Umwelt Bundesamt

THERMAL WASTE TREATMENT THROUGH GRATE COMBUSTION *)

APPLICATION OBJECTIVE

- Reduction of the volume and risk potential of waste destined for final disposal through a mineralization, destruction of organic compounds and the capture of large parts of the harmful inorganic components in a separable fraction
- Energy recovery from waste

*) The cleaning of exhaust and flue gases as an integrated process and technology is covered by a separate description (see the fact sheet „Emission control – exhaust and flue gas cleaning“)

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass		Light-weight packaging		Biowaste	
Paper / paperboard	X[1]	Mixed household waste	X	Bulky waste	X[1]
Lamps		Textiles		Electrical and electronic waste	
Scrap metal		Waste wood	X[2]	C&D waste	X[1]
Waste oil	X[3]	Old paint & lacquer	X	Waste tyres	
Hazardous waste	X	partly, only combustible fractions			
Branch specific waste	X	combustible fractions			
Other waste material	X	combustible fractions			

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION

Pre-treatment of the input material:
Input material must be freed from disturbing components such as large metal parts and should not contain any radioactive substances (entrance control !), a crushing of bulky waste items might be necessary.

Options for the utilisation of the generated output:
Combustion ashes and slag after a further processing can be used in other applications. The processing involves the removal of metals from the slag and a comminution/homogenization so that the material can be used for construction purposes (e.g. in road construction).

Options for the disposal of process output and/or residues:
Landfilling combustion residues (ashes and slag) is generally possible. Residues from exhaust and flue gas cleaning however must be handled as hazardous material and need to be deposited in facilities which are suitable and approved for this type of material. Preferred options for this are stowage-mines or underground deposits (see fact sheet on „Hazardous waste landfill“).

Aftercare requirements:
Residues which have to be deposited on landfills of the appropriate categories must be subject of monitoring and become part of the usual aftercare procedures applying to these landfills.

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[1] Recycling and the necessary sorting and mechanical processing this possibly requires shall be the preferred options for this waste. Grate combustion should be applied to treat only the combustible residues which remain after the sorting and processing of this waste.

[2] Any possibilities for this waste to be recycled should be examined and, whenever possible and economically feasible, applied first, in particular if amounts of wood in a natural or widely untreated state are involved. Energy generating facilities specialized on the combustion of woody biomass are also more suited for utilizing this waste in an energetically effective manner.

[3] in small quantities only , any possibilities for this waste to be recycled or material used should be examined first and, whenever possible and economically feasible, preferred. Other forms of thermal utilization should be considered as well, e.g. an industrial co-incineration (see also fact sheet on „Industrial co-incineration“).

Protective needs:
Exhaust and flue gases from the incineration must be appropriately treated and cleaned. Protective measures must ensure that no health risks or any negative impacts on sensitive media such as the soil, ground water or sites of special value do occur. Guidance what measures and limits may apply is provided in other documents and fact sheets (see fact sheet on "Exhaust and flue gas cleaning" and the document on "Technology-related EU regulations" in particular the "Directive on industrial emissions"). To erect an incineration facility in or close to dwelling areas requires that minimum distances to the nearest buildings and other precautionary measures, especially such serving noise protection, need to be observed.

Potential health risks:
A release of untreated flue gases pose a health risk which can be avoided if contemporary cleaning techniques and protective measures as indicated in this fact sheet and in the fact sheet on "Exhaust and flue gas cleaning" are employed and properly followed. Waste incinerators using state-of-the-art cleaning technologies are nowadays considered as not threatening human health any longer.

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION

Infrastructural conditions:
To allow for economical operations of waste incineration plants a minimum throughput capacity (approx. 50,000 Mg/a) shall be ensured. Areas with a concentration of waste generation (i.e. especially in or nearby large cities) are therefore favorable places for this type facilities. Such areas do also offer the necessary infrastructural conditions, like a good accessibility and connection to road, railway or waterways, and the possibility to supply nearby users with the electric energy and/or steam produced. An increase in traffic movements in the area of the plant must be considered.

Climatic conditions: No special restrictions apply.

Suitable financing mechanism:
The incineration of waste should be financed by charges imposed to the generators of the waste. Introducing an incineration tax or additional waste treatment fee specifically for the combustible waste may help to ensure that only the non-reusable, non-recyclable parts of the waste are forwarded to incineration, both are also instruments for an additional financing of the treatment.

