

**REAR-VENTILATED BOILER WALL PROTECTION
OR
HOW TO REDUCE MAINTENANCE COSTS**

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INTRODUCTION

The seemingly endless possibilities, which are offered for the refractory lining in WTE plants, have effected that new lining concepts have been developed and introduced again and again during the last decades. The objective of all lining systems from the start has been to reduce corrosion on the boiler walls to a minimum and to regulate heat loss in the first flue in such a way that all requirements according the 17th Federal Emission Laws are fulfilled.

The last mentioned demand has always been less of a problem. The prevention of corrosion on the boiler tube walls has been the far more difficult problem over several years. This was specifically the case if the incineration boiler was operated with increased saturated steam temperatures and corresponding pressures. In addition, variations in regard to the refuse composition with steadily increasing loads of chlorine have effected a growing importance in trying to prevent boiler tube corrosion.

Various refractory lining systems have been installed in the WTE plant of the Zweckverband Müllverwertung Schwandorf (ZMS) in Schwandorf, Germany, since it was first built. All these systems were carefully controlled and assessed. Due to the detailed and systematic documentation and observation of the rear-ventilated tile system by ZMS, after eight years of operation of the tube wall protection system it is now possible to obtain and present long-term results and make reliable statements on the performance of a rear-ventilated tile system.

**1. The WTE Plant Operated by Zweckverband
Müllverwertung Schwandorf (ZMS) in
Schwandorf, Germany**

The refuse incineration plant operated by ZMS has 4 incineration lines with a total throughput of approx. 450,000 t/a

refuse. The incineration lines 1 to 3 have a capacity of 12.5 t/h and line 4 has a capacity of 28.0 t/h. The refuse is mainly composed of household and bulky refuse plus industrial refuse of similar portions. The calorific value is on the average 10.5 kJ/kg during the year and, consequently, within the normal range.

The incineration lines 1-3 were built by the Steinmüller company (today Fisia Babcock). Concerning the grate systems they have a counter-flow overfeed grate which was supplied by W + E. Today the technology rights are the property of the company Martin in Munich, Germany. Boiler 4 was supplied by the Baumgarte company and also equipped with a W + E grate system.

The steam parameters of the boilers are at 72 bar and a live steam temperature of 410 °C. Consequently, these parameters are in the upper range for standard boilers in WTE plants. The steam amount of all four boilers is 216 t/h. The incineration temperatures above the grate are at approximately 1100 °C, in the area of the boiler roof 850 °C and at the inlet to the horizontal flue 600 °C. Figure 1 shows the cross-section of the plant in Schwandorf. As usual, the refractory lining is installed in the area of the incineration chamber and first flue.

**2. History of the Refractory Lining in Schwandorf
WTE Plant**

The first lining of the boiler walls in the incineration chamber area and in the 1st pass was out of refractory patching mixes based on 90% silicon carbide (SiC) with a chemical phosphate bonding. For anchoring the SiC mix with this lining method approx. 500- 550 Sicromal 10 boiler studs per square meter boiler wall were installed by the stud welding method. Next SiC caps were glued on the studs to ensure higher

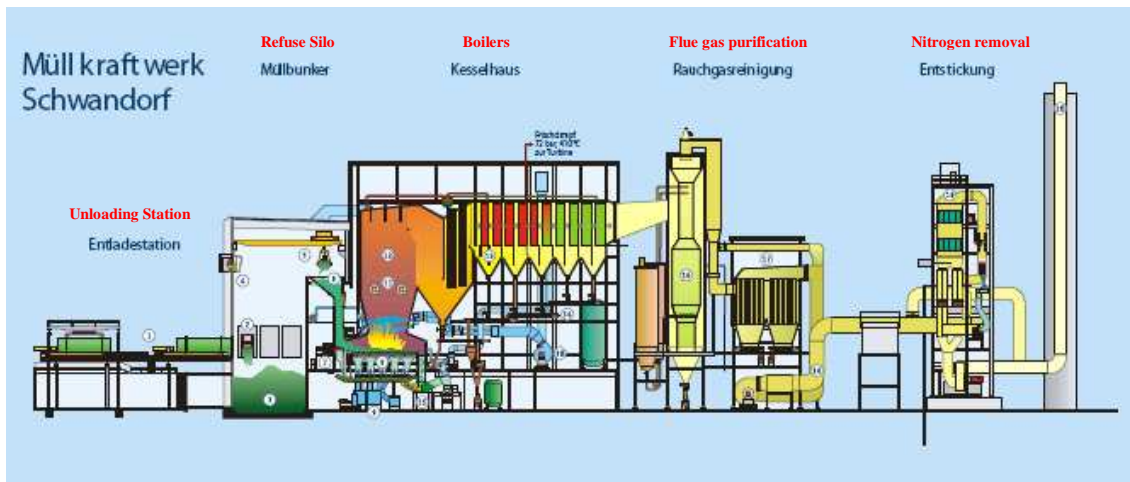


Figure 1: Cross-section of WTE plant in Schwandorf

corrosion protection. The SiC mix is installed flush on the tube wall up to the top edge of the caps to best protect the boiler wall.

After a few thousand hours of operation this refractory lining had already to be remodeled in certain areas. There was arching, spalling and destruction of the patching mix specifically in the area above the secondary air nozzles. Furthermore, one noticed intensive corrosion attack on the membrane wall of the boiler. High corrosion rates and specifically the potential danger that corrosion progresses unnoticed behind the refractory lining effected a high level of operational uncertainty. Consequently, all involved parties saw the necessity to find an alternative to the SiC mix.

In 1992, the first boilers were lined with the **JuSyS®Standard**. The glued tile system. This tube wall protection system features nitride-bonded SiC tiles which are held by heat-resistant metallic anchoring systems on the tube wall. The tube wall tiles are designed in such a way that each individual tile sits on a holding console. The holding consoles are welded to the fin of the tube wall so that a pressure test is not required. The SiC mortar is positioned between the tube wall and SiC tile.

As a pre-manufactured, machine-pressed, fired and nitrided shaped part, the SiC tile possesses a for more homogeneous structure than the SiC mix applied by hand. In addition, it has significantly better heat flux ability due to its different type of bond and significantly lower porosity which reduces the permeability for diffusion of the pollutants. This material reduces slag and ash coatings (deposits) on the lining due to its surface design. With this system it was possible due increase the service life to approximately 25,000 to 30,000 hours. Nonetheless, there were damages, specifically in the upper area of the incineration chamber, due to corrosion on the membrane walls. There was also intensified attack on the holding components due to chlorine corrosion.

