Cost Optimization through Use of Flexible Grate Systems in Combination with Modern Boiler Concepts

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Old method, new approach: for customer-oriented solutions. The demands on innovative grate technologies mean to explore the full potential of available technology and to push the technical boundaries further.

MH Power Systems Europe Service long-standing grate firing systems have been proven to be flexible in combination with modern boiler concepts, enabling the safe combustion of different fuel properties.

Taking these factors into account, various conditions which are placed on an optimal combustion, can be summarized as follows.

- the quality of the products of combustion, represented by on the one hand, a high flue gas side burning rate in the form of minimizing the CO/C total content and the NO_x content and on the other hand a recovery The residue-quality, characterized by a low proportion of unburned and minimizing leachate qualities of bottom ash,
- the economical operation of the plant, documented by a high availability and a long travel time.

The basic requirement for such a result is the careful coordination of the individual process areas with each other and considering the fuel-specific factors in the structural design of grate firing systems including boiler combustion chamber and thus leading to cost-effective operation.

1. Fuel properties

Non-fossil fuels are generally subject to an ongoing change in the surface-mix and physical properties. Wastes from different disposal areas exhibit this characteristic. An overlapping quality influencing process provides the degree of preparation of the combustion pre-switched mechanical/biological treatment. The heterogeneous mixture of organic and mineral ingredients can be shown here in terms of quality, calorific value, the size of property and consequently homogenized and the density within certain limits.

Untreated waste from the municipal and the commercial waste, sales packaging, sorting residues and waste fuels have different combustion behaviour on the firing. The characteristic burning material parameters lead to a short-changing energy release, due to the different composition of the fuel-substance. The firing system must compensate for this is now resulting uneven heat and mass transfer.

2. Implementation of technical specifications

The functional areas of the grate firing system, consist of fuel feeding, grate and grate deslagging. The fuel feed, the grate, the air supply, the primary air distribution below the grate system and the secondary air distribution in the vortex zone form the combustion space with their actuators the relevant functional areas. These functional areas adapt to the control concept by referring to the measured combustion parameters and load specifications.

The emphasis is placed on the combustion air supply. The system distribution in the primary-side and secondary-side air streams as well as the subordinate primary air distribution between the individual air zones or the secondary air distribution to the front wall and rear wall, is adapted to the respective fuel conditions.

The deslagger forms the completion of the firing system forms, which operates as a ram deslagger or belt conveyor.

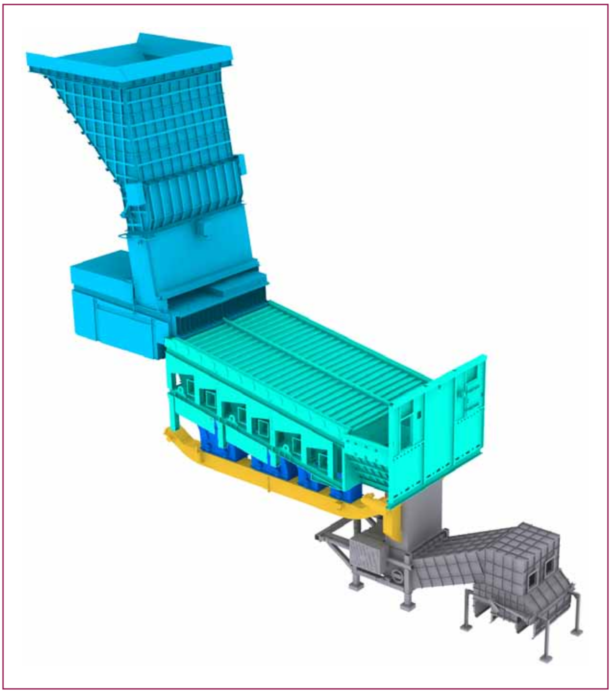


Figure 1:

Grate firing system

3. Combustion control systems

The primary objective of the combustion control systems is implemented by incorporating the process engineering variability and structural conditions, an efficient and emission-optimized fire management. The assessment measurement forms the control quality of the predefined steam mass flow.

The standard control concept adapted to these requirements includes the following control loops:

- Load controller,
- Combustion controller,
- Air supply controller,
- Primary air controller,

- Secondary air and O_2 controller,
- Fuel feeding controller,
- Grate speed controller.

