ΠΑΡΑΡΤΗΜΑ

ΠΑΡΑΡΤΗΜΑ 1. ΜΟΝΑΔΕΣ ΚΑΙ ΠΑΡΑΓΟΝΤΕΣ ΜΕΤΑΤΡΟΠΗΣ ΣΤΟ ΣΥΣΤΗΜΑ SI
(Ferguson, IC Engines, John Wiley and Sons, New York, 1986)

Table 1.1 Names of International Units

PHYSICAL QUANTITY	NAME OF UNIT	SYMBOL	FORMULA
	BASIC UNITS		
Length	meter	m	
Mass	kilogram	kg	
Time	seconds	s	
Electric current	ampere	A	
Temperature	kelvin	K	
Luminous intensity	candela	cd	
	DERIVED UNITS		
Area	square meter	m^2	
Volume	cubic meter	m^3	
Frequency	hertz	Hz	(s^{-1})
Density	kilogram per cubic meter	kg/m^3	
Velocity	meter per second	m/s	
Angular velocity	radian per second	rad/s	
Acceleration	meter per second squared	m/s^2	
Angular acceleration	radian per second squared	rad/s^2	
Force	newton	N	$(kg \cdot m/s^2)$
Pressure and stress	pascal	Pa	(N/m^2)
Kinematic viscosity	square meter per second	m^2/s	
Dynamic viscosity	pascal-second	Pa · s	$(N \cdot s/m^2)$
Work, energy, quantity of heat	joule	J	$(N \cdot m)$
Power	watt	W	(J/s)
Electric charge	coulomb	C	$(A \cdot s)$
Voltage, potential difference, electromotive force	volt	V	(W/A)
Electric field strength	volt per meter	V/m	
Electric resistance	ohm	Ω	(V/A)
Electric capacitance	farad	F	$(A \cdot s/V)$
Magnetic flux	weber	Wb	$(V \cdot s)$
Inductance	henry	H	$(V \cdot s/A)$
Wave number	1 per meter	m^{-1}	
Entropy	joule per kelvin	J/K	
Specific heat	joule per kilogram kelvin	$J\,kg^{-1}\,K^{-1}$	
Thermal conductivity	watt per meter kelvin	$W/m^{-1}\,K^{-1}$	
Radiant intensity	watt per steradian	W/sr	
	SUPPLEMENTARY UNITS		
Plane angle	radian	rad	
Solid angle	steradian	sr	

Table 1.2 Names of Multiples and Submultiples Of SI Units May Be Formed by Application of Prefixes

FACTOR BY WHICH UNIT IS MULTIPLIED	PREFIX	SYMBOL
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

Table 1.3 Physical constants

QUANTITY	SYMBOL	VALUE	ERROR (ppm)	UNIT
Speed of light in vacuum	c	2.997925×10^{8}	0.33	$m \cdot s^{-1}$
Gravitational constant	G	6.6732×10^{-11}	460	$N \cdot m^2 \cdot kg^{-2}$
Avogadro constant	N_A	6.022169×10^{26}	6.6	$kmole^{-1}$
Boltzmann constant	k	1.380622×10^{-23}	43	$J \cdot K^{-1}$
Gas constant	R	8.31434×10^{3}	42	$J \cdot kmole^{-1} \cdot K^{-1}$
Volume of ideal gas, standard conditions	V_0	2.24136×10^{1}	—	$m^3 \cdot kmole^{-1}$
Planck constant	h	6.626196×10^{-34}	7.6	$J \cdot s$
	$h/2\pi$	$1.0545919 \times 10^{-34}$	7.6	$J \cdot s$
Electron charge	e	$1.6021917 \times 10^{-19}$	4.4	C
Electron rest mass	m_e	9.109558×10^{-31}	6.0	kg
		5.485930×10^{-4}	6.2	[a]
Stefan–Boltzmann constant	σ	5.66961×10^{-8}	170	$W \cdot m^{-2} \cdot K^{-4}$

[a] The unified atomic mass unit (u) is equal to the fraction $\frac{1}{12}$ of the mass of an atom of the nuclide ^{12}C.

Table 1.4 Conversion To SI Units*

MULTIPLY THIS UNIT	BY	TO OBTAIN THIS SI UNIT
	ACCELERATION	
ft/s^2	3.048 * E − 01	meter/second^2
Free fall (standard gravity)	9.806 65 * E + 00	meter/second^2
in./s^2	2.54 * E − 02	meter/second^2
	AREA	
ft^2	9.290 304 * E − 02	meter^2
in.^{2}	6.4516 * E − 04	meter^2
	DENSITY	
gram/cm^3	1.00 * E + 03	kilogram/meter^3
lbm/in.^{3}	2.767 990E + 04	kilogram/meter^3
lbm/ft^3	1.601 846E + 01	kilogram/meter^3
slug/ft^3	5.153 788E + 02	kilogram/meter^3
	ENERGY	
British thermal unit (mean)	1.055 87E + 03	joule
British thermal unit (International Steam Tables)	1.055 06E + 03	joule
British thermal unit (Thermochemical)	1.054 35E + 03	joule
calorie (mean)	4.190 * E + 00	joule
calorie (International Steam Tables)	4.1868E + 00	joule
calorie (Thermochemical)	4.184E − 00	joule
electron volt	1.602 19E − 19	joule
erg	1.00 * E − 07	joule
ft lbf	1.355 82E + 00	joule
joule (International of 1948)	1.000 165E + 00	joule
watt h	3.60 * E + 03	joule
kW h	3.60 * E + 06	joule
	ENERGY/AREA · TIME	
Btu (thermochemical)/ft^2 s	1.134E + 04	watt/meter^2
Btu (thermochemical)/ft^2 min	1.891E + 02	watt/meter^2
Btu (thermochemical)/ft^2 h	3.152E + 00	watt/meter^2
Btu (thermochemical)/in.^{2} s	1.634E + 06	watt/meter^2
calorie (thermochemical)/cm^2 min	6.973E + 02	watt/meter^2
erg/cm^2 · s	1.00 * E − 03	watt/meter^2
watt/cm^2	1.00 * E + 04	watt/meter^2
	FORCE	
dyne	1.00 * E − 05	newton
kilogram force (kgf)	9.806 65 * E + 00	newton
kilopond force	9.806E + 00	newton
kip	4.448E + 03	newton
lbf (pound force, avoirdupois)	4.448E + 00	newton
poundal	1.382E − 01	newton

Table 1.4 Conversion To SI Units

MULTIPLY THIS UNIT	BY	TO OBTAIN THIS SI UNIT
	LENGTH	
angstrom	1.00 * E − 10	meter
ft	3.048 * E − 01	meter
in.	2.54 * E − 02	meter
micron	1.00 * E − 06	meter
mil	2.54 * E − 05	meter
	MASS	
kgf s^2/meter (mass)	9.806 65 * E + 00	kilogram
kilogram-mass	1.00 * E + 00	kilogram
lbm (pound mass, avoirdupois)	4.535 924E − 01	kilogram
slug	1.459 390E + 01	kilogram
	POWER	
Btu (thermochemical)/s	1.054E + 03	watt
Btu (thermochemical)/min	1.757E + 01	watt
calorie (thermochemical)/s	4.184 * E + 00	watt
calorie (thermochemical)/min	6.973E − 02	watt
ft lbf/h	3.766E − 04	watt
ft lbf/min	2.259E − 02	watt
ft lbf/s	1.355E + 00	watt
hp (550 ft lbf/s)	7.456E + 02	watt
kilocalorie (thermochemical)/min	6.973E + 01	watt
kilocalorie (thermochemical)/s	4.184 * E + 03	watt
	PRESSURE	
atmosphere	1.013 25 * E + 05	pascal
bar	1.00 * E + 05	pascal
dyne/cm^2	1.00 * E − 01	pascal
in. of mercury (60°F)	3.376 85E + 03	pascal
in. of water (60°F)	2.4884E + 02	pascal
kgf/cm^2	9.806 65 * E + 04	pascal
lbf/ft^2	4.788 026E + 01	pascal
lbf/in.^{2} (psi)	6.894 7572E + 03	pascal
mm of mercury (0°C)	1.333 224E + 02	pascal
torr (0°C)	1.333 224E + 02	pascal
N/m^2	1.00 * E + 00	pascal
	SPEED	
miles/h	4.4704E − 01	meter/s
ft/min	5.08E − 03	meter/s
in./s	2.54 * E − 02	meter/s
	TEMPERATURE	
Celsius	$T_K = T_C + 273.15$	kelvin
Fahrenheit	$T_K = (5/9)(T_F + 459.67)$	kelvin
Fahrenheit	$T_C = (5/9)(T_F - 32)$	celsius

VISCOSITY (s)
AT 210°F (98.9°C)
133.5
138.0
142.5
147.0
151.5
156.0
160.6
165.1
169.7
174.3
178.8
183.4
188.0
192.6
197.2
201.0
206.0
211.0
215.0
220.0
224.0
229.0
234.0
257.0
280.0
303.0
326.0
's SUS = mm²/: ×4.664

Table 1.4 Conversion To SI Units[a] (*Continued*)

MULTIPLY THIS UNIT	BY	TO OBTAIN THIS SI UNIT
	THERMAL CONDUCTIVITY	
Btu/h ft °F	1.731E + 00	watt/meter kelvin
Btu/s in. °F	7.478E + 04	watt/meter kelvin
	VISCOSITY	
centistoke	1.00 * E − 06	meter^2/second
ft^2/s	9.290 304 * E − 02	meter^2/second
in.^{2}/s	6.4516 * E − 04	meter^2/second
centipoise	1.00 * E − 03	pascal-second
lbf s/ft^2	4.788 026E + 01	pascal-second
poise	1.00 * E − 01	pascal-second
lbf s/in.^{2} (reyn)	6.894 757E + 03	pascal-second
rhe (1/pascal s)	1.00 * E + 01	meter^2/newton second
Saybolt Sec Universal[b]		
	VOLUME	
fluid ounce (U.S. fluid)	2.957 353E − 05	meter^3
ft^3	2.831 685E − 02	meter^3
gallon (U.K. liquid)	4.546 092E − 03	meter
gallon (U.S. dry)	4.404 884E − 03	meter^3
gallon (U.S. liquid)	3.785 412E − 03	meter^3
in.^{3}	1.638 706E − 05	meter^3
litre	1.00 * E − 03	meter^3
	TORQUE	
ft lbf	1.355 82E + 00	N-m
	SPECIFIC FUEL CONSUMPTION	
lbm/hp h	6.083 6E − 01	kg/kw - h

[a] Factors with asterisk are exact.
[b] Savbold Sec Universal and other units see Table B.5.

<u>ΠΑΡΑΡΤΗΜΑ 2</u> ΒΑΣΙΚΕΣ ΣΧΕΣΕΙΣ ΜΗ ΑΝΤΙΔΡΩΝΤΩΝ ΜΙΓΜΑΤΩΝ ΚΑΙ ΠΑΡΑΓΩΓΟΙ ΘΕΡΜΟΔΥΝΑΜΙΚΗΣ

Για μίγμα J συστατικών ισχύουν οι παρακάτω τύποι:

Συνολική μάζα: $m = \sum_{i=1}^{J} m_i$

Κλάσμα μάζας: $x_i = m_i/m$

Συνολικά moles: $N = \sum_{i=1}^{J} N_i$

Κλάσμα moles: $x_i = N_i/N$

Συνολική εσωτερική ενέργεια: $u = \sum_{i=1}^{J} x_i u_i$ $\quad U = \sum_{i=1}^{J} N_i u_i$

Ανάλογες σχέσεις για την ενθαλπία: $h = \sum_{i=1}^{J} y_i h_i$ $\quad H = \sum_{i=1}^{J} N_i h_i$

Μοριακό βάρος μίγματος: $M = \sum_{i=1}^{J} x_i M_i$

Ειδική σταθερά αερίων: $R = R_u / M$

σχέσεις P, V, T:

$$PV = NRT$$
$$PV = mRT$$
$$Pu = RT$$

Μερική πίεση συστατικού: $P_i = y_i P$

Εντροπία μίγματος: $S = \sum_{i=1}^{J} m_i s_i = \sum_{i=1}^{J} N_i s_i$ $\quad s = -R\ln(P/P_o) + \sum_{i=1}^{J} \chi_i (s_i^o - R_i \ln \chi_i)$

Εντροπία συστατικού: $s_i = s_i^o - R_i \ln(P_i/P_o)$ $\quad s = -R\ln(P/P_o) + \sum_{i=1}^{J} \chi_i (s_i^o - R \ln \chi_i)$

ΠΑΡΑΡΤΗΜΑ 3   ΣΤΟΙΧΕΙΑ ΥΠΟΛΟΓΙΣΜΟΥ ΣΤΑΘΕΡΩΝ ΘΕΡΜΟΧΗΜΕΙΑΣ

(Ferguson, IC Engines, John Wiley and Sons, New York, 1986)

1. ΘΕΡΜΟΔΥΝΑΜΙΚΑ ΔΕΔΟΜΕΝΑ ΣΥΝΗΘΕΣΤΕΡΩΝ ΠΡΟΪΟΝΤΩΝ ΤΗΣ ΚΑΥΣΗΣ ΥΔΡΟΓΟΝΑΝΘΡΑΚΩΝ (μικρό δείγμα από πίνακες Jannaf)

α) Μικρό εύρος θερμοκρασιών (υψηλότερη ακρίβεια)

$$\frac{c_p}{R} = a_1 + a_2 T + a_3 T^2 + a_4 T^3 + a_5 T^4$$

$$\frac{h}{RT} = a_1 + \frac{a_2}{2} T + \frac{a_3}{3} T^2 + \frac{a_4}{4} T^3 + \frac{a_5}{5} T^4 + \frac{a_6}{T}$$

$$\frac{s^o}{R} = a_1 \ln T + a_2 T + \frac{a_3}{2} T^2 + \frac{a_4}{3} T^3 + \frac{a_5}{4} T^4 + a_7$$

Table 3.1 Thermo Data ($300 \le T \le 1000$ K)

SPECIES	a_{i1}	a_{i2}	a_{i3}	a_{i4}	a_{i5}	a_{i6}	a_{i7}
0 Gasoline[a] C_7H_{17}	0.406E + 01	0.601E − 01	−0.188E − 05	−0	0	−0.4053E + 05	−0.28325E
1 CO_2	0.24007797E + 01	0.87350957E − 05	−0.66070878E − 05	0.20021861E − 08	0.63274039E − 15	−0.48377527E + 05	0.969514
2 H_2O	0.40701275E + 01	−0.11084499E − 02	0.41521180E − 05	−0.29637404E − 08	0.80702103E − 12	−0.30279722E + 05	−0.322700
3 N_2	0.36748261E + 01	−0.12081500E − 02	0.23240102E − 05	−0.63217559E − 09	−0.22577253E − 12	−0.10611588E + 04	0.235804
4 O_2	0.36255985E + 01	−0.18782184E − 02	0.70554544E − 05	−0.67635137E − 08	0.21555993E − 11	−0.10475226E + 04	0.430527
5 CO	0.37100928E + 01	−0.16190964E − 02	0.36923594E − 05	−0.20319674E − 08	0.23953344E − 12	−0.14356310E + 05	0.295553
6 H_2	0.30574451E + 01	0.26765200E − 02	−0.58099162E − 05	0.55210391E − 08	−0.18122739E − 11	−0.98890474E + 03	−0.229970
7 H	0.25000000E + 01	0	0	0	0	0.25471627E + 05	−0.460117
8 O	0.29464287E + 01	−0.16381665E − 02	0.24210316E − 05	−0.16028432E − 08	0.38906964E − 12	0.29147644E + 05	0.296399
9 OH	0.38375943E + 01	−0.10778858E − 02	0.96830378E − 06	0.18713972E − 09	−0.22571094E − 12	0.36412823E + 04	0.493700
10 NO	0.40459521E + 01	−0.34181783E − 02	0.79819190E − 05	−0.61139316E − 08	0.15919076E − 11	0.97453934E + 04	0.299745

Source: From Gordon and McBride (1971).

