Proceedings of the 18th Annual North American Waste-to-Energy Conference
NAWTEC18
May 11-13, 2010, Orlando, Florida, USA

NAWTEC18-3513

Industrial-scale R&D in Challenging Times

Ralf Koralewska

MARTIN GmbH für Umwelt- und Energietechnik
P.O. Box 40 12 29, 80712 Munich / Germany
Ralf.Koralewska@martingmbh.de, http://www.martingmbh.de

ABSTRACT

Thermal treatment of waste using grate-based systems has gained world-wide acceptance as the preferred method for sustainable treatment of waste. It is therefore necessary to develop innovative processes with safe process engineering technology that guarantee the treatment of waste in accordance with ecological and economic constraints in addition to complying with legal requirements.
This paper documents successful use of industrial-scale R&D using MARTIN technology in providing solutions for optimizing grate-based Energy-from-Waste technologies in terms of protection of climate and resources, reduction of environmental impacts as well as political, regulatory and market aspects.

Keywords: Energy-from-Waste, grate-based combustion systems, industrial-scale R&D

1. INTRODUCTION

Energy-from-Waste technologies have been confronted with numerous, changing challenges over the last decades. Various important factors have to be considered, not only the reduction of waste volume and mass and the destruction and separation of pollutants. Environmental concerns have demanded that flue gases are no longer a significant source of emissions, and waste and residues remaining after thermal treatment are to be transformed into reusable products. In view of the continual depletion of raw materials, sustainable processes for the recovery of recyclables are becoming increasingly important. Efficient use of the energy recovered (in the form of electricity, process steam, district heating / cooling) by developing innovative concepts is also in demand. In Europe, potential exists to increase the contribution of Energy-from-Waste to over 10% of the overall renewable energy produced, as half of the energy contained in municipal waste is of biogenic origin. All of these aspects have been pushed by political and public pressure, regulations as well as the financial market situation. Any new demand leads to an increase in the overall complexity of the thermal treatment process. Additional skills and competence are needed for plant design, process control and operation. Nevertheless, cost-benefit and eco-efficiency analyses clearly show that these additional efforts should be made. Whenever any new challenges occur, MARTIN GmbH works on optimizing its Energy-from-Waste technologies by means of industrial-scale R&D projects.
Primary and secondary measures have been tested in laboratories and on a semi-industrial and industrial scale, and have then been successfully implemented in Energy-from-Waste plants. There have been substantial developments in various fields: combustion control using fuzzy logic and an IR camera to determine the fuel bed temperature; NO_x reduction by means of Very-Low-NO_x concepts, the optimization of overfire gas distribution and SNCR; improvement of the energy efficiency of Energy-from-Waste plants through new technologies and concepts; the SYNCOM and SYNCOM-Plus processes, dry bottom ash discharge as well as treatment and recirculation of residues with recovery of recyclables.

2. GRATE-BASED COMBUSTION TECHNOLOGY

Thermal treatment of waste using a grate-based system has gained acceptance as the preferred system for sustainable treatment of waste world-wide. The reason for this is that the energy content of the waste is utilized and that quality products and residues are produced. In addition, modern flue-gas treatment processes reduce gaseous emissions to a minimum. Nevertheless grate-based processes must also keep pace with international requirements by further innovative development.

2.1 High Heating Value Fuels

Recent years have seen significant increases in the average heating values of wastes in Central Europe. Essentially, this can be attributed to recycling measures, separate recovery of waste streams, and pre-treatment and processing procedures in modified waste management concepts. As a result of the above and due to the increasingly frequent application of energy recovery procedures for commercial waste, the fuel input to Energy-from-Waste plants combusting household waste has been significantly influenced. In response to the associated increased thermal load, water-cooled systems using various technologies were developed and used for air-cooled forward-acting grate systems.
To keep abreast of the trend for generating products from waste pretreatment processes, e.g. fractions with high heating values produced by mechanical or mechanical-biological waste pre-treatment, or by pretreatment pro-

cesses for generating secondary fuels (Refused Derived Fuel), industrial-scale tests were carried out at a plant combusting household waste with a MARTIN reverse-acting grate. Fuels with heating values (LHV) of 13,000 kJ/kg (5,589 BTU/lb), 17,000 kJ/kg (7,309 BTU/lb) and 19,000 kJ/kg (8,169 BTU/lb) were combusted for periods of several days. The impact on the combustion system, the residues produced and the flue gas composition were examined. Operating parameters such as underfire air preheating and distribution, overfire air flow and distribution were adjusted to the relevant fuel heating values. Grate bar temperatures were measured at various points and were only approx. 20 K above the underfire air temperature [4].

