2300	286, 500	1..6	0.40
iso-Octane	C <sub>8</sub> H <sub>18</sub> (l) <sup>i</sup>	690	15 kg/kg	47.9	2300	261, 690	1..6	0.40
Propane	C <sub>3</sub> H <sub>8</sub> (g)	1.8	23.8 m <sup>3</sup> /m <sup>3</sup>	50.0	2250	170, 750	2.0..9.5	0.45
Propylene	C <sub>3</sub> H <sub>6</sub> (g)	1.8	21.4 m <sup>3</sup> /m <sup>3</sup>	48.9	-	-	2.4..11	-
Wood (dry, mean)	50% C 5% H 45% O(s) <sup>j</sup>	500..1000	5.6 kg/kg	20	2100	550, 700	-	-

All data for combustion with air, at 298 K and 100 kPa.

\*Maximum adiabatic combustion temperature for the oxyacetylene torch 3400 K.

<sup>a</sup>Flash point: minimum temperature for spark ignition near the condensed phase. Autoignition: minimum temperature for self ignition (without spark).

<sup>b</sup>% by volume of gaseous fuel in the mixture with air.

<sup>c</sup>% by weight, dry bituminous coal; C refers to total carbon content (fixed plus volatile matter), M refers to inert matter.

<sup>d</sup>% by weight; diesel or gas-oil is a distilled mixture with  $M=0.17..0.20$  kg/mol,  $T_b=470..530$  K (10% and 90% boiled),  $p_v(38\text{ }^\circ\text{C})=0.7$  kPa,  $\nu<4\times 10^{-6}$  m<sup>2</sup>/s at 55 °C (the flash point of diesel), 50..55 cetane number, and sulfur content <500 ppm, that may be approximated by C<sub>12</sub>H<sub>26</sub> (n-Dodecane). Cetane is n-hexadecane, C<sub>16</sub>H<sub>34</sub>. As for most hydrocarbons, the solubility in water is negligible, and it may be carcinogen.

<sup>e</sup>% by weight; fuel-oils are mixtures of residues and heavy fraction distillates (and maybe used and waste oils), with sulfur content <0.5%, and may be approximated by C<sub>14</sub>H<sub>26</sub>. Pour points are usually below 0 °C for distillates and below 20 °C for residuals, but they are heated for handling.

<sup>f</sup>% by weight; gasoline is a distilled mixture with  $M=0.10..0.12$  kg/mol,  $T_b=300..440$  K (10% and 90% boiled),  $p_v(38\text{ }^\circ\text{C})=60$  kPa for the summer blend and  $p_v(40\text{ }^\circ\text{C})=90$  kPa for the winter blend, 90..100 motor octane number, and sulfur content <300 ppm, that may be approximated by C<sub>7</sub>H<sub>17</sub> or C<sub>8</sub>H<sub>18</sub> (iso-octane), except for the vapour pressure. Composition differences yield a wide scatter in property values; e.g. the flash point may range from -230 K to 240 K, autoignition temperature from 550 K to 750 K.

<sup>g</sup>% by weight; kerosene (or kerosene) is a distilled mixture with  $T_b=450..600$  K (10% and 90% boiled),  $T_f=-40$  °C,  $\nu=8\times 10^{-6}$  m<sup>2</sup>/s at -20 °C, that may be approximated by n-dodecane (C<sub>12</sub>H<sub>26</sub>) or 1-dodecene (C<sub>12</sub>H<sub>24</sub>). Commercial (Jet A-1, Jet A, and Jet B) and military (JP-4, JP-5, JP-8...) jet propulsion fuels, are basically mixtures of kerosene and gasoline (half-&-half for JP-4, 99.5% kerosene for JP-5 and JP-8, 100% kerosene for Jet A-1), plus special additives (1..2%): corrosion inhibitor, anti-icing, and anti-static compounds. Jet A-1 is the international jet fuel with  $T_f=-50$  °C (-47 °C as a limit); Jet A (with  $T_f=-40$  °C) is a low-grade Jet A-1 only and mostly used in USA; and Jet B ( $T_f<-50$  °C), the commercial name of JP-4, is only used in very cold climates. They all have a lower heating value of 42.8..43.6 MJ/kg. Minimum flash point is 60 °C for JP-5, 38 °C for Jet A-1 and JP-8 (Jet A-1 typical value is 50 °C, with a vapour pressure at this point of 1.5 kPa; 1 kPa at 38 °C), and -20 °C for JP-4. Typical density at 15 °C is 810 kg/m<sup>3</sup> for Jet A-1, and 760 kg/m<sup>3</sup> for Jet B.

<sup>h</sup>Natural gas is a mixture with some 90% methane,  $M=0.017..0.019$  kg/mol,  $T_b=110..120$  K (10% and 90% boiled) and 120 motor octane number.

<sup>i</sup>Isooctane or trimethylpentane,  $T_f=166$  K,  $T_b=372$  K,  $c=2200$  J/(kg×K), Motor Octane Number MON=100.

<sup>j</sup>% by weight; wood is basically cellulose, a long polysaccharide (C<sub>6</sub>H<sub>10</sub>O<sub>5</sub>)<sub>n</sub> with  $n=5000..10000$  and  $M=500..10000$  kg/mol.