In 1999, the next development stage was reached in that the rear-ventilated **JuSyS®Air** tile system was installed in the upper area of the incineration chamber. Here, too, nitride-bonded SiC tiles were utilized which were inserted or rather hung in heat-resistant metallic anchoring components (no tension). Consequently, these tiles are held on the tube wall.

This measure effected that there were no more unscheduled shutdowns due to the refractory lining being damaged in the area above the secondary air nozzles. Continuous examinations have shown that there are no or only minor corrosion damages on the holding components for the tiles and on the tube wall. At the moment the service life of the rear-ventilated system is over 60,000 operation hours.

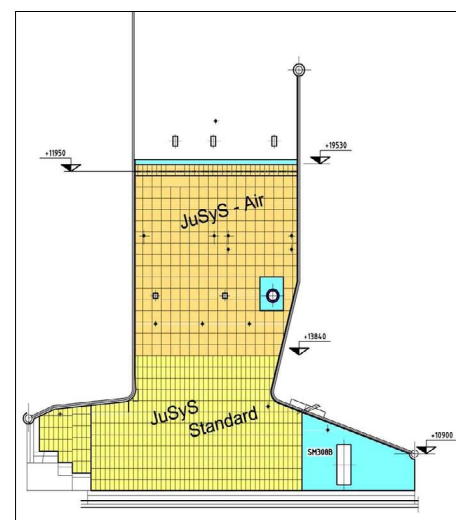


Figure 2: Refractory design with JuSyS tube wall tile systems in the combustion chamber and 1st pass

3. Development History of the Rear-Ventilated Tile System

Already in the mid-1990s, Jünger+Gräter came with the first ideas for a rear-ventilated tile system. The reasons for this development, were intensive corrosion problems in the WTE plant in Mannheim, Germany, and creative thinking by both sides involved. However, at that time the specific design of such a system was not yet envisaged. At that time the WTE plant

industry was noticing more and more boiler wall corrosion. This was also the case in incineration plants that achieved satisfactory operation periods with standard refractory linings. Various factors were responsible for the changed corrosion conditions. Among others, these included the observance of the new emission regulations and laws and connected measures in regard to flue gas purification, changing refuse composition and general trend to increase efficiency by utilizing higher boiler pressures and temperatures [1]. The combination of the various measures had the effect on several operators and the WTE in Schwandorf that the refractory lining in some areas was destroyed after only a few thousand operation hours. In addition and even worse, extremely intensive corrosion was noticed on the boiler walls [2].

After extensive review and analysis of the changed parameters for the incineration process it was noticed in particular in existing plants, where the corrosion phenomenon occurred to a much greater extent, that the incineration air was reduced significantly to achieve the waste gas requirements in the NO_x sector and further parameters concerning flue gas purification. This resulted in a significant decrease of the oxygen content in the flue gas [3]. Consequently, there was an increase of the corrosion potential of other oxidation partners than oxygen, for example the chlorine contained in the flue gas. This brought about the idea to use fresh air to increase the oxygen content right at the boiler wall and thereby achieve something like a dilution effect for the corrosive gases. This was the beginning of the idea involving rear ventilation with purging air. Now it only had to be realized. The biggest impairments, which had to be overcome in the development stage, were connected to getting the refractory lining “dense” enough so that not too much purging air gets into the incineration process as “foreign” air and, consequently, has a negative effect on the design of the flue gas system. Furthermore, it had to be clarified how the heat transition to the boiler wall can be best accomplished if considering that a good insulator, such as air, interrupts heat flux between the refractory materials and boiler wall.

In the beginning defined purging gas outlet openings were to be positioned in the refractory lining. This soon turned out to be counterproductive because no pressure could be generated in the gap between boiler wall and tile. Consequently, far too much purging air got into the incineration chamber. The system was changed in that these openings were closed and one could now speak of blocking air instead of purging air. There was significantly increased corrosion on the tube wall if the blocking air was not available. An early warning system was installed in the Schwandorf WTE plant in case of a pressure drop. This ensured a continuous control of the overpressure. It was further noticed that direct contact between the anchoring components and the refractory materials caused intensified corrosion. The system was modified in that all metallic components were supplied with a sufficient amount of blocking air to prevent corrosive gases from getting to the anchoring components. The heat transition problem turned out to be not relevant as had been presumed at the beginning. Due to the high radiation

component in the gap between tile and boiler wall (only a few millimeters), the tile system had a sufficient heat transition rate thus enabling the efficient use of the rear-ventilated tile system. Latest examinations have shown that – in contrast to what was known up to then – there is a considerable convective heat transition share in the gap. This explains why the tile system has proven to operate very well in the hotter zones of the incineration chamber.

Thus the rear-ventilated tile system has been through several development stages and adjustments until having arrived at its current design. These development stages were based on the combination of theoretical thoughts and empirical knowledge which enabled state-of-the-art. Due to major skepticism on the part of plant operators and plant engineering companies, the system needed about 10 years since the initial ideas to achieve acceptance on the market. The WTE plant in Schwandorf opted to apply this tile system at a very early stage and now have more than 8 years of experience with it.

4. Functioning and Design of the Rear-Ventilated Tile System – State-of-the-Art

The functioning of the rear-ventilated tile system has been extensively explained in many publications [4]. Consequently, only a brief survey on principle functioning of the system will be given here.

As illustrated in Figure 3, in the incineration chamber of the refuse boiler a refractory tube wall tile is connected by way of a special anchoring system to the boiler wall. Consequently, the tube wall tile hangs in a defined distance as protective layer in front of the boiler wall. This generates a defined gap between boiler wall and tube tile which is supplied with blocking air by an air distribution system. The air pressure of the blocking air in the gap is controlled in such a way that it is higher than the air pressure in the incineration chamber. This generates kind of an air haze which prevents the corrosive gases out of the flue gas from entering the air gap and causing corrosion damage on the boiler wall.

The sealing of the vertical joints between the shaped tiles for the tube, which are manufactured out of nitride-bonded silicon carbide, is done with a joint mix, which also mainly consists of silicon carbide, and a high temperature fiber string.