Through its agitating motion towards the front grate end and intimate mixing of the fuel, the MARTIN reverse-acting grate always ensures good thermal protection for the grate bars due to the "insulating" fuel and ash layer on the grate surface. The combustion control system makes automatic adjustments to deal with different heating values and can therefore be used to thermally treat the most varied fuels. Water-cooling of the grate bars is not necessary even in the case of high heating value ranges.

These experiences are further confirmed by investigations carried out within the framework of a research project to determine the fuel bed temperatures in two Energy-from-Waste plants combusting household waste. In this context, measurements were made on a MARTIN reverse-acting grate in both conventional combustion mode and in SYNCOM mode, during which the underfire air is enriched with oxygen. During the investigations, an infrared camera was used to determine the fuel bed surface temperature. Insertable thermocouples in the fuel bed, ball instruments and temperature probes added directly to the waste were also used. In-depth chemical and mineralogical analyses were carried out on the bottom ash. The experiences obtained and measurements performed conclusively proved that the MARTIN reverse-acting grate does not require water-cooling even for high heating value ranges.

2.2 Combustion control

Today's waste combustion plants are operated flexibly so that different goals such as maximum fuel throughput, maximum energy yield, minimized pollutant emissions or maximum service period can be implemented. Different goals require different control concepts, and MARTIN GmbH consequently developed and optimized the MICC system (MARTIN Infrared Combustion Control) on a large scale for combustion control. This is a flexible, extensible and independent system that can be integrated in conventional superordinate control systems. Due to its innovative, modular architecture, the MICC system can be complemented by the MARTIN operating mode concept, thereby allowing the Energy-from-Waste plant to be optimized to meet different operator-specific requirements and acquiring functionalities beyond those associated with classical combustion control. The MICC system comprises a hardware and software concept, so that it appears to the outside environment as an independent component with a clearly defined interface. The hardware is based on a high-end industrial PC that is available internationally over the long term. The software comprises various functional modules that are integrated in the MICC system:

- Fuzzy control of the combustion system
- Infrared camera including image analysis for process optimization
- Operating mode concept
- Operational data logging and visualization

MARTIN-specific closed-loop control system knowhow is implemented in the MICC system. There is a choice of three control modes: "steam flow", "furnace temperature" or "steam flow / IR temperature". The quality of steam flow / IR temperature control is significantly improved by the IR camera controller.

The combustion control system uses fuzzy control, an interesting alternative to conventional control, particularly with regard to waste combustion. The basic advantage of fuzzy control is its ability to find the "best compromise". Waste combustion can be further optimized using special IR-camera technology for particular bandwidths. An infrared camera system that records the temporal and spatial behaviour of the fuel bed surface from the boiler roof is used to do this. The image information delivered by the infrared camera is processed in an image analysis program developed to meet MARTIN specifications. Values then are calculated for the combustion control system. Operating staff can also see the temporal and spatial distribution of the fuel bed surface temperatures and the fouling of boiler walls and overfire air nozzles on a separate monitor in the control room. This expansion of the combustion control system and the visual information for the operating staff further restrict the combustion parameter fluctuation margin and make even smoother, more flexible plant operation than can be achieved with conventional concepts possible. The connected remote data transmission (RDT) unit enables MARTIN to provide immediate support from the head office.

2.3 Very-Low-NO_x concept

Most of the waste's nitrogen content is transferred to the flue gases during combustion as nitrogen oxide NO_x. In the EU, there is a combustion directive that defines maximum emission limit values of 200 mg/m^3 NO_x as a daily average value referred to 11% O_2. Compliance with these limit values is possible with the SNCR process, which injects ammonia or urea into the furnace. In some cases, SCR catalytic converters are used. However, these involve higher costs (investment / operation) and energy consumptions. Based on the National Emission Ceilings (NEC) defined by the Gothenburg Protocol, it can be expected that the limit values for NO_x in the EU will become even more stringent. In this respect, MARTIN GmbH and its co-operation partners developed the Very-Low-NO_x (VLN) process, which achieves much lower NO_x emissions than the conventional SNCR process without energy losses.