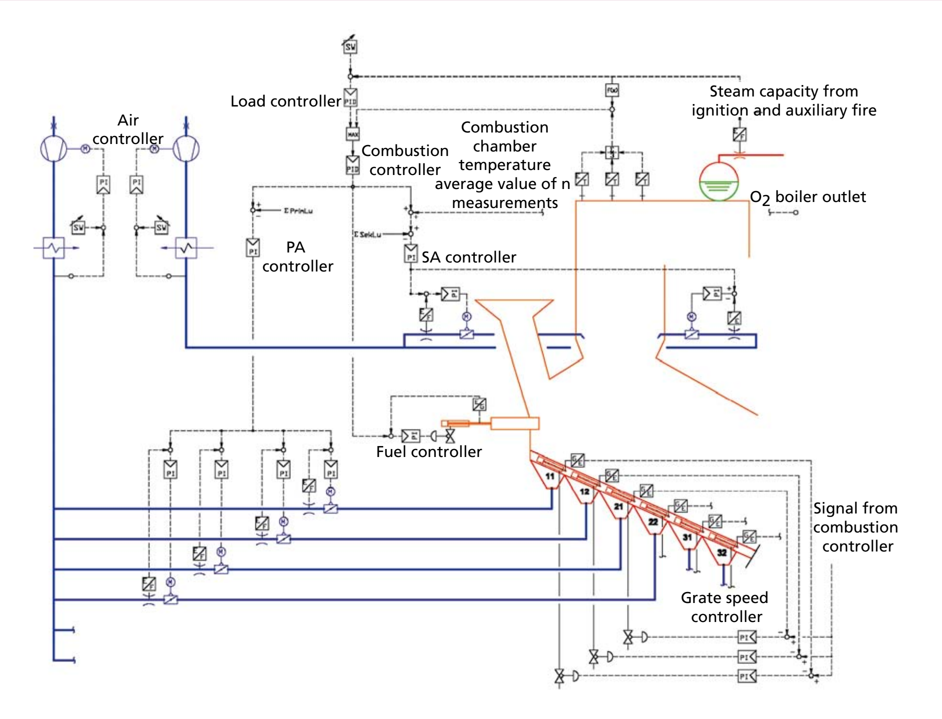


Figure 2: Control concept

4. Standard control concept

Load and combustion controller are configured as a cascade. The reference value for the load controller is the control deviation from the steam mass flow. The output of the load controller is the set point for the combustion controller. This receives a superimposed control size the combustion chamber temperature

The set points of the steam flow is the basic setting for the control of the secondary air distribution and primary air distribution as well as for the fuel feed and grate speed. The deviations of the firing controller lead as a first measure to adjust the primary air. The speeds of the grate and the fuel feed are changed to lower levels.

The O_2 content, measured at the end of the steam generator is applied as an auxiliary variable. A brief O_2 deviation controls the secondary air supply from within a limited range. Any further deviation is a disturbance in the fuel-air ratio. This effect also causes a change in the fuel pump in the main combustion zone.

The air supply regulator provides a stable air pressure at the duct inlet to the primary and secondary air dampers as a function of the boiler load. Thus they obtain the same time, decoupling of the underlying quantity control loops.

5. Modified control concept

The described standard control concept uses the steam generator as a calorimeter. On the firing side, changes affect the energy flow from the steam generation. Overlapping can cause uneven flow profiles in the after burning combustion chamber and disturbing influences on the operation.

Therefore, an occasional modification of the standard control concept uses the flue gas temperature as fast-reacting combustion parameters. Different concepts on the market are available with different modes of action sensor technologies (digital image evaluation of the flames, ultrasonic temperature measurement in the flue gas, infrared temperature measurement of the fuel bed, laser diode temperature measurement in the flue gas), that perform a timely profile of the exothermic reaction and represent the output of the combustion air distribution. The implementation of this supplementary measure requires process engineering optimization of the secondary air system.

The primary task of the secondary air system is to compensate O_2 variations arising, due to heating value fluctuations. In addition, the flue gas flow profile in the first boiler pass can be minimized here, by volume of air displacement from the front wall to the back wall (and vice versa), and also be influenced by imbalances between the right and left side of the boiler.