β) Μεγάλο εύρος θερμοκρασιών

$$h(T) = A + BT + c\ln(T) \qquad \left(\frac{KT}{kmole}\right)$$

$$c_p(T) = B + \frac{C}{T} \qquad (\text{kJ/kmol K})$$

$$c_v(T) = B - 8.314 + \frac{C}{T} \qquad (\text{kJ/kmol K})$$

$$u(T) = A + (B - 8.314)T + C\ln(T) \qquad (\text{kJ/kmol}) \qquad \text{C-3}$$

$$\phi(T) = B\ln(T) - \frac{C}{T} + D \qquad (\text{kJ/kmol K})$$

$$K_p(T) = \exp\left[\frac{a}{T} + \left(b + \frac{c}{T}\right)\ln(T) + d\right] \qquad (P \text{ in atm})$$

TABLE C.1
***A, B, C,* AND *D* COEFFICIENTS FOR EQS. C-3**

Gas	A	B	C	D
		$400 \leq T \leq 1600$ K		
CO	299180.	37.85	−4571.9	−31.10
CO_2	56835.	66.27	−11634.0	−200.0
H	357070.	20.79	−7.9	−3.9
H_2	326490.	40.35	−8085.2	−121.0
H_2O	88923.	49.36	−7940.8	−117.0
N_2	31317.	37.46	−4559.3	−34.82
O	265120.	24.60	−2729.2	13.86
O_2	43388.	42.27	−6635.4	−55.15
OH	217810.	37.36	−5561.4	−44.06
NO	111050.	37.81	−2874.8	−15.70
N	326040.	17.19	5371.4	64.67
		$1600 \leq T \leq 6000$ K		
CO	309070.	39.29	−6201.9	−42.77
CO_2	93048.	68.58	−16979.0	−220.4
H	357010.	20.79	0	−3.82
H_2	461750.	46.23	−27649.0	−176.6
H_2O	154670.	60.43	−19212.0	−204.6
N_2	44639.	39.32	−6753.4	−50.24
O	298360.	23.17	−6910.3	21.81
O_2	127010.	46.25	−18798.0	−92.15
OH	298750.	42.86	−17695.0	−92.24
NO	138670.	39.92	−7061.8	−33.90
N	486400.	26.91	−18159.0	−20.31

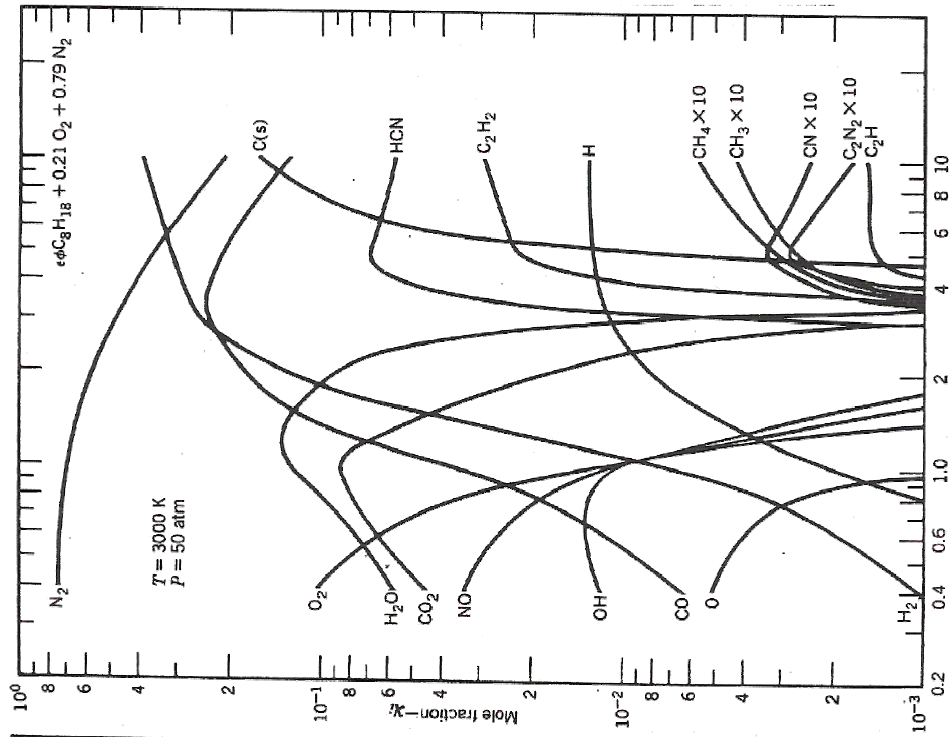
TABLE C.2
COEFFICIENTS FOR CALCULATION OF REACTION CONSTANTS K_p WITH THE EQUATION

$$K_p = \exp\left[\frac{a}{T} + \left(b + \frac{c}{T}\right)\ln(T) + d\right]$$

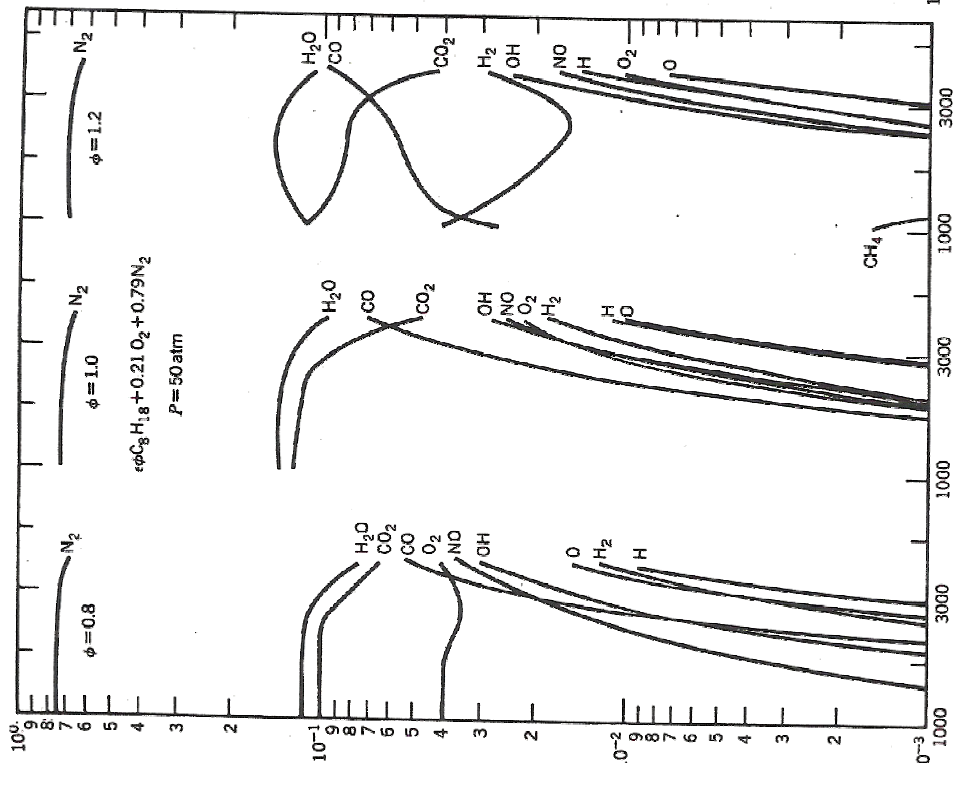
VALID FOR $1600 < T < 6000$ K. *Pressures must be in units of atmospheres.*

Reaction	a	b	c	d
$H_2 + ½O_2 \rightleftharpoons H_2O$	42450.	−1.0740	−2147.0	3.2515
$CO + ½O_2 \rightleftharpoons CO_2$	33805.	0.7422	165.8	−16.5739
$2H \rightleftharpoons H_2$	33587.	0.5604	3327.0	−20.8683
$2O \rightleftharpoons O_2$	57126.	−0.0100	599.0	−16.3201
$2H + O \rightleftharpoons H_2O$	104702.	−0.5181	1480.0	−25.8073
$O + H \rightleftharpoons OH$	44216.	−0.1319	1298.0	−13.1303
$CO + H_2O \rightleftharpoons CO_2 + H_2$	−8645.	1.8162	2312.0	−19.8254
$O_2 + N_2 \rightleftharpoons 2NO$	−14096.	−0.6893	−1375.3	9.668
$2N \rightleftharpoons N_2$	108142.	−1.744	−3558.2	0.595

<u>ΠΑΡΑΡΤΗΜΑ 4</u> ΣΥΝΘΕΣΗ ΚΑΥΣΑΕΡΙΩΝ ΣΕ ΧΗΜΙΚΗ ΙΣΟΡΡΟΠΙΑ



Συνθεση καυσαεριου μιγματος οκτανιου αεριου για φ=0.8, 1.0, 1.2 σε διαφορες θερμοκρασιες



Συνθεση καυσαεριων μιγματος οκτανιου αερα σε T=3000 K και P=50 atm

ΠΑΡΑΡΤΗΜΑ 5 ΔΕΙΓΜΑ ΠΙΝΑΚΑ ΜΕ ΘΕΡΜΟΔΥΝΑΜΙΚΑ ΔΕΔΟΜΕΝΑ ΓΙΑ ΙΔΑΝΙΚΑ ΑΕΡΙΑ

(Ferguson, ICEngines, John Wiley and Sons, New York, 1986)

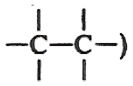
TABLE	SPECIES	SYMBOL
1	Carbon dioxide	$-CO_2$

Table E.1. Carbon Dioxide (CO_2); Molecular Weight = 44.00995.

	cal/(mol K)			kcal/mol			
T/K	Cp°	S°	$-(G°-H°_{298})/T$	$H°-H°_{298}$	ΔHf°	ΔGf°	Log K
0	0.000	0.000	INFINITE	-2.238	-93.965	-93.965	INFINITE
100	6.981	42.758	58.188	-1.543	-93.997	-94.100	205.645
200	7.734	47.769	51.849	-0.816	-94.028	-94.191	102.922
298.15	8.874	51.072	51.072	0.000	-94.054	-94.265	69.095
300	8.896	51.127	51.072	0.016	-94.055	-94.267	68.670
400	9.877	53.830	51.434	0.958	-94.070	-94.335	51.540
500	10.666	56.122	52.148	1.987	-94.091	-94.399	41.260
600	11.310	58.126	52.981	3.087	-94.124	-94.458	34.405
700	11.846	59.910	53.845	4.245	-94.169	-94.510	29.506
800	12.293	61.522	54.706	5.453	-94.218	-94.556	25.830
900	12.667	62.992	55.546	6.702	-94.270	-94.596	22.970
1000	12.980	64.344	56.359	7.984	-94.321	-94.628	20.680
1100	13.243	65.594	57.143	9.296	-94.371	-94.658	18.806
1200	13.466	66.756	57.896	10.632	-94.419	-94.681	17.243
1300	13.656	67.841	58.620	11.988	-94.469	-94.701	15.920
1400	13.815	68.859	59.315	13.362	-94.515	-94.716	14.785
1500	13.953	69.817	59.984	14.750	-94.562	-94.728	13.801
1600	14.074	70.722	60.627	16.152	-94.607	-94.739	12.940
1700	14.177	71.578	61.246	17.565	-94.650	-94.746	12.180
1800	14.269	72.391	61.843	18.987	-94.696	-94.750	11.504
1900	14.352	73.165	62.418	20.418	-94.742	-94.751	10.898
2000	14.424	73.903	62.974	21.857	-94.788	-94.752	10.353
2100	14.489	74.608	63.512	23.303	-94.834	-94.746	9.860
2200	14.547	75.284	64.031	24.755	-94.885	-94.744	9.411
2300	14.600	75.931	64.535	26.212	-94.936	-94.735	9.001
2400	14.648	76.554	65.023	27.674	-94.991	-94.724	8.625
2500	14.692	77.153	65.496	29.141	-95.048	-94.714	8.280
2600	14.734	77.730	65.956	30.613	-95.107	-94.698	7.960
2700	14.771	78.286	66.402	32.088	-95.170	-94.683	7.664
2800	14.807	78.824	66.836	33.567	-95.235	-94.662	7.388
2900	14.841	79.344	67.259	35.049	-95.305	-94.639	7.132
3000	14.873	79.848	67.670	36.535	-95.377	-94.615	6.892
3100	14.902	80.336	68.071	38.024	-95.451	-94.587	6.668
3200	14.930	80.810	68.461	39.515	-95.530	-94.560	6.458
3300	14.956	81.270	68.843	41.010	-95.611	-94.531	6.260
3400	14.982	81.717	69.215	42.507	-95.696	-94.495	6.074
3500	15.006	82.151	69.578	44.006	-95.784	-94.462	5.898
3600	15.030	82.574	69.933	45.508	-95.874	-94.421	5.732
3700	15.053	82.986	70.280	47.012	-95.968	-94.379	5.574
3800	15.075	83.388	70.620	48.518	-96.064	-94.331	5.425
3900	15.097	83.780	70.953	50.027	-96.162	-94.286	5.283
4000	15.119	84.162	71.278	51.538	-96.263	-94.237	5.149
4100	15.139	84.536	71.597	53.051	-96.367	-94.186	5.020
4200	15.159	84.901	71.909	54.566	-96.473	-94.130	4.898
4300	15.179	85.258	72.216	56.082	-96.583	-94.072	4.781
4400	15.197	85.607	72.516	57.601	-96.694	-94.015	4.670
4500	15.216	85.949	72.811	59.122	-96.807	-93.954	4.563
4600	15.234	86.284	73.100	60.644	-96.923	-93.885	4.460
4700	15.254	86.611	73.384	62.169	-97.040	-93.818	4.362
4800	15.272	86.933	73.663	63.695	-97.160	-93.746	4.268
4900	15.290	87.248	73.937	65.223	-97.281	-93.678	4.178
5000	15.306	87.557	74.206	66.753	-97.404	-93.603	4.091
5100	15.327	87.860	74.471	68.285	-97.530	-93.528	4.008
5200	15.349	88.158	74.731	69.819	-97.656	-93.450	3.927
5300	15.371	88.451	74.988	71.355	-97.783	-93.361	3.850
5400	15.393	88.738	75.239	72.893	-97.912	-93.280	3.775
5500	15.415	89.021	75.488	74.433	-98.042	-93.190	3.703
5600	15.437	89.299	75.732	75.976	-98.173	-93.104	3.633
5700	15.459	89.572	75.972	77.521	-98.305	-93.017	3.566
5800	15.481	89.841	76.209	79.068	-98.438	-92.918	3.501
5900	15.503	90.106	76.442	80.617	-98.572	-92.820	3.438
6000	15.525	90.367	76.672	82.168	-98.707	-92.724	3.377