Since the tile is only hung in front of the boiler wall, it is not tightly connected to the boiler. Consequently, the tile is not subjected to the system-immanent tensions and vibrations of the boiler to the extent the glued or rear-cast systems are. The system is hardly affected by stress cracking so that the corrosion protection is maintained over very long plant operation periods. Figure 3 exemplifies the arrangement of the air distribution for the rear ventilation of the tiles in a refuse boiler. Air distribution is effected by rotating comb boxes. The blocking air enters the gap between tile and tube wall through the openings in the tube webs of the boiler wall. Since the system is not completely airtight due to shrinkage cracks and very small hairline cracks,

depending on the boiler size an air amount of 1,000 to 3,000 Nm³ is required to maintain the required overpressure. The air supply can be realized via the burner cooling air supply, incineration air supply or by way of separate fans.

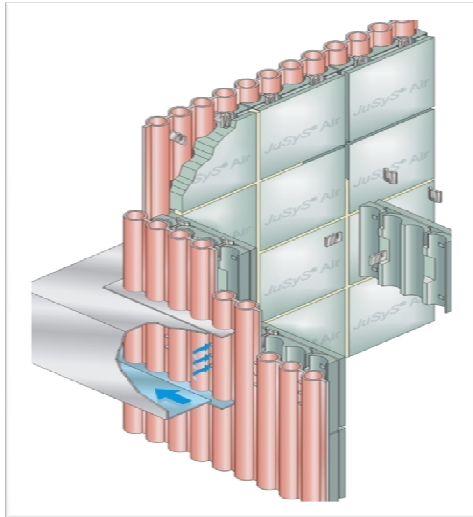


Figure 3: Rear-ventilated tile system *JuSyS*[®] Air

5. Long-Term Observation and Examination of the Tile Systems in the Schwandorf WTE Plant

In 1999, the combination of glued tube wall tiles in the area below the secondary air injection and the rear-ventilated tube wall tile system above was installed. Since that time extensive records have been kept concerning the replacement rates of the various tile systems. This documentation was always part of the annual inspection. In addition, the SiC tiles were examined chemically in regard to enrichment with pollutants, such as metallic salts out of the flue gas, and physical examinations were conducted to check any change of the porosity. Thanks to this documentation it was possible for the first time to provide detailed information on the long-term behavior of the rear-ventilated tile system. The behavior confirms the previous projections or, respectively, even surpasses them in the case of the Schwandorf WTE plant.

5.1. Replacement Areas and Rates of the Tile Systems in Comparison to Other Refractory Lining Variants

The pure tube wall tile areas were assessed for the evaluation of the replacement rates. This means that special areas, such as the ignition and burnout roofs, baffle or rather nose areas of the boiler, were not included in the evaluation. The refractory lining

areas of the boiler do not permit a comparative assessment of the 3 incineration lines because the service life or performance was significantly different in the incineration lines due to the wear mechanisms in these exposed areas. In order to prevent an overlapping or false interpretation of the results, respectively, only the replaced pure and large tube wall tile areas were carefully assessed to make reliable statements. Consequently, the specific new refractory linings in the boilers were not considered here.

Based on the evaluations in Figure 4 one can clearly see that the first tile areas did not have to be replaced until at least three years had passed. Consequently, at the Schwandorf WTE plant the refractory lining enabled operation times that were not even conceivable with the refractory linings out of refractory patching mixes used up to that date. Furthermore, it is noticed that the replacement of rear-ventilated plates (blue beams) is noticeably less than that of the glued tile systems (red beams) despite the total refractory lining surface for the rear-ventilated system being significantly larger in all 3 incineration lines. Overall, no more than 19m²/a had to be replaced with the glued system and 13m²/a with the rear-ventilated system. The superb performance of the refractory lining is really in the spotlight if making a comparison between the combined tile lining (glued and rear-ventilated) and the original lining out of SiC patching mix (refer to Figure 5).

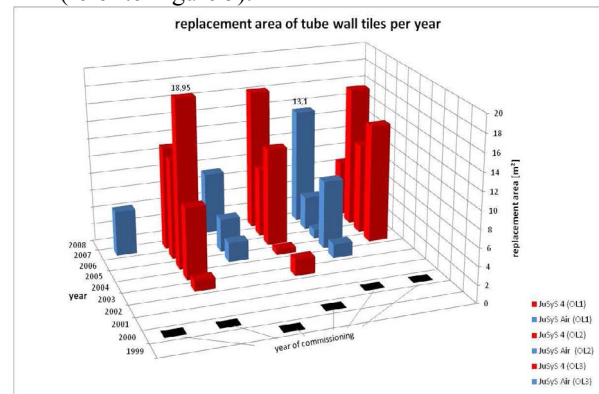


Figure 4: Tube wall tile replacement per year

It can be seen that with the SiC mix lining the first lining areas already had to be repaired during the second year of operation and that during the third operation year it became necessary to make repairs in over 25 % of the total area. In addition to the damage to the refractory lining there was also major corrosion on the boiler wall of up to 3 mm in some spots (compare Figure 16). As already mentioned above, this effected the switch of systems used for the refractory lining. Due to this switch a significant replacement of the glued tiles was not required until approximately 5 years had past by. Replacements for the rear-ventilated system were not required until 6 to 7 years later. After applying the new lining system it was practically possible to eliminate corrosion on the boiler walls. Corrosion is now only a few micrometers (compare Figure 15).

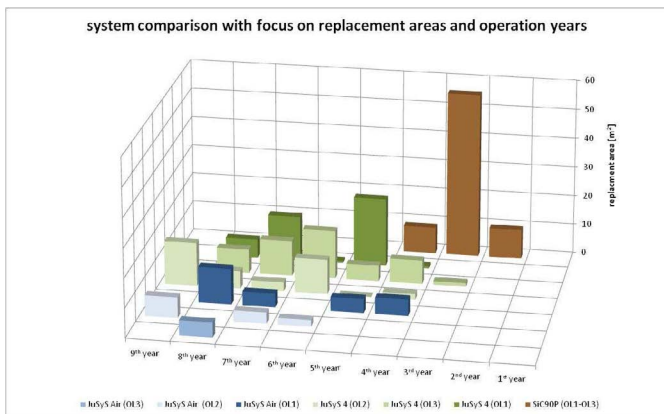


Figure 5: System Comparison

All plant operators are specifically interested in the replacement rates of systems. For this reason the relative replacement rates, based on the total system area, were recorded and documented over a period of 8 operation years. It was seen that during this entire period the glued tiles in incineration lines 1 and 3 had to almost be completely replaced. For incineration line 2 it became necessary to replace approximately 40 %. The replacement rates for the rear-ventilated plates are extremely low. Nobody would have guessed this at the start of service of the rear-ventilated system. After 8 years of operation less than 10 % of the total area of the system had to be replaced in the incineration lines 2 and 3. However, in incineration line 1 there are higher replacement rates. These increased rates are due to damages to the upper tile rows having occurred in the years 2004 and 2005 because the sealing by the SiC mix was not completely ensured in that area. Consequently, the upper tile rows had to be replaced due to corrosion on the holding components. If one disregards this replacement work, incineration line 1 would also have a replacement rate of under 10 % of the total area of the system. In summary, the service life or performance, respectively, of the rear-ventilated tile system is at a remarkable and record-breaking level in all 3 incineration lines.