This makes it possible to achieve a balance of the flue gas temperatures by a correspon-ding temperature sensor in the first boiler pass. This has the following positive effects:

- Maintaining a constant thermal power and thus maximize the fuel flow rate,
- Reduction of temperature peaks above the ash softening point and thereby reducing the heating surface fouling to extend the travel time,
- Maintaining optimum flow conditions in the boiler pass 1 to obtain the lowest possible emissions.

Above the secondary air level, the flue gas temperatures in the six secondary air zones can be detected by a corresponding sensor. Calorific value changes in the fuels also affect the fire situation in the transport direction and thus the heat release in the first boiler pass.

By shifting the secondary air content from the front wall to the rear wall (and vice versa), homogeneous temperature compensation is obtained.

Grate firing systems with large power output use several grate paths. Imbalances in firing can often occur, which also affect the temperature distributions.

A homogeneous distribution is again set through a reciprocal secondary air distribution between the left-middle-right side.

6. Combustion chamber design

Optimisation of the combustion chamber

The quality of the combustion chamber gases is based on the low-kept emission potential, which establishes the conditions for economic plant operation. The geometry of the combustion chamber/after burning combustion chamber plays an emphasized importance in connection with the secondary air supply. The quality of the combustion gases is based on the one hand to keep a low emission potential and on the other hand, is the condition for an economic plant operation.

The journey time of the steam generator depends primarily on a uniform combustion. The high demands that are placed on the heat and mass transfer in the first boiler pass, can be implemented through the use of CFD studies. The simulation considers the range of the flue gas temperature, flue gas velocity, O_2 and CO content in the course of the flue gas path and allows conclusions about the performance. Depending on the intensity of the secondary air supply in the front wall or back wall area, the flow path can be clearly directed. Comparative grid measurements confirm the assertions of these computational models.

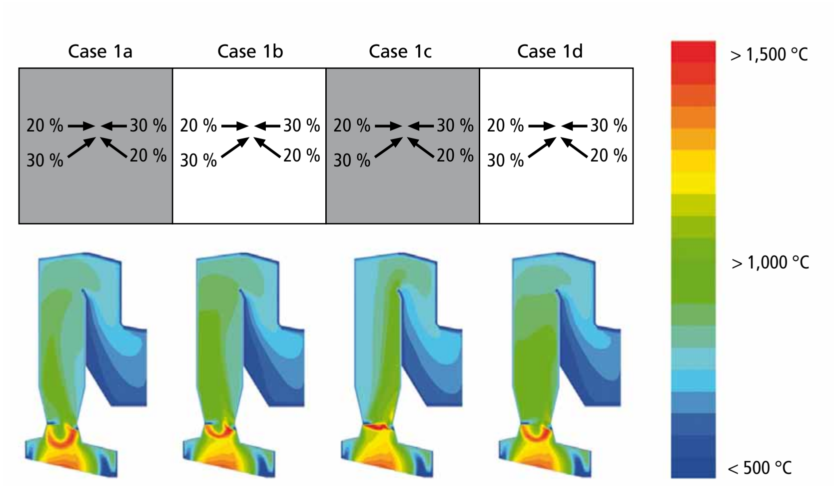


Figure 3: Temperature profiles of a CFD study

7. Mid-stream firing

The consistent implementation of various optimization studies relating to the combustion chamber geometry, the formation the vortex zone for secondary combustion and the location and direction of the momentum of secondary air is realized in the form of mid-stream firing. This concept shows the front wall ceiling directing the combustible gases from the start of the combustion reaction in the area of the hot flue gas flow from the main combustion zone. The area in the vortex zone that is supplied by secondary air intensifies the subsequent afterburning of these material flows.

The responsiveness of the fuel is taken into account when forming the front combustion chamber cover (ignition cover) and rear combustion chamber cover (burnout cover). Adapted to the energy content of the flue gases, the lining of the evaporator walls ensure the required flue gas temperature in the combustion chamber and after burning combustion chamber.

