17th European Symposium on Computer Aided Process Engineering – ESCAPE17
V. Plesu and P.S. Agachi (Editors)

Novel types of equipment for off-gas cleaning

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Abstract

This paper describes three new technologies/equipments, which effectively reduce the amount of pollutants in off-gases produced by incineration plants, refineries or various chemical and similar plants. These equipments have low investment and operational costs and effectively remove pollutants.

Keywords

waste gas, off-gas, flue gas, air pollutants, emission reduction

1. Introduction

Process and chemical industry produce large amount of off-gases polluted by several types of dangerous pollutants, such as: VOC (volatile organic compounds), CO (carbon monoxide), NO_X (nitrogen oxides), SO_2 (sulfur dioxide), HCl (hydrogen chloride), HF (hydrogen fluoride), solid particulates and PCDD/F (dioxins). In order to meet more and more strict legislation requirements it is necessary to remove these pollutants from off-gases using modern technologies with small investment and operational cost as well as with high efficiency. Therefore three novel equipments have been developed to effectively remove pollutants present in off-gases. Up-to-date computational methods (e.g. Computational Fluid Dynamics - CFD) together with experience and know-how were applied in order to support research and development as well as a feedback from industrial applications.

2. Novel types of equipment

2.1. Equipment for thermal and catalytic treatment of waste gases polluted by VOC and carbon monoxide (alternatively NO_X)

The equipment in Figure 1 has been designed to remove VOC, carbon monoxide and NO_X [1]. It should be used especially for treatment of small flow rates of off-gas with a large concentration of the already mentioned pollutants. For the removal of VOC and carbon monoxide thermal oxidation process with temperatures in the combustion chamber higher than 600°C or catalytic oxidation with temperatures between 150 do 350°C are used. For catalytic oxidation catalysts Pt/Al_2O_3 or Pd/Al_2O_3 are used most frequently but others including Rh, CrO_3, CuO, Co_2O_3 or V_2O_5 distributed as layers on Al_2O_3, SiO_2, TiO_2 carriers or zeolites can also be used. For the removal of NO_X the process of selective catalytic reduction (SCR) is used i.e. at temperatures between 200 to 250°C flue gas passes through a catalyst bed (usually V_2O_5/TiO_2), where NO_X with NH2-X compounds react (with X = H, CN or $CONH_2$). These compounds are injected into the flow of flue gas before the equipment.
This equipment helps to process off-gas with a concentration of pollutants from hundreds of mg/m_N^3 to units of g/m_N^3 [2]. For the treatment at lower levels (tens of mg/m_N^3) and high flow rates (up to hundreds of thousands m_N^3/h) it is advised to combine this equipment with units for concentration of off-gases, i.e. adsorbtion systems or rotary concentrators.
The equipment consists of three main parts – cylindrical combustion chamber, catalytic reactor and coaxial heat exchanger, these parts are integrated into one equipment. Preheating of waste gas provides the special heat exchanger, which consists of several concentric cylindrical plates. Flue gas from the combustion chamber (catalytic reactor) and waste gas (which is heated by flue gas) spiral flow in the spaces between these plates. Thanks to this solution good effectivity of heat exchange is achieved. Thermal/catalytic oxidation of waste gas proceeds in cylindrical combustion chamber/catalytic reactor. The combustion chamber is placed inside the coaxial heat exchanger in its axial axis and the catalytic reactor is placed below the combustion chamber. Therefore the equipment is very compact – the combustion chamber, catalytic reactor and heat exchanger are concentrated in small volume.

Figure 1 Compact equipment

There are no pipelines needed for connection of combustion chamber, catalytic reactor and heat exchanger in this case. Next advantage of designed construction is low heat losses. It follows easier achieving of the auto-thermal regime (it is not necessary to supply next auxiliary fuel into the natural gas burner), namely at combustion of higher concentration of combustibles pollutants. Then the auxiliary fuel is used at starting/stopping equipment only or in time, when the concentration of combustibles pollutants in waste gas is low.