ΠΑΡΑΡΤΗΜΑ 6   ΟΝΟΜΑΤΟΛΟΓΙΑ ΥΔΡΟΓΟΝΑΝΘΡΑΚΩΝ

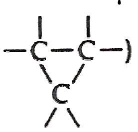
ΑΛΚΥΛΙΑ (Alkyl compounds)

Παραφίνες
(alkanes)
(μονού δεσμού


CH_4, C_2H_6 , C_3H_8 , C_4H_{10} , … , C_vH_{2v+2}
methane, ethane, propane, butane … ευθείας αλυσίδας
iso-butane … διακλαδούμενης αλυσίδας
Όλα είναι κορεσμένα δηλ δεν μπορούμε να προσθέσουμε άλλα άτομα Η. Ριζικά στα οποία λείπει ένα άτομο Η παίρνουν τα ονόματα methyl, ethyl, Propyl κλπ

Olefins
(alkenes)
(περιέχουν διπλούς δεσμούς


C_2H_4 , C_3H_6 , C_4H_8 , … , C_nH_{2n}
ethene, propane, butane
(ethylene, propylene, butylene)
Οι διολεφινες περιέχουν δυο διπλούς δεσμούς. Είναι ακόρεστες ουσίες διότι C_nH_{2n} μπορεί να κορεσθεί σε C_nH_{2n+2}

Cycloparafines
(cycloalkanes)
(μονού δεσμού


C_nH_{2n} χωρίς διπλούς δεσμούς
cyclopropane, cyclobutane, cyclopentane
Ακόρεστες ουσίες εφ’ όσον ο δακτύλιος μπορεί να διασπασθεί
$C_nH_{2n} + H_2 \rightarrow C_nH_{2n+2}$

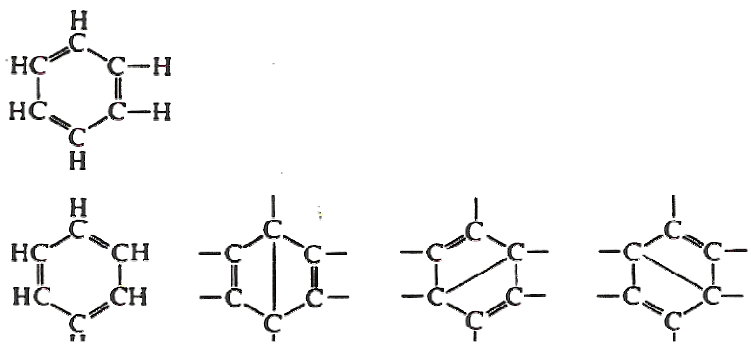
Acetylenes
(alkynes)
(περιέχουν τριπλούς δεσμούς)


C_2H_2 , C_3H_4 , C_4H_6 , … C_nH_{2n-2}
ethyne, propyne, butyne
(acetylene, methyl acetylene, ethyl acetylene)

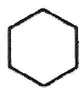
Ακόρεστες ουσίες

<u>ΑΡΩΜΑΤΙΚΟΙ (Aromatics)</u>

Η δομική ομάδα των αρωματικών είναι ο δακτύλιος της C_6H_6 (benzene) που είναι πολύ σταθερός.



Η δακτυλιοειδής δομή του benzene γράφεται εν συντομία



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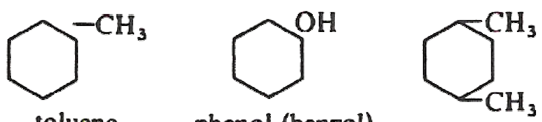


toluene phenol (benzol) xylene

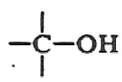
Το xylene είναι ortho, meta, ή para σύμφωνα με το αν οι ομάδες μεθυλίου (methyl) διαχωρίζονται από ένα, δυο ή τρία άτομα C αντίστοιχα.

<u>ΑΛΚΟΟΛΕΣ (Alcohols)</u>

Αυτές οι οργανικές ουσίες περιέχουν μια ομάδα (-OH) –υδροξυλίου

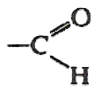
CH_3OH	C_2H_5OH
methanol	ethanol
(methyl alcohol)	(ethyl alcohol)

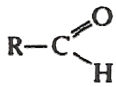
Η διάταξη του δεσμού είναι πάντοτε



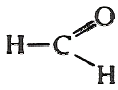
<u>ΑΛΔΕΥΔΕΣ (Aldehydes)</u>

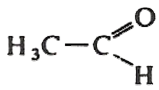
Οι αλδευδες περιέχουν τη χαρακτηριστική ομάδα (ριζικό formyl)

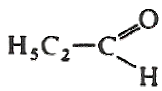


και γράφονται εν γένει 

όπου R μπορεί να είναι ένα άτομο Η ή ένα οργανικό ριζικό

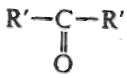

formaldehyde


acetaldehyde

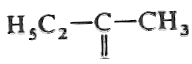

proprionaldehyde

<u>ΚΕΤΟΝΕΣ (Ketones)</u>

Οι κετόνες περιέχουν το χαρακτηριστικό group

και μπορούν να γράφουν γενικά 

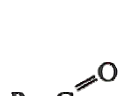
όπου R' είναι οπωσδήποτε ένα οργανικό ριζικό



Το ανωτέρω συμβολίζει την μεθυλεθυλική κετόνη.

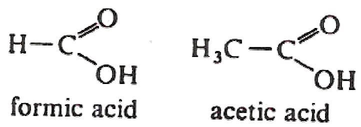
<u>ΟΞΕΑ (Acids)</u>

Τα οργανικά οξέα περιέχουν την ομάδα

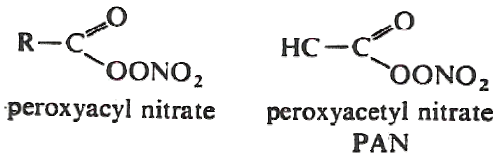


και γενικά

όπου R μπορεί να είναι ένα άτομο H ή ένα οργανικό ριζικό



ΟΡΓΑΝΙΚΑ ΑΛΑΤΑ (Organic salts)



ΛΟΙΠΕΣ ΟΥΣΙΕΣ

Οι αιθέρες έχουν τον τύπο $R^1 – O – R^1$, όπου R^1 είναι οργανικό ριζικό.
Τα υπεροξείδια είναι $R^1 – O – O - R^1$ η΄ $R^1 – O – O – H$ όπου τότε χρησιμοποιείται ο όρος υδροπεροξείδιο.

ΠΑΡΑΡΤΗΜΑ 7 Πίνακες ιδιοτήτων μεταφοράς (μ, Cp, k κλπ)(Kanury (1975))

TABLE D.1

Viscosity ($\times 10^{-6}$) of Gases and Vapors
(in gms/cm/sec)

T °C	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
0			171	94		139	166		83	85	91	102						
10			180		72	140	170		84	87	92	103		170	81		76	
20			183		76	148	173		87	91	101	109		178	84		80	
30			186		79	153	175		90	94	104	113		184	88		84	
40			190		82	157	177		92	98	108	117		188	90		87	
50		68	194		85	168	180		94	101	110	120		192	94		90	
75		82	210		91	180	188	98	100	108	120	129	127	203	100	63	96	
100	105	93	218		97	190	196	108	105	114	126	133	125	211	108	68	102	126
150		110	242		108	211	218	124	113	127	140	148	136	229	120	77	114	144
200		125	255		120	232	240	138	122	141	154	160	152	245	134	85	125	164
250		136	275		132	250	266	153	130	155	167	170	170	253	151	92	137	183
300		147	295		145	268	294	166	139	171	180	181	188	280	170	100		202
350		158	313		158	286		180	148			193	211	295				221
400		166	332		174	304		194	156			205		311				241
500			360			333			171			226		340				
600			390			361			185			256		369				
700			420			389			198			285		381				
800			442			415			211					419				
900			470			440			224					440				
1,000			500			470			235					460				

Legend: 1. Acetic Acid Vapor, 2. Acetone Vapor, 3. Air, 4. Acetylene, 5. Benzene Vapor, 6. Carbon Dioxide, 7. Carbon Monoxide, 8. Ethyl Alcohol Vapor, 9. Hydrogen, 10. Ethane, 11. Ethylene, 12. Methane, 13. Methyl Alcohol Vapor, 14. Nitrogen, 15. Propylene, 16. n-Octane Vapor, 17. Propane, 18. Water Vapor.

Units: 1 gm/cm/sec = 1 poise = 1 dyne sec/cm^2 = 10^2 centipoise = 10^6 micropoise.

TABLE D.2

Thermal Conductivity of Gases and Vapors

Gas	$K_0(T_0 = 273\ °K)$ cal/cm/sec/°K	Gas	$K_0(T_0 = 273\ °K)$ cal/cm/sec/°K
*Air	5.83×10^{-5}	*Helium	32.40×10^{-5}
*Argon	3.90×10^{-5}	Heptane	2.56×10^{-5}
Acetone	2.32×10^{-5}	Hexane	2.68×10^{-5}
Ammonia	5.02×10^{-5}	*Hydrogen	40.40×10^{-5}
Amyl alcohol	2.58×10^{-5}	Methane	7.33×10^{-5}
Benzene	2.20×10^{-5}	Methanol	3.05×10^{-5}
Butane	3.17×10^{-5}	Methyl bromide	1.50×10^{-5}
Butyl alcohol	2.64×10^{-5}	Methyl chloride	2.20×10^{-5}
*Carbon dioxide	3.60×10^{-5}	*Nitrogen	5.50×10^{-5}
*Carbon monoxide	5.30×10^{-5}	Octane	2.33×10^{-5}
Carbon tet	1.43×10^{-5}	*Oxygen	6.25×10^{-5}
Chloroform	1.52×10^{-5}	Pentane	2.94×10^{-5}
Cyclohexane	2.32×10^{-5}	Propane	3.64×10^{-5}
Ether	3.11×10^{-5}	Steam	3.61×10^{-5}
Ethane	4.52×10^{-5}	*Sulfur dioxide	2.00×10^{-5}
Ethanol	3.08×10^{-5}	Toluene	3.08×10^{-5}

$K = K_0(T/T_0)^n$
$n \approx 0.94$ for permanent gases (asterisked), $T_{max} < 1{,}000$ °C
$n \approx 1.83$ for condensible gases, $T_{max} < 600$ °C
1 cal/cm/sec/°K = 134.5 BTU/ft/hr/°F

TABLE D.3

Viscosity and Conductivity of Mixtures

X_1	μ	K	X_1	μ	K
	$H_2 + CO_2$			$H_2 + O_2$	
0.000	13.69×10^{-5}	3.60×10^{-5}	0.000	20.45×10^{-5}	6.25×10^{-5}
0.100	13.86×10^{-5}	5.10×10^{-5}	0.034	20.44×10^{-5}	6.51×10^{-5}
0.142	13.92×10^{-5}	5.70×10^{-5}	0.250	19.94×10^{-5}	11.12×10^{-5}
0.250	14.06×10^{-5}	7.70×10^{-5}	0.500	18.55×10^{-5}	18.27×10^{-5}
0.355	14.15×10^{-5}	10.00×10^{-5}	0.750	15.88×10^{-5}	27.49×10^{-5}
0.500	14.17×10^{-5}	13.50×10^{-5}	0.947	10.88×10^{-5}	37.44×10^{-5}
0.750	13.41×10^{-5}	22.70×10^{-5}	1.000	8.87×10^{-5}	41.80×10^{-5}
0.901	11.63×10^{-5}	31.50×10^{-5}			
1.000	8.54×10^{-5}	40.40×10^{-5}			
	$H_2 + CO$			$H_2 + Ar$	
0.000	17.06×10^{-5}	5.30×10^{-5}	0.000	21.35×10^{-5}	3.90×10^{-5}
0.163	17.15×10^{-5}	8.00×10^{-5}	0.090	21.26×10^{-5}	5.50×10^{-5}
0.272	16.49×10^{-5}	10.30×10^{-5}	0.180	21.11×10^{-5}	7.30×10^{-5}
0.566	15.38×10^{-5}	18.00×10^{-5}	0.400	20.20×10^{-5}	12.60×10^{-5}
0.634	14.88×10^{-5}	20.90×10^{-5}	0.600	18.63×10^{-5}	18.70×10^{-5}
0.794	13.03×10^{-5}	27.00×10^{-5}	0.802	14.80×10^{-5}	27.00×10^{-5}
1.000	8.53×10^{-5}	40.40×10^{-5}	1.000	8.54×10^{-5}	40.40×10^{-5}
	$H_2 + N_2$			$N_2 + Ar$	
0.000	16.88×10^{-5}	5.50×10^{-5}	0.000	20.89×10^{-5}	3.85×10^{-5}
0.159	16.70×10^{-5}	8.00×10^{-5}	0.204	29.37×10^{-5}	4.17×10^{-5}
0.390	16.00×10^{-5}	12.70×10^{-5}	0.359	30.64×10^{-5}	4.44×10^{-5}
0.652	14.49×10^{-5}	19.40×10^{-5}	0.611	30.43×10^{-5}	4.90×10^{-5}
0.795	12.85×10^{-5}	25.20×10^{-5}	0.780	28.63×10^{-5}	5.24×10^{-5}
0.803	12.74×10^{-5}	25.70×10^{-5}	1.000	16.59×10^{-5}	5.66×10^{-5}
1.000	8.53×30^{-5}	40.40×10^{-5}			

X_1 is the mole fraction of the ligher component.
μ is in gm/cm/sec.
K is in cal/cm/sec/°C.
(All mixtures at $T = 273$ °K except $H_2 + O_2$ which is at 295 °K.)