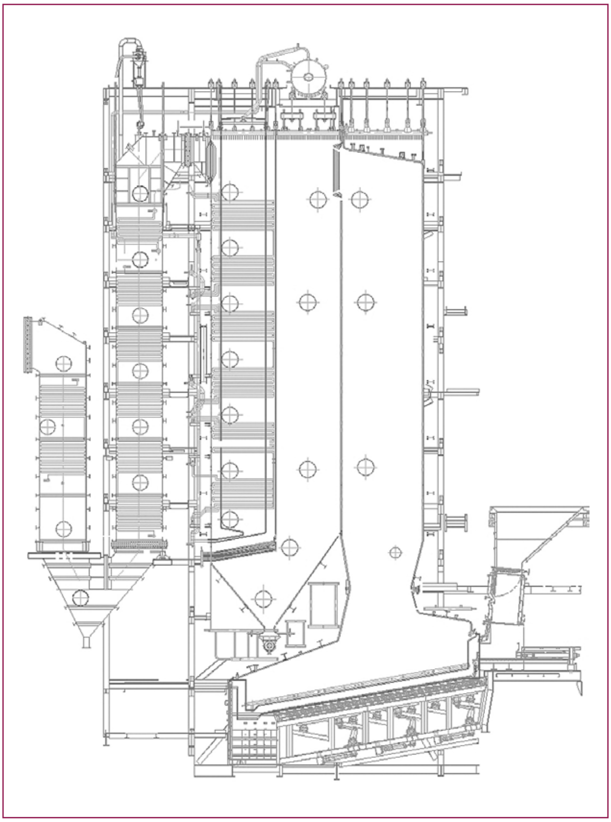


Figure 4:

Grate system with mid-stream firing

8. Basic consideration for the grate construction

The design of a grate system depends primarily on the properties of the fuel, which determine the ignition and combustion behaviour of the solid matter. This then constitutes the input variables for determining the grate length and the fuel layer height. Furthermore, the lumpiness of fuel is to be included when considering the transport behaviour and the combustion quality.

In addition to these fuel-related parameters, the grate area is defined by empirical values relating to the mechanical and thermal load grate area. In conjunction with the design data of the combustion control diagram, which is determined by gross heat and fuel mass flow, the required grate area is calculated. Since the grate length is set by default for untreated wastes from municipal waste or substitute fuel, the grate width keeps a certain degree of freedom.

9. Selection of the grate surface

The selection of the grate surface depends on the specific energy potential of the fuel. Figure 5 indicates the type of grate bar cooling using the heating value. Hence, air-cooled is for low calorific waste and water-cooled grate surface is used for higher calorific waste. This is characterised by a longer operating life compared to the pure air cooling and allows for higher thermal loads. The construction of the grate system is structured without a design change at any time, so there is a shift between the water-cooled air-cooled grate rods.

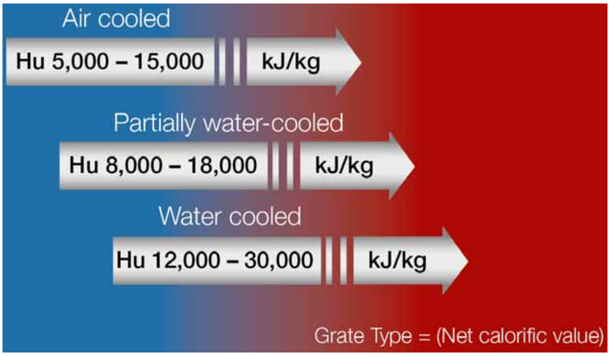


Figure 5:

Selection criteria for grate surface

Only the intensive water cooling of the grate bar allows a process-optimized reduction in primary air rate, along with the reduction of excess air and also a parameter with relating to the NO_x formation.

In the transition region of low caloric to higher caloric waste, there is the possibility of combining both types of cooling. The grate bars of the thermally highly stressed grate zones receive water cooling, while the grate bars of burnout zone are provided with a pure air cooling.

10. Combustion air system

The fluid dynamic characteristics of the combustion air system depend on the quality of the fuel used. The characteristic parameters of fuel lead to a short-changing energy release due to the different composition of the fuel. The firing system must compensate from this resulting in uneven heat and mass transfer.

In this regard, the combustion air supply is of particular importance. The system breakdown in the primary-side and secondary-side air streams and the lower primary air distribution between the individual air zones of the grate and the secondary air distribution to the front wall and rear wall is controlled. This is adapted to the respective fuel conditions.

In order to improve the combustion process on the grate at low caloric waste materials, caused by a high water content, and to support the flue gas temperature in the vortex zone of the after burning combustion chamber, a primary air preheater is used.