TECHNICAL DETAILS

GENERAL OVERVIEW

ABSTRACT	Grate combustion is one of the most widely applied incineration techniques, which in the way presented hereafter, is also used for the mass combustion of mixed commercial and municipal solid waste and provides the leading technology in this segment in the world. Grate combustion can be used for an energy recovery from waste especially in combination with combined power and heat production. Opposite to other incineration techniques, the waste is burnt here on a grate in the combustion chamber.

BASIC REQUIREMENTS	- Quality requirements for the input stream:
	  - Net calorific value: - >6MJ/kg to 12 MJ/kg and above in the case of air-cooled grate bars; - 6MJ/kg to 25 MJ/kg in the case of water-cooled grate bars
	  - Particle size: <300 mm, in exceptional cases up to 1000 mm
	- Integrated emission control and exhaust gas cleaning (see fact sheet on "Exhaust and flue gas cleaning")
	- there should preferably exist:
	  - a possibility to supply surplus thermal energy (steam or warm water) or cooling produced out of it to external users
	  - alternatively or supplementary: a connection to feed electrical energy into a public grid

EXPECTED RESULTS	Output: - slag - caldron dust - exhaust gas Quality requirements for the output: - slag: C ‹ 3% by weight, in modern systems the ignition loss of burnt out slag comes to less than 0.5 percent by weight
SPECIFIC ADVANTAGES	- Reliable and long proven technology which provides for a reduction of the hazardous potential and reactivity of waste destined for final disposal in combination with the highest possible volume reduction (security of disposal) - Possibility to recover the energetic content of the waste for the generation of electricity and heat/cooling - Possibility to recover ferrous and non-ferrous metals by way of processing the combustion ashes/slag - Treatment of harmful waste fractions and components resulting in the discharge and elimination of pollutants and hazards from recycling circuits
SPECIFIC DISADVANTAGES	- Investment intensive (especially to comply with environmental protection needs) - occasionally greater problems of acceptance and the need to overcome these within the population

APPLICATION DETAILS

TECHNICAL SCHEME

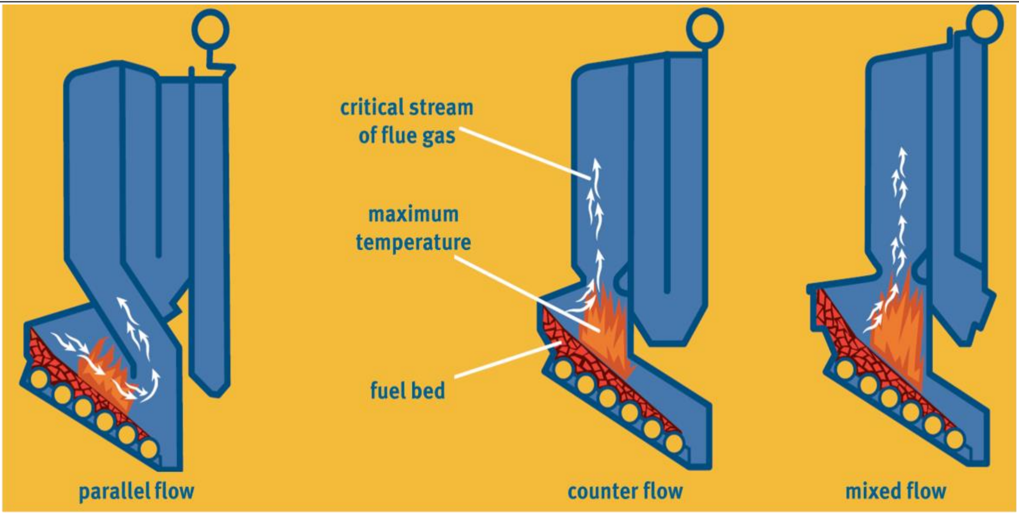
In grate combustion the waste is incinerated all around the clock and hence continuously fed by feeding systems onto the grate whereas the incoming waste arrives at the plant discontinuously (mostly during daytime only). To make sure that a certain stock of input is permanently available, a deep-bunker is always set before the grate combustion. This installation also ensures the waste mix to become more homogenous (also in terms of a stable and balanced calorific value) at the time it is fed into the combustion chamber.

Combustion on the grate takes place at temperatures of 850 to 950°C. At the end of the moving grate, the burnt out residues drop into a slag extractor filled with water.

The flue gases generated in combustion mostly reach an after-burning chamber where they burn out completely at 850° C. In the subsequent steam boiler, the flue gas is cooled to 200°C to 240°C and overheated steam (max. 40 bar, 400° C) is produced. The steam can be used to generate electricity, for district heating and to make process steam out of it.

