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Absorption Flue Gas Cleaning – "Spheric O-element" New Prototype of First Stage and HCl Reduction

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Current interest in environmental issues is closely linked to issues of waste treatment. Produced waste is mostly categorized as dangerous and other types of waste. Waste which is not suitable for material utilization may be processed in several other ways; it may be landfilled, thermally processed, etc. Though landfilling may seem like the best solution, it causes piling of produced waste, polluting of surroundings and underground water, spread of infection and so on. Processes of thermal decomposition are necessary not only for detoxication, but also for reduction of negative impacts on the environment. At the same time, waste serves as secondary source of energy.
However, thermal processing has its drawbacks as well. These include release of emissions into the atmosphere, residual waste and water pollution. Waste incinerators are equipped with various types of technologies for flue gas cleaning which require various physical-chemical technological procedures and devices to efficiently clean flue gas. Dry, semi-dry and wet flue gas cleaning methods are used for capture of gaseous components of acidic nature (SO_2, HCl). This paper focuses on wet cleaning.
This paper presents results of research at two stage equipment for flue gas cleaning and describes new prototype of first stage wet cleaning of flue gas. This "spheric O-element" prototype replaces old type Venturi scrubber equipment for intensive contact between gas and liquid. Paper will also give results from experimental measuring of efficiency of HCl absorption in various operating conditions.

1. Introduction

Regarding structure of waste, incineration plants are usually divided into two categories, i.e. municipal solid waste incineration plants and hazardous waste incineration plants. Hazardous waste comprises various components of different concentrations (Chopey, 2004). Therefore, hazardous waste incineration plants have to engage more sophisticated procedures and technologies for reduction of these hazardous materials than municipal solid waste incineration plants. Based on this knowledge, Fig. 1 gives an overall view of hazardous waste incineration plant (Figure 1).

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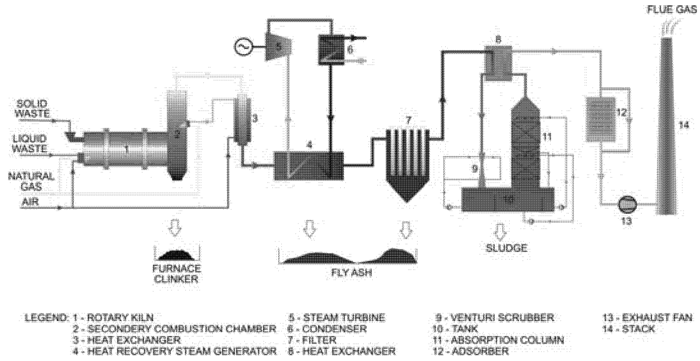

Figure 1: Overall view of experimental unit for flue gas cleaning

Waste incinerators are equipped with various types of technologies for flue gas cleaning which devices to efficiently clean flue gas. Dry, semi-dry and wet flue gas cleaning methods are used for capture of gaseous components of acidic nature (SO_2, HCl). Pilot plant of flue gas wet scrubber was put into service at the Institute of Process and Environmental Engineering (IPEE) (Figure 2). Experimental equipment of two-stage flue gas cleaning consists of "O-element" first stage (Filip, 2009) and second stage of packed column (Jecha, 2010). O-element (Figure 3) device developed at IPEE substitutes Venturi scrubber device which is commonly used as a first stage of absorption in practice. Design of packed column consists is packs with structured packing.

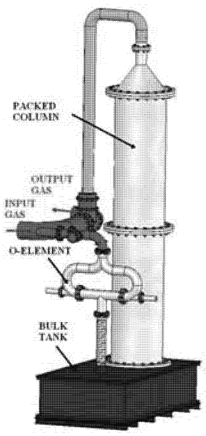

Figure 2: Overall view of experimental unit for flue gas cleaning

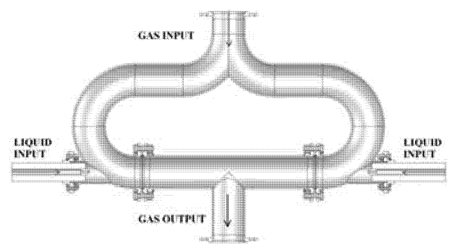

Figure 3: Description of flowing in O-element

2. Spheric O-element - new prototype of first stage

First stage of wet flue gas cleaning is designed as O-element which substitutes device for intensive contact between gas and fluid which is called Venturi scrubber. Homogenizer called O-element is a piece of device which serves for homogenization of gaseous-liquid mixture and was already used for similar purposes (Bébar et al., 1975).

