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Report on operation of heat recovery boiler cleaning system based on shock wave generators

In the year 2010, a sulphuric acid recovery plant with its auxiliary lines was put into operation at the company of Petrochemia-Blachownia S.A. The plant was constructed on the basis of the Danish technology of Haldor Topsøe. The purpose of the plant is to produce sulphuric acid above 97.5% from post-refinery mixture and benzene forerunnings. The post-refinery mixture is a semi-product which is formed during acid refining of BT fraction (benzene, toluene fraction). It consists mainly of unreacted sulphuric acid and organic compounds (e.g. sulfonic acids of organic compounds, salts of organic bases, polymerisation products and hydrocarbons alkylation). Benzene first running is a semi-product obtained as vapours. It contains mainly paraffins, naphthenes which boil below 80°C, carbon disulphide, small quantities of benzene, as well as other low-boiling pollutants of raw benzene. The nominal production capacity of the sulphuric acid recovery plant is 1,358 kg/h of 97.5% sulphuric acid.

Photo 1. Sulphuric acid recovery plant.

The main problem encountered during the first months of the sulphuric acid recovery plant operation was fouling of smoke tubes in 1st and 2nd pass of the heat recovery boiler. Boiler tubes on the process gas (flue gas) side were systematically fouled with fast sinter, originating from deposition of sodium sulphate, iron oxides – (II) and (III) and other salts. Such clogging with deposits in the boiler second pass appeared when alkali metals content in the post-refinery mixture was over 800 ppm. The clogging speed in the 2nd pass in the aforementioned conditions was exponential and lasted from 1 to 4 days. Moreover, the applied addition of aluminium sulphate to the post-refinery mixture, which slowed down clogging in the boiler 1st pass, resulted in accelerated clogging of the boiler 2nd pass, consequently rendering impossible longer operation of the entire plant.

Photo 2. Smoke tube with deposits restricting flu gas flow to the boiler 1st pass.

Heat recovery boiler 1st and 2nd pass.

The sulphuric acid recovery plant comprises a heat recovery boiler, which includes two smoke tube exchangers mounted in series. The smoke tube exchangers are connected by a duct, having the length of 2,000 mm. The flue gases at the temperature exceeding 1,200°C in the first pass (smoke tube exchanger) are cooled down to the temperature of approx. 650°C. The flue gas at the heat recovery boiler outlet have the temperature of approx. 300°C and are directed for further processing.

Inspection of the heat recovery boiler before installation of shock wave generators.

In May, 2014, before installing the cleaning system based on the shock wave technology, an inspection of the boiler had been carried out with regard to fouling of the 1st and 2nd pass smoke tubes. Boiler shutdown for manual cleaning was caused by total clogging of the flue gas flow in the high temperature zone in its first pass. The area of the flue gas inlet to the heat recovery boiler is shown in photos 2 and 3.

Photo 3. Fouled smoke tubes in the heat recovery boiler first pass.

In the second pass and intermediate header there were fine deposits on all surfaces. The outlet tube sheet of the first pass was covered with a thick layer of deposits, which did not restrict the flue gas flow.

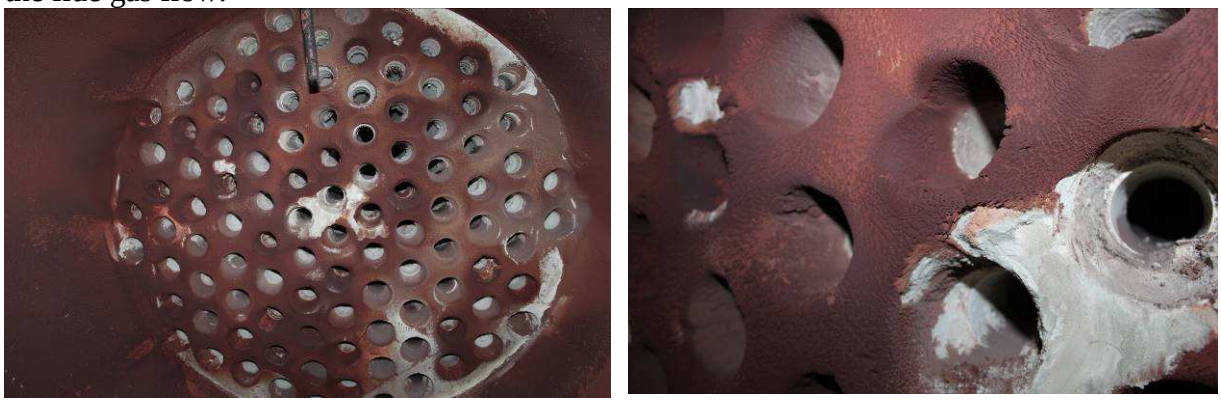

Photo 4. Thick layer of fine deposits on the tube sheet at the first pass flue gas outlet.