Presently, numerous systems of grate combustion are available on the market. They vary in their way of flue gas distribution and how the waste is transported on the grate. There exist three principal alternatives of how flue gases are distributed.

Figure 1: Alternatives for gas flow distribution in a grate combustion process



	For the variants of parallel gas flow, counter flow and mixed flow the main waste transportation and gas flow routes are shown in the graphic. - *Parallel flow* turns out to be advantageous in connection with waste of high calorific value (>9 MJ/kg). The incompletely burned flue gas is forced to pass the zone with the highest temperature so that an improved burnout is reached. Thus, an after burning chamber may be unnecessary. Various surveys have shown that the burnout of flue gas and slag is better in parallel flow systems than in others. - *Counter flow* turns out to be advantageous in connection with waste of lower calorific value. Drying and firing of waste is supported by high flue gas temperatures. A possible danger is that the flue gas is badly intermixed, such that an after burning chamber is absolutely necessary. - *Mixed flow systems* constitute a compromise for plant layout if a wide range of calorific values has to be dealt with. The grate system on which the waste is transported should be such as to allow good poking (circulation). There exist three different grate systems. - On a *stoker with reciprocating grate bars*, grate bars transport the waste. Thus, an inclined grate area is not needed although offered by some manufacturers. Increasing grate motion leads to faster transport. This will allow to control the waste retention time in the furnace and to adapt to fluctuations in load. Stokers with reciprocating grates are at present the most important grate type used in new plants. - On *reversed feed grates*, gravitation enables the transport of waste. Thus an inclined grate area is necessary, since the grate bars and the waste move in opposite directions. Reversed feed grates are particularly suitable for wet waste. Water-cooled grate bars can be used for both grate systems. - On *roller grates*, it is a combination of gravitation and roller motion that enables the transport of waste. Roll rotation transports the waste downwards an inclined grate area. Faster rotation leads to faster transport but not to better circulation of the bed, however.
QUANTITY ASPECTS	Input: - Municipal solid or household-like commercial waste - water (for cooling and steam generator), the minimum demand of fresh water is 1 m^3/h per Mg/h throughput Output: - 200–350 kg slag/Mg input - 25 to 40 kg caldron dust and ashes from gas cleaning per Mg input (source: VDI 3460) - 4,500 to 6,000 m^3 exhaust gas/Mg input - water (from steam generator)
SCALE OF APPLICATION	For economical operations the capacity of an incineration plant should reach 50,000 Mg/a in the minimum which is equivalent to 6.5 Mg/h throughput. On the leading end can be found capacities of 225,000 Mg/a which is equivalent to 30 Mg/h throughput per incineration line. There is practically no limit as to the number of lines installed in a plant. The largest plants have currently a capacity of 800,000–1,000,000 Mg/a. New water-cooled grate systems allow to handle high calorific wastes with a heating value up to 16 MJ/kg. In previous grate fired plants the calorific value of the waste had to be kept down to approx. 12 MJ/kg. Otherwise the thermal loading of the grate system would have been too high resulting in a drastically shortened life time of the grate.

INTEROPERABILITY	A grate combustion in principle can be combined with all processes for a preceding treatment of wastes, given that its general objective is to mineralize any combustible waste components which cannot otherwise be used or recycled and to recover the remaining energy content. An asset is the possibility that synergies with processes marked by a high demand of thermal energy can be create and their supply with steam and power arranged. Waste incinerators can also assume the function of a source for base load supply for district heating/cooling networks. - The incineration process in any case must be combined with an exhaust gas cleaning because the untreated flue gas from the grate combustion of waste usually contains harmful components in considerable extent (see fact sheet on "Exhaust and flue gas cleaning").
OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION	

ENERGY BALANCE	Energy balance of a practical case example (established 2010, by Alwast, Riemann[4])
	Input:
	- Mixed municipal solid waste (MSW) 100 %
	- Supporting energy, e.g. natural gas ‹ 3 % of MSW input
	Output:
	- Exhaust and firing losses: 18%
	- Steam: 82%, from which
	  - 1,6% own steam consumption
	  - up to 29% turned into electricity,
	    →81% fed to the electricity grid
	    →19% own consumption
	  - up to 69% waste heat
	Combinations of electrical and thermal energy supplies are possible and desirable but the rule is that the more thermal energy is supplied the less electric current can be generated. Typical combinations found in average sized plants are for example: 5 % electricity plus 35 % heat supply or 10 % electricity plus 20 % heat supply. Contemporary plants achieve to have a higher efficiency and better power ratios, depending also on the location and user structure.