Of course the conclusions of this comparison give rise to the question why rear-ventilated tiles are not also installed in the lower area of the plant. It has been seen in the past that this is only possible to a limited extent because the surface temperature of the tile lining is much higher due to the significantly higher incineration temperatures in the incineration chamber of the plant. It has been noticed that with the rear-ventilated tile system the oxidation rate of the silicon carbide is higher in comparison to the glued tiles due to the higher surface temperature. For this reason glued tiles are installed in the lower area of the plant. This is also done because in the hot area of the plant the corrosion potential of the flue gases is much lower than in the first flue. Consequently, with glued tiles in this area the plant operator has acceptable service life and less corrosion on the boiler walls.

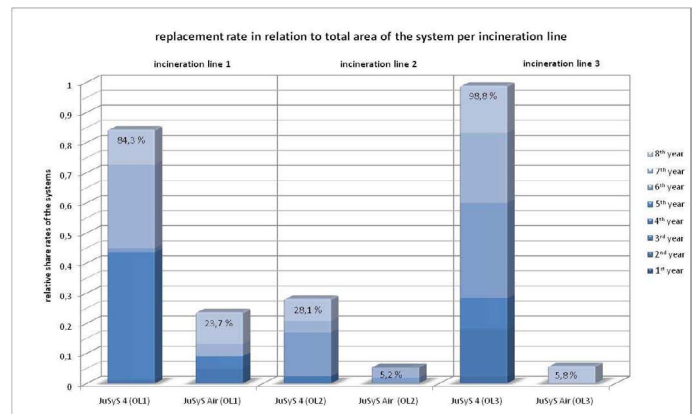


Figure 6: Replacement rates of the tiles systems

The varying service life performance of the three lining systems (glued tiles, rear-ventilated tiles, patching mixes) is illustrated well in Figure 7. For example, one can see that the glued tile system, when compared with the original lining out SiC 90 patching mix, has an almost 50 % lower replacement rate if the lining out of refractory mix would have accomplished a fictive operation period of 8 years. Since the lining out of refractory mix was replaced with tiles after 4 years, the replacement rates were projected for 8 years. This generated the calculated replacement rates to be 120.7 % for the system with refractory patching mixes.

Consequently, in comparison with the SiC patching mix lining and based on the specific total area of the system, glued tiles had a twice as long service life and rear-ventilated tiles up to a tenfold as long service life (refer to Figure 7). Due to this precise evaluation work at the Schwandorf WTE plant, the previously made service life projections or assumptions, respectively, were significantly surpassed. This is especially the case for the rear-ventilated system.

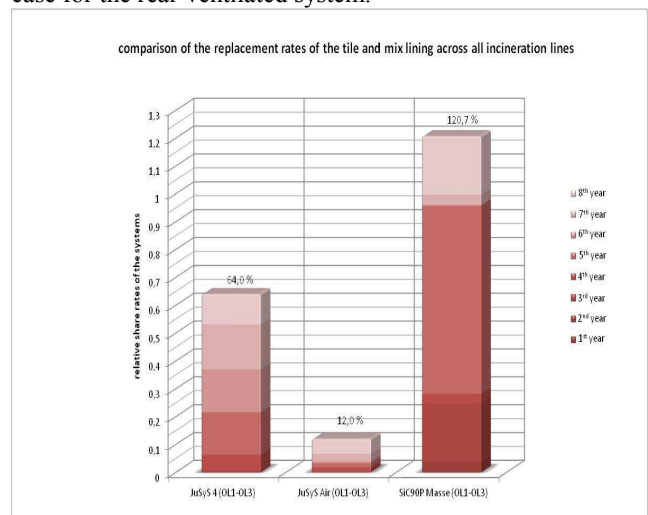


Figure 7: Replacement rates of the various lining systems

5.2. Evaluation of the Chemical Stress (Load) on the Tile Systems

In addition to the documentation on the replaced areas in all 3 incineration lines, chemical examinations were also conducted on the used shaped tiles for tubes in incineration line 2. Samples were taken from different height levels in the plant and based on different operation times. Next the X-ray fluorescence analysis process was applied to quantify the various substances causing stress. The analyses were conducted in various depth zones of the tile to be able to make a statement on penetration depth and varying degree of enrichment of the pollutants. With the glued tile system the tube wall tile is positioned in a refractory SiC mortar. Consequently, the refractory mortar at the tube wall and between the tiles was examined chemically (compare Figure 8). This chemical examination focused on the corrosion-relevant substances such as chlorine, sulfur and typical alkali and heavy metal salts. These effect the high temperature chlorine corrosion and salt melting corrosion.

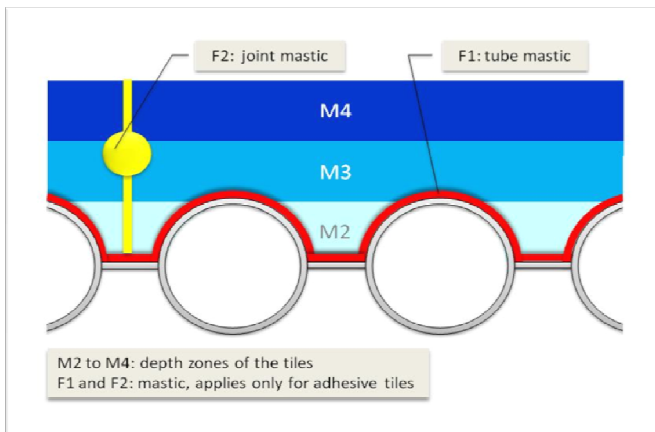


Figure 8: Illustration of the areas where the sample tiles were taken

The analysis of the chlorine stress on the shaped tiles for tubes at first shows no clear differences between the chlorine concentration in both different tile systems.