Figure 6:

Starting operation: ignition of waste fuel

11. Mechanical construction of the grate system

11.1. Fuel feeding

A crane system normally takes the fuel from the bunker and transports it to the fuel hopper to the furnace. The difference in side inclination of the hopper walls prevent bridging when filling. At the entrance of the fuel chute, there is a central hydraulic driven fuel isolating flap that needs to be closed under certain operating conditions, e.g. during start-up and shut-down. Below the fuel isolating flap component a protection device is installed with water or steam injection, limiting the impact of any return fire from the combustion chamber. The constructive design of the filling-area, including the upper part of the fuel duct is air-cooled.

The fuel hopper and the subsequent fuel chute are adjusted by a choice of materials and sheet thickness according to the requirements of mechanically highly stressed areas. The fuel in the fuel chute acts as an air seal of the combustion chamber. Level measurements, performed as a microwave barrier, controlling and signalling the degree of filling to be used in the fuel chute. The expansion of the fuel chute downwards, that is, in the direction of transport, counteracts clogging.

The lower part of the fuel shaft comprises a double layer with water cooling to protect against heat stress, such as during the starting process. The open pressure-less cooling system operates on the principle of the evaporative cooler. The single or multi-part, hydraulically actuated ram fuel feeder receives the fuel from the fuel chute and dispenses it regulated by the ram feed table, above the ram feed structure on to the grate. In high calorific waste, a calorific value of 15 MJ/kg to 30 MJ/kg, a water-cooled ram feed slider and ram feed table are provided. These have proven to be a useful component protection.

The constructional design of the feed opening in the transition to the combustion chamber ensures on the one hand an air seal to the fuel chute and on the other hand a uniform continuous feeding system on to the grate.

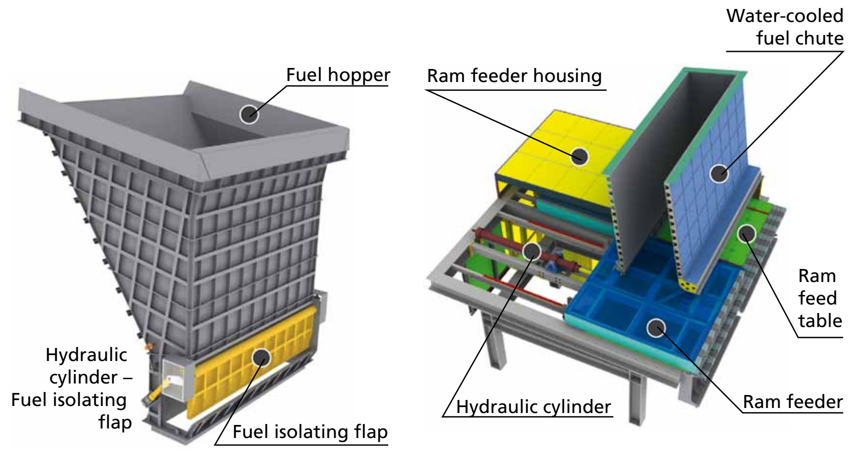


Figure 7: Design of the ram feeder device

11.2. Stoker grate

The operation of the combustion grate, designed as a grate and the internal structure of a grate zone, can be seen from the picture below. The grate path is characterized by an inclination to the horizontal of 10°. External hydraulic drives control, via a lever system, the advance and return stroke movements of the moving grate rows of each grate zone in accordance with the control requirements. The fixed and movable grate bar rows alternate in succession in a grate path and are each placed on separate grate frames. The constructive bearing formation of the movable grate frame in the form of a prismatic ball guide, assures a translational directed movement.

The uniform and long stroke movement in feed, due to the grate bar con-struction, lead to a gradual fire management. The return stroke follows the same speed. This movement is characterized as opposed to a short-stroke operation in order to reduce wear out. Another advantage of this method is the additional cooling effect by the surface of the grate bars due to the long travel to the grate bar head. The grate bar head especially in the air-cooled grate bars is protected separately against thermal corrosion and is described under the section of the air-cooled grate bars.

