As one of the first companies, LAB dedicated itself to the development of turn-key flue gas cleaning installations, in particular in the thermal waste management industry and quickly gained a good reputation due to its innovative technology and reliable components. Founded as a plant manufacturer for flue gas cleaning in 1953, the company with headquarters in Lyon, Stuttgart and La Seyne sur Mer, has been designing and manufacturing for more than 50 years components for flue gas cleaning and is in that area with over 300 reference plants one of the market leaders in Europe and worldwide. Today, LAB is a company of the Groupe CNIM with headquarters in Paris; in addition there are worldwide branch offices and affiliates.

LAB has a complete portfolio of own processes and offers for each individual project the relevant parameters adjusted to the most reasonable technology for the respective requirement, considering dry sorption with hydrated lime or bicarbonate as well as semi dry, wet type, multi stage or combined processes for the acid gas separation. Likewise, catalytic denitrification methods are designed and carried out. Principally, all processes are developed in our company and most of them are also patented, as, for example, the new VapoLAB process which significantly increases once more the performance, profitability and energy efficiency of dry sorption technology.

Our range of products and services comprises conception, designing and realisation of plants for flue gas cleaning of domestic waste incineration plants and for the desulphurization of power plants as well as service, maintenance and repair.

LAB offers you from one single source qualified counselling, designing of individual components of flue gas cleaning, turn-key delivery and assembly, commissioning, documentation according to your instructions and training for your future operating staff.

An excerpt from LAB’s current references:

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- MKK Bremen
- EEW Delfzijl
- Twence Afvalverwerking
- SWD Düsseldorf
- Fortum Värme Högdalen
- IRU WTE Tallinn
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LAB GmbH
Bludenzer Str. 6 – D-70469 Stuttgart
Tel. +49 (0)711/222 49 35-0 – Fax. +49 (0)711/222 49 35-99
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Inerting and hygienisation of domestic refuse and similar waste materials by means of thermal treatment has a long history. The first plant of this kind on the European continent, for example, became operative in Hamburg in 1896. Since that time the technology has progressed considerably, based on advances in manufacturing and materials. Substantial contributions to this development were delivered by the firms of L & C Steinmüller, Deutsche Babcock Anlagen and Noell KRC, our predecessor companies. Figure 1 is showing a drawing from year 1936 on which a moving grate with combustion chamber and the lower part of the radiation pass are illustrated. The photograph affords a look into a typical design and drawing office at that time.

Combustion and boiler engineering have been improved enormously, especially during the past 15 to 20 years, based on growing knowledge, increased requirements and improved production possibilities. The following is a description of the current state of the art and technology.
2. The overall plant

With regard to the incineration of waste the reliable and eco-friendly disposal of the delivered waste material has been the sole concern for a long period of time. Today the efficient utilisation of the energy contained in the waste is gaining growing importance because of the question of suitable energy carriers and the CO₂ problems – as about 50 % of the waste is of biological origin and, therefore, is climate-neutral when incinerated. The continuously increasing demands on the plants are asking for the careful planning of the process chain.
Exemplarily, a longitudinal section of an overall plant is shown in Figure 2. The most important sections are the firing system with the grate, the steam generator (boiler) and the flue gas cleaning system. Not shown here is the energy generating section, which is also part of the overall plant. The steam which is generated in the boiler is delivered to a turbine and used there for electricity generation or the energy is used for district heating. A combination of both systems is also common.

Below, particular attention is given to the grate firing system and the steam generator, and an example for a flue gas cleaning plant will be described.

3. Combustion section

3.1. Grate system

The core of any waste incineration plant is the firing system with the moving grate. Figure 3 is showing the waste feeding chute, the feeder and the actual grate which, in this case, is of 2-track design. The grate is slightly inclined for optimising waste movement and, as a peculiarity, has 2 steps. The first step is positioned in the main combustion area between the 2nd and the 3rd grate zone. By means of this, larger waste particles are broken up and the fuel is overturned in order to intensify the combustion process. The second step is positioned behind the 4th zone and breaks up any possibly existing slag agglomerations. Both zones contribute to a substantial improvement of burnout and, thereby, to optimized slag quality.

