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Measures for Extending the Service Run of Lignite-Fired Boilers

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Abstract

Extending the operating period of lignite-fired boilers

The units of the Neurath power plant are shut down every three years for a scheduled inspection. During these outages, the prescribed in-service inspections and any necessary maintenance work and conversions are performed on the steam generators. In addition to maintenance/refurbishments, monitoring and optimising the day-to-day operation of the plant are also of major importance. For this reason, various plant surveillance and diagnostic tools such as leak monitoring, optical and infrared cameras and a statistical process control system have been installed. Furthermore, a model-based process quality optimisation scheme has been introduced in all units to identify further optimisation potentials. Thanks to these measures, the non-scheduled unavailability (NSUA) has remained under control in recent years despite more stringent demands.

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Introduction

As agreed upon, the recurrent inspections on the steam generators relevant for approval take place every three years. During these shutdowns, other maintenance and retrofit measures are executed at the same time. In order to keep plant downtimes between the so-called overhauls and general inspections as short (?) as possible, various measures regarding wear and tear, fouling, process quality, and combustion have to be taken that will be explained at greater detail below. Longer inspection intervals are aimed for by using lifetime monitoring systems.

Brief introduction of the plants and goals

Installations at the Neurath power plant

The Neurath power plant consists of seven units with an installed capacity of 4,168 MWnet and thus belongs to the largest power plants in Germany.

The steam generators in detail:

– Unit A and B: 300 MW EVT-Sulzer single-pass boiler with reheating and flue gas recirculation; years of construction: 1972 and 1973
– Unit C: 300 MW Babcock-Benson single-pass boiler with reheating; year of construction: 1974
– Units D and E: 600 MW EVT-Benson single-pass boiler with reheating; years of construction: 1975 and 1976
– Units F and G: 1,100 MW HPA-Benson single pass boiler with reheating and optimized plant technology (BOA), years of construction: 2006-2011.

Goals

The efficiency-optimized plant operation and large load flexibility are two of the goals becoming more and more important as a result of the fast addition of renewables and the CO_2 certificate trading. Due to fluctuating coal qualities in open-cast mining, it is essential that a large range of lignite types can be used in the boilers. The net calorific values in the strip mines of Garzweiler and Hambach are between 6,800 and 12,000 kJ/kg. Coal components relevant for fouling like silicon, iron, and alkalies contents vary as well. In addition, the plants are to have a high security standard which requires an early detection of predictable losses and damages. Furthermore, a high planning security of the shutdowns is desired in order to schedule the downtimes and repair times at economically favorable periods. Together with the goals mentioned above, short downtimes and repair times are to result in a low non-scheduled unavailability of the plant.

Recurrent inspections and boundary conditions of the plants

Recurrent inspections

Every three years, each boiler has a planned shutdown. Besides the inspections required by law, standard inspections and result-dependent maintenance measures are carried out then. Retrofit measures and complex maintenance measures in damage areas are carried out as well.

The planned shutdowns are overhauls and general inspections in turns. They differ regarding the volumes of repair and maintenance, with overhauls taking 57 to 67 days and general inspections 42 to 46 days. Between the overhauls and general inspections, respectively, a so-called pit stop taking five to eight days can be scheduled if needed.

Boundary conditions

Because of their good combustion properties, Units A through C are supplied with highly fouling-critical coals, which might result in brief intermediate shutdowns for cleaning purposes. In the lower heating surfaces, the fouling occurs due to the high temperatures and the properties of the ash. Fig. 1 shows a fouled supporting tube bulkhead that was cleaned by tank cleaning head. The result is shown in Fig. 2.

Additionally, obstructions due to falling chunks of ash occur in the upper heating surfaces of Units A and B, which accumulate there because of the rigid support construction of the upper heating surfaces. With rising flow rates in the cross sections unobstructed at that time, erosion will increase there. This makes a shutdown for cleaning purposes necessary after approx. 1.5 years, carried out in the context of a pit stop.

Monitoring of the plant quality and diagnosis of changes and damages

The tools for monitoring and diagnosis described at greater detail below serve to

Fig. 1. Unit A: Fouled supporting tube bulkhead.