TABLE D.4

Conductivity of Mixtures

X_1	K	X_1	K	X_1	K
He + Ar (273 °K)		$H_2 + CO_2$ (273 °K)		H_2O + Air (353 °K)	
0.000	3.89×10^{-5}	0.000	3.39×10^{-5}	0.000	6.86×10^{-5}
0.270	7.41×10^{-5}	0.170	6.08×10^{-5}	0.197	7.15×10^{-5}
0.454	10.76×10^{-5}	0.370	10.35×10^{-5}	0.306	7.08×10^{-5}
0.847	23.18×10^{-5}	0.607	17.24×10^{-5}	0.444	6.89×10^{-5}
0.946	29.40×10^{-5}	0.834	27.98×10^{-5}	0.519	6.73×10^{-5}
1.000	33.89×10^{-5}	1.000	41.66×10^{-5}	1.000	5.23×10^{-5}
NH_3 + Air (293 °K)		H_2 + CO (273 °K)		C_2H_2 + Air (293 °K)	
0.000	6.00×10^{-5}	0.000	5.30×10^{-5}	0.000	6.00×10^{-5}
0.246	6.31×10^{-5}	0.163	8.00×10^{-5}	0.141	5.96×10^{-5}
0.366	6.28×10^{-5}	0.272	10.30×10^{-5}	0.320	5.84×10^{-5}
0.608	6.09×10^{-5}	0.566	18.02×10^{-5}	0.536	5.66×10^{-5}
0.805	5.75×10^{-5}	0.634	20.91×10^{-5}	0.630	5.55×10^{-5}
1.000	5.49×10^{-5}	0.794	26.99×10^{-5}	0.900	5.30×10^{-5}
		1.000	40.43×10^{-5}	1.000	5.22×10^{-5}
NH_3 + CO (295 °K)		$H_2 + C_2H_4$ (278 °K)		CO + Air (291 °K)	
0.000	5.74×10^{-5}	0.000	5.28×10^{-5}	0.000	5.97×10^{-5}
0.220	5.97×10^{-5}	0.170	8.61×10^{-5}	0.108	5.95×10^{-5}
0.338	6.03×10^{-5}	0.314	11.48×10^{-5}	0.321	5.90×10^{-5}
0.620	5.94×10^{-5}	0.514	16.91×10^{-5}	0.562	5.83×10^{-5}
0.790	5.82×10^{-5}	0.611	20.61×10^{-5}	0.978	5.69×10^{-5}
1.000	5.55×10^{-5}	0.865	32.90×10^{-5}	1.000	5.68×10^{-5}
		1.000	43.73×10^{-5}		
CH_4 + Air (295 °K)					
0.000	6.04×10^{-5}				
0.076	6.13×10^{-5}				
0.390	6.49×10^{-5}				
0.700	6.87×10^{-5}				
0.880	7.08×10^{-5}				
1.000	5.98×10^{-5}				

X_1 is mole fraction of the first gas.
K is in cal/cm/sec/°C.

TABLE D.5

Binary Diffusion Coefficients*
(at T_0 = 298 °K and P_0 = 1 atm)

Gas pair	D_0 cm²/sec	Gas pair	D_0 cm²/sec
N_2–He	0.71	H_2–nC_4H_{10}	0.38
N_2–Ar	0.20	H_2–O_2	0.81
N_2–H_2	0.78	H_2–CO	0.75
N_2–O_2	0.22	H_2–CO_2	0.65
N_2–CO	0.22	H_2–CH_4	0.73
N_2–CO_2	0.16	H_2–C_2H_4	0.60
N_2–H_2O	0.24	H_2–C_2H_6	0.54
N_2–C_2H_4	0.16	H_2–H_2O	0.99
N_2–C_2H_6	0.15	H_2–Br_2	0.58
N_2–nC_4H_{10}	0.10	H_2–C_6H_6	0.34
CO_2–O_2	0.18	Air–H_2	0.63
CO_2–CO	0.14	Air–O_2	0.18
CO_2–C_2H_4	0.15	Air–CO_2	0.14
CO_2–CH_4	0.15	Air–H_2O	0.23
CO_2–H_2O	0.19	Air–CS_2	0.10
CO_2–C_3H_8	0.09	Air–Ether	0.08
CO_2–CH_3OH	0.09	Air–CH_3OH	0.11
CO_2–C_6H_6	0.06	Air–C_6H_6	0.08
O_2–C_6H_6	0.07	H_2O–CH_4	0.28
O_2–CO	0.21	H_2O–C_2H_4	0.20
CO–C_2H_4	0.13	H_2O–O_2	0.27

$$D = D_0(T/T_0)^m(P_0/P)$$

$m \approx 1.75$ for permanent gases
$m \approx 2.00$ for condensible gases
1 cm²/sec = 3.875 ft²/hr

Compare values of D with $\alpha = 0.187$ cm²/sec and $\nu = 0.133$ cm²/sec for air at 298 °K and 1 atm.

*Compiled partly from A. A. Westenberg, *Combustion and Flame*, 1, p. 346 (1957), with permission of the Combustion Institute, and partly from various data sources.

TABLE D.6

Viscosity of Liquids

Liquid	μ gm/cm/sec	at T °C
Acetaldehyde	2.20×10^{-5}	20
Acetic acid	11.55×10^{-5}	25
Acetone	3.16×10^{-5}	25
Aniline	37.10×10^{-5}	25
Benzene	6.52×10^{-5}	20
Butanol (n)	29.48×10^{-5}	20
Carbon tetrachloride	9.69×10^{-5}	20
Caster oil	$9{,}860.00 \times 10^{-5}$	20
Chloroform	5.42×10^{-5}	25
Cyclohexane	10.20×10^{-5}	17
Dodecane	13.50×10^{-5}	25
Ethyl acetate	4.41×10^{-5}	25
Ethanol	12.00×10^{-5}	20
Ethylene glycol	199.00×10^{-5}	20
Formic acid	18.04×10^{-5}	20
Heptane	3.86×10^{-5}	25
Hexane	2.94×10^{-5}	25
Methanol	5.47×10^{-5}	25
Octane (iso)	5.40×10^{-5}	20
Octane (n)	5.42×10^{-5}	20
Phenol	127.00×10^{-5}	18
Propanol	22.56×10^{-5}	20
Propyl acetate	5.90×10^{-5}	20
Toluene	5.90×10^{-5}	20
Water	10.02×10^{-5}	20
Xylene (o)	8.10×10^{-5}	20

TABLE D.7

Conductivity of Liquids

Liquid	K_{30} cal/cm/sec/°C	ω °C^{-1}	Range °C
Acetic acid	40.56×10^{-5}	1.20×10^{-3}	15–90
Acetaldehyde	44.30×10^{-5}	2.60×10^{-3}	12–31
Acetone	37.50×10^{-5}	2.20×10^{-3}	15–50
Aniline	41.25×10^{-5}	0.45×10^{-3}	15–90
Benzene	34.58×10^{-5}	1.80×10^{-3}	15–71
Butanol (n)	36.11×10^{-5}	1.40×10^{-3}	15–90
Carbon tetrachloride	24.31×10^{-5}	1.65×10^{-3}	15–90
Caster oil	42.78×10^{-5}	0.45×10^{-3}	15–90
Chloroform	27.36×10^{-5}	1.80×10^{-3}	15–70
Cyclohexane	29.31×10^{-5}	1.80×10^{-3}	12–38
Dodecane	31.25×10^{-5}	—	—
Ethyl acetate	34.30×10^{-5}	2.10×10^{-3}	16–50
Ethanol	39.72×10^{-5}	1.40×10^{-3}	16–91
Ethylene glycol	61.11×10^{-5}	-0.75×10^{-3}	15–90
Formic acid	63.89×10^{-5}	0.30×10^{-3}	15–90
Glycerol	68.05×10^{-5}	-1.20×10^{-3}	15–90
Heptane (n)	30.00×10^{-5}	1.80×10^{-3}	13–90
Hexane (n)	29.44×10^{-5}	2.00×10^{-3}	16–60
Kerosene	35.72×10^{-5}	—	—
Lube oil	32.50×10^{-5}	0.45×10^{-3}	15–90
Methanol	47.78×10^{-5}	1.20×10^{-3}	13–51
Octane (iso)	23.61×10^{-5}	1.80×10^{-3}	16–90
Octane (n)	30.56×10^{-5}	—	—
Pentanol	32.64×10^{-5}	0.90×10^{-3}	15–90
Phenol	38.33×10^{-5}	—	—
Propanol (n)	37.50×10^{-5}	1.40×10^{-3}	15–70
Propyl acetate	33.05×10^{-5}	—	—
Toluene	31.72×10^{-5}	—	—
Water	146.50×10^{-5}	2.48×10^{-3}	0–60
Xylene (o)	31.25×10^{-5}	—	—

$K = K_{30}[1 - \omega(T - 30)]$, T in °C

TABLE A.3

Molar Heat Capacity*

$C_p = a + bT + cT^2$ cal/gm-mole/°K

Gas	a	b	c	a	b	c
H_2	6.1830	4.7107×10^{-3}	-10.9215×10^{-6}	4.1033	3.9818×10^{-3}	-1.4265×10^{-6}
H	4.9680	0	0	4.9680	0	0
O_2	7.3611	-5.3696×10^{-3}	20.5418×10^{-6}	8.4391	-0.3765×10^{-3}	0.6217×10^{-6}
O	5.9741	-4.2419×10^{-3}	7.9312×10^{-6}	4.7434	0.4809×10^{-3}	-0.3647×10^{-6}
N_2	7.7099	-5.5039×10^{-3}	13.1214×10^{-6}	5.6492	3.5790×10^{-3}	-1.7943×10^{-6}
N	4.9665	0.0115×10^{-3}	-0.0333×10^{-6}	4.8457	0.0808×10^{-3}	0.0879×10^{-6}
H_2O	7.9888	-1.5063×10^{-3}	6.6661×10^{-6}	3.4019	9.4330×10^{-3}	-4.0674×10^{-6}
NH_3	7.0405	1.2091×10^{-3}	18.3300×10^{-6}	20.5150	-14.0320×10^{-3}	13.2660×10^{-6}
NO	8.4623	-10.4067×10^{-3}	27.5488×10^{-6}	6.5902	2.6042×10^{-3}	-1.2912×10^{-6}
NO_2	6.6101	5.4313×10^{-3}	12.7251×10^{-6}	9.9490	4.4936×10^{-3}	-2.3473×10^{-6}
N_2O	4.8267	20.1393×10^{-3}	-22.1361×10^{-6}	9.8739	5.6103×10^{-3}	-2.9067×10^{-6}
SO	5.9203	4.6547×10^{-3}	0.0476×10^{-6}	7.8755	1.2776×10^{-3}	-0.6382×10^{-6}
SO_2	5.9262	14.4706×10^{-3}	-7.3970×10^{-6}	11.0304	3.4772×10^{-3}	-1.7638×10^{-6}
SO_3	3.9208	37.8380×10^{-3}	-41.6000×10^{-6}	15.0470	5.6292×10^{-3}	-3.0148×10^{-6}
CO	7.8122	-6.6683×10^{-3}	17.2830×10^{-6}	5.9665	3.2889×10^{-3}	-1.6605×10^{-6}
CO_2	4.3249	20.8089×10^{-3}	-22.9459×10^{-6}	8.1530	8.4114×10^{-3}	-4.7952×10^{-6}
CH_4	7.9184	-11.4172×10^{-3}	63.7345×10^{-6}	2.3689	24.0868×10^{-3}	-11.7510×10^{-6}
C_2H_2	1.6509	47.7840×10^{-3}	-81.0300×10^{-6}	8.2241	12.4790×10^{-3}	-5.6128×10^{-6}
C_2H_4	1.5087	31.9260×10^{-3}	-5.8508×10^{-6}	6.5490	26.0090×10^{-3}	-12.7360×10^{-6}
C_2H_6	1.3750	41.8520×10^{-3}	-13.8270×10^{-6}	—	—	—
C_3H_8	6.8008	28.7100×10^{-3}	62.3490×10^{-6}	2.5532	55.1590×10^{-3}	-20.8220×10^{-6}
C_4H_{10}	-39.7720	412.9000×10^{-3}	-991.7400×10^{-6}	8.5028	56.4720×10^{-3}	-23.0920×10^{-6}
C_6H_6	1.6505	68.4460×10^{-3}	-2.9566×10^{-6}	9.1653	57.2620×10^{-3}	-22.3540×10^{-6}
C_6H_{14}	7.3130	104.9060×10^{-3}	-32.3970×10^{-6}	—	—	—
Cl_2	7.5755	1.3133×10^{-3}	-0.9650×10^{-6}	—	—	—
	←	$300\ °K < T < 2{,}000\ °K$	→	←	$2{,}000\ °K < T < 6{,}000\ °K$	→

* By the permission of The Combustion Institute: from Prothero, A., *Combustion and Flame*, 13, p. 399 (1969).