The VLN process (figure 1) is based on a classical grate-based combustion system for municipal waste, where the so-called "VLN gas" is drawn off at the rear end of the grate and is reintroduced into the upper furnace just below the ammonia injection positions. The positive effect of this patented process is twofold: On the one hand, drawing off the VLN gas leads to combustion conditions which promote the inherent NO_x reduction processes such that fuel NO_x is to a large extent reduced to nitrogen. On the other hand, the reinjection of the VLN gas cools the flue gases down and enforces their mixing with injected ammonia or urea. This leads to improved efficiency of the SNCR system.

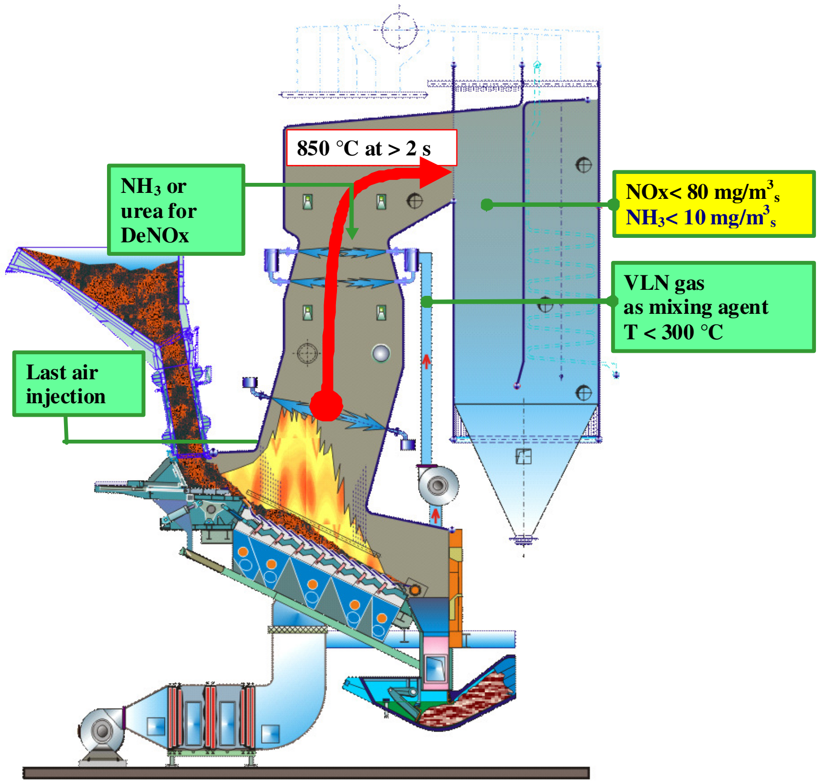

Fig. 1 VLN process (NO_x referred 11% O_2)

NO_x values of 80 mg/m^3 with an NH_3 slip of less than 10 mg/m^3 have been reached in tests at the Energy-from-Waste plant in Bristol/USA. Further industrial-scale tests in Thiverval/France and Oita/Japan have confirmed these results. At the Thiverval plant, which has a municipal solid waste throughput of 12 t/h, NO_x could be reduced from 190 mg/m^3 to 80 mg/m^3 during test operation with the VLN components.

The VLN gas has a temperature below 300°C and is re-injected at a position at which the furnace temperature is around 1,000°C. This typically corresponds to a level of 8 to 12 m above the grate depending on the capacity of the unit and the type of waste. The overfire air pressures are reduced to around 10 mbar, which is considerably less than in conventional Energy-from-Waste plant design. Nevertheless, superstoichiometric conditions are reached at the overfire air level, which is an advantage compared to air-staged or fuel-staged combustion systems. The residence time from the last combustion air injection at the overfire air level to the 850°C level in the furnace is significantly increased. A further advantage of the VLN system is the reduced flue gas velocity in the lower furnace due to internal recirculation via the VLN duct. This leads to a reduction in the fly ash carried over to the boiler.