Fig. 2. Unit A: Cleaned supporting tube bulkhead.

detect damages early on and to avoid or aggregate unplanned shutdowns.

Statistical process control

By means of statistical process control, various plant components are checked for creeping changes using three statistical methods (Shewart X-bar; cumulative sum; exponentially weighted moving average). If the limit of a standardized plant characteristic is transgressed with two out of three statistical methods, an alarm is generated and, where required, sent out by e-mail.

For example, the degree of fouling of the air pre-heaters is monitored using SR::SPC (SR products by STEAG Energy Services GmbH) by statistically evaluating the behavior of the volume flow-corrected pressure drop across the air pre-heater.

Model-based process quality optimization

The process quality of each unit and its components is determined in the expert system SR::EPOS. An EBSILON®Professional model of the unit is stored here as calculation kernel. By means of the available in-service measurements, it assesses the current plant condition compared to a reference condition, calculates various what-if scenarios and shows potentials for optimization in terms of increase in efficiency and cost savings at five-minute intervals.

Moreover, a limit monitoring and a measured value validation are carried out by the process quality optimization in order to reliably detect faulty in-service measurements. To ensure that the calculation model also works in the case of faulty measured values, a SOM (self-organizing map)-based monitoring is used. It generates a substitute value for faulty in-service measurements, which was learned by the system based on previous modes of operation.

Monitoring with optical and infrared cameras

By means of retractable or inflexible optical cameras (EUvis insitu; EUtech-Scientific Engineering GmbH), the fouling status in the first superheater heating surfaces of the boiler, the ash load of the flue gas, and the cleaning effect of the steam blowers can be observed and assessed. The images are saved in a sequence of five minutes and can also be used for subsequent analysis.

Furthermore, depending on the size of the furnace of the boilers, two up to four infrared cameras (CMV Systems GmbH & Co. KG) are used that fully automatically enter the boiler once per hour and take infrared pictures that are represented as a flat projection of the boiler by an evaluation server. These images serve to assess the fouling of the furnace, because slagging has an insulating effect, and as a result the surface temperatures of fouled surfaces are significantly higher than those of clean surfaces. The cleaning of the furnace is described at greater detail in the chapter “Infrared camera-based furnace cleaning”.

Monitoring the pipes in the creep range

The consumption of service life of the live steam and hot reheat pipes is analyzed and displayed by the steam pipe monitoring (SR::SPM). For this, displacement and force measurements have been installed at significant locations. These measured values are processed every five minutes in a Rohr2 model, and the pipe system is statically calculated.

Monitoring of thick-walled components

By means of SR1, the thick-walled components in the creep range are checked for thermal alternating stresses, and a consumption of service life is displayed. To do so, the component stresses are calculated with the measured values of significant temperature measuring points and the specifications according to TRD and DIN EN 12952-4, respectively.

Pressure difference monitoring of the flue gas paths and air pre-heaters

One indicator for the degree of fouling of the heating surfaces and air pre-heaters on the flue gas side is the pressure drop of the flue gas path. Therefore pressure measurements are installed between all heating surfaces as well as up- and downstream of the air pre-heaters, which measure the behavior of the flue gas pressure from the end of the furnace. This is graphically displayed in the process quality optimization and monitored in the statistical process control.

Leakage monitoring with acoustic systems

These programs for diagnosis examine the sound frequencies of 21 microphones in the boiler. Four microphones are required in the furnace, whereas the other 17 sound sensors are installed between the convective heating surfaces. The sound level of selected frequencies is important for the leakage monitoring. Here, an alarm limit is defined the transgression of which is signaled in the DCS.