ΠΑΡΑΡΤΗΜΑ 8 ΤΕΧΝΙΚΑ ΔΕΔΟΜΕΝΑ ΚΑΥΣΗΣ (Kanury (1975), Strehlow (1968), Glassman (1968), Lewis and Von Elbe (1961), Jost (1946), Gaydon and Wolfhard (1960), Goodger (1975)CRC (1988))

TABLE 6

CORRELATION OF COMBUSTION WAVE PARAMETERS WITH QUENCHING DISTANCES d (MINIMUM FLAME DIAMETER) BY MEANS OF THE CONCEPT OF CRITICAL FLAME STRETCH, USING $K = 4(\eta_0/d)(\rho_u/\rho_b)^a$

TABLE 4.4*

Fuel: Per cent	Fuel: Stoichiometric fraction[b]	S_u (cm./sec.)	T_b (°K.)	$k \times 10^5$ cal. sec.$^{-1}$/cm. °C.	c_p cal./g. °C.	$\rho_u \times 10^3$ g./cm.^{3}	ρ_u/ρ_b	$\eta_0 \times 10^3$ cm.	d (cm.)	K
					CH_4–O_2					
10	0.22	80	2200	6.3	0.33	1.24	7.3	1.92	0.078	0.7
15	0.35	175	2650	6.4	0.36	1.20	8.8	0.85	0.050	0.6
25	0.67	304	3000	6.5	0.43	1.14	10.0	0.44	0.035	0.5
40	1.47	305	3000	6.7	0.57	1.04	12.7	0.37	0.050	0.4
50	2.00	112	2650	6.9	0.63	0.98	13.3	0.98	0.16	0.3
					C_2H_6–O_2					
7.4	0.4	240	2500	6.1	0.30	1.35	9.0	0.64	0.036	0.6
13.1	0.8	382	3000	5.9	0.32	1.37	11.3	0.35	0.026	0.6
19.3	1.2	320	3000	5.8	0.36	1.41	13.6	0.36	0.029	0.7
21.9	1.4	235	2800	5.7	0.37	1.41	14.3	0.47	0.034	0.8
22.7	1.47	190	2750	5.7	0.37	1.41	14.5	0.58	0.037	0.9
	N_2/O_2				CH_4–O_2–N_2, stoichiometric fraction = 1.1					
35.5	0	326	3050	6.2	0.52	1.07	10.8	0.34	0.040	0.4
26.4	0.5	240	2940	6.3	0.45	1.09	10.2	0.54	0.045	0.5
21.5	1.0	170	2810	6.4	0.41	1.10	9.7	0.83	0.053	0.6
16.1	1.86	110	2620	6.5	0.37	1.11	9.1	1.42	0.079	0.6
10.3	air	42	2200	6.5	0.33	1.12	7.5	4.2	0.25	0.5
					H_2–air					
20	0.60	100	1910	7.2	0.30	0.96	5.7	2.5	0.071	0.8
30	1.01	195	2300	8.0	0.34	0.93	6.5	1.3	0.064	0.5
40	1.58	265	2240	9.0	0.39	0.81	6.5	1.1	0.076	0.4
57	3.15	190	1850	9.0	0.51	0.61	5.5	1.5	0.165	0.2
					CH_4–air					
6.84	0.7	15	1900	6.5	0.30	1.14	6.3	12.5	0.29	1.1
7.76	0.8	27	2000	6.5	0.31	1.14	6.7	6.8	0.22	0.8
8.62	0.9	35	2150	6.5	0.32	1.13	7.2	5.2	0.20	0.8
9.50	1.0	43	2250	6.5	0.32	1.12	7.5	4.2	0.21	0.6
10.3	1.1	42	2200	6.5	0.33	1.12	7.5	4.2	0.25	0.5
11.6	1.25	25	2100	6.5	0.34	1.12	7.5	6.9	0.45	0.5
					C_3H_8–air					
2.86	0.7	28	1870	6.5	0.278	1.18	6.4	7.1	0.42	0.4
3.64	0.9	35	2170	6.5	0.282	1.19	7.5	5.5	0.24	0.7
4.02	1.0	40	2240	6.5	0.285	1.20	7.8	4.8	0.19	0.8
5.08	1.28	27	2120	6.5	0.290	1.20	7.8	6.9	0.17	1.3
5.52	1.40	17	2030	6.5	0.292	1.21	7.5	10.8	0.20	1.6
5.91	1.50	12	1830	6.5	0.294	1.22	6.9	16.4	0.25	1.8

[a] Pressure = 1 atmosphere, T_u = 300°K.
[b] Stoichiometric fraction = (% fuel/% O_2)/(% fuel/% $O_{2\ stoich}$); stoichiometric combustion to CO_2 and H_2O.

Combustion Kinetics, Flame Temperatures and Space Heating Rates

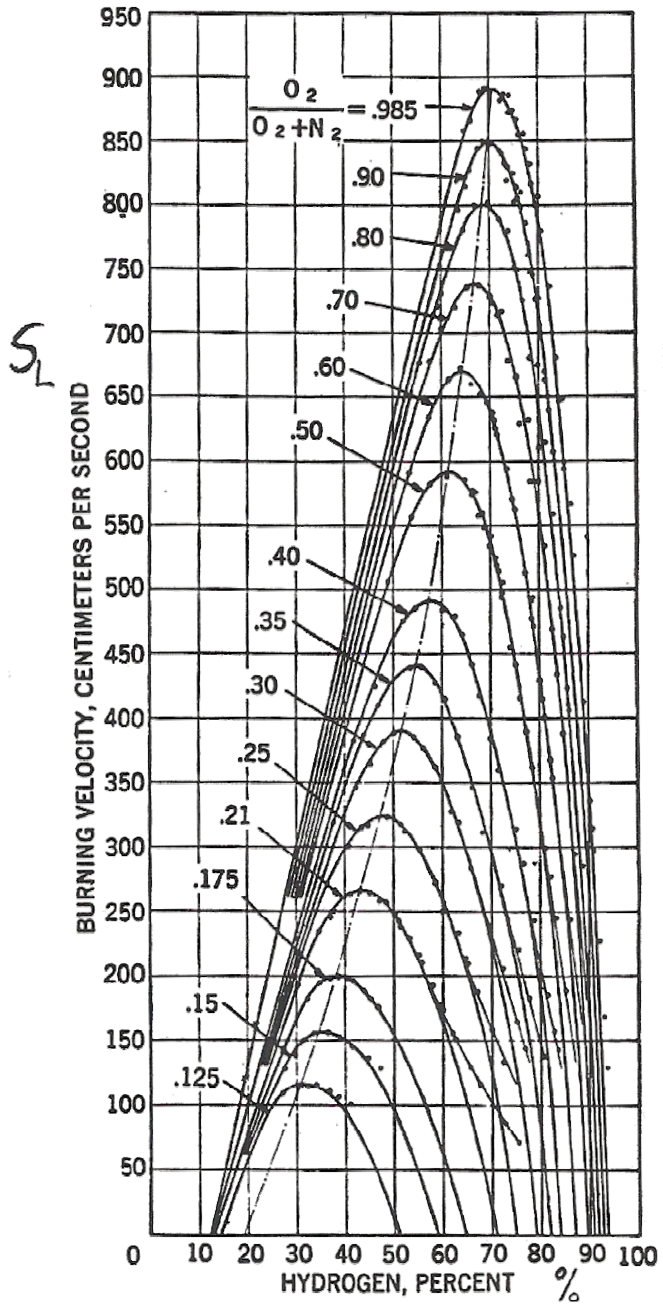
Fuel	Oxidant	Pressure atm.	Initial temp. °K	Activation energy kcal/mole	Preexponential	Overall order	Flame temp. °K	Average reaction rate moles/cm³/sec	Maximum reaction rate moles/cm³/sec	SHR max. BTU/ft³/hr
Propane	Air	—	378	31.0	2×10^{14}	1.56	2,250	—	—	—
Propane	Air	—	400	31.0	—	1.60	2,313	1.04	3.27	$6.44 \cdot 10^8$
Propane	Air	—	483	—	—	—	2,351	—	—	—
Propane	Air	—	558	—	—	—	2,384	—	—	—
Propane	Helium "air"	—	—	—	—	1.63	2,557	2.94	8.40	$1.66 \cdot 10^9$
Propane	Argon "air"	—	—	—	—	1.71	2,557	3,82	11.30	$2.24 \cdot 10^9$
Propane	$0.17\ O_2 + N_2$	—	313	—	—	—	2,051	—	—	—
Propane	$0.21\ O_2 + N_2$	—	—	—	—	1.90	2,253	—	—	—
Propane	$0.30\ O_2 + N_2$	—	—	—	—	—	2,558	—	—	—
Propane	$0.50\ O_2 + N_2$	—	—	—	—	—	2,844	—	—	—
Propane	$0.70\ O_2 + N_2$	—	—	—	—	—	2,970	—	—	—
Methane	Air	—	—	29.0	—	1.60	2,236	1.60	5.07	$3.90 \cdot 10^8$
Methane	O_2	—	—	—	—	—	3,020	—	—	—
Ethane	N_2O	—	—	49.0	—	—	2,740	—	—	—
Ethane	NO	—	—	—	—	—	2,840	—	—	—
Butane	O_2	—	—	21.0	5.4×10^{13}	2.00	2,256	—	—	—
Hexane (*n*)	Air	—	—	51.0	—	—	2,239	—	—	—
Decane (*n*)	Air	—	—	51.0	—	1.62	2,286	—	—	—
Octane (*iso*)	Air	—	—	32.4	—	1.52	2,302	0.24	0.72	$3.6 \cdot 10^7$
Octane (*n*)	Air	1	400	40.0	—	1.80	2,251	—	—	$1.0 \cdot 10^9$
Octane (*n*)	Air	15	400	40.0	—	1.80	2,316	—	—	$7.3 \cdot 10^{10}$
Octane (*n*)	O_2†	1	400	40.0	—	1.80	3,056	—	—	$4.5 \cdot 10^{11}$
Octane (*n*)	O_2†	15	400	40.0	—	1.80	3,422	—	—	$2.7 \cdot 10^{14}$
Hexene	Air	—	—	43.2	—	—	2,324	—	—	—
Decene	Air	—	—	—	—	—	2,322	—	—	—
Benzene	Air	—	—	47.2	—	—	2,365	—	—	—
Acetylene	N_2O	—	298	31.0	—	—	2,940	—	—	—
Acetylene	NO	—	—	—	—	—	3,080	—	—	—
Ethylene	Air	—	298	—	—	1.60	2,362	5.00	15.10	$1.93 \cdot 10^9$
Ethylene	N_2O	—	—	—	—	—	2,820	—	—	—
Ethylene	NO	—	—	—	—	—	2,920	—	—	—
Ethylene oxide decomposition		—	298	—	—	—	1,217	—	—	—
Ammonia	O_2†	1	400	49.5	—	1.70	2,782	—	—	$1.50 \cdot 10^{10}$
Ammonia	O_2†	15	400	49.5	—	1.70	3,041	—	—	$3.00 \cdot 10^{12}$
Hydrogen	Air	—	313	15.0	1.6×10^{12}	2.17	2,380	1.69	4.63	$1.10 \cdot 10^9$
Hydrogen	O_2†	1	400	18.0	—	2.00	3,018	—	—	$4.60 \cdot 10^{11}$
Hydrogen	O_2†	15	400	18.0	—	2.00	3,384	—	—	$1.10 \cdot 10^{15}$
Hydrogen	Br_2(40%)	—	323	—	—	1.50	1,490	—	—	—
Hydrogen	F†	1	400	50.0	—	2.00	3,962	—	—	$7.00 \cdot 10^{13}$
Hydrogen	F†	15	400	50.0	—	2.00	4,546	—	—	$1.60 \cdot 10^{17}$

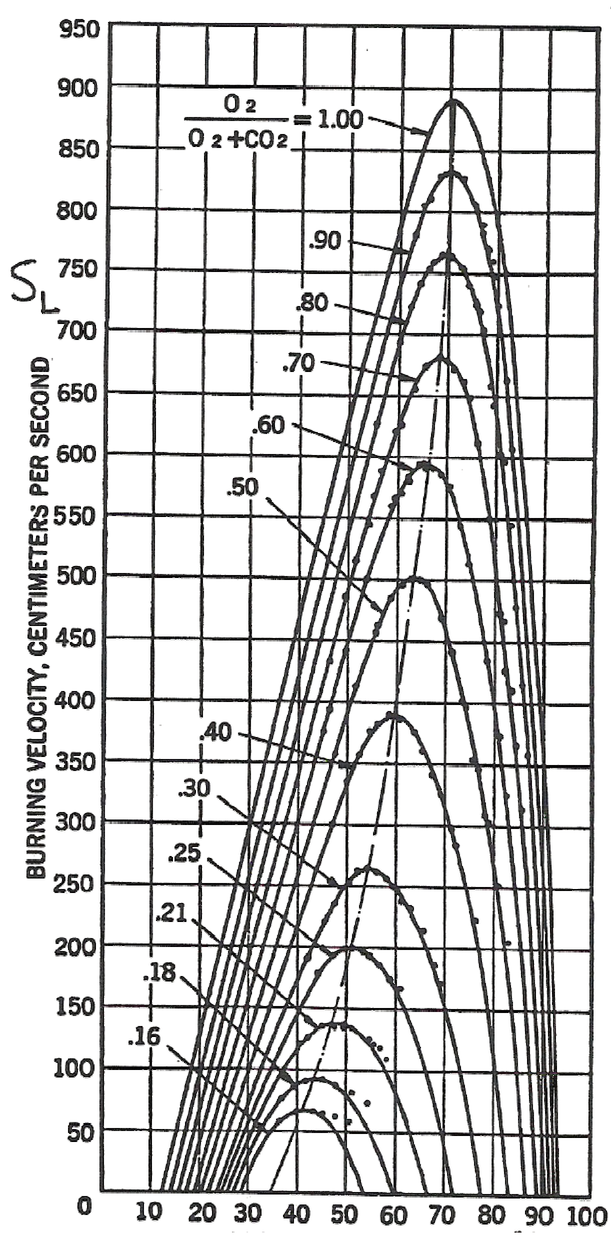
TABLE 4.2

Quenching Distance and Ignition Energy for S

mixtures at Room Temperature and

Fuel	Oxidant	d_q (mm)	E_{min} ($10^{-5} \times$ cal)	$-\frac{d \ln d_q}{d \ln P}$
Hydrogen	45% Bromine	3.63	—	0.87–0.98
Hydrogen	Air	0.64	0.48	1.14
Hydrogen	Oxygen	0.25	0.10†	1.08
Methane	Air	2.55	7.90	—
Methane	Oxygen	0.30	0.15†	—
Acetylene	Air	0.76	0.72	—
Acetylene	Oxygen	0.09	0.01†	—
Ethylene	Air	1.25	2.65†	—
Ethylene	Oxygen	0.19	0.06†	—
Propane	Air	2.03	7.29	0.88
Propane	Argon "air"	1.04	1.84†	—
Propane	Helium "air"	2.53	10.83†	—
Propane	Oxygen	0.24	0.10†	—
1-3 Butadiene	Air	1.25	5.62	—
iso-Butane	Air	2.20	8.22†	—
n-Pentane	Air	3.30	19.60	—
Benzene	Air	2.79	13.15	—
Cyclohexene	Air	3.30	20.55	—
Cyclohexane	Air	4.06	32.98	—
n-Hexane	Air	3.56	22.71	—
1-Hexane	Air	1.87	5.24†	—
n-Heptane	Air	3.81	27.49	—
iso-Octane	Air	2.84	13.71†	—
n-Decane	Air	2.06	7.21†	0.89
1-Decane	Air	1.97	6.60†	—
n-Butyl benzene	Air	2.28	8.84†	—
Ethylene oxide	Air	1.27	2.51	—
Proplyene oxide	Air	1.30	4.54	—
Methyl formate	Air	1.65	14.82	—
Diethyl ether	Air	2.54	11.71	—
Carbon disulfide	Air	0.51	0.36	—