Fine deposits were also observed on the intermediate header walls, which connects the first and second passes of the heat recovery boiler.

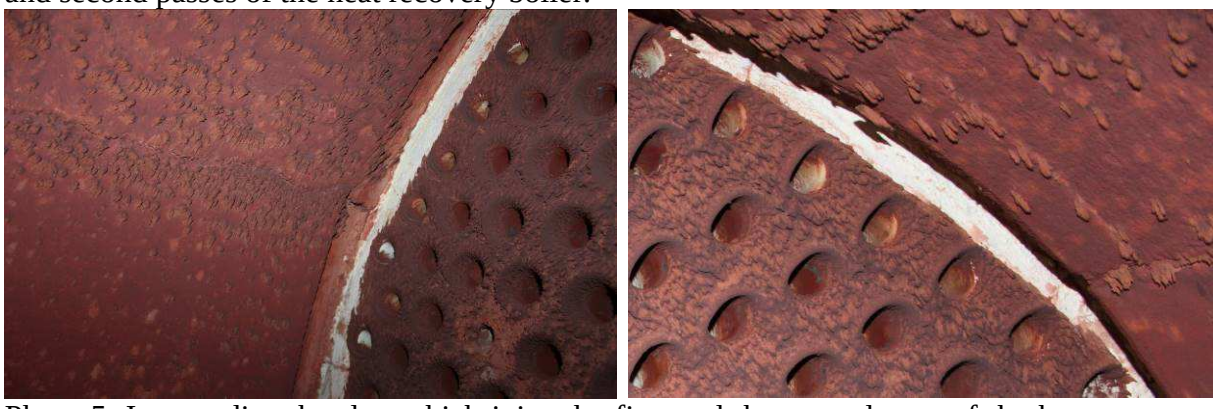

Photo 5. Intermediate header, which joins the first and the second pass of the heat recovery boiler, with its walls covered with deposits.

In the second pass of the heat recovery boiler, a thick deposit layer was detected on the tube sheet, showing the tendency to restrict the flue gas flow. These deposits were fine ones and easy to remove. The phenomenon of the smoke tube clogging was intensified by a concrete layer, which protected the metal tube sheet against high-temperature corrosion.