2.2. Equipment for wet cleaning of flue gases polluted by SO_2, HCl and HF with new type of homogenizer "O-element"

The equipment for wet cleaning of flue gases polluted by SO_2, HCl and HF with a new type of a homogenizer "O-element" is an alternative to present equipments for wet cleaning of flue gases with a traditional homogenizer "Venturi" [3]. The equipment is suitable especially for incineration plants of municipal and industrial waste.

In the wet cleaning system liquid absorbent is injected into the flow of flue gas. The absorbent is usually an alkali solution of lime or NaOH, which reacts with pollutants dissolving resp. diffusing into the liquid [4]. Transition area is the most important factor for complete cleaning. Usually the equipment for wet cleaning of gases has a two levels design. The first level is frequently created by a homogenizer of "Venturi" or "O-element" type, the second level is created by a packed column.

The homogenizer "O-element" design has been described in Figure 2, where the large transition phenomenon is created in the area where both flows meet.

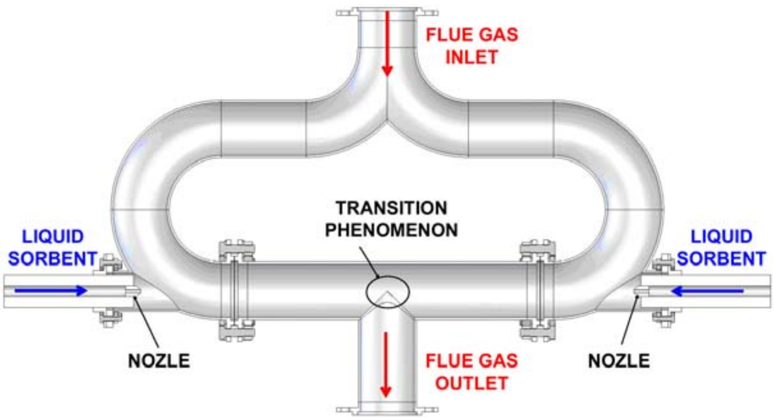

Figure 2 Equipment for wet cleaning of flue gases

The advantage of this equipment is a low pressure drop compared to "Venturi" type whilst maintaining the same level of wet cleaning. Lower pressure drop can notably reduce investment and operation costs for transport of flue gases in industrial plants.

2.3. Combined experimental equipment for cleaning of waste gases polluted by solid particulates, SO_2, HCl, HF and heavy metals (alternatively NO_X or PCDD/F)

Combined experimental equipment (see Figure 3) has been developed to verify the technology for cleaning of flue gases in chemical and process industry, mainly the following processes of flue gases cleaning: filtration/catalytic filtration of solid particulates and PCDD/F [5], dry cleaning of flue gases – i.e. reaction of SO_2, HCl and HF with injected adsorbent $NaHCO_3$, adsorption of VOC, heavy metals and PCDD/F on a layer of active carbon [6, 7] and selective catalytic reduction NO_X (SCR).

Developed experimental equipment is designed to process 1000 m^3/h of waste gas (flue gas) at max. temperature 250°C and will be connected to a process with a underpressure of about 10 kPa. Maximum processed levels of pollutants: solid particulates – 2 g/m_N^3, VOC – 500 mg/m_N^3, SO_2 – 2,000 mg/m_N^3, HCl – 1,000 mg/m_N^3 and HF – 50 mg/m_N^3.

The design of this experimental equipment is rather specific. The most important is a mobility feature and its installation directly at industrial plants. For this reason, it is a stand alone equipment and apart from connection to the power line (~400V/63A) and standard mains of water, it is completely self-sufficient. From a design point of view, the experimental equipment has been divided into filter, replaceable side modules and drive unit.