HYDROGEN, PERCENT %

A) Burning velocities of mixtures of hydrogen, oxygen & nitrogen room temperature & atmospheric pressure

B). Burning velocities of mixtures of hydrogen, oxygen & carbon dioxide. The oxygen gas contained 1.5% N_2. Room temperature & atmospheric pressure

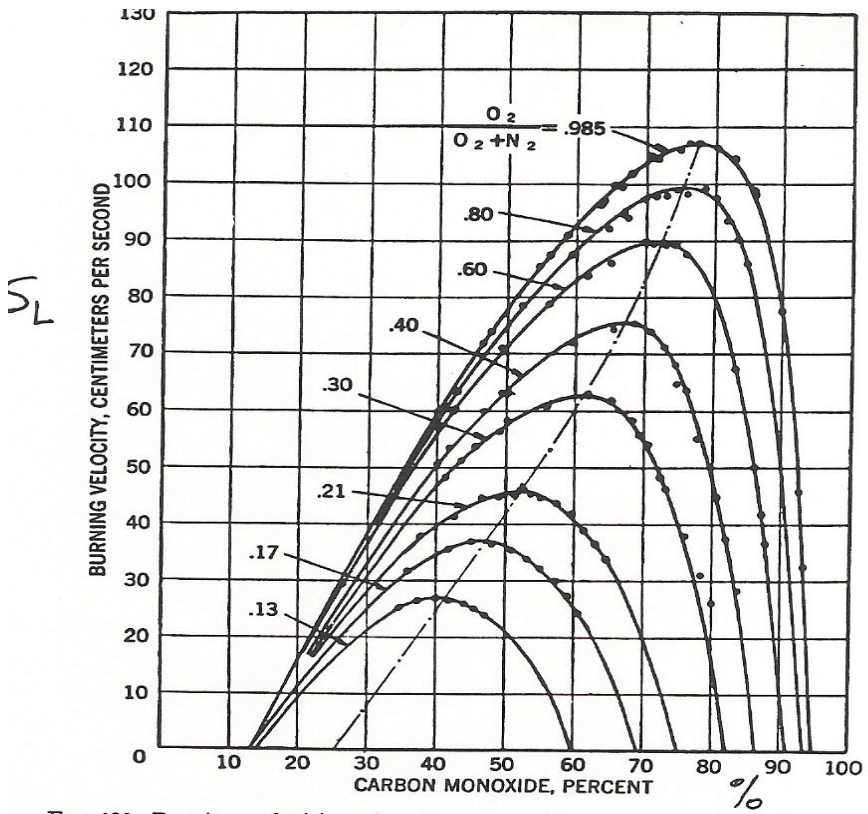


FIG. 190. Burning velocities of carbon monoxide, oxygen, and nitrogen at room temperature and atmospheric pressure. The carbon monoxide gas contained 1.5% H_2 and 1.35% H_2O (Jahn).

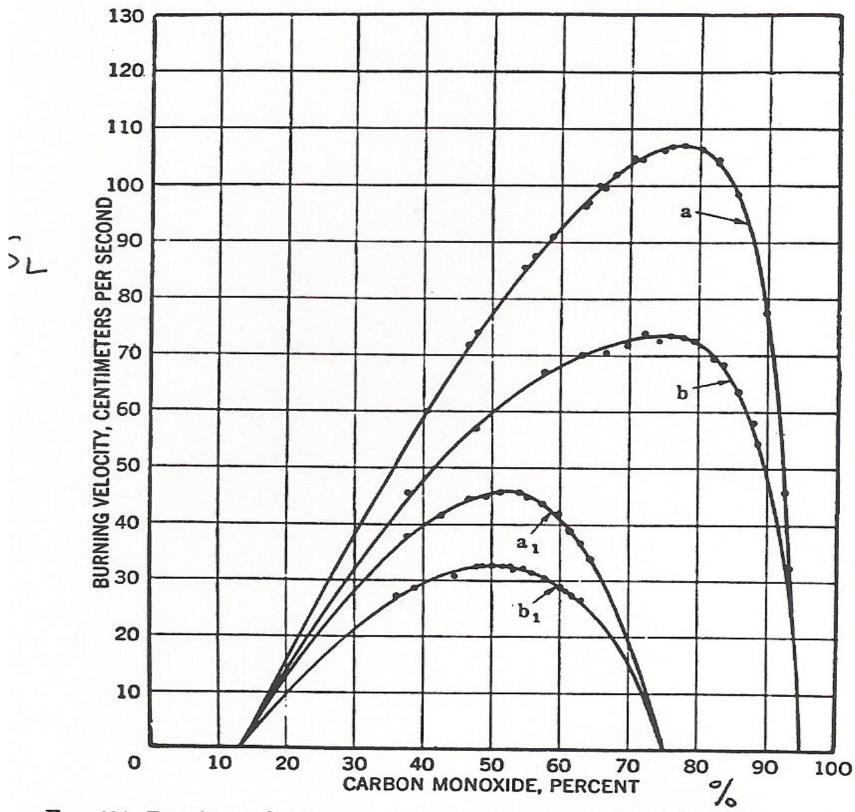


FIG. 191. Burning velocities of mixtures of carbon monoxide, oxygen, and nitrogen with and without hydrogen (Jahn).

Carbon monoxide-oxygen mixture: (*a*) CO contained 1.5% H_2 and 1.35% H_2O. (*b*) CO contained 1.35% H_2O. Carbon monoxide-air mixture: (a_1) CO as in (*a*). (b_1) CO as in (*b*). The oxygen gas contained 1.5% N_2. Room temperature and atmospheric pressure.

π 8.5

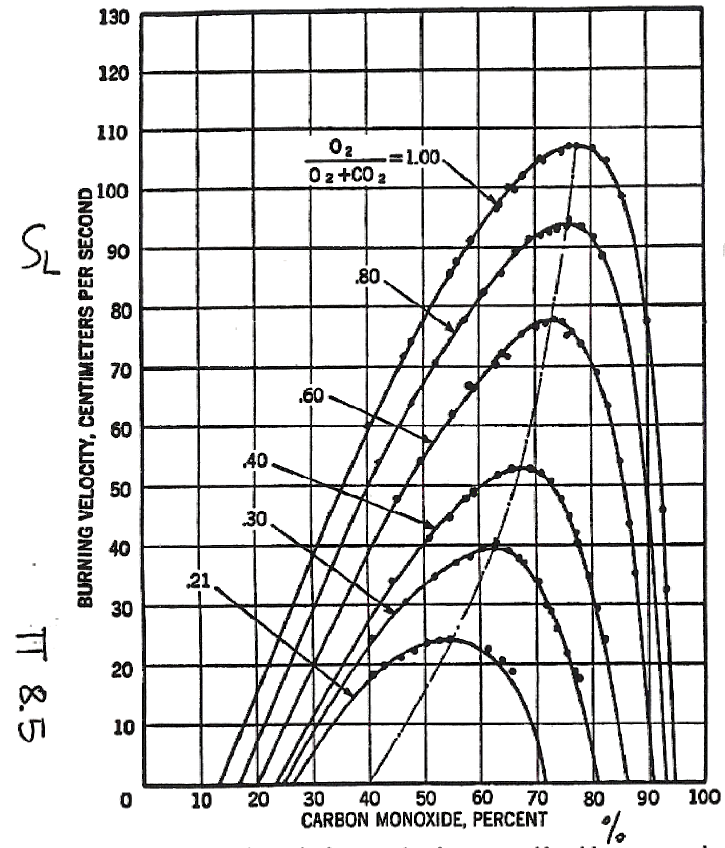


Fig. 192. Burning velocities of mixtures of carbon monoxide with oxygen and carbon dioxide. The carbon monoxide gas contained 1.5% H_2 and 1.35% H_2O. The oxygen gas contained 1.5% N_2. Room temperature and atmospheric pressure (Jahn).

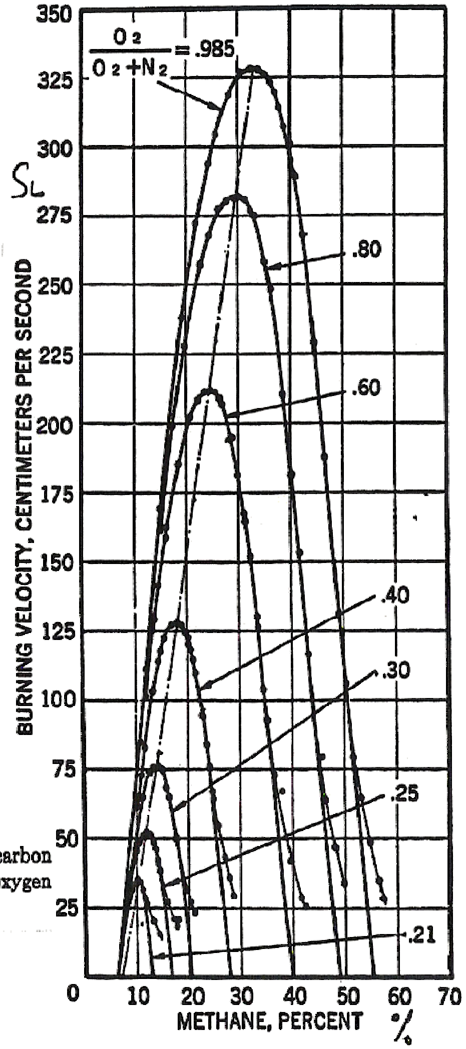


Fig. 193. Burning velocities of mixtures of methane, oxygen, and nitrogen at room temperature and atmospheric pressure (Jahn).

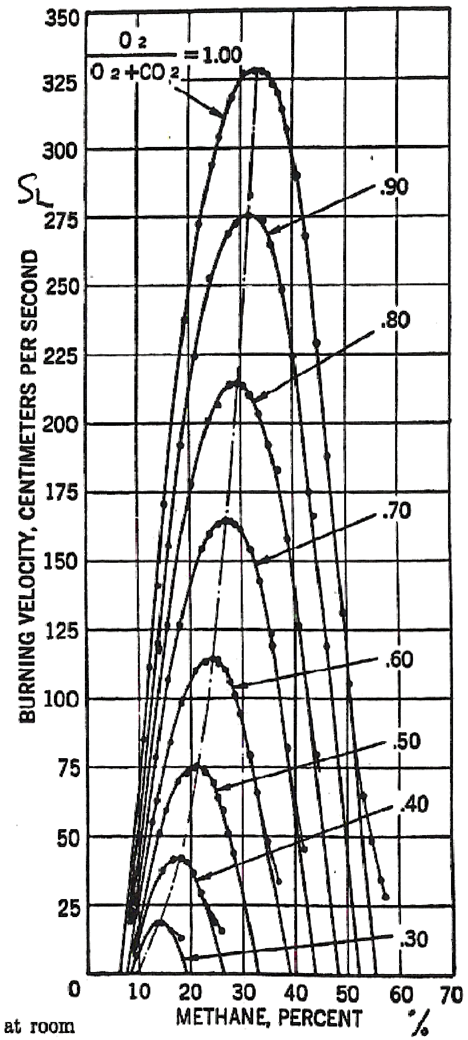


Fig. 194. Burning velocities of mixtures of methane, oxygen, and carbon dioxide at room temperature and atmospheric pressure. The oxygen gas contained 1.5% N_2

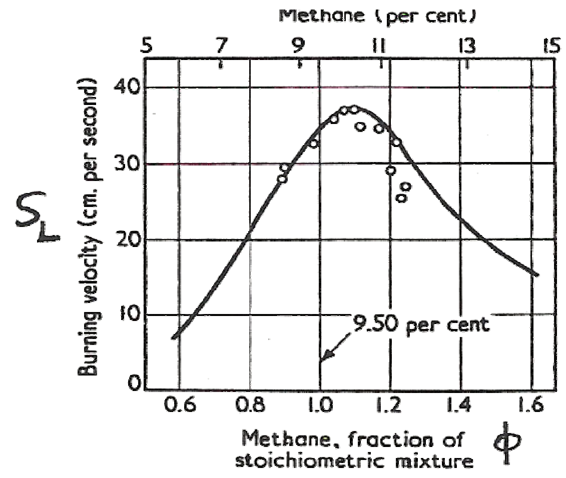


FIG. 195. Burning velocities of methane-air mixtures. Curves drawn from data by Jahn and Denues and Huff. Data points from Singer, Grumer, and Cook.