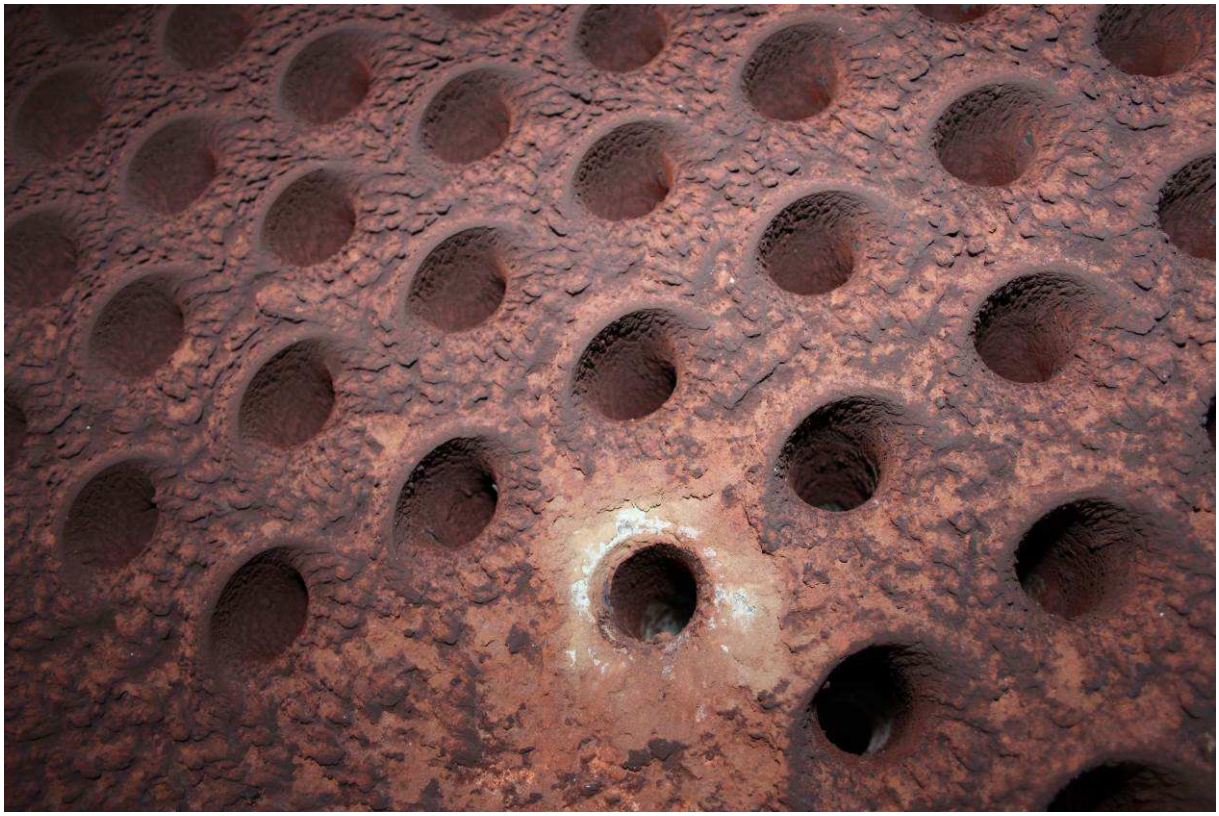

Photo 6. Second pass inlet tube sheet covered with deposits.

Cleaning system based on GFU-24/8 shock wave generators.

In the month of April, 2014, the company of Petrochemia - Blachownia S.A. submitted the RFQ to EKOZUB S.A. for a proposal to maintain the heat recovery boiler second pass free flow capability (i.e. that of the smoke tube exchanger's) by means of the shock wave technology. After the inspection at site and the consideration of the deposit types a decision was made to install a tentative installation, with the objective to prove the operational efficiency and good results of the shock wave generators. Two GFU-24/8 generators, mounted at the heat recovery boiler flue gas outlet, were used to clean the second pass. The shock wave cleans smoke tubes in counter-current mode. The compressed air, from the existing compressor, at pressure 7.5 bar, was used to supply the generators. The two shock wave generators were placed in the neighbouring building. Owing to the overpressure, prevailing in the boiler on the flue gas side, as well as the considerable concentration of the sulphur trioxide, shielding air was used to protect the pipelines and generators. The shock wave was released automatically at twenty-minute intervals.

Photo 7. Two GFU-24/8 shock wave generators, located in the electrostatic precipitator room.

The commissioning of the cleaning system, which included two GFU-24/8 shock wave generators, took place on 23 June, 2014. Before start-up, the smoke tube exchangers had been cleaned manually.

Photo 8. Shock wave inlet for smoke tube cleaning.

First inspection of the heat recovery boiler's second pass after installation of GFU-24/8 shock wave generators.

Following the continuous operation for 21 days, the sulphuric acid recovery plant was shut down for internal revision on 14 July, 2014. The fouling degree of the first and second passes was such that further operation of the plant was still possible. The shock wave, released by the generators, had systematically been removing deposits in the entire plant, particularly from the second pass of the heat recovery boiler. During the revision on 14 July, 2014, decreased quantities of deposits were observed on the first pass outlet tube sheet and the intermediate header walls. The smoke tubes in the boiler second pass were free from deposits restricting the flue gas flow. Additionally, pressure measurements, taken upstream and downstream the smoke tube exchanger second pass, showed no flue gas flow resistances. In the course of the revision no damages were detected concerning the brickwork on the tube sheets or intermediate headers walls. During the operation of the sulphuric acid recovery plant no influence of the shock wave on the operational parameters was observed. As had been expected earlier, the impact of the shock wave and cleaning was seen not only on the second pass but also on the intermediate header and outlet tube sheet of the first pass.

