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THE RECONSTRUCTION OF FLUE CHANNELS AND THE DESIGN OF 100-METER CHIMNEY IN THE THERMAL POWER PLANT "KAKANJ"

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SUMMARY
After passing a certain filtering process, the flue gases generated during fuel combustion process in the boiler of a thermal power plant are discharged into the environment by flue channels and a chimney.
For a long time, the Thermal Power Plant "Kakanj" has used 300-meter chimney to discharge the treated flue gases into the environment. During the overhaul of the block 7 and reconstruction of 300-meter chimney, which were done in the period September-December 2014, it was shown necessary to redirect the flue gases from blocks 5 and 6 toward the 100-meter chimney.
This paper presents the calculation of operating parameters and design analysis of 100-meter chimney in order to determine whether blocks 5 and 6 could work without problems when connected to 100-meter chimney. Also, the installation of new flue channels from blocks 5 and 6 to the 100-meter chimney is shown.
Keywords: flue gases, flue channels, chimney, thermal power plant

1. INTRODUCTION
As a product of fuel combustion in the boiler of a thermal power plant, gas emissions that can be harmful to the environment occur. These gases must pass certain filtering process before being discharged through the chimney into the environment. Chimneys are construction structures that are used for evacuation of filtered gases arising from the fuel combustion process into the environment. Depending on their purpose, chimneys differ by their geometric properties (width, height, wall thickness, etc.), the type of material from which they are made and so on. Thermal Power Plant "Kakanj" uses the chimney of 300 m height for the purpose of evacuation of combustion gases generated in blocks 5, 6 and 7. During the remediation of 300-meter chimney in the process of maintenance and the overhaul of block 7 facility, it was shown necessary to redirect gases to the alternative chimney of 100 m height which is in the vicinity of block 6. This was accomplished by previous reconstruction of the gas channels.

2. FLUE CHANNELS RECONSTRUCTION
During revitalization of the electric filter in block 6 (110 MW) in 2012, the elimination of the smoke fans, which were already worn out, as well as the associated pipelines from electro-filter to the mutual collector channel was performed. During installation of new channels behind the fan of block 6, the terminals or the canal branches were not provided for using the 100 m chimney, which was utilized before the construction of 300 m chimney in 1988. The 100 m chimney that was previously used to block 5 was obsolete and has been removed.
During the time of reparation and maintenance of 300 m chimney, the exclusion of all three production blocks from the electricity should be provided (deadlock). To enable the operation during repair and maintenance of 300 m chimney, it was necessary to reconstruct the existing gas channels of blocks 5 and 6 to connect them to the previously used 100 m chimney of block 6.

The process of reconstruction of gas channels in thermal power plants is a very challenging undertaking. Therefore, very detailed preparations were performed. These included the analysis of necessary qualified specialists and equipment, necessary documentation showing the past and present condition after reconstruction, analysis of reconstruction place and the available space, and so on. The efforts had to be put on to perform the optimal reconstruction with the least possible disturbance in the status quo. Construction of new channels should contribute to the efficient operation of blocks 5 and 6. In order to prevent the gas flow to the 300-meter chimney, a flap of dimensions of 3800x5400 mm was built-in near the compensator KO31.
On investor's request and to reduce the costs, the route of the new channels of block 5 is defined over the existing channels. The new collection channel of block 5 is located above the existing channel and turns towards the nearer opening at 100 m chimney. It is partly traced over an existing channel of block 6, and then descends and joins the chimney. This solution is economically more acceptable than the case when the channel of block 5 connects to the farther opening of the chimney. In addition, the existing channel of block 6 was impossible to connect the nearer hole of the chimney due to the lack of available space. The described solution reduced the length of block 5 channel and increased the length of block 6 channel, but using the new channels of block 5 and 6 the overall difference in the gas flow resistance was reduced, Figure 1.

