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# Investigation of Process Optimization Measures in MSWI Plants with an Online-Balancing Program

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**Abstract**

In Germany municipal solid waste is treated in more than 60 incineration plants (MSWI plants) with an overall capacity to treat over 16 million tons per year. A number of operational measures are under development to improve waste thermal treatment processes including the reduction of pollutant emissions, the improvement of ash quality, the increase of efficiency, and the reduction of corrosion. Although much work has been done in this area there still exists a high potential for additional process optimization.

In order to investigate the effects of different optimization measures, detailed information is required about the operational behaviour of the process as it relates to the actual operating conditions. As such, an Online-Balancing program has been developed that relates the actual operational conditions of a MSWI plant with real time calculated values using detailed mass and energy balances for the different process units of the plant.

## 1. Introduction

The optimization of municipal solid waste incineration plants (MSWI) requires detailed information and data about the actual operating conditions. This information can be obtained from the plant's existing process control system. Modern process control systems utilize computers to collect and store process data as well as to control the actual process conditions. These control systems can report the actual measured process values in the plant as well as the time behaviour of these values. Process data includes air and flue gas flow rates, flue gas component concentrations ($CO_2$, CO, $O_2$, $N_2$, $H_2O$, etc.), mass rate of steam generated as well as steam temperature and pressure. In the newer MSWI plants the process control systems can provide sufficient information to allow mass and energy balances to be modelled for each of the process units and consequently for the overall process.

The following information is of special interest for optimization of MSWI plants:

- Mass flow (kg/hr), composition (weight percent) and calorific value (kJ/kg) of the waste and fuels fired in the combustion process
- Flow rates of combustion air and estimated infiltration air into the combustion systems
- Air flow rates used in the flue gas treatment system (compressed air, pulse air, or air used to convey solids)
- Combustion air preheating temperatures
- Total, electric and thermal efficiency ratios for the overall process
- Boiler and turbine efficiency
- Heat needed for condensate and feed water preheating, etc.

With this data the operational staff would have sufficient information to perform real time process optimization calculations and to implement process modifications of plant operations in order to increase the system efficiencies. Furthermore, it is envisioned that some of the manual process changes could be programmed into the existing control system to automate the optimization process.

Existing MSWI plants are not equipped with possibilities to model mass and energy balances “online”. However, with such a tool of Online-Balancing operational staffs are able to manually adjust the operational parameters in order to optimize the overall process.

**2. Basic Principles of Balancing**

As is usual in process engineering, implementing a model for mass, material and energy balances for an MSWI plant first requires that the boundaries be established for each unit operation (for aggregates, apparatuses, etc. [1]) in the MSWI plant process. Figure 2.1 shows a schematic of a typical MSWI plant with the main input streams being the waste, air, energy, water and operation material, and the main output streams being the flue gas, residues, energy for utilization and (heat) losses. Single unit operations can be combined to form the paramount balance units which in this paper will be termed as (calculation) modules, for example for the bunker, firing, boiler, scrubber, etc. The combination of modules leads to single process units and the paramount process subdivisions such as the main thermal process (incineration process), energy conversion system, flue gas treatment system, etc. (Figure 2.1).

Once the boundaries of each module were defined the next process

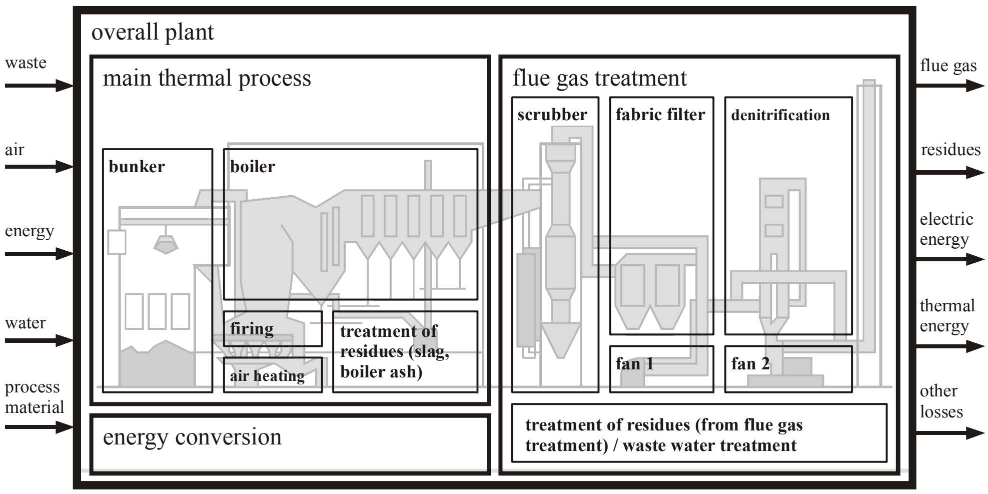


*Figure 2.1. Balance modules for modelling a typical MSWI plant.*

engineering step is to define the mass, material and energy balances for each of the modules taking into consideration each of the input and output streams. Simply stated, the sum of all input mass and energy streams to a module must equal the sum of all output mass and energy streams from the module.