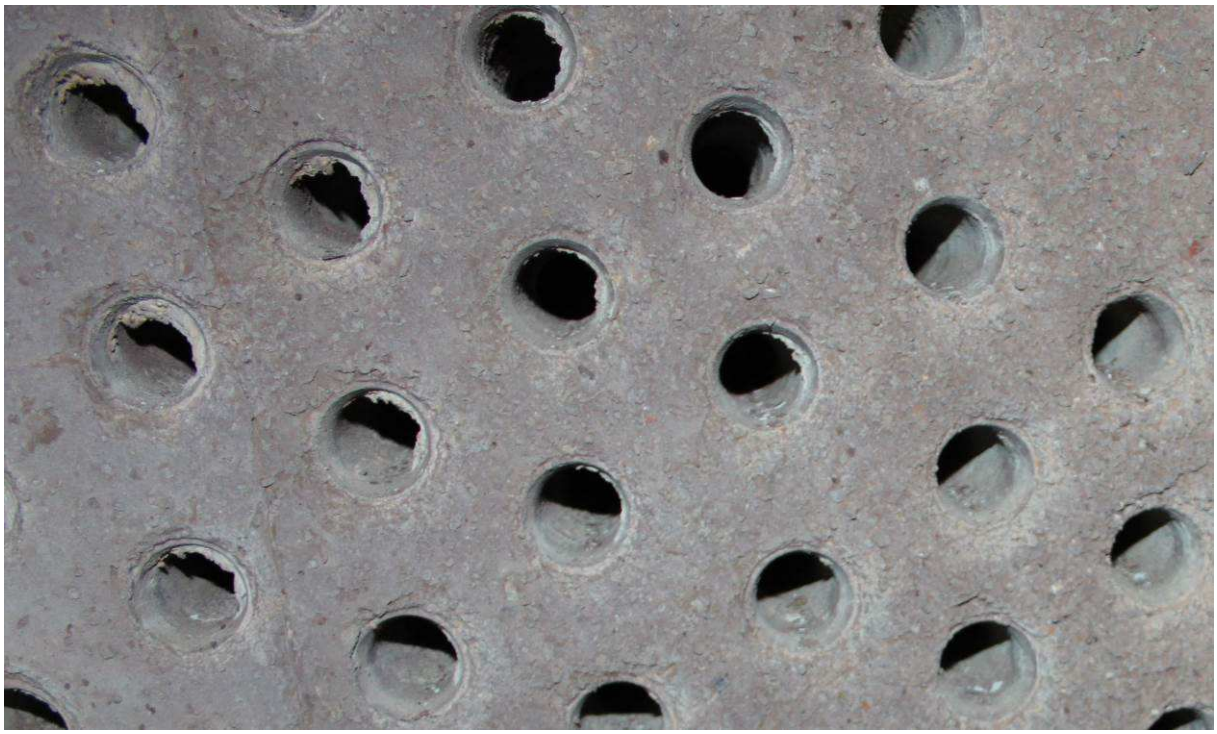

Photo 9. Inlet tube sheet to the second pass cleaned in counter-current by shock wave.