However, it is generally noticed that the chlorine concentration increases with the installation height in the plant and operation time. This is valid for both systems.

At least the increase of the chlorine concentration during the operation time seems very logical since over time the chlorine enriches more and more due to condensation as alkali chloride. Furthermore, the chlorine concentration in both front depth zones M4 and M3, which face the incineration chamber, is generally higher than in the last depth zone in direct vicinity to the tube wall. This phenomenon is far more distinguished with the glued system than for the rear-ventilated tile. One reason for this can be that with the rear-ventilated system the blocking air impairs penetration of the polluting gases and enrichment of the salts only occurs in the front depth zones.

The concentration increase, which is dependent on the operation time of the system, is clearly noticed in the rear-ventilated tile. The stress (load) continuously increases specifically in depth zone M4. This effect is not as distinguished in zone M2 that faces the tube wall. This can certainly be explained by the fact that the concentration will be lower or higher depending on the proper functioning of rear ventilation (see Figure 9, Diagram 1). This proves that permanent rear ventilation with blocking air is an important parameter for the functioning of the rear-ventilated system and its duty to protect against corrosion.

This becomes even more obvious by taking a look at Diagram 2 in Figure 9. The pillar with an operation time of 31,000 hours and a height of + 18 mm represents the upper tile row of the rear-ventilated system. This tile row was installed in the glued version in order to accomplish good sealing to the boiler chamber. It is clearly noticed how intensive chlorine enrichment can be in the upper area of the tile lining if no purging air or blocking air, respectively, can “push” the polluting gases out of the tile. Consequently, the functioning and sustainability of corrosion protection by the rear-ventilated tile system can be seen very clearly by this analysis in comparison with the glued version.

Even if one also considers the mortar (compare Figure 9 / Diagram 3), it is possible to see the high concentration of the chlorine which is represented by the red beams. However, it must also be stated that the chlorine concentration is also extremely low with the glued system once comparing it to the experience gained in other plants. The concentrations in the glued system are at a not critical level. This is proven by the low concentration rates since the installation of this system.

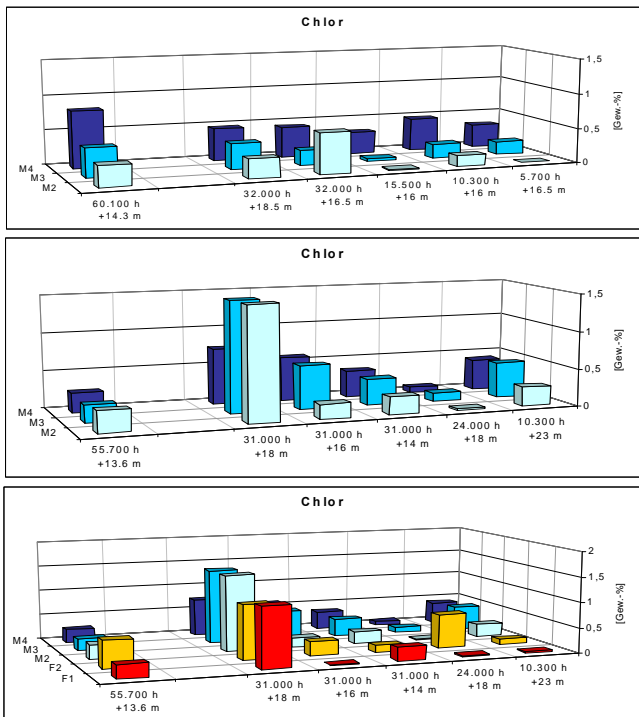


Figure 9: Chlorine concentration in rear-ventilated tile, glued tile and glued tile plus mortar

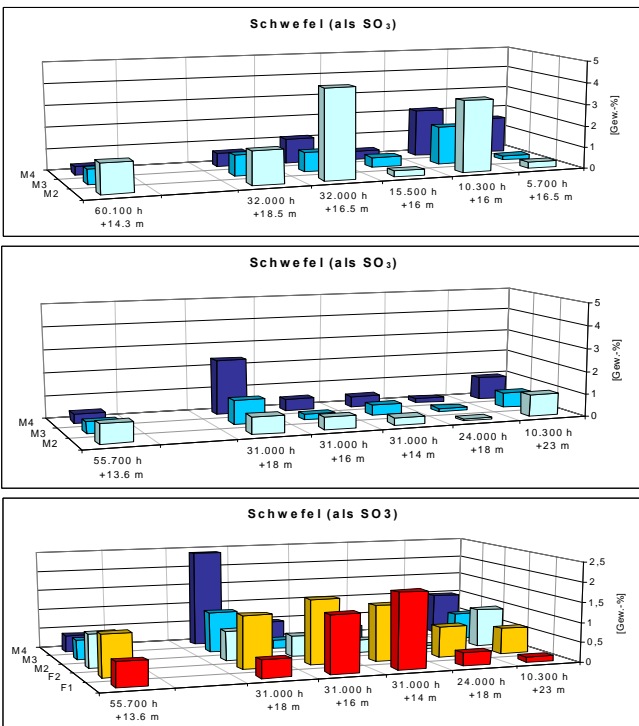


Figure 10: Sulfur concentration in rear-ventilated tile, glued tile and glued tile plus mortar

When taking a look at other alkali metals having an influence on corrosion, such as sodium and potassium, one generally sees an increased concentration in the M2 layer with the rear-ventilated system and in the mortar area F1 with the glued system. Here, too, the functioning of the rear ventilation can be clearly seen. The rear ventilation gap interrupts the diffusion of the corrosion elements to the tube wall. In addition, the coldest area of the tile is located in the M2 layer. Consequently, this leads to condensation of alkali salts. These have a hard time reaching the tube wall because of purging and the distance between the system components. In contrast to this, there is a visible increased concentration of the corrosive elements in the mortar layer of the glued tile system. The corrosive elements can reach the tube wall by way of diffusion processes. In the end, corrosion is the result.

As already mentioned for chlorine, only low concentrations of <3 % by weight are noticed over a period of 8 years.

