Part 1

AIR PROTECTION FROM POWER INDUSTRY EMISSIONS

1.3. Sulfur oxide emission reduction

1.3.1. Formation mechanism and standards for sulfur oxide emissions

1.3.1.1. Formation mechanism of sulfur oxides at organic fuel combustion

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Any organic fuel, except natural gas, contains sulfur as a part of its organic fraction (organic sulfur), or in the form of pyrite FeS_2, included in its mineral component.

Sulfur dioxide and trioxide are produced at oxy-firing of fuel sulfur:

$$S + O_2 = SO_2;$$

$$2FeS_2 + 5O_2 = 2FeO + 4SO_2.$$

Hydrogen sulfide H_2S is formed at reductive combustion for generator gas production, which is then burned, converting to the same dioxide:

$$H_2S + 3O_2 \rightarrow 2SO_2 + 2H_2O.$$

Concentration of sulfur dioxide SO_2 in flue gases is typically in the range of 0,02 ... 0,5%, and this substance itself does not affect energy generation in fact as already mentioned. A part of sulfur dioxide is oxidized to the trioxide SO_3 in the process of fuel combustion:

$$2SO_2 + O_2 = 2SO_3.$$

Trioxide content in flue gases due to sorption of this substance by the boiler heating surfaces as well as by ash (the latter absorbs sulfur trioxide in the electric field especially actively) decreases in boiler gas ducts, so that its concentration before the chimney is usually 5 ... 10 ppm.

In the presence of water vapor in gas-phase, sulfur trioxide immediately forms sulfuric acid, usually in the form of vapor:

$$SO_3 + H_2O = H_2SO_4.$$

Although a concentration of this substance in flue gases is low (5 ... 60 ppm), it leads to sulfuric acid dew point at which flue gas temperature is selected, affecting a thermal efficiency of the boiler. Sulfuric acid dew point is also one of the key factors that ensure efficient operation of electrical gas purification.

Up-to-day TPP is considered to be such a one, which has the required gas treatment facilities to ensure energy generation in accordance with the normative SO_2 content in flue gases, considering all the consequences of emitting of the unnormalized sulfur dioxides into environment at the present time.

Geographically, high-sulfur coal deposits in Russia are located in the European part of Russia and in the Urals. Coal of Siberia and the Far East usually contains low sulfur. Domestic energy black oil contains about 2,0 ... 3,5% of sulfur.

Sulfur dioxide concentration in flue gases is measured by the following:

- by mass, referred to 1 m^3 under normal conditions, g/m^3;
- in volume fractions of flue gases (volume concentration), % or in million fractions, ppm (parts per million);
- by mass per unit of heat generated at fuel combustion (specific emission), g/MJ.

Relationship between the units of mass concentration and fractions of gas volume is given below:

Unit	%	ppm	g/m^3
%	1	10^4	29,3
ppm	10^{-4}	1	$29,3 \cdot 10^{-4}$
g/m^3	0,0341	341,3	1

It should be noted that naming the values of mass and volume concentration of sulfur dioxide, it is always needed to indicate an oxygen excess in flue gases. Specific emission is not associated with air suction into the gas path of the boiler, in contrast. Sulfur dioxide specific emission (*n*, g/MJ) is related to 1 MJ of the burned fuel, which eliminates a need to control air suction into the gas path. Specific emission *n* is connected with the mass concentration *c*, g/m^3 by the following:

$$c = n\frac{Q_i^r}{V_g^0} \qquad (1.38)$$

where Q_i^r - low fuel calorific value, MJ/kg; V_g^o - specific flue gas volume generated at combustion of 1 kg of fuel and the given air-fuel ratio, m^3/kg.

Mass concentration *c* is converted into specific emission *n*, g/MJ:

Initial specific emission of sulfur oxide *n'*, g/MJ, from the boiler without considering binding of this substance in the furnace by ash components is evaluated as follows:

$$n = c\frac{V_g^0}{Q_i^r} \qquad (1.39)$$

$$n' = 20{,}5S^r, \qquad (1.40)$$

where $S^r = S^w / Q_i^r$ — reduced fuel sulfur content, % kg/MJ;

S^w — sulfur content in the working mass of fuel,%.

Conversion of specific emissions of sulfur dioxide to the volume concentration and vice versa is carried out through the mass concentration.