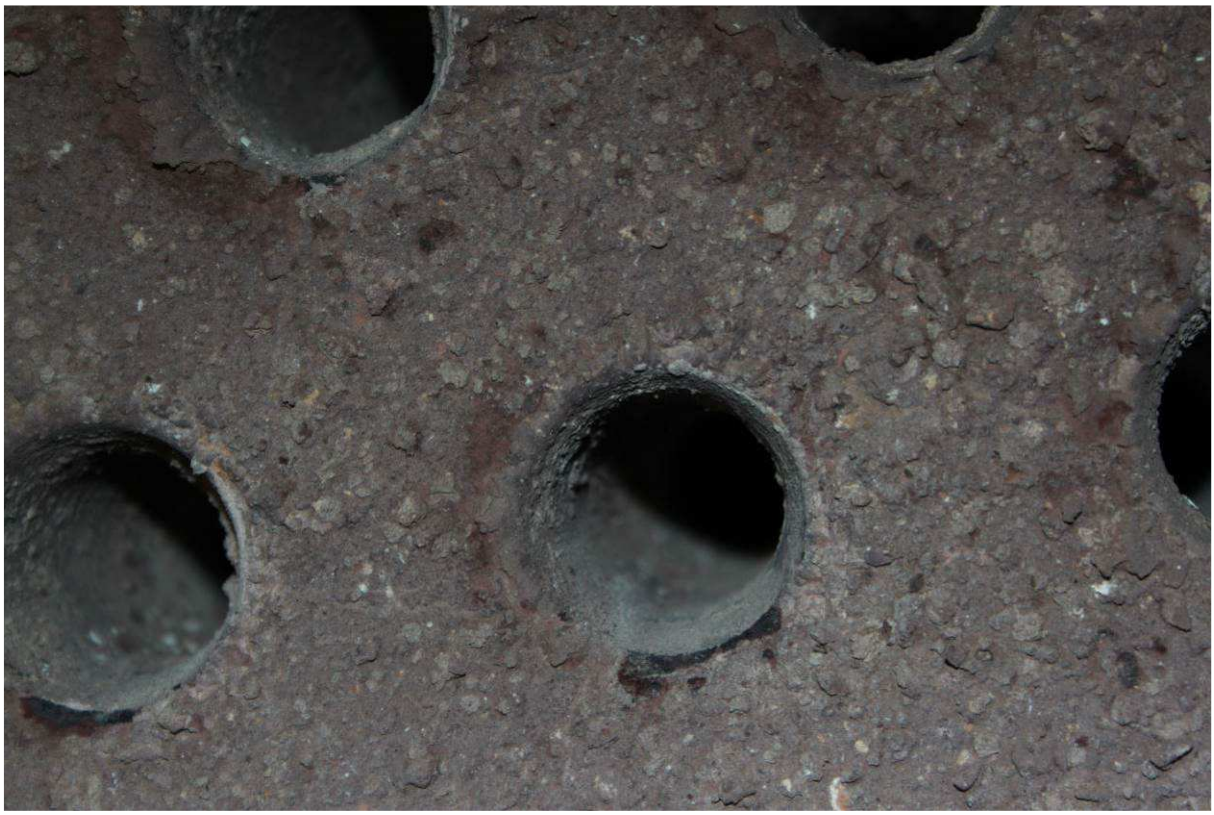

Photo 10. Smoke tubes with no fine deposit at all.

Additional effect of shock wave cleaning on intermediate header walls and first pass outlet tube sheet.

During the three-week operation of the cleaning system based on the shock wave generators, we observed the additional effect of decreased amount of deposit on the intermediate header walls and the first pass outlet tube sheet. Some insignificant amount of hard deposit was only found on the bottom of the intermediate header, which most probably resulted from additional cleaning of the first pass from hard deposits, forming at the smoke tube inlet.

Photo 11. Additional cleaning effect using shock wave. The first pass outlet tube sheet with no deposits restricting flue gas flow.

Second inspection of the heat recovery boiler after another twelve days the sulphuric acid recovery plant operation with the application of the shock wave technology.

On 4 August, 2014 there was another inspection of the heat recovery boiler. The shutdown of the sulphuric acid recovery plant was due to the planned overhaul of the entire factory. After twelve days of the plant operation no considerable increase of the flue gas flow resistance in the heat recovery boiler second pass was detected.

After entering the boiler it was fond out that owing to the action of the shock wave the second pass, the intermediate header and the first pass tube sheet were completely cleaned. No negative impact of the shock wave was noticed on the tube sheet brickwork or intermediate header walls. No damages to the steel profiles at the inlet to the smoke tubes between the first and second pass were found, either. Similarly to the first inspection, on the bottom of the intermediate header there was some small amount of solid/hard deposit from the first pass. In our opinion, the released shock wave cleans in the counter-current very effectively five-meter long tubes of the smoke tube exchanger. During the revision of the heat recovery boiler second pass and following another twelve days, no fine deposits were observed. At this stage, we confirm one-hundred per cent effectiveness of the GFU-24/8 shock wave generators in cleaning of the heat recovery boiler second pass.

Photo 12. Upper part of the second pass tube sheet with no fine deposits at all.


Photo 13. Insignificant quantities of hard deposits on the bottom of the intermediate header, which are systematically removed from the first pass.