The blue graph in Fig. 3 represents the sound level development of a microphone during the emergence of damage. The relatively strong fluctuations of the sound level result from the steam blower runs that the sensors perceive as boiler damage at first, which are, however, blocked out by the leakage system. The regression line (Fig. 3)

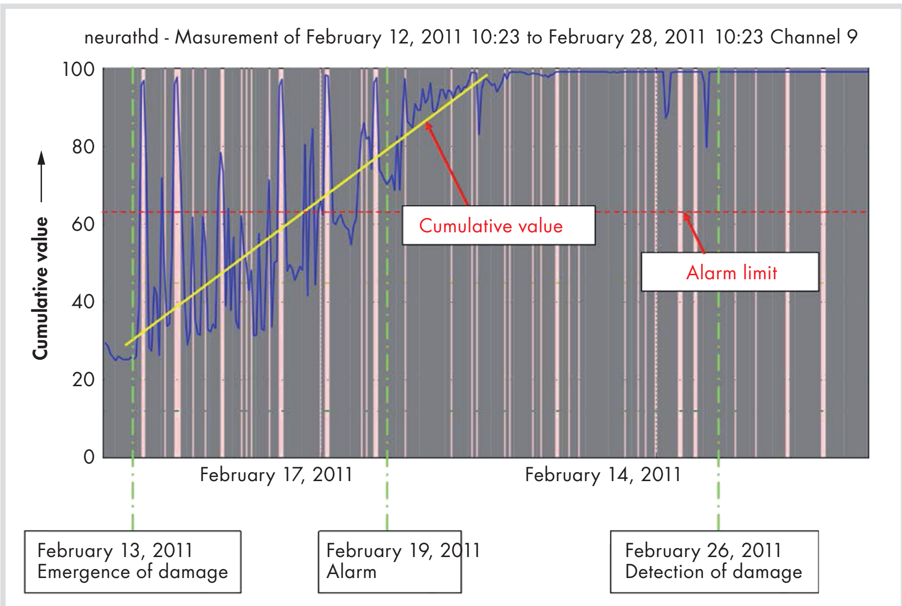


Fig. 3. Sound level of a microphone during the emergence of damage (Source: Inspecta of A. Lang GmbH).

shows that the damage occurred on February 13, 2011 and continued growing until the alarm limit was permanently transgressed on February 19, 2011. The damage was perceived for the first time by inspection staff as late as on February 26, 2011 because then the sounds of the flow could be perceived by the human ear. This means that in this case, the leakage monitoring could have effected a planning margin of one week. In this specific example, this advantage could not be used because the system had not been activated yet.

Monitoring and improving the combustion as a central task for increasing the availability

To improve the combustion of a boiler, primary measures (retrofit measures and changes in the mode of operation) as well as secondary measures (optimizing the combustion control using expert systems) can be carried out.

Primary measures

Pulverized coal diffusers for homogenizing the flow

A correct air/coal ratio is essential for low-emission combustion. One condition for this is the homogeneous distribution of the coal to the pulverized coal nozzles of the burner. This distribution is of particular importance in the Neurath boilers A through C because the combustion of fouling-critical coal is only possible with over-stochiometric operation of the coal burners (burn-out air vents closed).

For this reason, the diffusers shown in Fig. 4 have already been installed in three of six mills of Unit A. Both the designing and configuration of the diffuser were effected with modern flow simulation programs. By narrowing the cross section, the coal plumes are diverted to the center, and subsequently the gas volume flow is accelerated. As a result, the coal plumes are "ripped open" and thus a more homogeneous distribution of the pulverized coal to the three burner nozzles is effected. Fine adjustments are possible by means of the two upper flaps (Fig. 4).

Mill retrofitting and optimization

Besides the even distribution of the pulverized coal to the burners (cf. chapter "Pulverized coal diffusers for homogenizing the flow"), a reduction of the uncontrolled burner air (false air) is necessary because these remain nearly constant independently of the load and lead to emission problems in the case of more and more frequent load decreases. For this, the feeders are sealed and the flue gas recirculation gate valves (above the mill inlet) are retrofitted successively. Due to the decrease in false air that at the same time serves as cooling air, the mills get hotter. Therefore the intake behavior of the mill has to be adjusted to the changed air situation.

The shape and size of the impact plates is crucial for the intake behavior, because they also act as fan blades. The size of the impact plates decreases due to wear, and the intake behavior of the mill deteriorates, leading to a decrease in the quality of fuel drying in the mill and thus also of the combustion. Therefore currently a maintenance concept is being developed that represents a compromise between good combustion and low maintenance costs.