The VLN gas is re-injected into the front and rear side of the narrow section of the upper furnace. This leads to an intensive barrier of turbulence, which reduces the flue gas temperature and blocks the passage of flames or unreacted gases. The test plant results give rise to the expectation that corrosion is significantly reduced in the furnace above the VLN level as well as in the superheaters. On the other hand, temperatures between the overfire air and the VLN level are higher than in conventional combustion and higher grades of furnace protection material should be used there. Another advantage of the VLN system is the reduced excess air rate, which allows cost reduction in the boiler and flue gas cleaning and improved boiler efficiency.

3. ENERGY CONCEPTS

Municipal waste has characteristics that make it particularly suitable for the generation of heat and power. Waste is generally available close to the location of heat and power consumption in towns and densely populated areas. In cooperation with university institutes, MARTIN GmbH investigates and evaluates methods and concepts for increasing efficiency by optimizing the combustion system and water-steam circuit using practice-oriented models for preparing large-scale implementation [5].

The standard Energy-from-Waste technology in Europe consists of grate-based combustion systems. Typically, these sometimes quite old plants produce 546 kWh of electricity per ton of waste, which corresponds to a gross energy efficiency of 18% referred to the gross heat input from waste and additional fuels (basis: heating value of 10.44 MJ/kg and electricity production only). Due to in-plant consumption of an average of 150 kWh per ton of waste, this results in an average exported electricity of 396 kWh (net efficiency of 13%). Most recent Energy-from-Waste plants use steam parameters of 40 bar / 400°C. Typically, these plants produce 650 kWh of electricity per ton of waste, which corresponds to a gross energy efficiency of 22% (heating value of 10.44 MJ/kg). With an in-plant consumption of 150 kWh, this typically results in exported electricity of 500 kWh (net efficiency of 17%). These data refer to the Best Available Technology document on waste incineration by the EU IPPC directive (BREF).

In some European countries, landfilling of municipal waste is restricted and efforts are being concentrated on further improving the energy efficiency of Energy-from-Waste plants beyond the values mentioned above. The driving force behind the implementation of high-energy systems is usually a premium for renewable electricity from waste.
There is a large potential for improving the use of the energy contained in municipal waste. On the one hand, waste can be diverted from landfilling and, on the other, the energy efficiency of Energy-from-Waste plants can be improved. In this respect, the main topics apply to power generation: steam parameters (pressure and temperature of superheated steam), flue gas heat losses (temperature at boiler outlet, excess air rate), steam condensation conditions (air or water condensers), thermal cycles (intermediate superheating, external superheating, 2 or 3 pressure systems), in-plant consumption (SNCR/SCR, excess air rate).
Examples of recent innovative Energy-from-Waste plants with MARTIN grate technology and highly efficient power generation can be found in Brescia (Italy), Amsterdam (The Netherlands) and Bilbao (Portugal). The Brescia plant has an increased gross efficiency of produced electricity of 27% through increased steam parameters, reduced flue gas losses and minimized in-plant consumption. The new plant in Amsterdam achieves 30% with additional intermediate superheating and water condensers. A further increase in energy efficiency is then only possible by external superheating with natural gas in combined cycle plants, as in Bilbao. However, innovations also took place in the field of heat recovery. The Malmö plant (Sweden) is an example, where efficiency has been increased by using heat generated from flue gas condensation for district heating. Twence (The Netherlands) is another example, where a high degree of energy recovery is achieved by combining heat and power production.
In the case of power generation, the main limitation on increasing energy efficiency is posed by the increased cost and corrosion risk. For the use of heat, climatic limitations and the cost of district heating grids are important considerations. In Europe, potential exists to increase the proportion of Energy-from-Waste to over 10% of the overall renewable energy produced as half of the energy contained in municipal waste is of biogenic origin.

4. RESIDUE QUALITY

4.1 SYNCOM / SYNCOM-Plus

Bottom ash produced during thermal waste treatment accounts for the largest mass flow of the waste input at approx. 25% by weight. However, a considerable percentage is sent to landfills because compliance with certain quality criteria for building material cannot be ensured.
MARTIN GmbH has developed the SYNCOM process, in which combustion air is enriched with oxygen, so that fuel bed temperatures are considerably higher, thereby causing increased sintering of the bottom ash. To further improve bottom ash quality, the SYNCOM-Plus process (figure 2) was developed, whereby a downstream wet-mechanical treatment process to separate a granulate is added to the SYNCOM process [1,2,3].