Main objective of the O-element (Figure 3) is a perfect mixing of individual flows and formation of large mid-phase area which is secured by formation of dispersed flow. This further enables increase of mass transfer intensity during absorption. Other objectives include minimization of hydraulic resistance.

Very interesting technological solution of first stage wet scrubber using new type umbrella plate scrubber is presented by (Caiting et al., 2008). Similar solution was applied absorption for PCF device (Caiting et al., 2011). Further on, already implemented methods of acid components reduction using venturi scrubber are improved (Gamisans et al., 2002). Combined NO_x and SO_2 removal from flue-gas mixture in an integrated wet scrubber-electrochemical cell system (Moon et al., 2009) is not that commonly used.

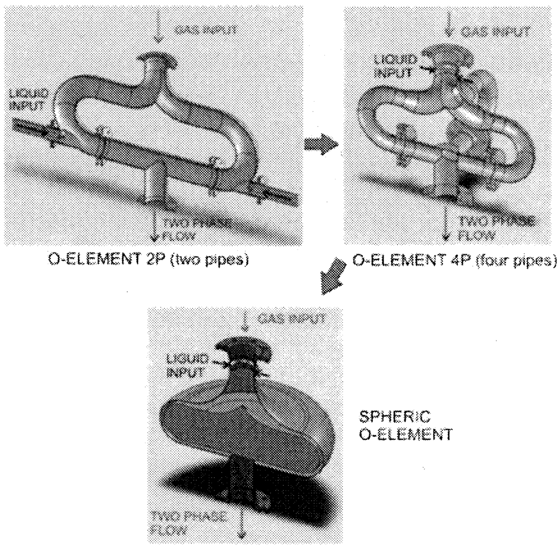

Figure 4: Development of O-element prototype

Gradual change from plane type O-element (further on as O-element 2P) to special arrangement gave rise to 4 pipe O-element (further on as O-element 4P). Final product is a prototype of spheric O-element (Fig. 4) with the main reason being minimization of dimensions for easier flue gas streaming because municipal solid waste incineration plants and hazardous waste incineration plants produce flue gas of flow rate reaching dozens of thousands of m^3/h. O-element 2P is too big for this amount of flue gas. Design of individual prototypes required maintaining the high efficiency for reduction of harmful substances along with low hydraulic resistance as opposed to conventional Venturi scrubber.

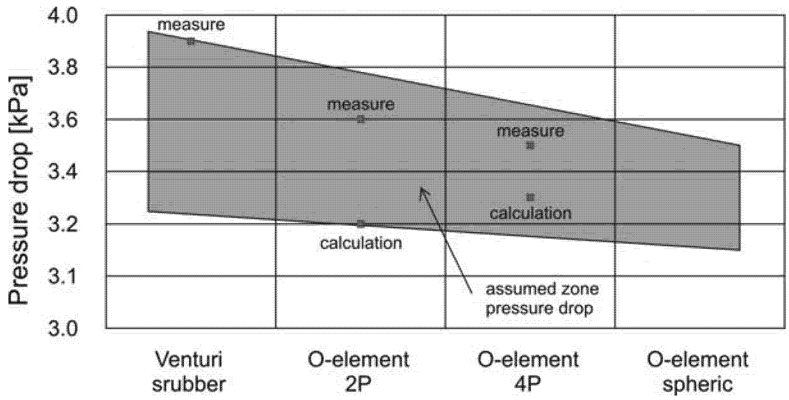

Figure 5: Comparison of hydraulic resistance of individual O-element prototypes with gas flow rate being 1000 Nm^3/h and liquid flow rate being 1.5 m^3/h

Measured and calculated values of hydraulic resistance for Venturi scrubber (Filip, 2009), 2P O-element (Jecha, 2010) and 4P O-element (Jecha, 2010) give a clear picture that hydraulic resistance is declining (Figure 5). Results in Figure 5 clearly show reduction of pressure drop at 2P O-element, as opposed to Venturi scrubber, which in average amounts to 15 %.