λ mode of operation

In lambda mode of operation, as much air as possible is added via the burners in order to complete the burn-out early and to keep the fouling of the convective heating surfaces low. Optimally, the burn-out air vents are closed during operation. This is necessary because as open-cast mining progresses, the coal quality varies and becomes more fouling-critical regarding the boiler tubes.

The geometries of the burners were checked using simulation calculations in order to implement the lambda mode of operation. Due to the simulation calculations, the decision was taken to retrofit some of the burners. Here special attention was paid to the difference in velocity of air and coal and to the formation of the tangential whirl.

Secondary measures

Emission control with SPPA-P3000 combustion optimization by Siemens

The main task of emission control is to ensure a homogeneous combustion and thus to decrease the NO_x and CO emissions. For this, a laser-based measurement with 15 paths is installed in a measuring level between burn-out air vent 1 and burn-out air vent 2. It determines the contents of H_2O, O_2, CO, and CO_2 as well as the temperature of the flue gas by means of absorption spectroscopy. The distribution of these values in the measuring level are calculated from this, using computed tomography. The model-based closed-loop control evaluates the distributions, detects local CO plumes (among other things) and trims the air at the burners and burn-out air vents, respectively, in such a way that a homogeneous combustion results. In doing so, the load-dependent rotation of the tangential firing is considered.

Due to the more homogeneous combustion, the excess of air can be reduced without an increase of emissions. As a result, the on-site power decreases and the efficiency rises.

3cons flame monitoring and tomography

Analogously to the laser measurement, the flame monitoring of 3cons GmbH tests the flue gases for the concentration of CO and NO_x, and a tomography is created. The substances of content are measured by means of emission spectroscopy with four cameras. At this point in time, there is no further evaluation and feedback for the closed-loop control in the form of air trimming. Currently this system is only used by the process engineer for assessing the firing quality.

Prediction with neural networks

The statistical method of neural networks (Atlan-Tec Systems GmbH) is used to obtain a dead-time controller concerning the nitrogen oxides. Here the actual emission measurements are replaced by a prediction value of the neural networks, and the dead time due to the distances between the end of the furnace and the emission measurements behind the electrostatic precipitator is neutralized. The big advantage is that the overshooting and undershooting, respectively, of the specified λ-value is reduced.

"Intelligent cleaning" between fouling and wear

Monitoring and control of the coal components

The components of the coal have to be known in order to allow for a coal-opti-

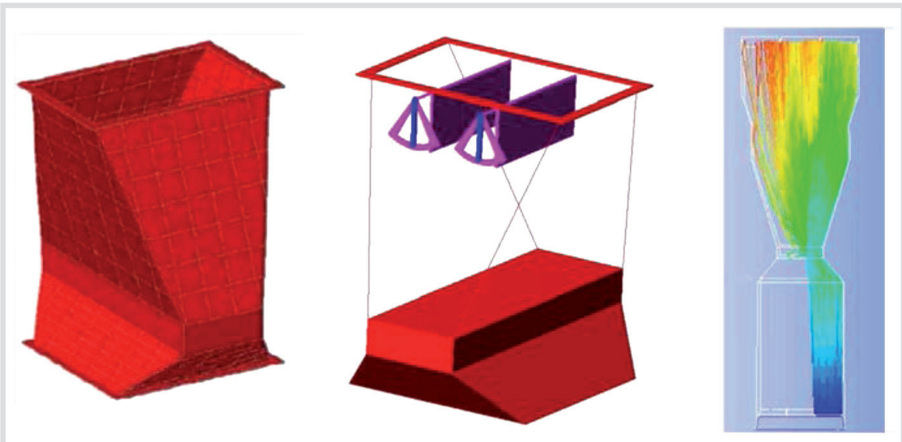


Fig. 4. Design and flow simulation of the pulverized coal diffuser (Source: Greenbank/Th. Scholten GmbH & Co.).

Fig. 5. Left: Unit D: Supporting tube bulkhead after being cleaned by a steam blower (Source: EUvis insitu).