Figure 3 Equipment filtration/adsorption (SCR)

Filter contains 15 filter bags with a diameter of 152 mm and is 2,500 mm long. Two replaceable modules are on the each side of the filter. These modules can be adapted for adsorption process of waste gas, or for storage of a catalyst for selective catalytic reduction NO_X (SCR). Area of adsoprtion layer is 3.5 m^2 and high of the layer is 0.25 m. The last part of the experimental equipment is so-called drive unit, which will supply transport of waste gas and pressure gas for pulse-jet regeneration of filter bags. This module also contains adsorbent injection system (especially for sodium bicarbonate), and can also be further equipped with a liquid injection system (injection of NH2-X compounds).

The main contribution of an experimental multifunctional equipment is that individual technologies for off-gas reduction can be tested, modelled, and optimized directly in operation mode, i.e. without previous laboratory analysis and scaling-up.

3. Controlling of equipments/processes

To be able to verify the efficiency of these new types of equipments for off-gas cleaning it was necessary to design experimental pilot unit with a control and collecting system of the measured data. An example of a controlling combined experimental equipment for waste gas cleaning is described in 3.1.

3.1. Controlling of combined experimental equipment for cleaning of waste gases polluted by solid particulates, SO2, HCl, HF and heavy metals

Whole control unit is proposed like a mobile switchboard with PC controlling of experimental equipment (see Figure 4). Controlling of whole equipment and record of measured data are accomplished by software „Control Web“. Control equipment is connected to mains (~400V/63A). A colour touch monitor is one component of the control equipment. The filter (3 kW) and individual components of driving module (like fan (15 kW) and compressor (1,1 kW)) are connected by means of the control unit. All connections are made as unmistakable connectors.

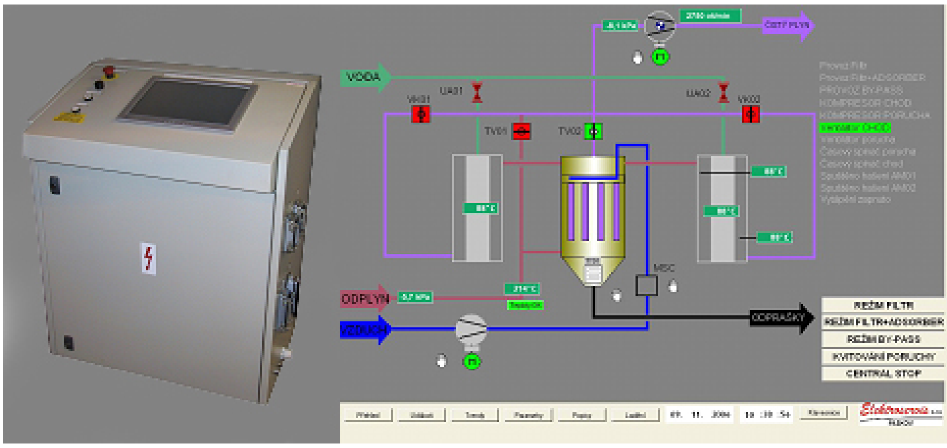

Figure 4 Mobile control panel and its screen

Control and collecting system is expandable and is suitable for sensors with current output 4/20 mA. The basic number of inlets and outlets for control equipment is BI = 24, BO = 16, AI = 8, AO = 8. The control equipment is able to display 22 actions and 8 trends at the same time.

4. Conclusions

Three pilot units for off-gas cleaning with control and collecting system have been designed. Needed data for design of similar equipments (for industry) were obtained from experimental tests. The equipment for thermal or catalytic treatment of waste gas has already been applied in four cases in the chemical and food industry. Further two equipments are planned to be tested directly in industry.

Acknowledgements

We gratefully acknowledge financial support of the Ministry of Education, Youth and Sports of the Czech Republic within the framework of research project No. MSM 0021630502 "Waste and Biomass Utilization focused on Environment Protection and Energy Generation" as well as support from the Czech Science Foundation within project No. 101/05/2469.

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