Fossil fuel combustion flue gases

Source: U.S. EPA
Coal-fired power plant flue gas stacks

Fossil fuel combustion flue gases refer to the emissions of combustion product gases resulting from the burning of fossil fuels such as coal, oil, and natural gas.[1]

Most fossil fuels are combusted with ambient air being the oxidant (as differentiated from combustion with pure oxygen) and this article is based on the use of ambient air as the combustion air.

Discussion of flue gas components

Since ambient air contains about 79 volume percent gaseous nitrogen (N_2),[2] which is essentially non-combustible, the largest part of the flue gases from most fossil fuel combustion is uncombusted nitrogen. The next largest part of the flue gas is carbon dioxide (CO_2) which can be as much as ten to fifteen volume percent or more of the flue gas. This is closely followed in volume by water vapor (H_20) created by the combustion of the hydrogen in the fuel with atmospheric oxygen. Much of the s*moke* seen exiting from flue gas stacks is this water vapor forming a fog cloud as it contacts cool air and condenses into water. The above photograph is a good example of the white plumes formed by the condensation of water vapor in the emissions from some flue gas stacks (often referred to as chimneys or smokestacks).

Flue gas pollutants

A typical flue gas from the combustion of fossil fuels will also contain some small amounts of nitrogen oxides (NOx), sulfur dioxide (SO_2) and particulate matter.[1] The nitrogen oxides are derived from the nitrogen in the ambient air as well as from any nitrogen-containing compounds in the fossil fuel. The sulfur dioxide is derived from any sulfur-containing compounds in the fuels. The particulate matter, sometimes termed*black carbon*, is composed of very small particles of solid materials and very small liquid droplets which give some flue gases their smoky appearance.

Calculated flue gas emissions from burning fossil fuels

The steam generators in large electric power plants and the process furnaces in large petroleum refineries, petrochemical and chemical plants, and municipal solid waste incinerators burn very considerable amounts of fossil fuels and therefore emit large amounts of flue gas to the ambient atmosphere. The table below presents the total amounts of flue gas typically generated by the burning of fossil fuels such as natural gas, fuel oil and coal. The data in the table were obtained by stoichiometric calculations.[3][4]

It is of interest to note that the total amount of wet flue gas generated by coal combustion is only ten percent higher than the flue gas generated by natural gas combustion, but the total amount of dry flue gas generated by coal combustion is about 22 percent higher than the flue gas generated by natural gas combustion. This is due to the fact that burning natural gas produces more water vapor than does the burning of coal since the hydrogen-to-carbon ratio of natural gas is higher than that of coal.

However, what may be of more interest is that the amount of CO_2 emitted by coal combustion is about 1.7 times the amount emitted by natural gas combustion.

EXHAUST FLUE GAS GENERATED BY COMBUSTION OF FOSSIL FUELS
(In SI metric units and in U.S. customary units)

Combustion Data	Fuel Gas	Fuel Oil	Coal
Fuel properties:			
Gross caloric value, MJ / Nm³ [see (1) below]	43.01		
Gross heating value, Btu / scf [see (2) below]	1,093		
Gross caloric value, MJ / kg		43.50	
Gross heating value, Btu / gallon		150,000	
Gross caloric value, MJ / kg			25.92
Gross heating value, Btu / pound			11,150
Molecular weight	18		
Specific gravity		0.9626	
Gravity, °API		15.5	
Carbon / hydrogen ratio by weight		8.1	
weight % carbon			61.2
weight % hydrogen			4.3
weight % oxygen			7.4
weight % sulfur			3.9
weight % nitrogen			1.2
weight % ash			12.0
weight % moisture			10.0
Combustion air:			
Excess combustion air %	12	15	20
Wet exhaust flue gas:			
Amount of wet exhaust gas, Nm³/ GJ of fuel	294.8	303.1	323.1
Amount of wet exhaust gas, scf / 10^6 Btu of fuel	11,600	11,930	12,714
CO_2 in wet exhaust gas, volume %	8.8	12.4	13.7
O_2 in wet exhaust gas, volume %	2.0	2.6	3.4
Molecular weight of wet exhaust gas	27.7	29.0	29.5
Dry exhaust flue gas:			
Amount of dry exhaust gas, Nm³/GJ of fuel	241.6	269.3	293.6
Amount of dry exhaust gas, scf / 10^6 Btu of fuel	9,510	10,600	11,554
CO_2 in dry exhaust gas, volume %	10.8	14.0	15.0
O_2 in dry exhaust gas, volume %	2.5	2.9	3.7
Molecular weight of dry exhaust gas	29.9	30.4	30.7
CO_2 emissions, Nm³/GJ of fuel	26	38	44
CO_2 emissions, scf / 10^6 Btu of fuel	1,027	1,484	1,733

(1) Normal cubic metres (Nm³) are at 0 °C and an absolute pressure of 101.325 kPa.
(2) Standard cubic feet (scf) are at 60 °F and an absolute pressure of 14.696 psi.

References

- Compilation of Air Pollutant Emission Factors, from the website of the United States Environmental Protection Agency.
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Source: http://www.eoearth.org/view/article/51cbf2487896bb431f6a896e/?topic=51cbfc98f702fc2ba812eaa6