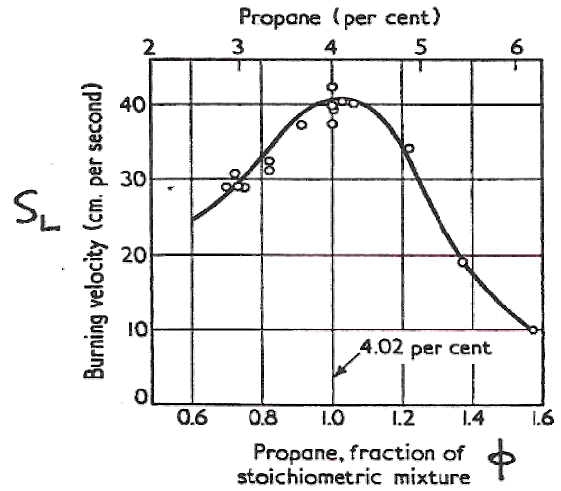


FIG. 196. Burning velocities of propane-air mixtures. Data from Harris, Grumer von Elbe, and Lewis.[29]

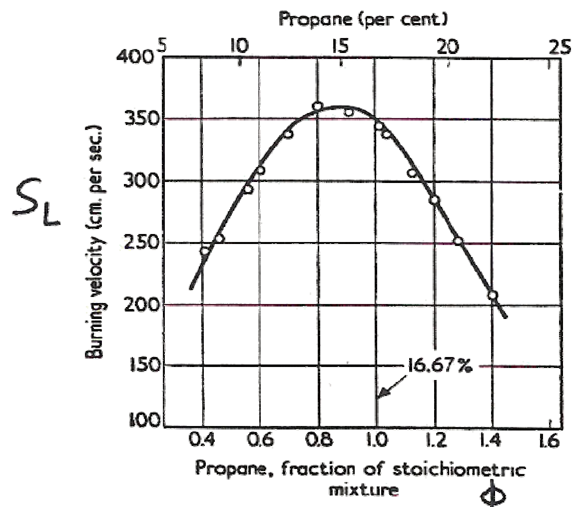


FIG. 197. Burning velocities of propane-oxygen mixtures. Data from Singer Grumer, and Cook.

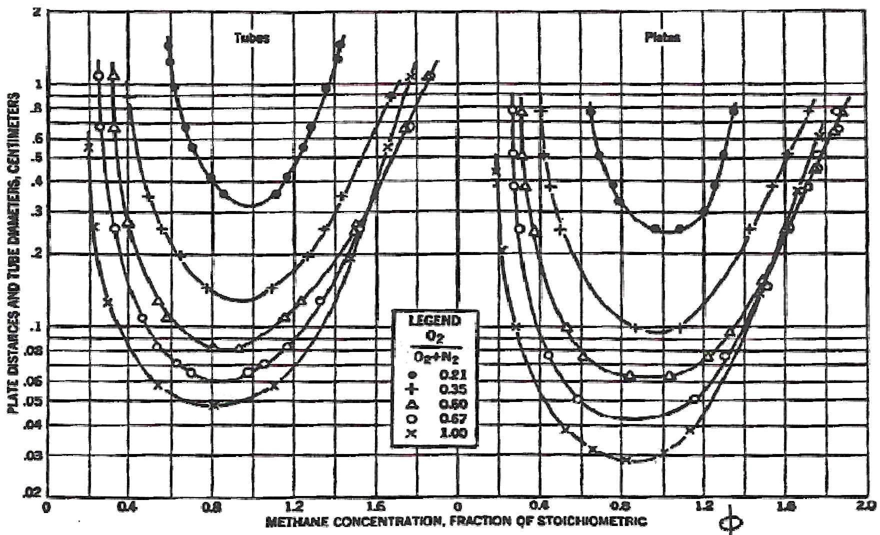


Fig. 103. Quenching distances $d_{\parallel}$ between parallel plates, and quenching diameters d_0 for mixtures of methane-oxygen-nitrogen at room temperature and atmospheric pressure (Harris, Grumer, von Elbe, and Lewis).

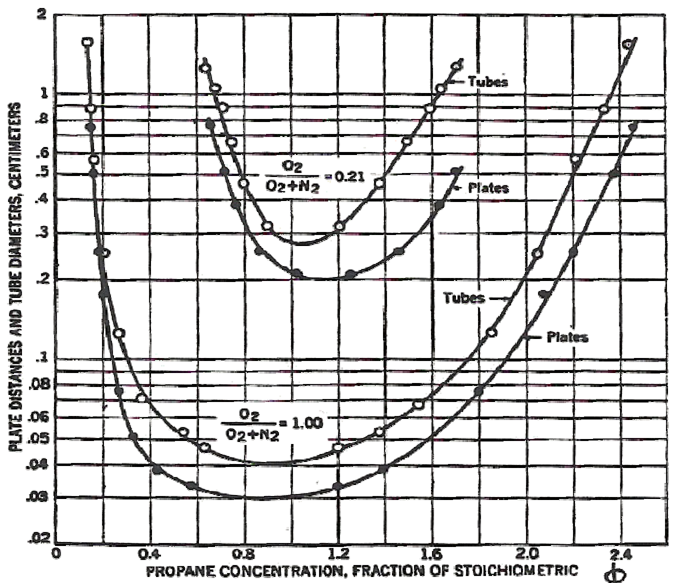


Fig. 104. Quenching distances $d_{\parallel}$ between parallel plates, and quenching diameters d_0 for mixtures of propane-oxygen-nitrogen at room temperature and atmospheric pressure (Harris, Grumer, von Elbe, and Lewis).

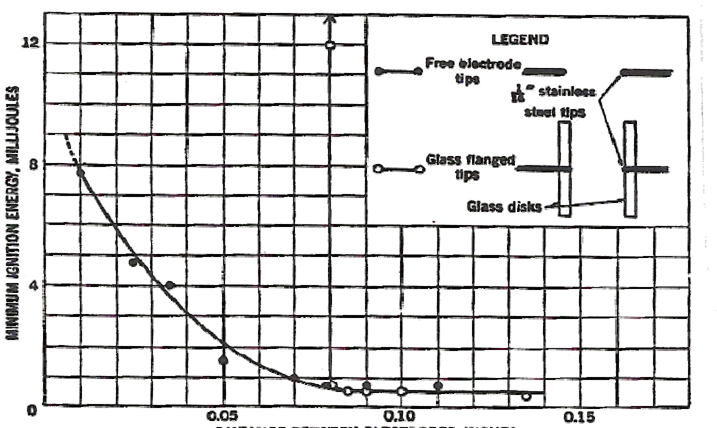


Fig. 155. Minimum ignition energies for free and glass-flanged electrode tips as function of electrode distance. Stoichiometric mixture of natural gas (about 83% CH_4 + 17% C_2H_6) and air at 1 atmosphere pressure.

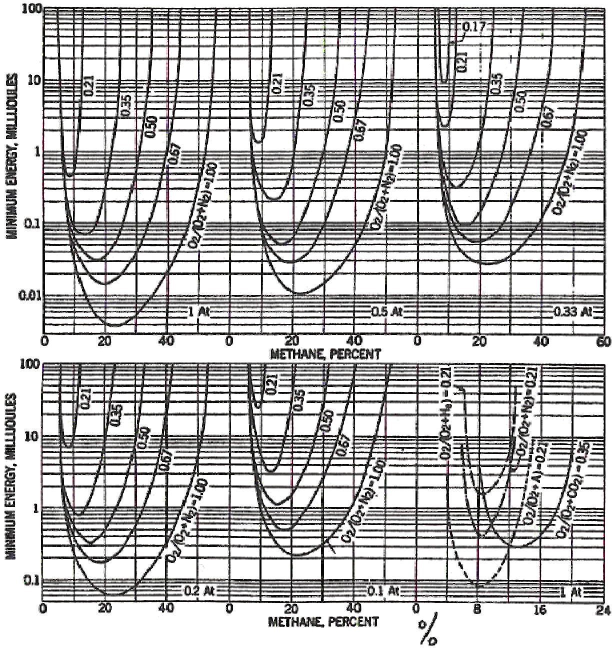


FIG. 159. Minimum spark ignition energies in millijoules of mixture of methane, oxygen, and inert gases at 1 atmosphere pressure and lower. Curves correspond to constant ratios of oxygen and inert gas. 1/16-in. diameter glass- or quartz-flanged electrodes.

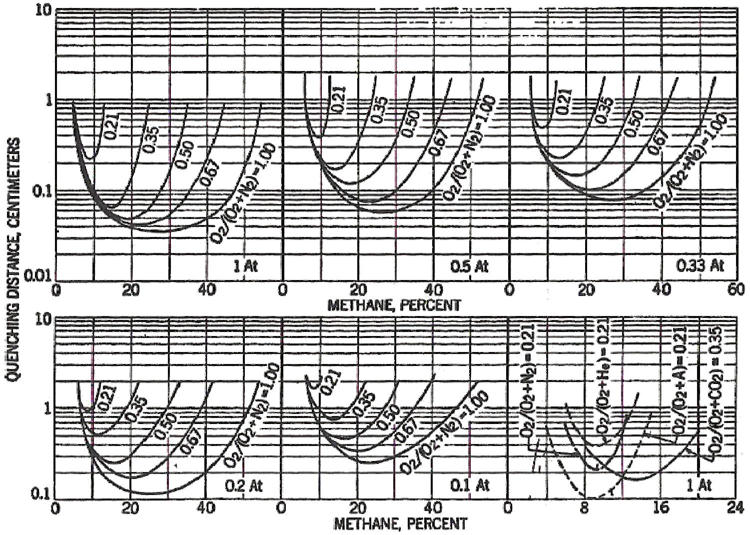


FIG. 160. Quenching distances for mixtures of methane, oxygen, and inert gases.

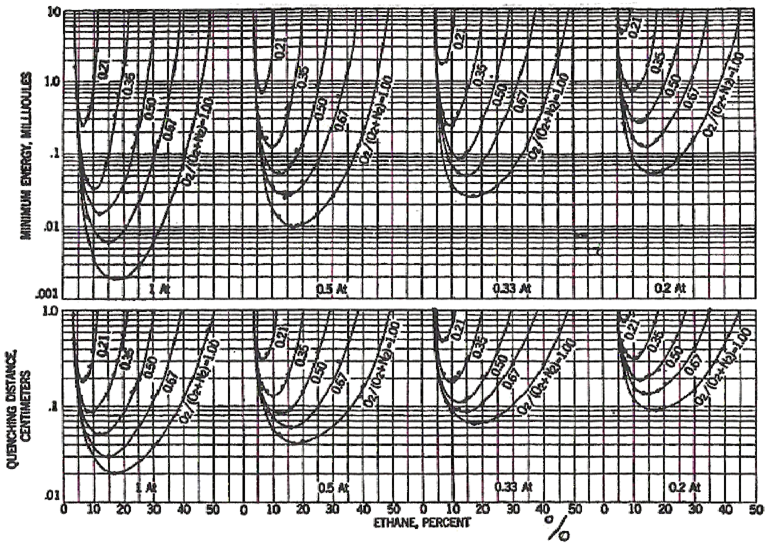


FIG. 161. Minimum spark ignition energies in millijoules of mixtures of ethane, oxygen, and nitrogen at 1 atmosphere pressure and lower, and quenching distances between flanged electrodes for the same mixtures. Curves correspond to constant ratios of oxygen and nitrogen.

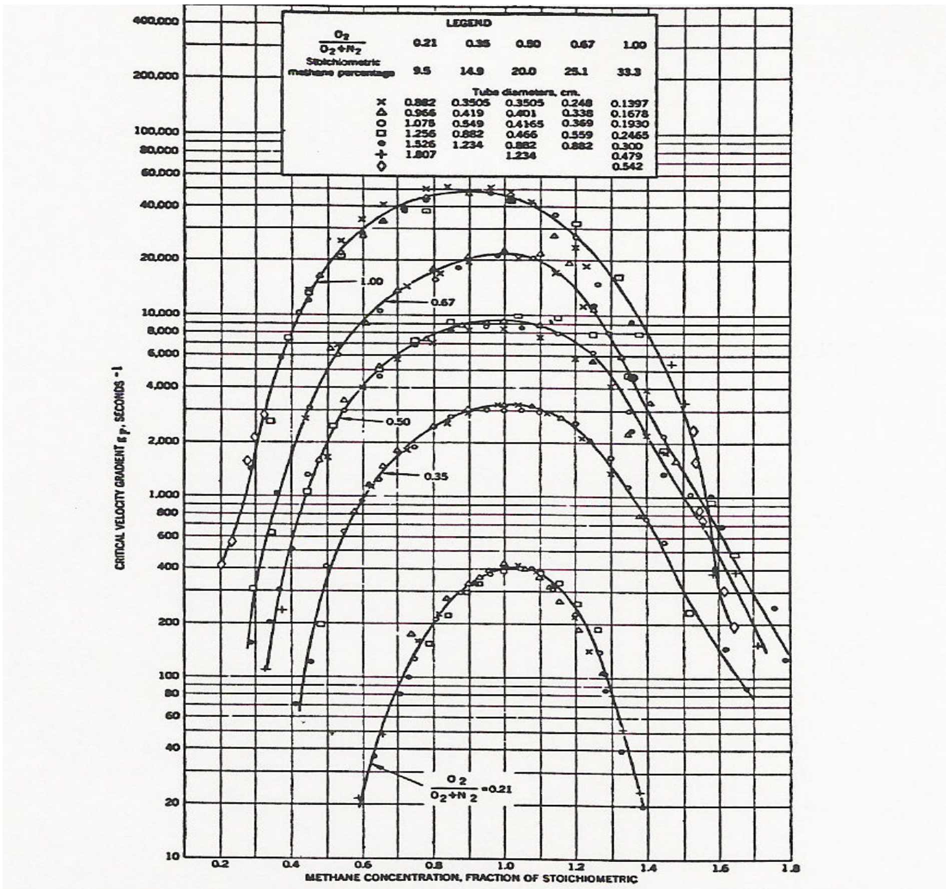


FIG. 99. Critical boundary velocity gradients g_F for flash-back in cylindrical tubes different diameters. Methane-oxygen-nitrogen mixtures at room temperatures and nospheric pressure (Harris, Grumer, von Elbe, and Lewis).