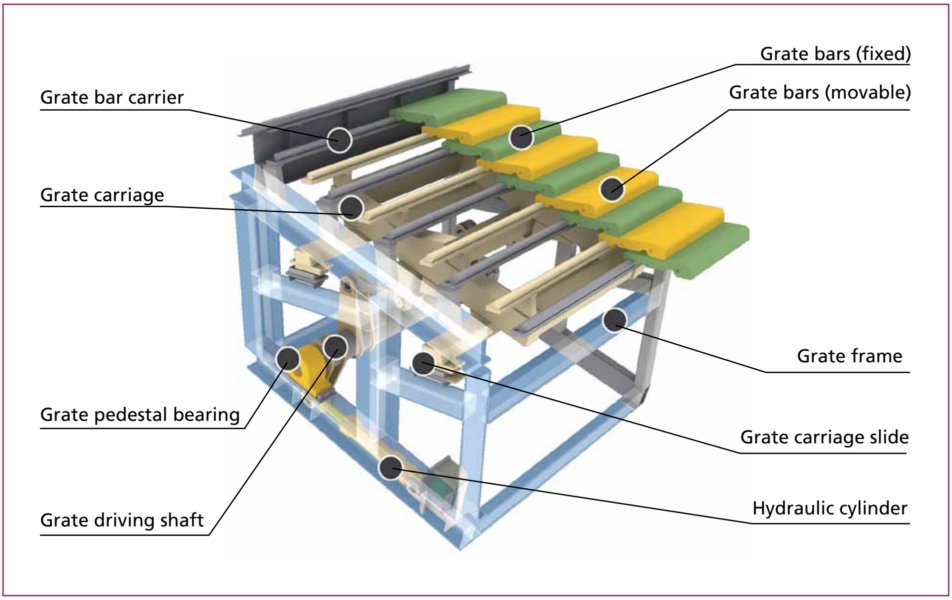


Figure 8: Structure of the moving grate

The grate system is normally composed of three successive grate zones. Each grate zone is situated above and supplies two grate hoppers. The hoppers also serve as part of the grate ash in the discharge end of the conveying element as well as the primary air system. The total width of the grate, as a result of the predetermined fuel mass flow, determines the number of grate paths. Grate track dividers take over the constructive and therefore procedurally useful subdivision of grate tracks. The hydraulic drives of the individual grate zones are located on one side of the grate track. Fuel-related factors can be taken into account by modifications in the grate division. Figure 9 below shows the external appearance of a 2-lane grate system including the primary air zone channels and grate hoppers.

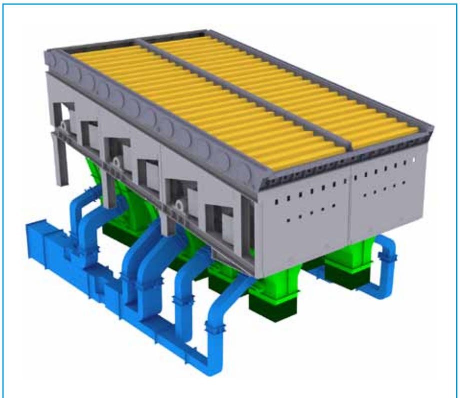


Figure 9: 2-track grate system

The control of the components of the grate firing system is taken over by a central hydraulic station. This includes the drives of the fuel isolating flap, the ram feed slider, the grate zones and the ram slag extractor.

11.3. Grate surface

Depending on the circumstances of the fuel side, air-cooled grate bars are used, such as patented turning grate bar that have a second wear bulkhead in the grate bar head or patented water-cooled grate bars. The type of layout may include both types of grate bar in the limits of calorific value ranges.

11.4. Air-cooled grate bars with second sealed front wall in head area

In the air-cooled grate bars the cooling is provided by the primary air. The grate bar is made of a heat-resistant steel casting. The grate bars are held together by screws and form the grate bar rows.

On the combustion grate, the air-cooled grate bars are equipped with a second wear wall in the grate bar head. The patented air-cooled grate bars are designed for a longer operating life. This is achieved by a second wear bulkhead that is protected from temperature-induced corrosion, arranged and concealed behind the head area. In the thermal wearing of the outer head area are the other functions of the grate bar, which guarantees the extension of the total duration. The grate bars are designed as turn-around grate bars. The turn-around grate bar can be turned back into the grate bar head after thermal wear of the second wear bulkhead.

