Note: This is a reference cited in *AP 42, Compilation of Air Pollutant Emission Factors, Volume I Stationary Point and Area Sources.* AP42 is located on the EPA web site at www.epa.gov/ttn/chief/ap42/

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Chemical Engineers' Handbook

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FOURTH EDITION

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Table 9-10. Combustion Data for Various Alcohol and Benzol Fuels

Fuel	O_2 required for combustion, lb./lb.	Air required for combustion, lb./lb.	Products of combustion, lb./lb.			Approximate higher heating value, B.t.u./lb.
			CO_2	H_2O	N_2	
Ethyl alcohol (C_2H_6O)	2.08	9.04	1.91	1.17	6.95	12,780
Methyl alcohol (CH_4O)	1.5	6.50	1.38	1.12	5.0	9,550
Benzol (C_6H_6)	3.1	13.32	3.39	0.69	0.24	18,000
Denatured alcohol	1.81	7.83	1.66	1.15	6.02	11,600
50% mixture of alcohol and benzol	2.45	10.60	2.53	0.92	8.16	14,200

and highly specialised devices. The devices that use any one of these higher-priced fuels are usually made as a unit by the manufacturer, who supplies detailed instructions as to quality of fuel suitable and method for using most satisfactorily.

Industrial use of such liquid fuels as shale oils, coal tar, tar oil, and distillates or residues from low-temperature carbonisation of coal is sometimes justified. Suitable methods for using such materials are to be learned only by trial, and little in the way of generalisation can be offered.

Coal Tar. Coal tar is a by-product of the manufacture of coke and of coal gas. This tar is a viscous mixture consisting, for the most part, of aromatic compounds. Its heating value varies from 15,000 to 16,500 B.t.u./lb. In order to burn coal tar in regular fuel-oil burners, the tar must be filtered and preheated to such a temperature that its viscosity is reduced to that of the oils for which the particular burner is designed.

Tar Oil. Tar oil is obtained by the distillation of coal tar and consists of so-called "creosote oil," "anthracene oil," and other materials. Its heating value is about the same as that of coal tar.

Gasoline. The composition of an average gasoline is carbon, 83.5 to 85 per cent; hydrogen, 15.0 to 15.8 per cent; nitrogen plus sulfur plus oxygen, 0 to 1 per cent. The heating value is about 20,000 B.t.u./lb. Gasoline containing tetraethyl lead should not be used for heating equipment.

Kerosene. The average composition of kerosene is carbon 85 per cent, hydrogen 16 per cent. Sulfur should not exceed 0.125 per cent (United States government specification). The heating value varies from 20,000 to 21,000 B.t.u./lb. The government specifications require a distillation end point of 625°F. maximum and a flash point of 115°F. minimum.

Alcohol and Benzol. Table 9-10 gives pertinent combustion data for various alcohol and benzol fuels.

GASEOUS FUELS

Description of Various Gaseous Fuels

Natural Gas. Gaseous fuels consist of natural gas and various manufactured or by-product gases. Only natural gas has a substantial market for steam generation as the other gases are too high in cost except for those plants obtaining them as their own by-products.

Typical natural-gas analyses are given in Table 9-11. It will be noted that natural gas generally contains a high percentage of methane (CH_4) with varying amounts of ethane (C_2H_6) and inerts (CO_2, nitrogen, and helium). Most natural gas delivered by utilities will have under 10 per cent of inerts. The heating value will generally range between 1000 and 1100 B.t.u./cu. ft. for standard conditions of 62°F. and 30 in. Hg.

Natural-gas pipe lines are rapidly being extended into all the principal industrial areas of the United States. Natural gas generally is available for industrial process use but for boilers may be available only on an "interruptible" basis. That is, in winter, domestic home heating takes priority over boiler use, and gas for boiler fuel will be discontinued while the demands for home requirements are met. This requires industrial consumers with "interruptible" contracts to maintain a second fuel, oil or coal, for winter use.

Liquefied Petroleum Gases. These distillation products come from both natural gas and the oil refineries. These gases, particularly propane, are much used for domestic service. They are supplied either in tanks or by pipe lines. They are clean fuels, suitable for almost any service where they are priced competitively. Table 9-12 gives the properties of these fuels. Table 9-13 gives their combustion data.