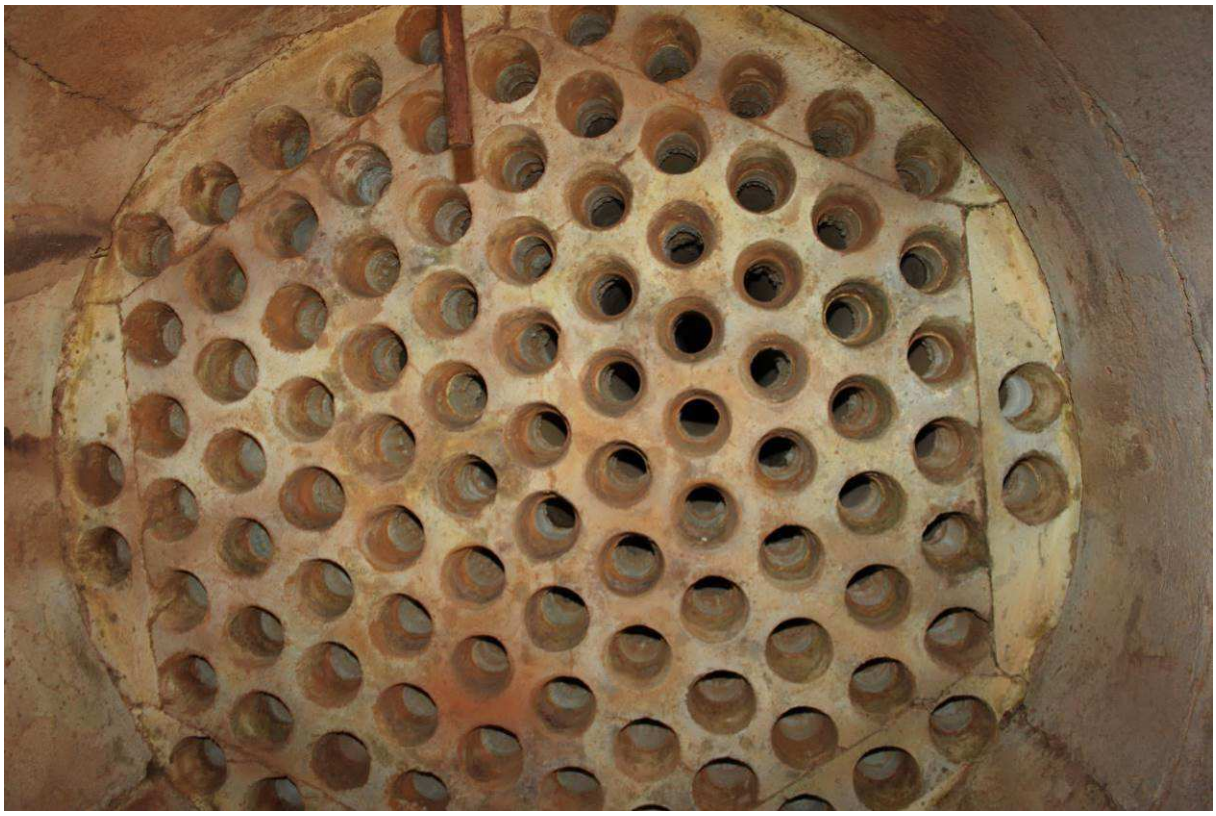

Photo 14. Completely cleaned concrete outlet tube sheet of the heat recovery boiler first pass. It is the additional effect of the shock wave action.

Outlet header of the heat recovery boiler second pass.

The outlet stubs of the shock wave were mounted on the heat recovery boiler flue gas header rear wall. The heat recovery boiler process gas outlet temperature is 300 °C. In order to use maximally the cleaning effect of the shock wave from the generator, the wave was divided into two streams. Therefore, the second pass is actually cleaned by four shock wave streams simultaneously.

In the course of the revision, no negative impact of the shock wave on the outlet header walls was observed. In this area no deposits whatsoever were noticed. Both the outlet header and the smoke tubes are kept in high degree of cleanness.

Photo 15. The flue gas outlet header downstream the heat recovery boiler with visible two inlets of the shock wave.

Conclusions drawn from cleaning of the second pass by means of the shock wave technology.

1. Having installed the shock wave generators, the sulphuric acid recovery plant have been operated for thirty three (33) days, with no need to be shut down owing to the fouling of the heat recovery boiler second pass.
2. The pressure measurements showed low flue gas flow resistances and high degree of cleanness of the second pass tubes.
3. After 33 days of the shock wave system operation, no negative influence of the shock wave on the intermediate header brickwork was observed. The concrete tube sheets and steel profiles were not damaged.
4. The cleaning system based on two GFU-24/8 shock wave generators was operated trouble-free within the aforementioned period, i.e. with no need for servicing of the system.

5. The overpressure in the flue gas system did not have any influence on the correct operation of the shock wave generators.

Summary.
During its thirty-three-day operation, the cleaning system based on two GFU-24/8 shock wave generators showed very high efficiency of fine deposit removal in the second pass of the heat recovery boiler. Mounting of the shock wave generators at the heat recovery boiler flue gas outlet and cleaning in counter-current did not decrease its effectiveness. Additionally, a phenomenon of cleaning the intermediate header from fine deposits was observed. During this period, the cleaning system was operating trouble-free, with no influence on the operational parameters of the sulphuric acid recovery plant. The operation of the cleaning system based on GFU-24/8 shock wave generators after thirty three days can be evaluated as very positive.

Truly yours,

PREZES ZARZĄDU
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