3. Reduction of HCl and other gaseous emissions

Technical measuring was carried out at a unit for wet cleaning of flue gas located in industrial waste incineration plant in order to determine efficiency of reduction of HCl and other harmful substances. Block of wet flue gas cleaning is divided into three parts (Figure 6). First, flue gas enters into Venturi Scrubber where liquid is injected into stream of flue gas and cools down the temperature of flue gas from 170 °C to ca. 50 °C. This is succeeded by multistage filling column with separated absorption liquids. NaOH solution is added to third stage of absorption in order to improve the process as it enhances its efficiency. Tanks deposited below wet scrubber block are arranged in cascades. Pure water and NaOH solution are supplied into third stage tank, excess of absorption liquid from third stage goes into second stage tank and then into first stage absorption. Absorbent from first and second stage absorption is continuously taken into neutralization station.

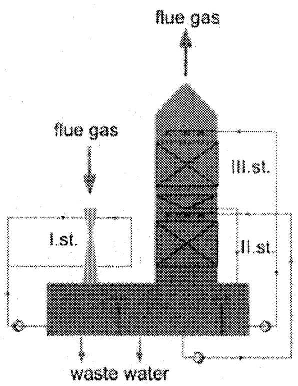

Figure 6: Scheme of unit for wet flue gas cleaning

Measuring of pH of absorbent in first stage (Venturi Scrubber) averaged 4.86; 7.44 at second stage and 7.17 at third stage. Technical measuring was conducted at the inlet and outlet from wet flue gas cleaning, O_2, SO_2, HCl, HF content was determined here. Technical measuring was also conducted between first and second stage, however, only O_2 and SO_2 content could be determined. Data in Table 1 clearly show that wet scrubber block is highly efficient in SO_2 reduction (99% efficiency) and HCl and HF reduction (60% reduction), see Table 1.

Table 1: Efficiency of reduction of particular substances in wet scrubber block

Element	**Reduced in 1st stage absorption**	**Reduced in 2nd and 3rd stage absorption**	**Not captured (released into air)**
	(% of inlet amount)		
SO_2	67.18	32.01	0.81
HCl	65.01		34.99
HF	57.05		42.95

4. Conclusion

First stage of wet flue gas cleaning is designed as O-element which substitutes device for intensive contact between gas and fluid which is called Venturi scrubber.

This prototype was researched using numerical and experimental methods and further developed. Original spatial arrangement transformed into spheric O-element. This type of equipment is usually analysed for its absorption efficiency and pressure drop. Increase of absorbent flow rate and constant flue gas flow rate results in increase of pressure drop. Measured pressure drop from O-element 2P was compared to calculated pressure drop from O-element 2P and 4P and measured pressure drop from Venturi scrubber. If we consider pressure drop from O-element 2P lower by 0.5 kPa than from Venturi scrubber, we may assume that operating savings for the ventilator will reach dozens of thousand of Czech Crowns a year; e.g. operating savings for the ventilator in waste incineration plant with flue gas flow rate of 26 000 m^3/h reach ca. 2 520 EUR/y (prices for electricity at 0.08 EUR/kWh, 80% ventilator efficiency and 7500 h/y of operating time.). This is the feedback for design of spheric O-element where even lower pressure drop and similar pollutant reduction efficiency is expected.

Absorption of gaseous pollutants, mostly HCl was also researched at industrial waste incineration plant and the assumption about high efficiency of pollutant reduction was proved. Measured data show that original reduction of HCl at 0.762 mg/m^3 was decreased to 0.258 mg/m^3, which corresponds to 65% reduction efficiency. HF content was also analysed and original reduction of HCl at 0.308 mg/m^3 was decreased to 0.128 mg/m^3, which corresponds to 57% reduction efficiency. Reduction of SO_2 reached 99% efficiency, original content of 257 mg/m^3 was decreased to 2 mg/m^3.

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