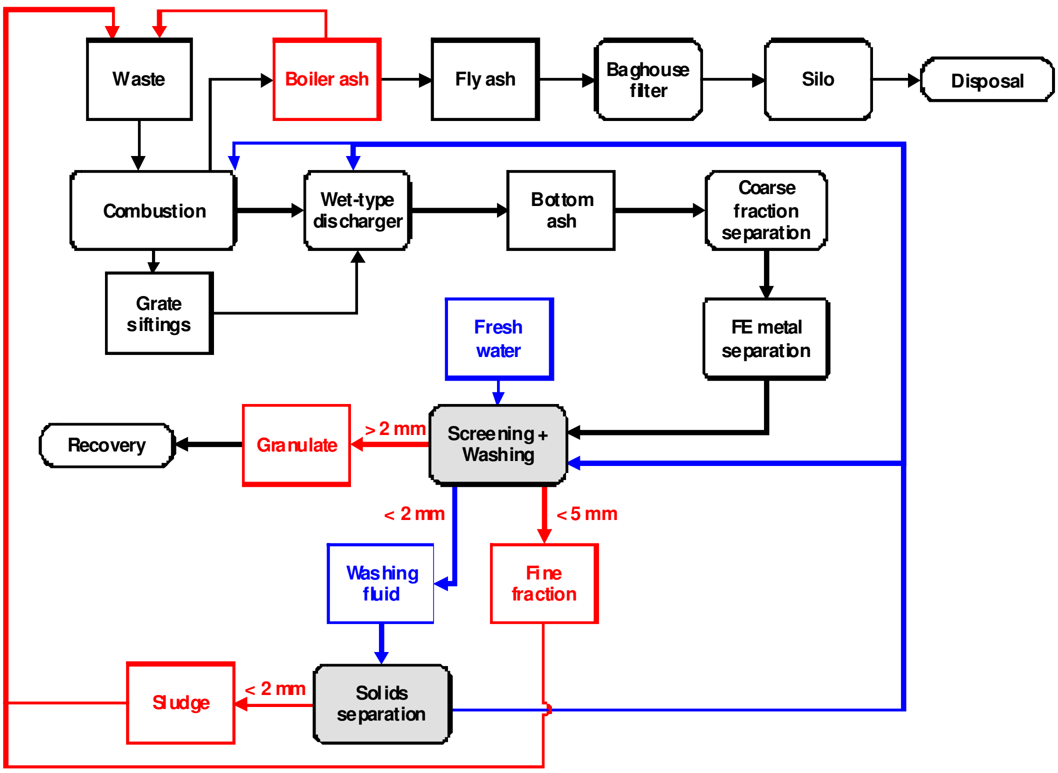

Fig. 2 SYNCOM-Plus process

In an industrial-scale pilot plant, studies on wet-mechanical treatment of bottom ash using the SYNCOM-Plus process were carried out in the SYNCOM Energy-from-Waste plant in Arnoldstein (Austria). Granulate of > 2 mm (figure 3) and fine fraction of < 5 mm were produced by dry screening, washing and wet screening. Additionally, sludge was separated from the wash water. The fine fraction and sludge as well as the boiler ash were recirculated into the furnace.

Fig. 3 SYNCOM-Plus granulate

The SYNCOM-Plus trials demonstrated successful results in continuous operation mode. Both wet-mechanical treatment and recirculation in continuous operation are feasible. No influence on combustion or the raw gas could be detected. The granulate was of an optimized quality, as a result of which it can also be used as a building material. The removed material flows (fine fraction and sludge) and the wash water can be recirculated within the process so that SYNCOM-Plus produces no residues for disposal and the entire process is effluent-free.

4.2 Dry bottom ash discharge

Dry discharge of bottom ash from waste combustion is becoming increasingly important in the context of recycling raw materials from combustion residues. Particularly in Switzerland, but also in numerous other countries, there has been much interest over the last few years in this process. Discharge of graded, dry bottom ash is on the one hand economically interesting because metal is separated more efficiently, returns from metal recovery are maximized and disposal costs are reduced through reductions in weight and lower transport costs. On the other hand, there are advantages due to the better quality of the dry discharged bottom ash and the fact that subsequent treatment, processing and recycling is easier.
The simple and robust technology used in the MARTIN dry discharge system is based on generally known process-engineering separation and transport procedures and uses the advantages of a fractioned bottom ash discharge. The MARTIN ram-type discharger is therefore used in unchanged form but with a newly developed and patented air separator and a cyclone separator (figure 4).