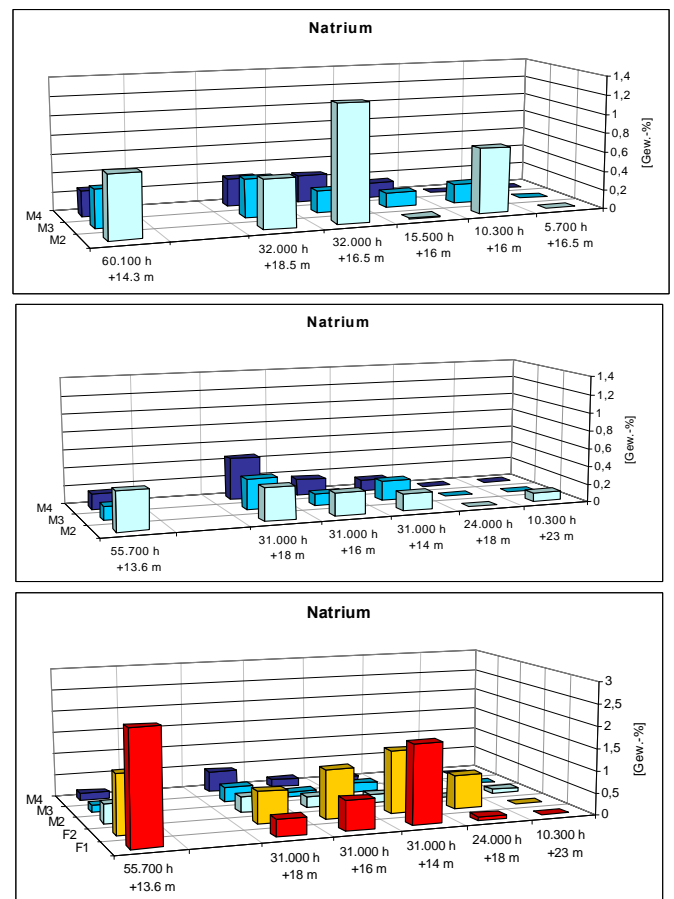


Figure 11: Sodium concentration in rear-ventilated tile, glued tile and glued tile plus mortar

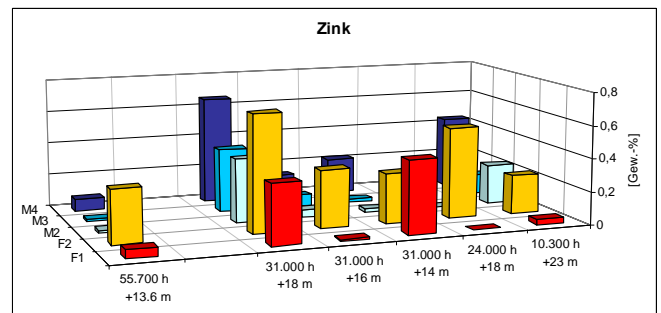
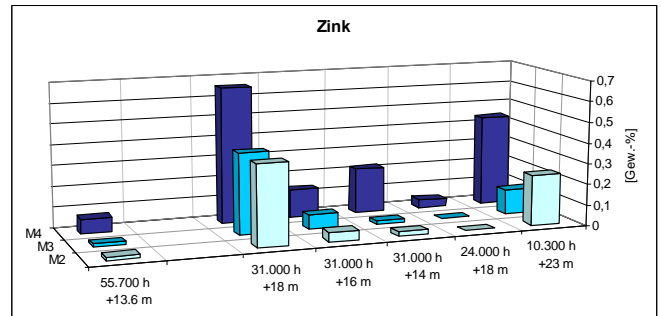
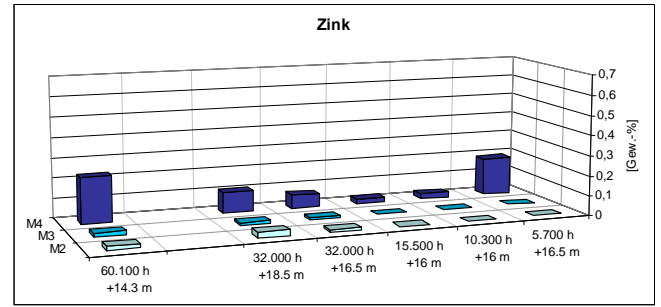
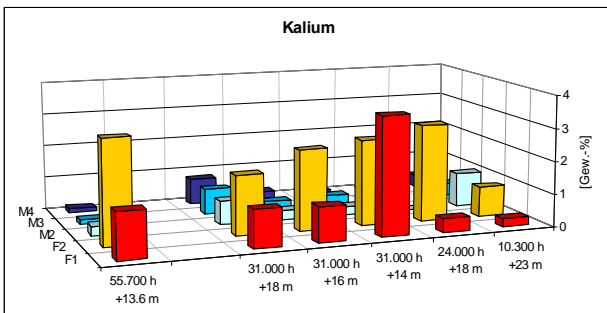
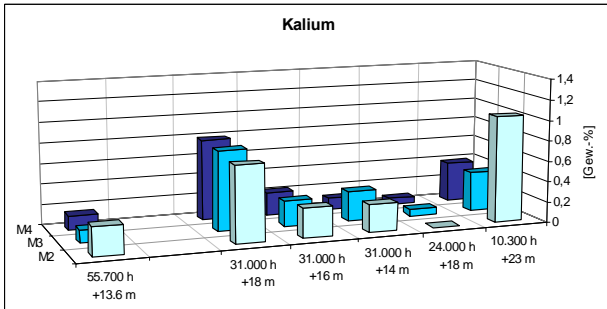
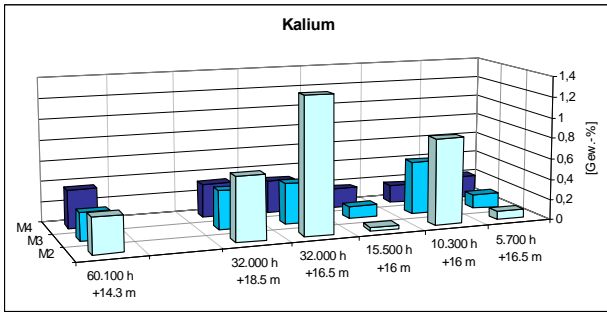


Figure 12: Potassium concentration in rear-ventilated tile, glued tile and glued tile plus mortar

Figure 13: Zinc concentration in rear-ventilated tile, glued tile and glued tile plus mortar

The positive properties of the rear-ventilated tile become very obvious when taking a look at the results of the analysis of the stress caused by zinc and lead (Figures 13 and 14). These metals, which as chlorine salts have relatively low melting points (approximately 200-300 °C), get very close to the tube wall and can, consequently, release chlorine for effecting corrosion on the tube wall. However, the examination showed that for the rear-ventilated system, in comparison with the glued version, these metals are practically not detectable. With the glued tile system there is a noticeable increase of the metals zinc and lead, specifically in the mortar area on the tube. In contrast to the alkali salts, with their generally higher melting points (approximately 350-450 °C), these heavy metal salts condensate comparatively close to the cooled tube wall. With the rear-ventilated tile this temperature range of condensation is, however, first possible in the blocking air gap. Consequently, a coating (deposit) is not possible at this location due to the supply of blocking air. This in turn underscores the functionality of the system in regard to providing good protection against corrosion.