Some streams are difficult if not impossible to measure in real time and as such these streams will require an alternative calculation strategy. For example, the mass flow and composition of the actual solid waste feed to the incinerator is difficult to measure. This is calculated backward by the Online-Balancing program in the subdivision process "air preheating, firing and boiler" from the measured values within the subdivision process "flue gas treatment". The calculation strategy therefore is shown in Figure 2.2.

In modern MSWI plants the connection of the Online-Balancing program can be realized directly via a dedicated OPC-Server[1]. Where possible, the

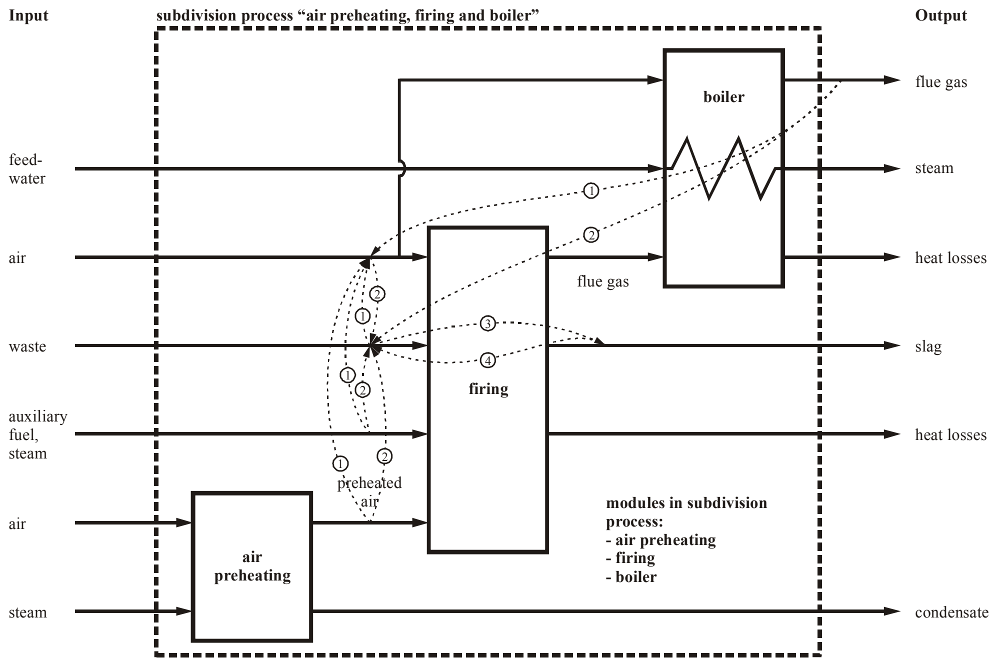


*Figure 2.2. Subdivision process "air preheating, firing and boiler" in the MSWI-plant Schwandorf – Calculation strategy for mass flow and composition of waste (within step 1 to 4, illustration of important mass and energy streams).*

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[1] OPC...OLE (Object Linking and Embedding) for Process Control. An OPC-Server is a hardware device driver enabling OPC capable standard software (OPC-Clients) to communicate with external devices without additional programming work.

program uses measured data when performing the heat and mass balance real time calculations. This measured data is imported into the program and validated before use in the model as follows:

1. Reads and records the measured data from process transmitters via the OPC-Server,

2. Converts the measured digital or analogue signals and correcting the values to the calibration of the measuring device (if necessary),

3. Checks that the measured value is valid and the transmitter is not in a failed state. This is accomplished by checking if the value is within an individually defined ratio (upper and lower limit) and

4. Checks that primary operational parameters are at steady state (The model can be used to verify that the MSWI plant primary operational parameters are at steady state in accordance with German guideline VDI 3986 [2], [3]).

Furthermore, the measured values can be checked that they do not contradict with other (in over determined balancing equations) measured data and – when indicated – these data can be mathematically corrected within the model.