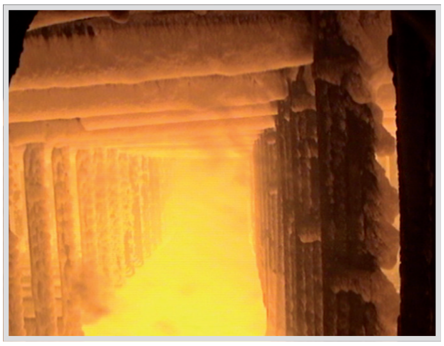


Fig. 6. Left: Unit D: Supporting tube bulkhead cleaned six hours ago (Source: EUvis insitu).

Fig. 7. Right: Unit D: Supporting tube bulkhead is being cleaned by a steam blower (Source: EUvis insitu).

mized plant operation. For this, the coal is examined by means of the coal online analysis (Kole, APC GmbH) behind the coal crushers.

Critical coal components like iron or clay are detected rapidly, and tightened soot blower parameters can be set. Moreover, more compatible boiler coals can be mixed by changes in the coal type blending in the context of day-to-day bunker management. The coal blending is effected by different tilting and reclaiming of the "coal trains" from the ditch bunker (vertical tilting and horizontal reclaiming). The adjustment of the blend takes about one day. For further optimization, a direct blending on the belt via impellers is planned. A feasibility study for the implementation is being developed.

Efficiency-controlled cleaning of the heat recovery areas with SR::BCM

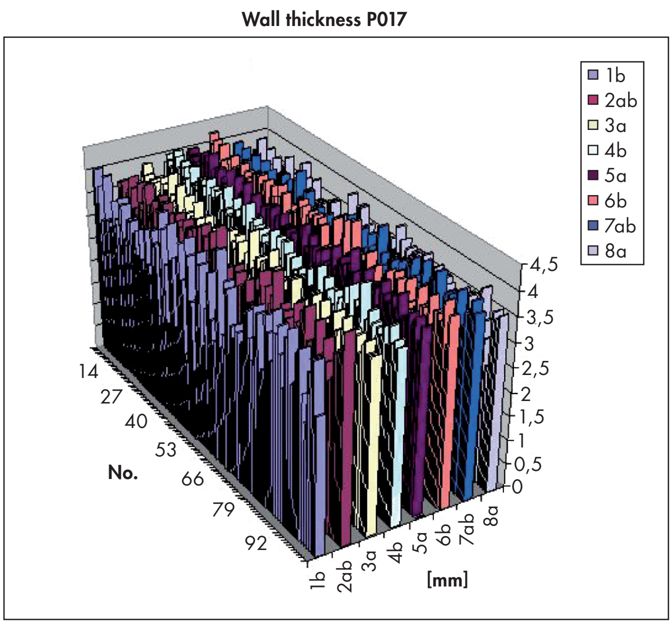
Due to the different fouling behavior of the coals, a purely time-controlled steam blower cleaning of the superheater heating surfaces is less efficient than an efficiency-controlled cleaning. With this approach, the efficiency of each heating surface is calculated by means of flue gas temperatures and steam temperatures. There are time limits and efficiency limits per heating surface that are processed by means of fuzzy algorithms and define an optimal steam blower sequence. Here a bottom-up grouping of blower levels is preferred because the ashes cleaned off the lower heating surfaces form the grit for the upper soot blowers (important for coals lean in sand).

In spite of the efficiency calculation, a maximum time limit is necessary because the deposits on the heating surfaces solidify both thermally and chemically over time, making it difficult to clean them off. Fig. 5 through 7 show the progression of fouling in the area of the supporting tube bulkhead. In spite of the rapidly growing deposit build-up, after the cleaning (Fig. 7) the initial state of the previous cleaning is achieved again (Fig. 5).

