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An optimal algorithm to assess the compliance with the T_{2s} requirement of Waste-to-Energy facilities

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Abstract

The gas resulting from the incineration of waste must be raised, after the last injection of combustion air, in a controlled and homogeneous fashion and even under the most unfavorable conditions, to a temperature of at least 850 °C for at least two seconds (Art. 50.2 Directive 2010/75/EU). This norm and its variations (i.e. 1,100 °C for 2 s if the chlorine content of the incinerated waste exceeds 1% by mass), called "T_{2s} requirement", oblige all Waste-to-Energy (WtE) plant operators to monitor the post-combustion conditions and to turn on auxiliary burners in the occurrence of noncompliance with such a requirement. In a WtE boiler, the determination of the mean temperature reached by combustion gas in the post-combustion zone, after an ideal residence time of 2 s, is carried out by an algorithm implemented in the Distributed Control System (DCS) of the plant. Currently, since many different algorithms are used, it appears that further investigation on this subject is required.

This work considers, as a case study, an existing WtE boiler and, by means of a calibrated long-furnace model of the post-combustion zone, investigates all the possible operating conditions as well as their connections with the monitored variables. The most relevant influences on the T_{2s} temperature are highlighted and some control algorithms are proposed.

The results so far obtained show that the T_{2s} is affected both by boiler load and gas-side fouling in the same way and for the same extent. Therefore, since gas-side fouling in the post-combustion zone is an uncontrollable variable, boiler load is not usable in as input variable of a reliable algorithm. Moreover, the results highlight the significant role that can be played in the algorithm for the estimation of the T_{2s} by the oxygen content in secondary flue gas.

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1. Introduction

The gas resulting from the incineration of waste must be raised, after the last injection of combustion air, in a controlled and homogeneous fashion and even under the most unfavorable conditions, to a temperature of at least 850 °C for at least two seconds [1]. This norm and its variations (i.e. 1,100 °C for 2 s if the chlorine content of the incinerated waste exceeds 1% by mass), called "T_{2s} requirement", oblige all Waste-to-Energy (WtE) plant operators to monitor the post-combustion conditions and to turn on auxiliary burners in the occurrence of noncompliance with such a requirement. In a WtE boiler, the determination of the mean temperature reached by combustion gas in the post-combustion zone, after an ideal residence time of 2 s, is carried out by an algorithm implemented in the Distributed Control System (DCS) of the plant. Currently, no standard algorithm structure exists. A survey of the used methods was carried out and showed that different variables are measured and used for the estimation of the T_{2s} temperature, as well as algorithm parameters vary from plant to plant and even among the identical incineration lines of the same WtE plant. Table 1 summarizes the variables used by the algorithms adopted in five WtE plants.

Table 1. Variables used by the algorithms adopted in five WtE plants.

	Plant 1	**Plant 2**	**Plant 3**	**Plant 4**	**Plant 5**
Measured temperatures	X	X	X	X	X
Boiler load	X	X		X	X
Flue gas flowrate at stack			X		
Concentration of oxygen in flue gas				X	X

The T_{2s} temperature is normally estimated by means of such a sort of algorithm, which is typically calibrated by means of experimental procedures (like the one adopted in Germany [2]), based on the measurement of temperature in the post-combustion zone with suction pyrometers. However, the measurements cannot be presumed to be representative of any working condition of the boiler, since they are normally carried out in a limited set of conditions. The only operating parameter whose influence is explicitly investigated during the measurements is usually the boiler load (i.e. the steam production).

The T_{2s} temperature primarily depends on the mean temperature of flue gas in the post-combustion zone and on the flowrate of such gas. More schematically, it can be related to the flue gas flowrate and to its temperature at the entrance of the post-combustion zone. However, both these data are not easily retrievable: the flowrate is usually measured only at the stack of the plant, with some minutes of delay and after the unmeasured dilution operated by the ambient air introduced along the gas path; the temperature can be measured with a reasonable accuracy only by means of laboratory instruments, like suction pyrometers, and for limited time.

To warrant the compliance with the norm, during WtE plant operation, the T_{2s} temperature must be estimated with a sufficient safety margin based on easily available data, like the boiler load, the concentration of oxygen, measured temperatures, etc. The preference of most operators is to limit as much as possible the number of variables involved, by considering only those directly measured on the boiler, rather than those measured on other plant sections (like the flue gas flowrate, normally measured only at the stack).

The aim of this work is to investigate the dependence of the T_{2s} temperature of a WtE boiler from controllable (e.g. boiler load, oxygen concentration) and exogenous (e.g. LHV of the burned waste, boiler fouling) variables, to define possible algorithms that, based on few easily available operating data, can estimate with sufficient reliability the T_{2s} temperature. The sought result, considering also the effect of the exogenous factors, should always be a conservative estimate of the actual T_{2s}, featuring a sufficient safety margin with respect to the normative requirement.

2. Case study

The boiler of an existing WtE plant, on which some measurements have been recently carried out, has been considered as a case study for this work. This allowed calibrating all the parameters of the model later described