The Online-Balancing program uses, in addition to the measured values, stream data that can not be measured in real time and as such must be estimated and entered into the program by the user. These estimated values (in the program termed as parameters) must be checked to determine their potential impact on the results from the real time calculations. An example showing the impact a deviation from the actual conditions of the estimated ash content and atmospheric humidity on the calculation of the waste mass flow rate is shown in Figure 2.3. The graph in Figure 2.3 indicates the following:

- High deviations from actual conditions in the estimated atmospheric humidity has a relatively minor impact on the calculated mass flow of waste – at a 25% deviation in humidity the mass flow of waste is only impacted by approximately 2%.
- High deviations from actual conditions in the estimated ash content also has a minor impact on the calculated waste feed – at a 25 % deviation in ash content the mass flow of waste is only impacted by 8 %.

This analysis shows that it is unnecessary to continuously (real time) measure the atmospheric humidity and ash content in order to achieve good for the waste mass flow rate.

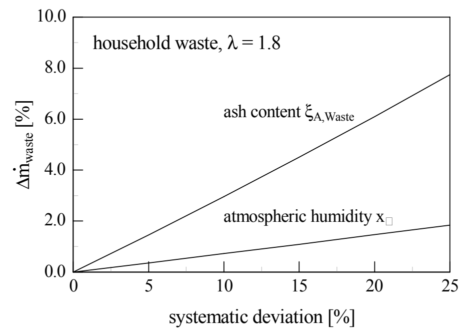


*Figure 2.3. Example for Propagation of uncertainties of measurement.*

In some modules the equations used in the model will not balance because the model is over determined with more (measured and estimated) values than required. In these processes it is possible to apply mathematical methods like the “Gaussian correction principle” [4] to detect and remove systematic measured deviations.

## 3. Process Optimization

In order to increase the overall net energy output from an MSWI plant it is necessary to either reduce the demand of external energy to the system or to increase the production of heat and/or electric power (Figure 3.1). One easy way to increase the overall net energy output from an MSWI plant is to produce more electric power which can be accomplished by increasing the enthalpy difference between live and exhaust steam on the steam turbine. Since the live steam properties are dictated by the boiler design and operating temperatures the enthalpy difference must be obtained by lowering the exhaust steam parameters (number 9 in Figure 3.1).