Acetylene. The use of acetylene as a fuel and illuminant is generally limited to cutting and welding operations requiring high flame temperature, to small isolated lighting plants, and to single "carbide" lights. It is made from calcium carbide and water. To avoid a dangerous rise in temperature, sufficient water (about ½ gal./lb. carbide) should be present in the generator. The crude gas contains as impurities ammonia, hydrogen sulfide, and phosphine, which must be removed before the gas can be used for indoor illumination. Acetylene forms explosive acetylides, particularly with copper, has wide explosive limits when mixed with air, and is explosive per se at pressures of 5.9 lb./sq. in. gage or greater and at 15 lb./sq. in. requires only 540°C. to set it off. It ignites at 635°C. at atmospheric pressure. Its use as a liquid is therefore prohibited, and it is ordinarily dis

Table 9-11. Analyses of Fuel Gases*

Gas	Constituents of gas, % by volume									Sp. gr. air = 1.000	Cu. ft. of air required for combustion of 1 cu. ft. gas	B.t.u./cu. ft. gross	B.t.u./cu. ft. net	Products of combustion, cu. ft./cu. ft. gas				Ultimate CO_2, %	Net B.t.u./cu. ft. of the products of combustion	Flame temperature corrected for dissociation
								Illuminants						CO_2	H_2O	N_2	Total (dry)			
	CO	CO_2	H_2	N_2	O_2	CH_4	C_2H_6	C_3H_8	C_4H_{10}											
Natural gas, Texarkana	....	0.80	....	3.20	....	96.00	....	....	....	0.57	9.17	967	873	0.97	1.92	7.29	8.26	11.7	80.2	3580
Natural gas, Cleveland	....	....	....	1.30	....	80.50	18.20	....	....	.65	10.70	1131	1025	1.17	2.16	8.50	9.67	12.1	81.1	3600
Natural gas, Oil City, Pa	....	....	....	1.10	....	67.60	31.30	....	....	.71	11.70	1232	1120	1.30	2.29	9.26	10.56	12.3	81.7	3620
Retort coal gas (horizontal)	8.6	1.5	52.5	3.5	0.3	31.4	.....	1.1	1.1	.42	5.00	575	510	0.50	1.21	3.99	4.49	11.2	83.5	3665
Coke-oven gas	6.3	1.8	53.0	3.4	.2	31.6	.....	2.7	1.0	.42	5.19	588	521	.51	1.25	4.13	4.64	11.0	82.7	3660
Coke-oven gas, Koppers ovens	6.8	2.2	47.5	6.0	.3	33.9	.....	2.6	0.9	.44	5.23	591	525	.54	1.23	4.19	4.73	11.4	82.3	3650
Carbureted water gas	33.4	5.9	34.6	7.9	.9	10.4	.....	6.7	2.2	.65	4.37	536	496	.74	0.75	3.54	4.28	17.2	88.5	3815
Blue water gas	42.8	3.0	49.9	3.3	.5	0.5	.....	...	...	.53	2.26	308	281	.46	.51	1.82	2.28	22.3	89.7	3800
Theoretical water gas	50.0	.....	50.0	.....	.....	.....	.....	...	...	.52	2.39	325	298	.50	.50	1.89	2.39	20.9	90.3	3830
Anthracite producer gas	24.0	7.5	16.5	50.2	.6	1.2	.....	...	...	.85	1.05	134	124	.33	.19	1.36	1.69	19.5	65.6	3000
Bituminous producer gas	27.0	4.5	14.0	50.9	.6	3.0	.....	...	...	.86	1.24	150	140	.35	.19	1.49	1.84	19.0	69.2	3160
Blast-furnace gas	27.5	10.0	3.0	58.0	1.0	0.5	.....	...	...	1.00	0.78	102	100	.38	.04	1.21	1.59	23.9	61.0	2800
Oil gas (Protero 1920)	6.8	1.0	59.2	2.7	0.1	25.4	.....	3.8	1.0	0.35	4.91	575	510	.47	1.21	3.91	4.38	10.7	84.2	3725

* From "Combustion," 2d ed., Table 20, p. 34, American Gas Association, 1926. Reproduced by permission.