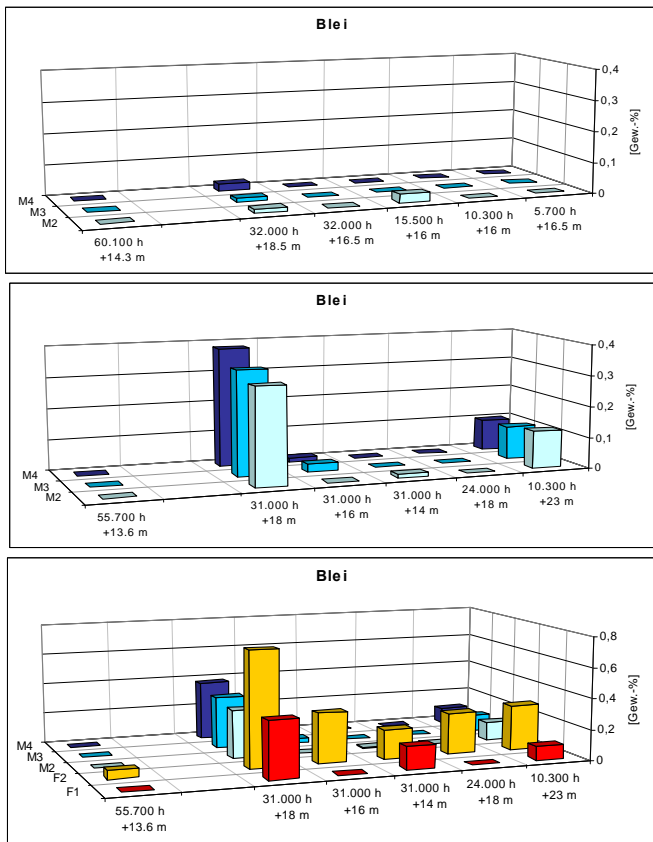


Figure 14: Lead concentration in rear-ventilated tile, glued tile and glued tile plus mortar

One can also visually see the difference between both systems (rear-ventilated and glued). As part of the continuous plant inspections, samples were taken from both systems in the area of the tile sections that had to be replaced. These samples were taken in June 2008. In Figure 15 the breakout area of a rear-ventilated tile and glued tile is illustrated. It can be clearly seen that thicker salt coatings (deposits) and corrosion layers have formed in the area of the glued tile than is the case in the area of the rear-ventilated tile. The tube wall behind the rear-ventilated tile does not have any visible salt coatings (deposits) and only small corrosion layers. Furthermore, the holding components of the tiles look almost as if they were new and hardly show any signs of corrosion attack. In contrast, in the glued tile area there are clearly visible signs of wear on the holding component as result of corrosion. Nonetheless, these components are amazingly still in a very good condition after an operation time of 60,100 hours. In contrast, Figure 16 shows dramatic wear and extreme corrosion. Here you see a studded tube wall with a refractory lining out of SiC mixes. This lining became defective during the operation of the plant. Such corrosion phenomena during an operation period of 4 years were the reasons or rather cause that during the first operation years of the Schwandorf

WTE plant the partial boiler corrosion in that area was up to 3 mm.



Figure 15: Breakout area of *JuSyS®Air* (1) and *JuSyS®Standard* (2)



Figure 16: Tube wall with refractory lining out of SiC mixes after approx. 2 years of operation

If one subjects the corrosion coatings (deposits) on the boiler wall to a chemical examination, one will see that, except for the heavy metals zinc and lead, there is no significant difference regarding the chemical composition between the glued and rear-ventilated tiles (compare Figure 17).

However, the share of alkali chlorides is somewhat higher with the rear-ventilated system. Generally the concentrations are at a very low level so that during the long operation of the systems there was no boiler tube wear worth mentioning since the first installation of both tile systems.

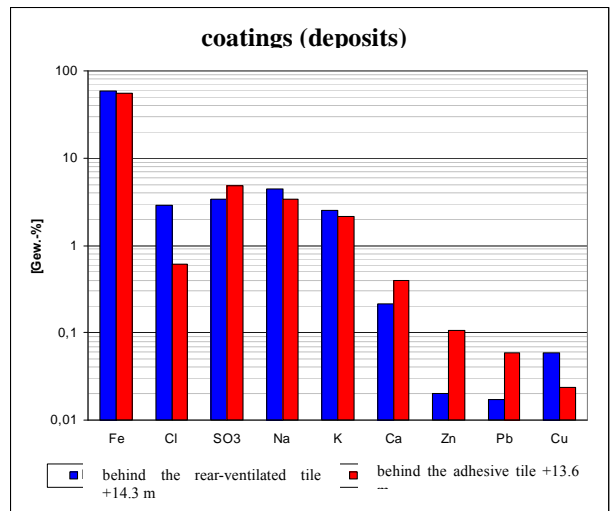


Figure 17: Comparison of the chemical composition of the coatings (deposits) behind the tiles

6. Consideration of the Efficiency of the Rear-Ventilated Tile System After an Operation Time of 8 Years

Not only does the boiler operation method have a decisive influence on the service life of any refractory lining but also the right and carefully considered choice of the lining system. Based on the conducted examinations it could be proven that the right choice of the refractory lining system has a decisive influence on the service life of the boiler tube walls and, consequently, on efficient operation of the refuse incinerator.

In addition to the varying technical advantages depending on the specific system, the operator of a refuse incineration plant should consider long-term efficiency of the systems to be the decisive decision criteria for choosing the company to provide engineering and installation of the refractory systems. Unfortunately, at the moment most decisions are based on short-term economic considerations or benefits so that often plants are equipped with linings or tile systems, respectively, that turn out to be problematical or inefficient during later operation. Often less proven engineering is preferred instead of long-term economic benefits. In the end, plant operators are often faced with significantly higher “consequential costs“ as a result of reduced plant availability and high maintenance costs.