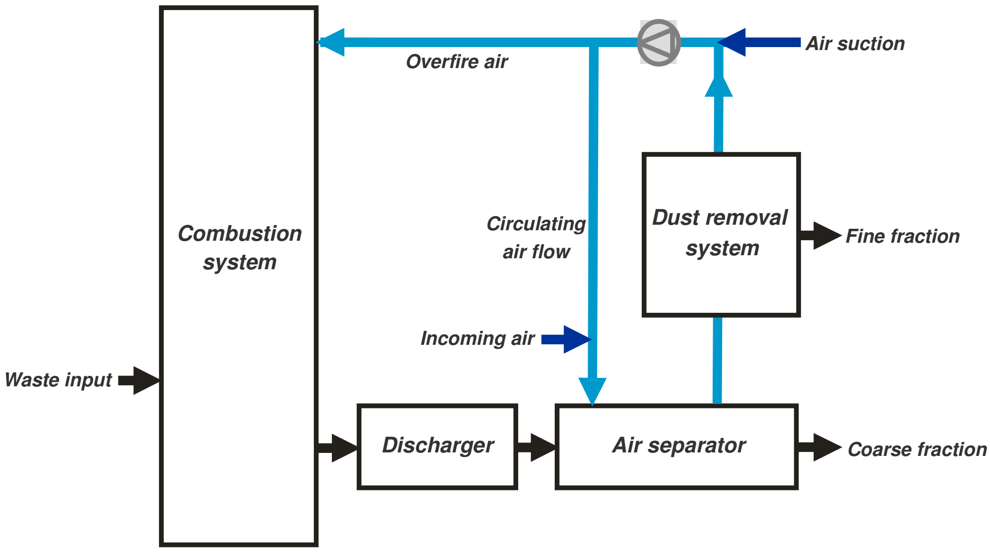

Fig. 4 Dry bottom ash discharge process

For MARTIN dry discharge, the ram-type discharger is operated without water. The bottom ash is discharged in dry form from the combustion system. The dry discharged bottom ash is conveyed directly to an air separator. The fine fraction and bottom ash dust is extracted in a defined manner. Depending on the extraction speed, the fine fraction and dust particle size is set to values between ≤ 1 mm - 5 mm. The air separation area is enclosed by a housing, in which negative pressure is constantly maintained, thereby preventing false air from entering the furnace or dust from getting into the boiler house. All subsequent transport facilities need no additional housing. Similar to wet-type discharge, the surface temperature of the discharger lies in the range 40°C to 60°C in the dry discharge mode.
Essentially, three product streams are separated out of the dry bottom ash: coarse fraction, fine fraction and bottom ash dust. The latter two are discharged out of the air separator with the air flow and conveyed to a cyclone separator, which ensures that they are separated from the air flow. The unburdened air, containing a minimal amount of residual bottom ash dust, is conveyed in a defined manner to the combustion air system via the overfire air. The fine fraction separated in the cyclone separator is sent to a recycling process or landfilled.

On the basis of the successful semi-industrial preliminary tests, the operator of the Monthey Energy-from-Waste plant (Switzerland) decided to implement MARTIN dry discharge systems in both combustion lines for industrial-scale operation.

4.3 Recirculation of fly ash / recovery of recyclables

In view of the continual depletion of raw materials, sustainable processes for the recovery of recyclables are increasingly becoming more important. In response to this need, MARTIN GmbH and partners have tested cost-effective, process-integrated methods. The process of selective zinc recovery from the acid-scrubbed fly ash of thermally treated waste is one example of recovering economically profitable heavy metals.

In the context of acidic fly ash extraction (figure 5), inorganic pollutants contained in the ash from the electrostatic precipitator in thermal waste recovery - in particular heavy metals - are extracted from the fly ash and sent for selective recycling / recovery. Organic pollutants, above all polychlorinated dibenzodioxins and furans (PCDD/Fs), remain in the washed filter cakes with this treatment. PCDD/Fs are only completely destroyed when the filter ash cakes are returned to the combustion system after the acidic washing stage. No increased PCDD/F content is then detected in the resultant bottom ash during ash recycling.