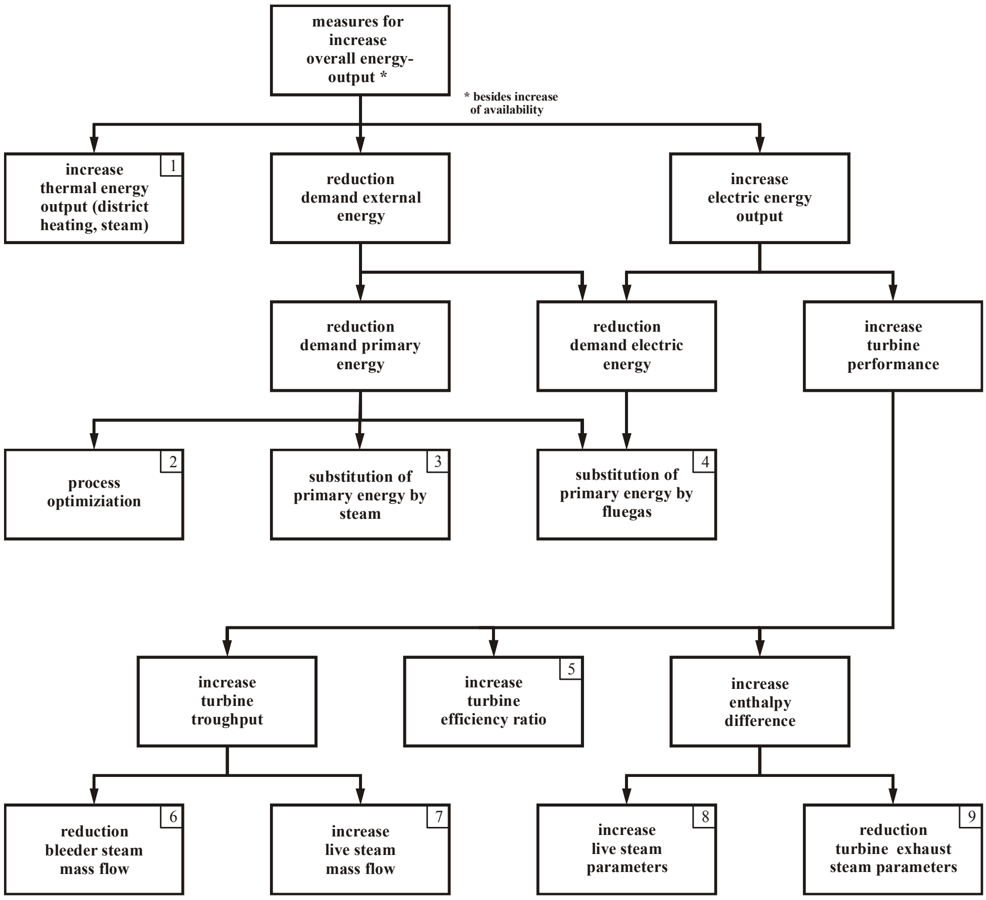


*Figure 3.1. Methodology for Increasing the Net Energy Output of MSWI Plants.*

In the Schwandorf MSWI plant this optimization measure was implemented by increasing the capacity of the fans on the air cooled condensers in order to “sub-cool” the condensate. The sub-cooling of the condensate is limited by the design capacities of the fans as well as by the water content of exhaust steam (turbine blade corrosion increases with increasing water content).

It is difficult to estimate the affect on the energy efficiency of the plant with the implementation of this optimization measure because of the complex interferences between all the operating parameters. These parameters include higher energy supply to the air cooled condenser fans, the increase in electric energy production in the turbine, the increase in heat needed for condensate preheating and the improvement of thermal efficiency of the water steam cycle.

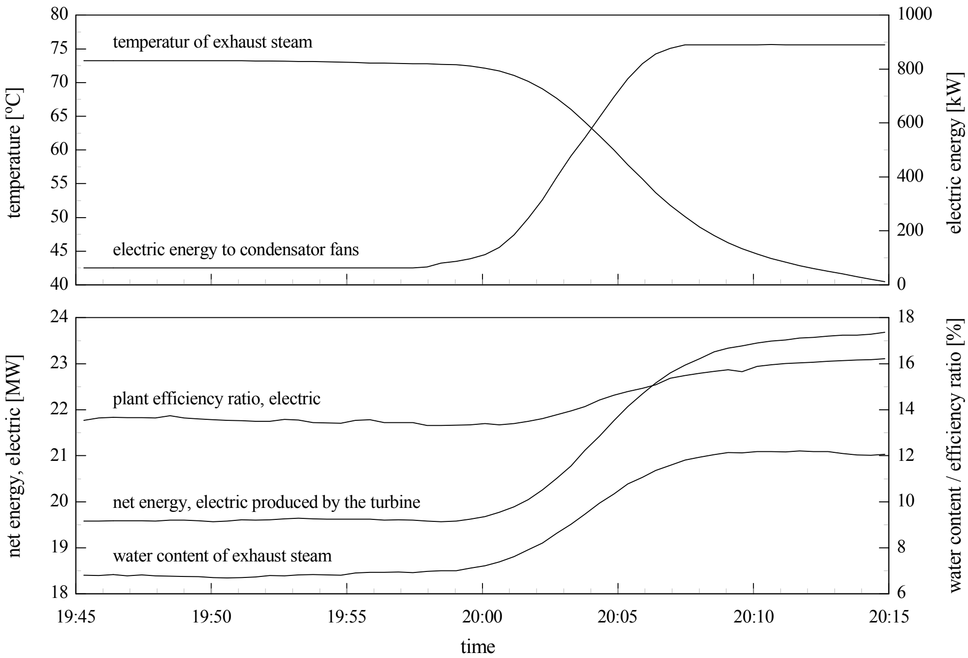


*Figure 3.2. Reducing exhaust steam parameters in the MSWI plant Schwandorf - results of investigation.*

The calculated plant efficiency ratio, electric and the water content of exhaust steam (assuming evaporation equilibrium) is plotted against the measured values of turbine exhaust steam temperature, electric energy to the fans on the air cooled condenser and the net electricity produced by the turbine is shown in Figure 3.2 for an investigation period of ½ hour. An approximately 800 kW increase of energy to the condenser fans results in this example in an increase in electric energy production of approximately 4 MW and therewith in a significant increase in energy efficiency of the plant from approximately 13.5 % to 16 %. The maximum water content of exhaust steam in this example was 12 %.

It is obvious from this example that the Online-Balancing program has application in the optimization of the condenser performance in order to increase energy efficiency and to minimize the potential for turbine blade corrosion from water droplets. Additionally the program would assist in preventing the condenser from freezing in colder seasons. Therewith the program can be used to optimize the turbine-condenser performance under actual varying process conditions.

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