CO_2-BALANCE	- A positive balance can be obtained through the saving of primary fossil fuels and the utilization of the renewable waste components as an energy source
AIDS/ADDITIVES NEEDED	- fuel oil or natural gas for start up and shut down operations and for support heating when temperatures in the afterburner section go down - for exhaust gas cleaning: adsorbents and further chemical reagents (among others lime, liquid ammonia, for more details see fact sheet on "Exhaust and flue gas cleaning")
HUMAN RESOURCES	- a minimum of 15 skilled persons per incineration line including exhaust gas cleaning per day for the 24h/7 days operation mode, at least 1 engineer and 2 foreman should be among the staff, additional personnel for maintenance, cleaning services and gate control, especially qualified personnel is needed for the technical management - the number of incineration lines is less influencing on the staff count than t he exhaust cleaning system applied
SPATIAL NEEDS	Minimum space demand is in the range of: - approx. 10,000 m² for a throughput rate of 50,000 Mg/a - approx. 30,000 m² for a throughput rate of 200,000 Mg/a

[4] Verbesserung der umweltrelevanten Qualitäten von Schlacken aus Abfallverbrennungsanlagen, Texte 50/2010, Umweltbundesamt (Hrsg.), http://www.uba.de/uba-info-medien/4025.html.

OPERATIONAL BENCHMARKS: COST DIMENSIONS	
INVESTMENT COSTS	- can vary strongly in dependence on the applied technology and process equipment and could reach amounts in the range from approx. EUR 50 million to EUR 200 million (and above) for new constructions. - The specific investment costs for ten comparable incineration plants built after 2005 in Germany with grate combustion techniques ranged between approx. 350 EUR/Mg input and 600 EUR/Mg input per annum (including the exhaust gas cleaning system). Further indices can be obtained from the reference literature and sources listed below.
OPERATING COSTS	- vary strongly and had been in the range of 34 EUR/Mg to 102 EUR/Mg input in the year 2010 when comparing the figures from six plants in Germany Repair and maintenance - for each structural element approx. 1% of the initial investment - machinery and electronic: 3 - 4% of the initial investment Personnel costs - depending on the price on the local labour market Further indices can be obtained from the reference literature and sources listed below.
POSSIBLE PROCEEDS	- from the supply of electricity and steam/warm water
MASS SPECIFIC OVERALL COSTS	- for rough orientation in the range of 80–150 EUR/Mg (inclusive the exhaust gas cleaning); higher capacity of the plant, less sophisticated exhaust gas cleaning procedures and equipment and a good market situation for the sale of electricity and steam normally improve the cost ratio significantly
OTHER RELEVANT ASPECTS	
MISCELLANEOUS	
MARKET INFORMATION	
REFERENCE FACILITIES *(Note: the list of sites and/or firms does not constitute a complete compilation)*	The incineration of solid mixed municipal and commercial wastes under the application of grate combustion technology is in worldwide use and has strongly evolved recently. Today, there are over 100 plants in Germany (state of 2016) burning different kind waste materials with this technique. Reference facilities in Germany are for example: - Magdeburg Rothensee (650,000 Mg/a, 4 Lines) www.mhkw-rothensee.de - Hamburg Borsigstraße (320,000 Mg/a; 2 Lines) www.mvr-hh.de - TREA Breisgau (175,000 Mg/a, 1 Line) www.eew-energyfromwaste.com Other countries where waste incinerators are operated on a large scale with this type of process are: France, Switzerland, Netherlands, Austria, Italy, China, Japan and Scandinavia.
RECOGNIZED PRODUCER AND PROVIDER FIRMS *(Note: the list of firms does not constitute a complete compilation of companies)*	Recognized producer/provider firms for grate combustion technology and related plant components are for example: - MARTIN GmbH für Umwelt- und Energietechnik, München www.martingmbh.de - Steinmüller - Babcock Environment GmbH, Gummersbach www.steinmueller-babcock.com - Oschatz GmbH www.oschatz.com - Hitachi Zosen Inova Kraftwerkstechnik GmbH, Landsberg www.hz-inova.com

ADDITIONAL REMARKS AND REFERENCE DOCUMENTS

As important reference documents on this combustion technique are available:

VDI 3460 and Reference Document on the Best Available Techniques for Waste Incineration

Further information and compilations on relevant details and plants can be obtained from:
- ITAD – Interessengemeinschaft der thermischen Abfallbehandlungsanlagen in Deutschland e.V. www.itad.de
- CEWEP – Confederation of European Waste-to-Energy Plants www.cewep.com