In the course of time the grate has been optimised continuously and adapted to the current requirements (increasing calorific values, RDF etc.). In this development, the basic concept has not been changed during the recent decades because of the good experience made and
the robust and sturdy construction. Part of the installation is in particular the grate carriage, see Figure 4, with which every second grate row can be moved for transporting the waste. These grate rows move continuously forward and in reverse with a velocity which is governed output-related by the combustion control system. The movement of the grate carriage is effected by means of a hydraulic drive, arranged at the grate center. By means of a mechanical device, the so called rocker shaft, the grate carriage is on both sides forced to maintain an absolutely parallel movement. Therefore, any electronic control, which could fail, is not required.

Figure 4: Grate Module and Grate Movement

With low to medium calorific values of the fuel, air-cooled grate bars are used as grate surface (Figure 5). The grate bars are not connected to each other, but are moveable and placed at a defined distance for thermal expansion. From this kind of installation results a well distributed free cross section for the passage of the primary air and, because of this, uniform combustion. Installing the bars at a distance has also the advantage that the bars can move freely against each other and a self-cleaning effect is obtained. In addition, the grate bars can be replaced during standstill periods very easily and quickly if necessary.

For higher calorific values, for instance with RDF, water-cooled grate bars are used (Figure 6). These are somewhat wider than the air-cooled bars, but have in longitudinal direction the same length and contour. Therefore, the same substructure can be used and it is possible at any time, also subsequently, to replace air-cooled grate bars by water-cooled bars and vice versa. Depending on the respective level of the calorific value, either only the main combustion areas, grate zones 2 and 3, or also additional areas are equipped with water-cooled grate bars. Based on the material selected, these grate bars have excellent emergency operation properties and can continue to operate, therefore, for more than one year without water cooling. Thus, it is not necessary to shut down the plant in case of problems with the cooling system.
Figure 5: Air Cooled Grate Bars

Figure 6: Water Cooled Grate Bars
In longitudinal direction the grate is consisting of 5 combustion zones (Figure 7). These zones can be controlled independently of each other with regard to air supply or to reciprocating grate bar movement. This is possible because there are measuring devices and control dampers provided in the air supply lines to the individual zones. For independent grate movement each zone has its own driving arrangement. This makes it also possible to control individual zones to run faster or slower in case of operating problems. Driving system and air control are integrated into the combustion control system for optimising the combustion process.

Because of the modular design of the grate, allowing to modify the length and width of the individual modules, the grate can be adapted very well to the various existing calorific values or to possibly given building configurations. The grate width of a track ranges from 2.25 m to 3.55 m. If these dimensions should not be sufficient it is possible to arrange several grate tracks parallel to each other. New to our portfolio is, that the grate can be composed of up to 4 tracks (Figure 8). In this way, a grate width of maximum 14.35 m can be implemented. Accordingly, the operational capacity can range from approximately 8 t/h up to about 45 t/h. The illustration is showing the relationship between the number of grate tracks and the respective maximum grate width.

The complete grate, including the feeder and the waste charging part, is mounted on a frame (Figure 9). This frame is suspended by sling tubes which are articulated in the drum level area to the boiler support frame. These grate support tubes are integrated into the natural circulation of the boiler. Because of this, the differential expansion between boiler and grate during heating up and during operation of the plant is reduced to a minimum.