Infrared camera-based furnace cleaning

An efficiency-controlled evaporator cleaning is not helpful because the furnace is not fouled homogeneously; instead, fouling occurs in certain central points. These will shift depending on the firing situation. Therefore the water lance blower (WLB) patterns to be cleaned are determined according to the infrared thermal image by the evaluation server (cf. chapter: "Monitoring with optical and infrared cameras")

Evaluation unit (selectable)		1	= Date: 00.00.03 Results for selected wall thickness:				
			o	m	u	Sum	
Boundary wall thickness: (mm)		1,9					
Barrel change in WD	≤	3,0	7	19	41	67	Number of tubes
Pipe protection for WD	≤	3,0	0	0	0	0	Number of tubes



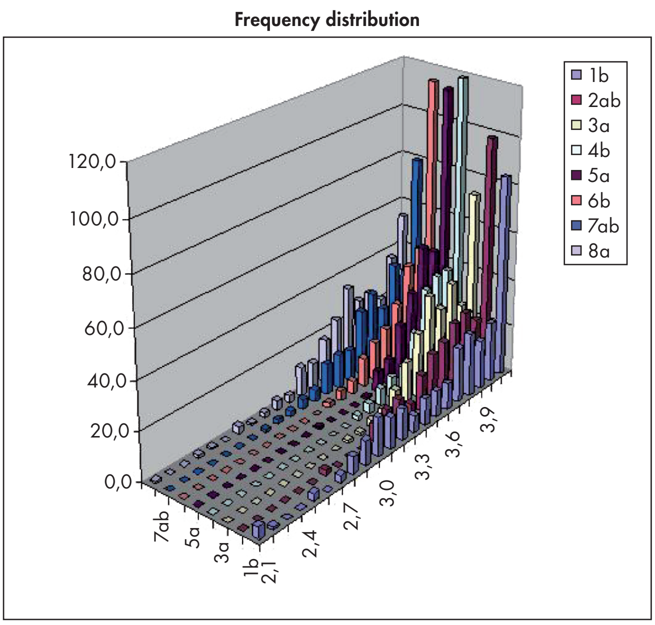


Fig. 8. Evaluation of the wall thickness measurements using the example of a platen heating surface.

and transferred to the soot blowing management. This also uses fuzzy algorithms to couple the information from the evaluation server with the minimum/maximum time limits of the WLB levels and determines the sequence of the WLB patterns.

Specific detection of increased wear in the boiler and measures in the overhauls and general inspections

A constant procedure has proven itself during overhauls and general inspections over the last years in order to reliably detect central areas of wear as well as damaged tubes: After the boiler has been shut down, it is cleaned, and subsequently a visual inspection of the lower heating surfaces is carried out. The heating surfaces with a segmentation of sufficient size are inspected, so that a person can examine the individual tubes of the platen heating surface. The results of the visual inspection are documented in the so called plate log. .

After or in parallel to the visual inspection, the ultrasonic wall thickness test takes place. Here the wall thicknesses of the tubes are measures and documented at defined measuring positions. For a 600 MW unit, there are approx. 60,000 defined measuring points. The results of the measurements are entered into a database and visualized as shown in Fig. 8.

The left chart (Fig. 8) shows the wall thicknesses of the position P017 that represents a measuring position defined by height on the supporting tube. Thus uneven zones of wear can be detected. The chart on the right (Fig. 8) shows the frequency distribution of the tube wall thicknesses in the supporting tube rows 1 to 8. A tube change is carried out when the total of limit wall thickness and the triple annual abrasion rate has been undershot because at this tube boiler damage during the next service run is very likely.

If central points of erosion or wear are detected by means of these evaluations, wear protection will be installed at these specific points. These measures, just like the tube changes, are entered into the plate log, which thus serves as a basis for work and billing.

In the case of the heating surfaces with narrower segmentation, the visual inspections in the heating surface package are carried out step by step while strutting the heating surfaces, and the damages detected in the process are remedied immediately. In the overhauls, all gaps (except the economizer) are opened, and in general inspections all or only part of the gaps are opened depending on the damages during the latest service run.

Summary

Without the measures mentioned above, a permanently efficient operation of the plants would be inconceivable. In recent years it has been possible to keep the non-scheduled unavailability stable in spite of increased requirements regarding emissions, deposit build-up-critical and erosive coal. The crucial point for all diagnostic programs is that on the one hand they are used, and on the other hand they are constantly enhanced and adjusted to changing requirements. Moreover, primary measures that remedy the problems at their source are to be preferred to the secondary measures because a boiler damage that does not occur will not have to be detected in the first place.