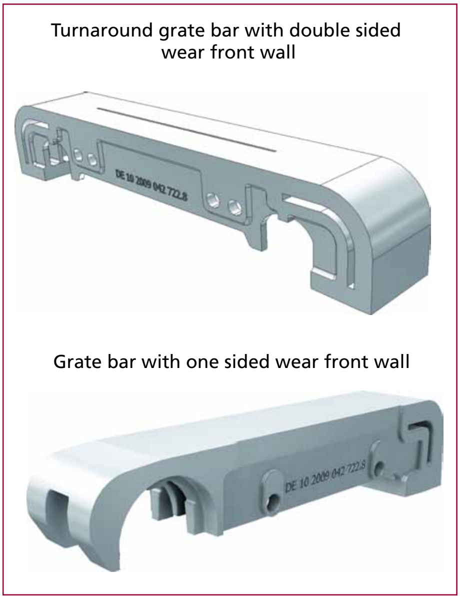


Figure 10: Patented air-cooled grate bar

The air-cooled grate bars receive a special ribbing in order to achieve the largest possible surface. The cooling takes place via the supplied primary air (underblast).

The grate riddlings of the stoker grate is minimized by low slot widths in the grate surface and a high underblast pressure.

The air-cooled grate surface can be replaced by a water-cooled grate lining.

11.5. Concept of the water-cooled grate surface

Heat extraction

Maximizing process efficiency also includes the use of waste heat. A closer look at the energetic processes exist for the use of the extracted heat flow integration possibilities for primary air, condensate preheating and district heating water over the grate surface.

A non-energy consuming variation is the re-cooling by heat exchanger on the roof. This procedure can be used as additional cooling reserve for extraordinary operating conditions.

The effectiveness of the heat integration in the economic cycle, that is, the economic dimensions of the heat exchanger depends mainly on the temperature difference of the heat-emitting/heat-absorbing material flows. The optimization efforts relating to the cooling water temperature should be kept within limits in this case. On the one hand this can reduce rising cooling water temperatures, the cooling effect based on the grate bar surface, and on the other hand temperature-induced fatigue in the moving connecting elements can appear. Finite element method, referring to thermal peak loads (e.g. hot spot effect) leave noticeable local temperature increases to be expected, which are used to design branch components. Depending on the load intensity on the water side temperatures of 40 °C to 60 °C may occur.

This approach is based on the determination of the static pressure. In any operating situation the cooling water temperature is to have a secure distance from the resting pressure-related boiling point. One of the thermal loads adjusted high speed cooling water in the grate bars guarantees a defined derivative of the grate bar fixed heat.

Cooling water system

The basic circuit of the cooling circuit can be seen in the figure 11 below. Starting with the water-cooled grate surface, the individual rows of grate bars, the water-cooled expansion elements of grate side ends and the grate track separation as heat-absorbing component, takes over a downstream heat exchanger system, the purpose-driven extraction of heat. The return-flow temperature of the grate system determines this as a control variable the load behaviour of the heat exchanger.

Circulator pumps promote the cooling water in a closed circuit, a pressure maintaining device that imparts the required static pressure. Safety devices protect the cooling system against excessive pressure. A make-up feed water system serves to compensate for any loss of water.

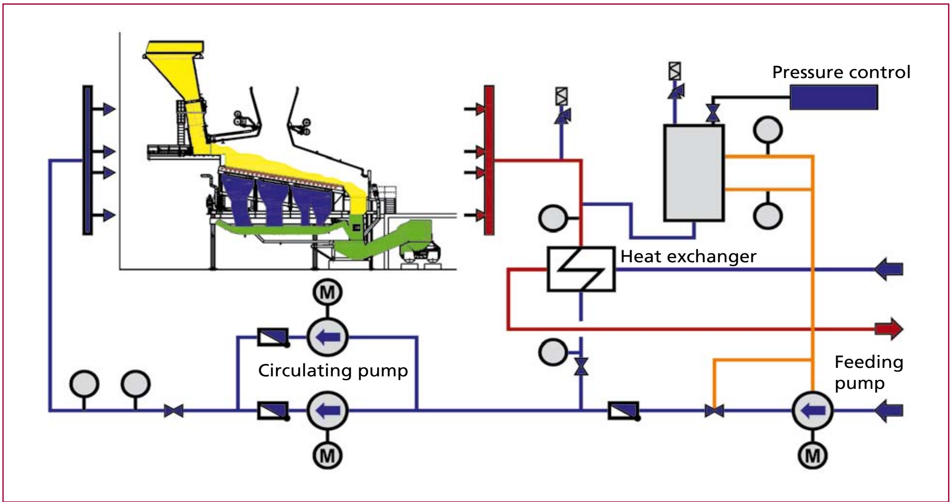


Figure 11: Schematic diagram of the cooling circuit

11.6. Water-cooled grate surface

The water-cooled grate surface is distinguished from the air-cooled grate bar by higher thermal loads. The water-cooled grate bar is made of a heat-resistant cast steel and includes a cast-steel pipe; as a result cast microstructure-related leaks cannot occur. The thermal loads from the combustion process and the mechanical loads from the movement takes over the structural design of the grate bar.