In the transitional area between boiler and grate so called grate side wall tubes are installed at both outer sides. These are running parallel to the grate surface and are for cooling also integrated into the natural circulation of the boiler. The tubes are protected by means of cladding with Inconel 625 on the combustion chamber side against corrosion and wear. The cooled tube surface prevents reliably caking of dust and waste particles and assures in this way continued, unhampered waste transport.
3.2. Furnace geometry and secondary air injection

The geometry of the combustion chamber has been adapted during the course of years to the changing quality of the waste (Figure 10). With the previously low calorific values of straight domestic waste the combustion chamber roof was low and the whole combustion chamber was of a compact design in order to be able to utilize the combustion heat optimally for pre-drying the fed waste. The waste of today with higher calorific values does no longer require these measures and ignites very early already. For taking care of these changes with regard to ignition behaviour and in order to provide more space to the fire to develop the combustion chamber has become larger and secondary air injection has moved further up.
Combustion chamber geometry and secondary air injection have continuously been optimized, first by using flow models and now mainly by using CFD simulation. In the middle of the nineties, already, a special secondary air injection feature had been developed by our predecessor companies, by means of which a horizontally positioned double-vortex is superimposed on the main flow (Figure 11). This is achieved by secondary air nozzle diameters which are staged over the boiler width. The larger nozzle diameters are located...
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at the front wall in the center and at the rear wall at the sides, from which the schematically shown pattern, results (Figure 12). The double-vortex ensures thorough mixing of the flue gas with the combustion air and, therewith, optimum burnout on the flue gas side. At the same time an optimum distribution of temperature and velocity in the 1st pass is achieved. This type of secondary air injection has proven its value impressively and is applied by us as a standard. For every new plant an individual CFD simulation is carried out for tuning and optimising the system consisting of firing section, furnace geometry and secondary air injection.

3.3. Corrosion protection

Because of the high flue gas temperatures and the corrosive flue gas constituents the firing system and the 1st boiler pass must be protected against corrosion (Figure 13). For the selection of a suitable concept several criteria must be observed like, for instance, the legally required flue gas temperature, special requirements regarding part load performance, calorific value, boiler size etc. If we assume a boiler with common steam parameters without any special requirements and a calorific value of 8 – 12 MJ/kg there remain two essential criteria:

- The temperature level of the flue gases in the 1st pass and the
- boiler size.

In Europe, the temperature level, with a residence time of 2 seconds above 850 °C behind the last secondary air injection, is prescribed by law. The influence of the boiler size is not obvious at first sight. The thermal output varies, however, over a wide band width between approximately 25/30 MW and 110/115 MW. Therefore, one must consider that with a small boiler the specific boiler surface is larger than with a larger boiler. This means that a small boiler must have a better insulation in order to keep the heat in the combustion chamber and to maintain the temperature requirements, compared with a larger boiler.
Our standard concept provides that certain areas must always be protected in the same way. This includes the grate side wall tubes and the area above the brick lining, which are protected by cladding and the area above the 5th grate area, which is protected by high alumina castable.

Regarding the area between the tube walls protected by Inconel cladding, we differentiate between an upper and a lower section. In the combustion chamber area we wish to have a lower surface temperature in order to prevent that doughy or molten fly ash particles stick to the walls. In the upper area, where the temperature level of > 850 °C for 2 s must be maintained reliably, we are using a lining with better insulating properties.

As is shown here, in Figure 14, our concept follows the philosophy just described. We assume standard conditions and an O₂ concentration of 8 vol %, dry. In the lower section a continuous low surface temperature is assured, while in the upper section materials of more or less high insulating properties are used, depending on the size of the boiler.

Because of the good experience we have had with Inconel cladding, it was only a small step to use cladding instead of ceramic tiles. In accordance with our philosophy, cladding is primarily used in the combustion chamber. The upper section, again, is insulated to a varying degree, depending on boiler size. In order to comply with the legally specified temperature level under all operating conditions, for instance with part loads, the boiler is designed accordingly and, if appropriate, excess air is reduced.

Figure 15 is showing the combustion chamber of a plant with backfilled tiles in the lower section. Above the secondary air injection nozzles there is a separation joint starting from which the air ventilated tiles are installed.
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4. Boiler

Similar to grate technology, the design and construction of steam generators has a long tradition at FBE and, respectively, its predecessor companies. A typical example is this boiler with a zone stoking grate from 1952 (Figure 16) already designed for steam parameters of 69 bar and 500 °C.