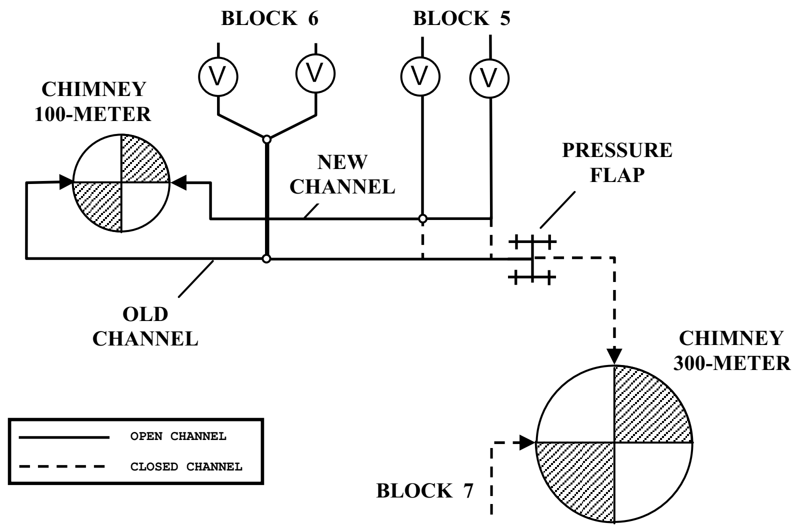

Figure 1. Schematic representation of the flue gases removal to the 100-meter chimney (deadlock at 300-meter chimney)

In the first phase, the flue gases of the block 6 were blocked to 300 m chimney by flap of dimensions 2790x3800 mm. Then, the new channel for flue gases from block 6 was connected to the existing channel at the point where it changes direction by 90°angle. Gas transmission channels were made of structural steel with built-in corrosion protection, insulated with glass wool insulation of 150 mm thickness and protected by Al-sheet of 1 mm thickness. Welded and flanged connections of the channels were tightened hermetically. The new channels are in a distance of 700 mm in height from the existing channels, so the steel supporting structure could be installed, [1].

3. CALCULATION OF THE 100-METER CHIMNEY OPERATING PARAMETERS

3.1. Input data

Basic geometric parameters of the chimney are: radius D_d=6,5 m, height H_d=100 m, geodesic height H = 235 m, volume flows in normal conditions 489600 m^3/h (block 5) and 543.600 m^3/h (block 6).
By calculating the operating parameters, it was necessary to determine the heat loss and pressure drop in the chimney and individual pipeline sections.

3.2. Calculation of heat losses and pressure drops in the chimney

Table 1 presents the calculation of heat loss and pressure drop through the chimney according to [1, 2, 3, 4].

In the same table, the calculation results for the 100 m chimney and block 5 and 6 individually are given, as well as the summary results for both blocks.