The cast-steel pipe guarantees a defined flow without vortex induced dead zones square channels, which induce an overheating hazard.

The quality-assured production of grate bars ensures, a material connection to the cast body, so that no air annular gap reduces the heat transfer near the surface of the steel tube.

The grate bars are mutually held together by screws and form the rows of grate bars.

The cooling water supply to the water-cooled grate lining via single strands each grate bar row. The individual grate bars are connected together with U-tube sections.

The sidebars are also water-cooled and have graduated separate cooling supply lines.

The fixed cooling line terminals and the moving grate rows are connected via hoses.

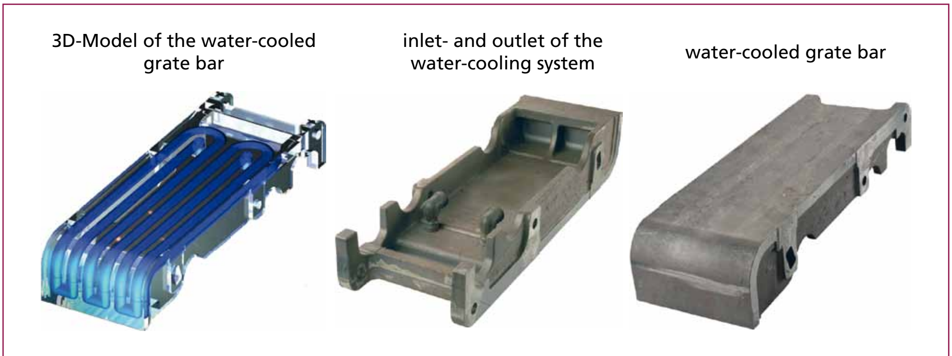


Figure 12: Water-cooled grate bars

11.7. Implemented grate firing system

MH Power Systems Europe GmbH has supplied nationally and internationally the necessary stoker grates with the appropriate combustion control for 21 incineration lines over the last 10 years.

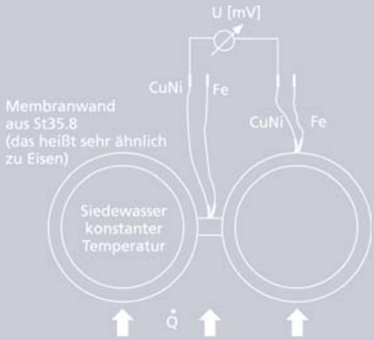
The cost optimization through the use of flexible grate systems in combination with modern boiler technologies is characterized by the list of statutory emissions values and recycling waste material, in a wide variety of applied cases of application in conjunction with the economic operation of the plant, documented by a high availability and a long travelling time.

The varieties of waste-throughput and thermal incineration services were carried out. Examples are the following references that illustrate the flexibility of combustion grate.

Table 1: Reference plants – calorific value range, throughput and thermal combustion capacity

Plant	Calorific Value Range	Throughput	Thermal Combustion Capacity
	MJ/kg	t/h	MW
MKK Bremen	8 to 18	40	110
MSZ3 Moskau	4,8 to 12	33.5	47
Samsung Electronic	15.5 to 23.4	3.2	17.25

Wärmestrommessung an Membranwänden von Dampferzeugern



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- die Feuerlage auf dem Rost oder in der Brennkammer,
- Schieflagen der Gasströmung in den Strahlungszügen,
- den lokalen Belegungszustand (Verschmutzungszustand) oder
- den Zustand des Wandaufbaus (Ablösen von Feuerfestmaterial)

zu bewerten.

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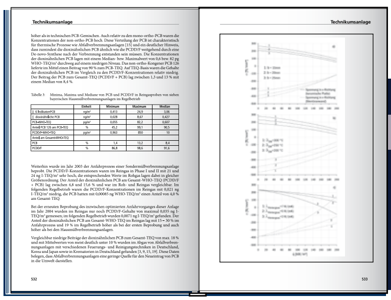

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