FBE supplies all types of steam generators for waste incineration plants and also specific boilers for hazardous waste incineration plants. In Figure 17 the Kristiansand plant in Norway is shown, which is of horizontal-pass design. The marked areas are showing the

![Figure 14: Combination of Lining Material and Conditions](image1)

![Figure 15: Boiler with Backfilled (Furnace) and Air Ventilated (1st Pass) Tiles](image2)
specific design features. There is, for instance, the header of the partition wall between 1st and 2nd pass, which is directed to the drum via outside arranged piping. Therefore, there are no tubes present in the transition area with high temperatures and flue gas velocities which must be protected. In addition, cornice formation is not possible. Furthermore, the hoppers below the horizontal pass are assigned to the bundle groups. This prevents undefined flow conditions. And in addition, there are separating plates installed in the hoppers preventing reliably bypass flow.

The Rüdersdorf plant (Figure 18) is designed as a vertical pass boiler. The particular feature of this plant is the reheat of the steam, increasing by this means the degree of efficiency. For this reason, there are final superheaters of the platen heating surface type installed in the 2nd boiler pass. The design consists of alternating platens for superheating the live steam and for reheating. Primary superheating takes place in the conventionally designed 3rd boiler pass in which case again the superheater banks for primary steam and for reheat are alternating. Similar to the horizontal pass boiler the grate with feeder and the steam generator are of suspended design.
Figure 17: Steam Generator EfW Kristiansand – Special Features

Figure 18: EBS – IKW Rüdersdorf
5. Examples of implemented plants

The combustion of waste on a grate with downstream steam generator is a technology proven over many years and of repeatedly confirmed reliability. The operational capacity ranges from 6 Mg/h with small plants to approximately 45 Mg/h with large plants. The acceptable band width regarding calorific values is also wide. It stretches from approximately 4.5 MJ/kg to approximately 20 MJ/kg. Because of the flexibility and reliability of this technology combustion on the grate is applied world-wide in more than 85 % of the plants for thermal waste treatment. Below are examples given for the adaptability of plant technology to the particular boundary conditions.

5.1. ETN Heringen

The ETN Heringen plant is designed for the utilisation of refuse derived fuel (calorific value range: 8 – 18 MJ/kg). It consists of two lines each with a nominal capacity of 17.5 Mg/h at a calorific value of 12.0 MJ/kg, corresponding to a thermal output of 58.3 MW per line, see Figure 19.

![Figure 19: EfW Heringen](image)

The plant supplies an existing industrial site with superheated steam. In this case the following boundary conditions had to be considered:

- The industrial facilities already on the site require a steam temperature of 520 °C at a pressure of 80 bar. Because of the corrosion problems related to fuel gases from waste incineration plants, the steam from the boiler is first superheated to the normal 400 °C. Subsequent superheating to 520 °C takes place externally.
- Also because of the existing conditions, the feeding water is delivered to the incineration plant as two split-streams with differing temperatures. The integration into the steam generator system had to be provided accordingly.
For superheating the steam to 520 °C an additional compact heat generator, fired with natural gas, was assigned to each combustion line. This additional heat generator consists of a cylindrical combustion chamber with a burner arranged in the bottom, see Figure 20. Final superheating takes place in the piping system installed in the periphery of the combustion chamber. Behind the combustion chambers follows first, in flow direction of the flue gases, the primary superheater. For controlling the flue gas temperature and for optimum utilisation of the flue gas heat content there is an economiser installed above, which is operating with a split-stream of the boiler feeding water.

![External Superheater ETN Heringen](Figure 20)

The water circuit system is shown in Figure 21. The split-stream from the external economiser is ducted with a temperature of about 280 °C to the drum of the waste incineration plant. As the gases are from a gas-fired plant, there is no exhaust gas cleaning plant required. The exhaust gases from the combustion chamber are leaving the system by means of natural chimney draught. The unit for external superheating has a thermal power of 10.7 MW.