Table 1. Heat losses and pressure drops in the chimney

Quantity	Formula for calculation	Block 5	Block 6	Blocks 5 & 6
$\dot{m}_{prod}\left[\frac{kg}{s}\right]$	$\dot{m}_{prod}=\rho_{prod,N}\cdot\dot{V}_{prod,N}$	180	200	380
$\dot{V}_{prod}\left[\frac{m^3}{s}\right]$	$\dot{V}_{prod}=\frac{\dot{m}_{prod}}{\rho_{prod}}$	239	265	504
$w_{prod,d}\left[\frac{m}{s}\right]$	$w_{prod,d}=\frac{\dot{m}_{prod}}{\rho_{prod}\cdot\frac{\pi\cdot D_d^2}{4}}$	7,20	7,98	15,2
$Re_{prod,d}$	$Re_{prod,d}=\frac{w_{prod,d}\cdot D_d\cdot\rho_{prod}}{\mu_{prod}}$	1 470 000	1 630 000	3 100 000
$\alpha_{u,d}\left[\frac{W}{m^2\cdot K}\right]$	$\alpha_{u,d}=\frac{\lambda_{prod}}{D_d}\cdot 0{,}037\cdot\left(Re_{prod,d}^{0,75}-180\right)\cdot Pr_{prod}^{0,42}\cdot\left[1+\left(\frac{D_d}{H_{d,ef}}\right)^{0,67}\right]\cdot\left(\frac{\xi_{hr}}{\xi_{gl}}\right)^{0,67}$	14,2	15,6	28,1
$k_d\left[\frac{W}{m^2\cdot K}\right]$	$k_d=\frac{1}{\frac{1}{\alpha_s}+\frac{\delta_z}{\lambda_z}+\frac{1}{\alpha_{u,d}}}$	0,526	0,528	0,536
NTU_d	$NTU_d=\frac{k_d\cdot S_d}{\dot{m}_{prod}\cdot c_{prod}}$	0,00564	0,00510	0,00272
$t_{prod,k}\ [°C]$	$t_{prod,k}=t_{ok}+\left(t_{prod,dg}-t_{ok}\right)\cdot\exp\left(-NTU_g\right)$	198,8	198,9	199,4
$t_{z,k}\ [°C]$	$t_{z,k}=t_{prod,k}-\frac{k_g}{\alpha_{u,g}}\cdot\left(t_{prod,k}-t_{ok}\right)$	190,8	191,6	195,3
$\Delta p_{tr}\ [Pa]$	$\Delta p_{tr}=\xi_{hr}\cdot\frac{H_d}{D_d}\cdot\frac{\rho_{prod}\cdot w_{prod,d}^2}{2}$	10	12	44
$\Delta p_{vu}\ [Pa]$	$\Delta p_{vu}=g\cdot\left(H_d+H_g\right)\cdot\left(\rho_{ok}-\rho_{prod}\right)$	599	599	599
$\Delta p_{din}\ [Pa]$	$\Delta p_{din}=\frac{\rho_{prod}\cdot w_{prod,g}^2}{2}$	20	24	87
$p_{kd}\ [Pa]$	$p_{kd}=\Delta p_{vu}-\Delta p_{tr}-\Delta p_{din}$	569	563	468

3.3. Analysis of calculation results

Summary of calculation results given in Table 2 shows that the pressure drop from the pressure flap to the chimney is higher in block 6 than in block 5. This is quite logical because of prolongated gas channels in block 6. Also this requires higher exertion of the fan in block 6 to overcome the loss of pressure from the pressure flap to the chimney exit.

Table 2. Summary of calculation results

Quantity	Working regime		
	Block 5	**Block 6**	**Block 5 & Block 6**
Pressure drop from the pressure flap to the chimney [Pa]	3038	3524	3524
Effective pressure at the root of the chimney [Pa]	569	563	468
Required exertion of the fan to overcome the loss of pressure from the pressure flap to the chimney exit [Pa]	2469	2961	3056

The values of flow velocity of combustion products is given in Table 3.

Table 3. Values of flow velocity

Quantity	Working regime		
	Block 5	**Block 6**	**Block 5 & Block 6**
Flow velocity in chimney [m/s]	7,20	7,98	15,2
Flow velocity in channels [m/s]	30,5	33,8	30,5 ÷ 33,8

The recommended velocity of combustion products flow in the chimney is 10 m/s when one block is operating, while the recommended flow velocity with two blocks operating is 20 m/s. The flow velocity in the chimney with blocks 5 and 6 operating increases to 15,2 m/s because of the increased amount of combustion products (approx. 2 times). Therefore, it can be concluded that the resulting velocity of the combustion products flow is within the recommended speed limits.

4. CONCLUSION

Taking into account the calculated pressure drops from the pressure flap to the chimney exit, which are about 2,5 kPa (block 5) and 2,96 kPa (block 6), it can be concluded that the fans have sufficient power and capacity to easily transport the total amount of combustion products from blocks 5 and 6. Also, it can be concluded that blocks 5 and 6 can easily operate when connected to the 100-meter chimney. Contrary to the 100-meter chimney near the block 5 which has been removed, the 100-meter chimney in block 6 will remain to be used as an alternative chimney in the future in cases of block 7 overhauls and during 300-meter chimney maintenance. It is anticipated that the flap dimensions are 2800x3800 mm, which reduces the pressure drop, although not significantly. Two chimney exits are positioned in distance of 1000 mm, to prevent the collision of two gas flows from blocks 5 and 6. If the channels are joined at an angle so that the flue gases direction is upward without sharp turns, the pressure drop at the chimney entrance would reduce. But this would be difficult to construct because of significant reconstruction of the chimney would be needed and very risky.

5. REFERENCES

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