It is well proven that the rear-ventilated tube wall protection system **JuSys®Air** achieves operation times of over 8 years with extremely low replacement rates of < 25 % with more than 64,000 operation hours. This corresponds to an average replacement rate of less than approximately 3 % annually. The service lives of SiC mix and refractory castable linings are about 2-3 years on the average. This corresponds to a

replacement rate of at least 25 % annually. Rear-cast or glued systems have an average replacement rate of approximately 10 % annually over their operation period of about 5 years. Consequently, the rear-ventilated system is far superior to all other standard systems when it comes to plant availability and maintenance expense.

Based on the long operation times of the rear-ventilated systems there will be far less downtimes for repairs than with all other standard refractory lining systems. In addition, the rear-ventilated tile does not require sandblasting and time-consuming dry heating. Problems with refractory materials have never been a limiting time factor during the regular inspection shutdowns since the first installation of the combined tile lining in the Schwandorf WTE plant.

A calculation was performed with the assistance of a model boiler in order to demonstrate the efficiency of the rear-ventilated tile system. The maintenance costs for a period of 10 years were totaled and subsequently divided by the number of operation years and based on 1m² boiler area. For the model boiler with 300 m² lining there was a repair time of 30 days in 10 years. This calculation is confirmed by the documentation collected in Schwandorf. In contrast to this, it must be considered approx. 200 days for installation of replacement refractory materials, if the lining consists of refractory castables or SiC mix. Without commenting this immense loss of production, the consideration of maintenance costs for the various systems alone demonstrates the superiority of the rear-ventilated tile system (refer to Figure 18).

Furthermore, the maintenance costs in Western Europe for the rear-ventilated system are under Euro 150.00/m² of lined boiler area in 10 years. These costs can be up to or even over Euro 750.00/m² boiler area if the refractory lining consists of 60 % SiC refractory castables.

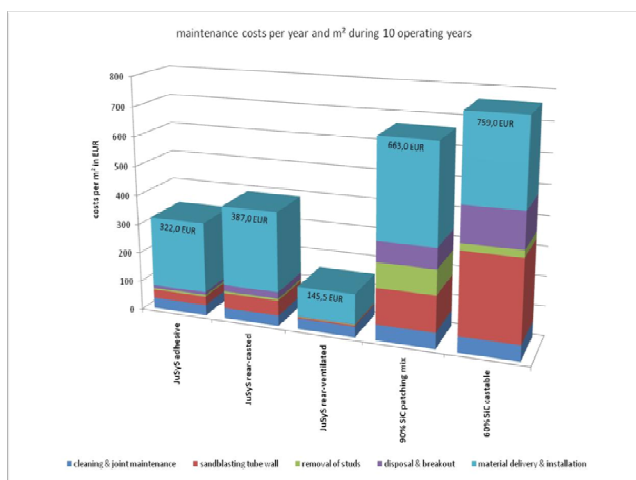


Figure 18: Maintenance costs for the various systems during 10 operation years

7. Summary and Outlook

Thanks to the precise documentation of inspection data by the responsible persons at the Schwandorf WTE plant and the long-term monitoring of the physical and chemical changes in the material of the tile systems it was now possible to confirm the previously only assumed analysis of the service life of the rear-ventilated tile system.

Consequently, it was seen that even after 8 years of operation the rear-ventilated tube wall tile protection system completely maintains its corrosion protection and heat transmission function. If this system is maintained well and operated by experience personnel, it should achieve a service life of more than 10 years. It must be stated that the replacement rates will probably increase starting the seventh year of operation. Considering the total replacement rate of under 25 % in 8 years this is a performance which had not been expected at the introduction of the rear-ventilated system. Furthermore, if thinking about the superb corrosion protection of the tile system, one starts to wonder why this system has not been designated as “the standard” for all new WTE plants. As is often the case, short-term economic success overrides long-term success. Due to its “technical extras”, for example air supply and measuring instruments, the rear-ventilated has higher initial costs than all other passive tile systems. Here the sensibility of the plant operator must be sharpened in regard to the long-term maintenance costs. During decision-making at the planning stage the plant operators should focus more on a reliable, safe tube wall tile system that does not cause problems. The rear-ventilated system is also an option for already existing older plants to greatly reduce maintenance costs. This is especially the case if the old refractory lining no longer offers sufficient corrosion protection due to changing parameters of the refuse composition, the incineration performance diagram or other conditions. Here the installation of a rear-invested system should be of major interest. This system will increase the operation time of the boiler walls because the boiler can be operated several years longer due to the rear-ventilated system. If considering all the expenses and connected downtimes it is almost self-explanatory that the investment for installing rear-ventilated tiles will pay off in comparison to a complete replacement of a boiler. Critics always mention that waste gas temperatures will increase and this could lead to problems for the existing flue gas purification. Another criticism is that the negligible blocking air streams (compared with the total flue gas volume) would have a negative impact on the observance of the emission limits. In the past it has been proven that these objections very rarely prevent the installation of the rear-ventilated system because the supplied amounts of blocking air are practically negligible in comparison to the flue gas volume. Furthermore, the scope in regard to the limit of the waste gas temperature is often not utilized.

The already completed change of the refractory lining system in several plants has proven that - with good project planning and

management in cooperation with an experienced partner - the switch to the new system will have a long-term positive effect on maintenance costs, subsequent operation costs and competitiveness of the plant. The growing importance of operation and installation safety of the plant is "only" mentioned on the side. Any plant operator should be aware of the advantage not to possibly stand in front of "collapsing new construction parts" when erecting the scaffolds for a boiler.

In regard to the intensified construction of power plants operating with substitute fuels it must also be stated that for this type of power plant only the installation of a proven rear-ventilated system pays off. These plants are particularly endangered in regard to boiler corrosion due to the corrosion potential of the fuel composition. In new plants it has been noticed that there is substantial corrosion after a short time of operation. The boiler areas, which were equipped with rear ventilation, have insignificant corrosion wear. Consequently, it is important to consult the supplier of refractory materials at the very beginning of the planning stage if intending to build such power plants. This will ensure that the key to the best possible refractory lining concept is found at an early stage.

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