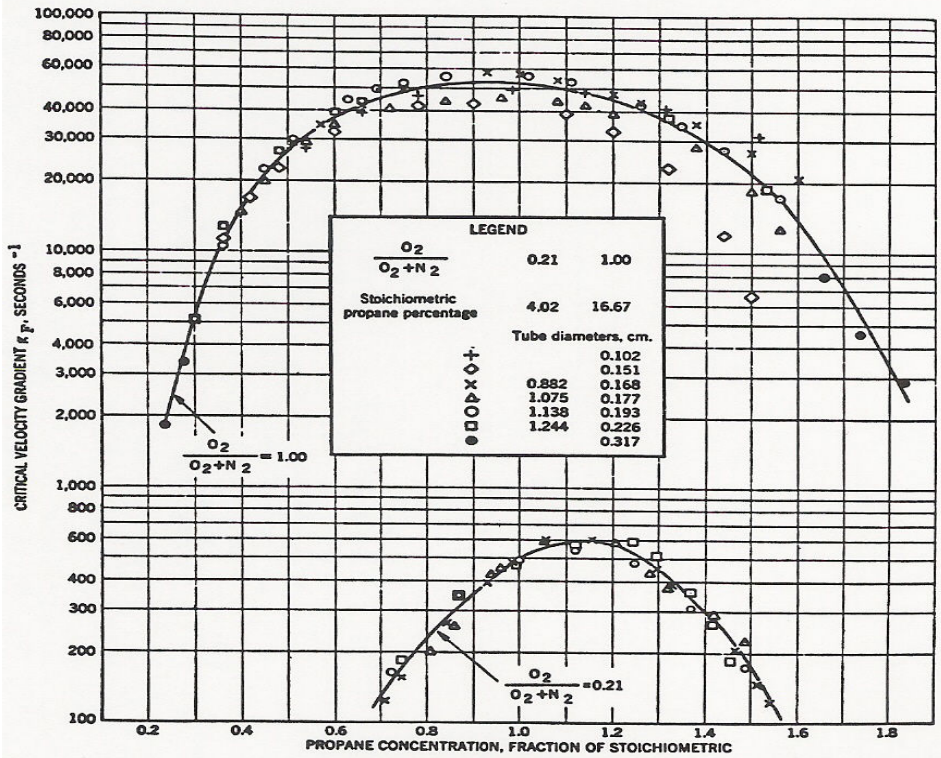


FIG. 100. Critical boundary velocity gradients g_F for flash-back in cylindrical tube different diameters. Propane-oxygen-nitrogen mixtures at room temperature an mospheric pressure (Harris, Grumer, von Elbe, and Lewis).

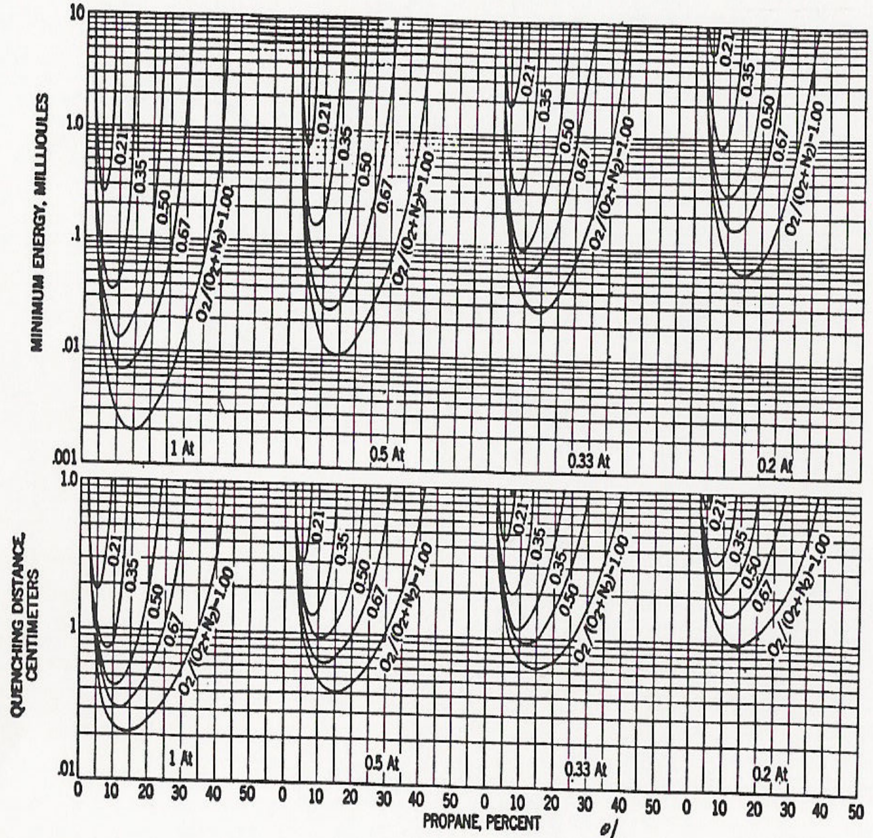


Fig. 162. Minimum spark ignition energies in millijoules of propane, oxygen, and nitrogen at 1 atmosphere pressure and lower, and quenching distances between flanged electrodes for the same mixtures.

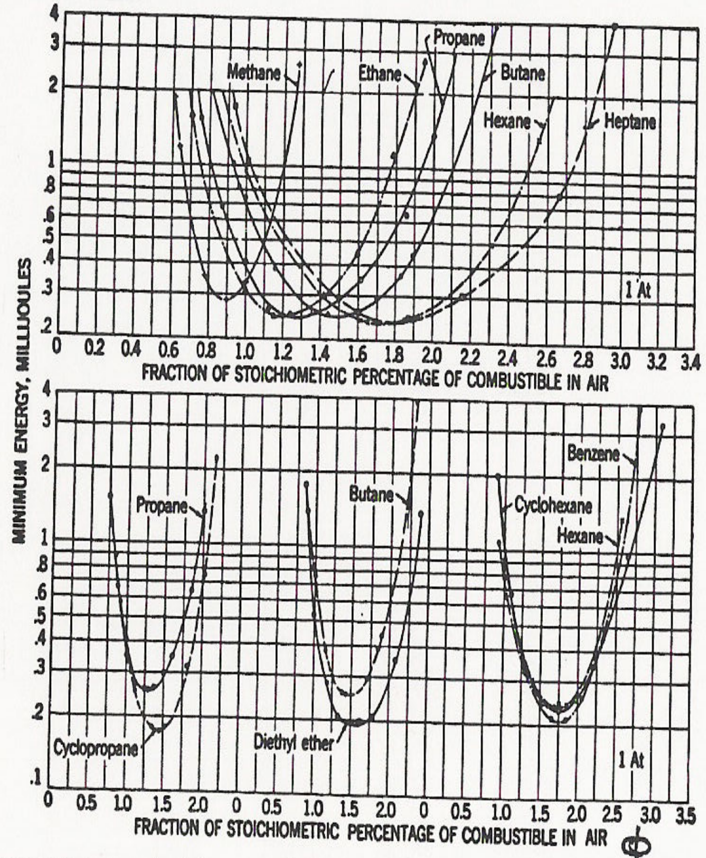


Fig. 163. Minimum ignition energies of combustible-air mixtures in relation to the stoichiometric percentage in air.

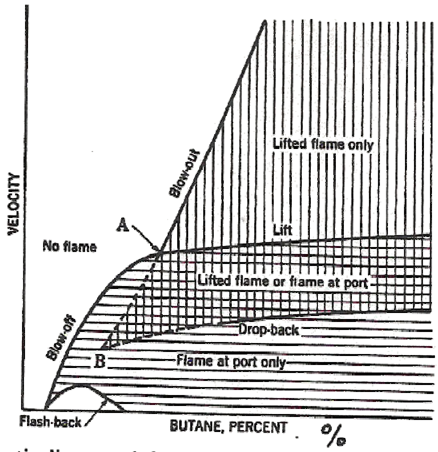


FIG. 107. Schematic diagram of the characteristic regions of flame stability (Wohl, Kapp, and Gazley).

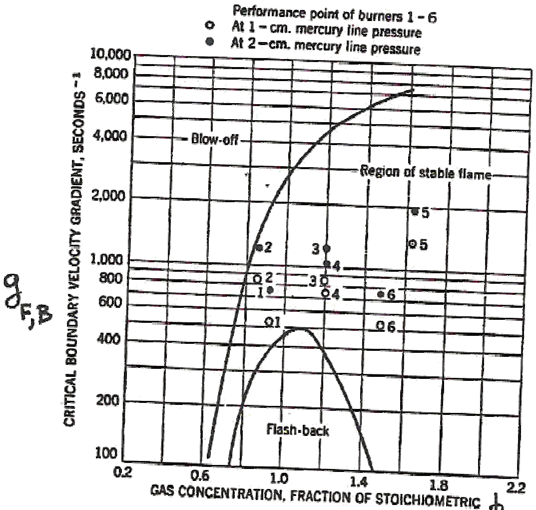


FIG. 267. Composite flame-stability diagram for paraffin-air mixtures (Lewis and Grumer).

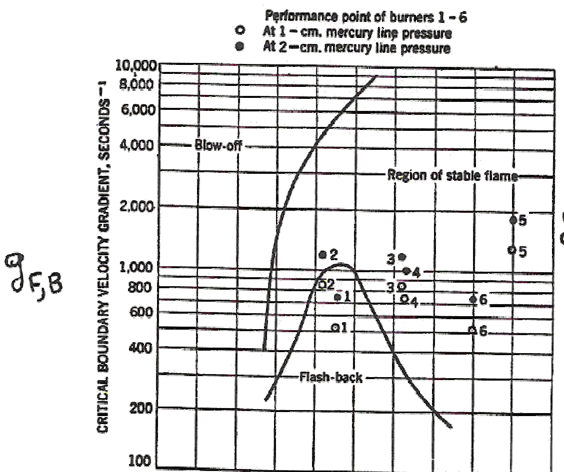


FIG. 268. Approximate flame-stability diagram for 60% propane and 40% hydrogen mixture (Lewis and Grumer).

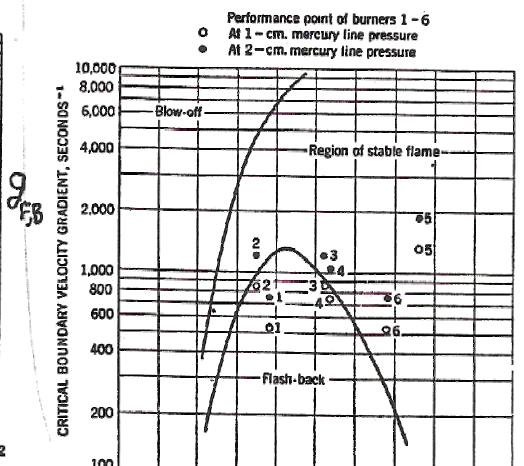


FIG. 269. Approximate flame-stability diagram for 40% propane and 60% hyd[illegible] mixture (Lewis and Grumer).

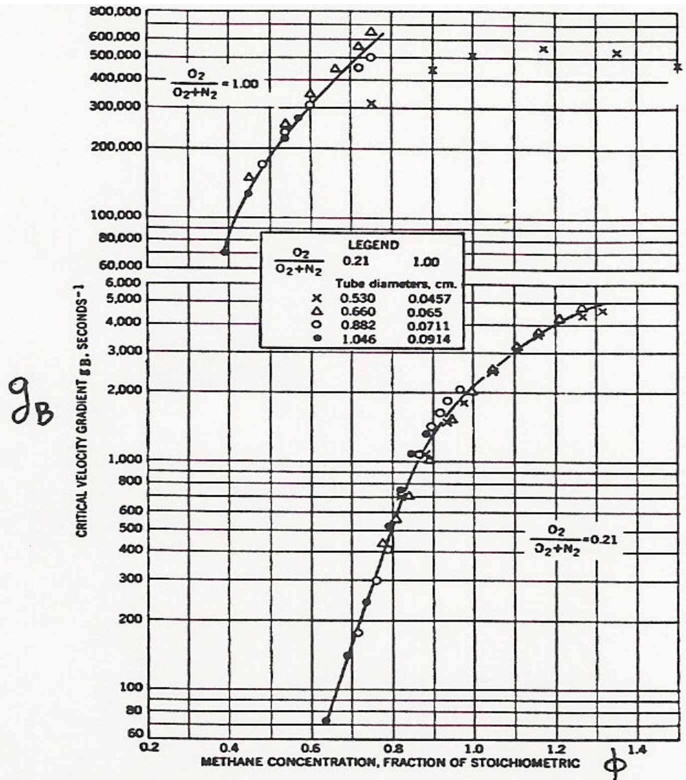


FIG. 101. Critical boundary velocity gradients g_B for blow-off in cylindrical tubes of different diameters. Methane-oxygen-nitrogen mixtures at room temperature and atmospheric pressure (Harris, Grumer, von Elbe, and Lewis).

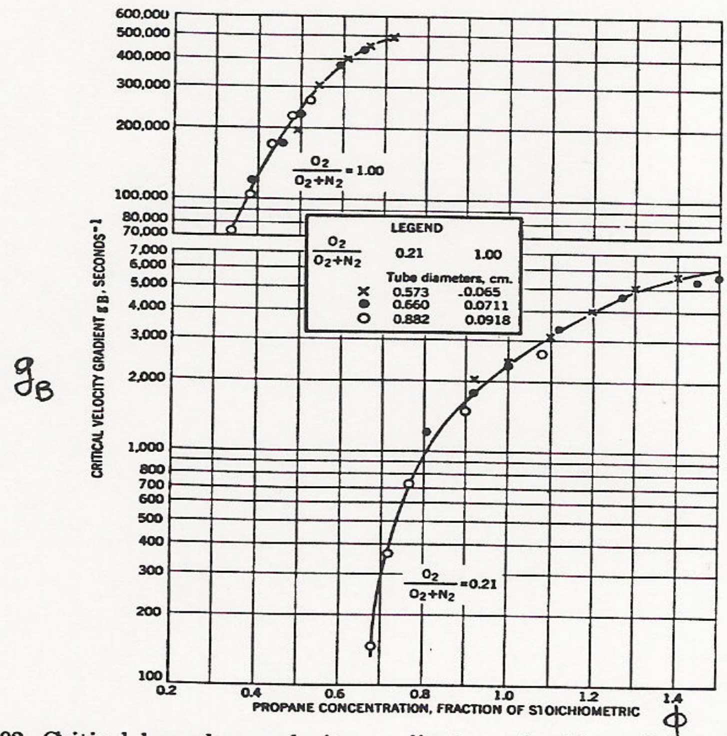


FIG. 102. Critical boundary velocity gradients g_B for blow-off in cylindrical tubes of different diameters. Propane-oxygen-nitrogen mixtures at room temperature and atmospheric pressure (Harris, Grumer, von Elbe, and Lewis).