In the mean time the live steam temperature at the boiler outlet has been increased from 400 °C to max. 440 °C. This has reduced the costly gas consumption accordingly.

Another particular feature of the plant is the feedwater supply with two split-streams, having differing temperatures (not shown in Figure 21). The existing feedwater system delivers feedwater having a temperature of 122 °C and a pressure of 100 bar, raised by the existing feedwater pumps. Subsequently, the water is split into two split-streams.

Feedwater A (approx. 47 % of the total volume) is not heated up any more and is fed by means of the booster pump into the new waste incineration plant. It is distributed there to the two lines and fed into the respective Economiser 1. A small part stream is taken to the economiser of the external superheater and is then fed directly into the boiler drum.
Feedwater B (approx. 53 % of the total volume) is ducted through the economiser of the existing boiler and heated there up to 235 °C. Via the booster pump the water is then delivered to the new plant. After distribution to the two lines it is delivered into the boilers upstream of the Economiser 3.

The plant became operative early in year 2009 without any problems and is delivering since that time the design output.

5.2. EfW Plant Ruhleben

In the case of the Ruhleben plant four aged smaller combustion lines are replaced. In this plant domestic waste from the city of Berlin undergoes thermal treatment. The design calorific value of 9,000 kJ/kg is relatively low. With a throughput of 36 Mg/h at the design point a thermal output of 90 MW is achieved (Figure 22). Complying with the customer’s requirements, the throughput can be increased to 40 Mg/h at a calorific value of 8,100 kJ/kg. The order includes in addition to firing system and steam generator also the supply of the flue gas cleaning plant.

Firing system and boiler

Because of the large rated waste throughput FBE is employing at Ruhleben for the first time a 4-track grate having a width of 11.25 m (Figure 23). In accordance with our standard design the grate is mounted on a supporting frame and suspended by means of support tubes in the boiler steel structure. Feeder and feeding chute however, are carried by a reinforced concrete structure because of their high weight and other local conditions. A common waste feeding chute is arranged across the full grate width while the feeders are assigned to the individual grate tracks. In the illustration the two grate steps are easy to recognise, these are of particular value by optimising combustion when calorific values are low. The grate is bordered on both sides by the grate side wall tubes, already described above.

The waste heat-and-power station Ruhleben does not have its own turbine. The live steam produced by the combustion lines is rather fed into the nearby hard-coal power station Reuter and is used there for the generation of electricity and heat. Because of this connection the
live steam parameters of 460 °C and 65 bar are stipulated. The steam generator of the waste incineration plant is designed as a horizontal pass boiler (Figure 24). The three radiation passes are supplied as blank passes. The superheater and economiser heating surfaces are installed in the downstream horizontal pass. The dimensions of the eco heating surfaces are such that the flue gas temperature can be controlled to constant 200 °C.
The extreme steam parameters and particularly the high live steam temperature are increasing significantly the risk of corrosion, so that special protection measures are being taken. An important measure is to arrange the Superheater 1.1 upstream of the final superheater (Figure 25). In this way the final superheater is protected from high flue gas temperatures while Superheater 1.1 in this constellation ensures sufficient support of live steam temperature in case of part loads.

In order to be able to replace the final superheater which is particularly exposed to corrosion, a specific dismantling concept has been developed. With this design the superheater is removed downwards and let down directly to zero-level of the plant passage. The new bank can then be raised up immediately and installed. In order to minimise possible shut-downs and to increase service life the customer later decided to protect this heating area by Inconel cladding.

Because of the link to the Reuter power station only steam with the specified parameters may be supplied to the steam turbine. In order to prevent visible steam clouds during start up and shut-down procedures and at part loads when it is not possible to maintain the steam parameters, the steam or part of the steam is directed into an auxiliary condenser. This auxiliary condenser is air-cooled and dimensioned for the condensation of 85% of the steam volume. It is placed on the roof of the waste bunker.