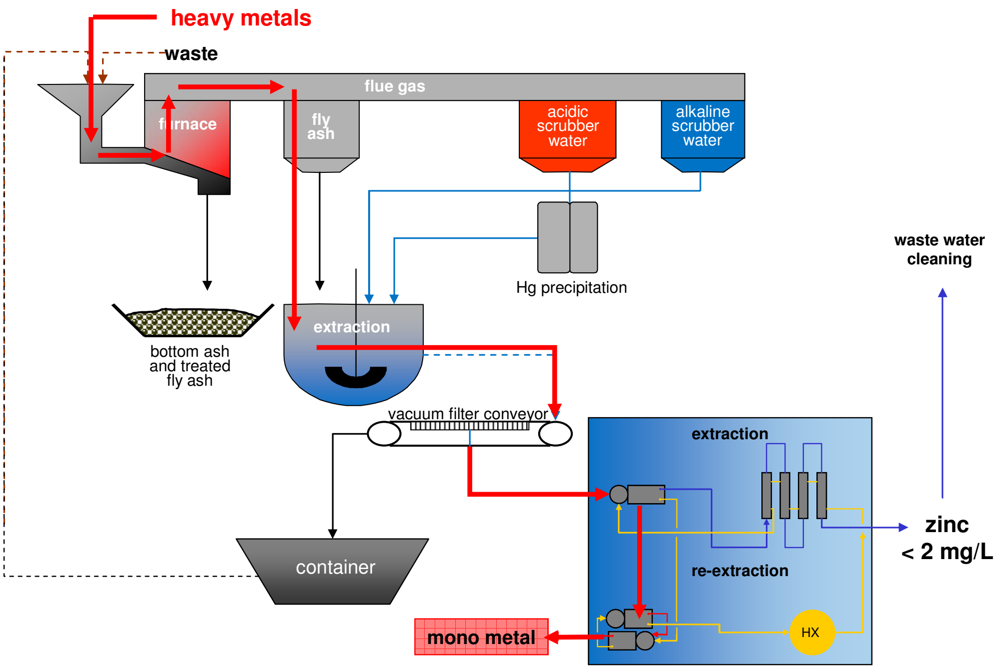

Fig. 5 Fly ash treatment process
(BSH Umweltservice AG, Switzerland)

Together with its cooperation partners, MARTIN GmbH has implemented development and research into treatment processes and the return of treated fly ash in industrial-scale plants for combusting household waste. Interest in this process is great specifically in Switzerland.

5. CONCLUSIONS

Further development and optimization of existing technologies and concepts are needed due to international requirements in the field of thermal waste treatment using grate-based combustion systems. By means of large-scale research projects in Energy-from-Waste plants, MARTIN GmbH has achieved significant improvements in the fields of combustion system technology, energy concepts and residue quality.

It has proven itself repeatedly that innovative technologies must first be developed and comprehensively investigated. In the future, MARTIN GmbH will continue to reliably ensure treatment of waste under ecological and economic constraints, using innovations and reliable process engineering technology and taking international statutory requirements into account.

REFERENCES

[1] Gohlke O., Busch M., Horn, J., Takuma M., Kuranishi M., Yanagisawa Y.: New grate-based waste-to-energy system producing an inert ash granulate. Waste Management World May-June, p. 37-46, 2003

[2] Martin J., Gohlke O., Tabaries F., Praud A., Yanagisawa Y., Takuma M.: Defining inert. Waste Management World 9/10, p. 70-73, 2005

[3] Gohlke O., Koralewska R., Zellinger G., Takuma M., Kuranishi M., Yanagisawa Y.: Alternatives to ash melting and gasification. 4th i-CIPEC, September 26-29, Kyoto, Japan, 2006

[4] Koralewska R.: MARTIN Reverse-acting grate system – The challenge of high heating value fuels. 14th NAWTEC, May 1-3, Tampa, Florida USA, 2006

[5] Gohlke O., Seitz A., Spliethoff H.: Innovative approaches to increase efficiency in EfW plants – Potential and limitations. ISWA, Amsterdam, 2007