Flue gas cleaning plant

The portfolio of Fisia Babcock Environment includes, in addition to firing system and steam generator, also the flue gas cleaning plant. In this field the complete range of wet, semi-dry and dry processes and combinations of these processes can be offered. Electrostatic
precipitators and wet electrostatic precipitators, as well as bag-type filters are produced according to our design. This business is backed by many years of experience and worldwide references and recommendations.

In the case of the Ruhleben incineration plant average emission values per day had to be guaranteed to fall about 30 % short of the statutory allowed limit values. In addition, the plant must be able to prevent extremely high peaks of hazardous substances - in particular HCl and SO2. For this reason, a four-stage process is used (Figure 26):

- A semi-dry cleaning stage, consisting of a spray absorber using lime slurry and water with a downstream fabric filter.
- A conditioned dry cleaning stage, consisting of one each injection plant for hydrated lime and hearth-furnace coke with entrained-flow reaction path.
- Recirculation of the reaction products separated in the fabric filter.
- NOx removal by a catalytic DeNOx system.

The flue gas cleaning system is producing no waste water. As the only residue product a dry mixed salt is produced. Because of the modular design, generous dimensions and resolutely redundant application of critical assembly groups the plant is in the position to provide an extremely high degree of availability.

The raw flue gases including the entrained fly ash from the steam generator enter first the spray absorber. At that point the acid hazardous gas constituents like HCl, SO2 and HF react with the finely atomized lime slurry. Due to evaporation of the simultaneously sprayed-in water the flue gas temperature is reduced to approximately 135 °C. During the retention time in the spray absorber the reaction products which have arisen are drying and are directed, together with the flue gases, to the downstream entrained-flow reactor.

Figure 25: EfW Ruhleben – Arrangement of Superheaters
In the entrained-flow reactor the necessary sorbents are injected, which are required for the conditioned dry cleaning stage. One of these is highly reactive hydrated lime which absorbs chemically still existing acid pollutants and the other is Activated Lignite which safely absorbs the organic and gaseous metallic substances, in particular mercury. The sorbents can be dosed independently of each other.

A special feature of the Ruhleben plant is a second hydrated lime injection into the flue gas duct upstream of the spray absorber. This injection system, having a tenfold injection capacity compared with normal operation, is switched on only in case of extremely high pollutant peaks or in case of spray absorber failure. Beyond that, the additional injection capacity ensures redundancy of sorbent supply. The position of this injection system permits to use effectively the long retention time in the spray absorber as reaction length for pollutant separation.

After leaving the entrained-flow reactor the flue gas passes, together with the entrained solids, the fabric filter in which the solids are nearly completely separated. For better sorbent utilisation a part of the solids collected in the filter bags, but still reactive, is re-circulated by injection into the entrained-flow reactor described above. The cleaned and dust-free exhaust gases are subsequently directed into the catalytic DeNOx plant by means of a variable-speed induced draught fan and from there discharged into the open via the existing chimneys.

The erection of the Ruhleben plant has taken place since approval was given without any delays in accordance with the laid-down time schedule. Current, the first commissioning activities are being prepared. Handing over to the customer is planned for the end of the coming year.
6. Final Remarks

The thermal treatment of waste in grate firing systems is a technology for which the experience of many decades is available. Therefore, it is well-developed and assures safely a high degree of availability. These plants can be designed for operational capacities ranging from a few tons up to a through-put of 40 Mg/h. Also the calorific value range which can be handled is wide. From low-calorific wet domestic waste to high-calorific plastics residues.

As is shown by the examples described above, grate firing systems can be adapted in an extremely flexible manner to predetermined boundary conditions and new statutory provisions. In line with new knowledge gained from currently operating plants the development is continuously going forward.

The plants for flue gas cleaning can be designed very accurately to comply with the respective requirements and to meet reliably the required legal limit values. Also in this respect a continual development towards very effective cleaning processes is evident.
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