

**Volzhskaya Territorial Generating Company OJSC, Saratov  
Operation and adjustment service**

**REPORT**

**on thermotechnical tests of BK3-320-140 boiler unit No.6 of power plant-3  
after overhaul repair when burning the mixture of natural and associated gas**

**Hours in service: from the date of putting into operation – 230647 hours  
from the last midlife repair – 15179 hours.**

**Project manager – Chief Engineer Y.B. Antoshin**

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Saratov**

## 1. TESTS PURPOSE

- 1.1. Determination of technical condition and economic indexes of boiler unit after overhaul repair.
- 1.2. Estimation of repaired equipment quality.
- 1.3. Correction of parameter chart.

## 2. INTRODUCTION

During overhaul repair, besides standard scope, the following works are fulfilled:

- 2.1. Full replacement of hot and cold end heat exchange elements of air heater PБП 6A and 6Б (for intensified heat exchange elements produced by Northern Interindustry Company "Alternative" Ltd).
  - 2.2. Replacement of furnace setting (walls, floor, ceiling)
  - 2.3. Replacement of ceiling steam superheater pipes.
  - 2.4. Replacement of power center regulator.
  - 2.5. Repair of burners embrasures, deposits removal and pressure test of gas nozzles
- Boiler tests were executed in September – October 2011 with the load 259 and 310 t/h.

## 3. TECHNICAL CONDITION OF THE BOILER

- 3.1. Air leakage into furnace and gas path before steam superheater outlet with boiler output = 303 t/h was 7.25% in the left side.
- 3.2. Air leakage into gas path from the steam superheater outlet to smoke exhauster outlet with boiler output = 303 t/h was 46 % in the left side and 44 % in the right side.
- 3.3. Air pressure of gas path was 146 kgf/m<sup>2</sup> with boiler output = 259 t/h and in comparison with the data before repair reduced by 10 kgf/ m<sup>2</sup>.
- 3.4. Air pressure of air path was 121 kgf/ m<sup>2</sup> with boiler output = 259 t/h and in comparison with the data before repair increased by 25 kgf/ m<sup>2</sup>.
- 3.5. After the deposit removal from gas nozzles the gas pressure before the burners as compared with the test data before repair with steam load 259 t/h reduced by 0.1 kg/cm<sup>2</sup> (0.13 instead of 0.23 kg/cm<sup>2</sup>)
- 3.6. Remarks concerning the setting condition and heat isolation of boiler unit are in separate report.

## 4. TEST RESULTS

The tests were carried out with steam load 259 t/h and 310 t/h, superheated steam parameters: P = 129 kgf/cm<sup>2</sup>, t = 550 °C and feed water temperature 231 – 239 °C when burning natural gas and associated gas from research and production association "Saratovneftegaz" OJSC. Load of power plant working mode was restricted.

Six burners were in operation.

Natural gas pressure behind control valve was 0.49 – 0.58 kgf/cm<sup>2</sup>, burners pressure (average) was 0.13 – 0.17 kgf/cm<sup>2</sup>.

Burner air dampers are fully opened.

Air pressure (average) to burners was 53-80 kgf/ m<sup>2</sup>.

Air surplus coefficient behind steam superheater was 1.09 – 1.06.

Fuel burning was satisfactory. Shifting of flame after steam superheater and incomplete combustion are not observed.

Steam coolers of primary, secondary and tertiary superheater section were turned off by regulating valves.

Calorifiers were off. Air temperature at blow fan suction was 23-16 °C, before air heater was 31-25 °C.

Smoke exhausters A and B were in operation and blow fans A and B, electric engines of which were at the 1 level with steam load up to 250 t/h. When the load was 310 t/h, electric engine of blow fan B was at the 2 speed, blow fan A was at the 1 speed.

NO<sub>x</sub> concentration measured by gas analyzer TESTO-343-3 was 335-361 mg/ m<sup>2</sup>. When the load was 310 t/h, flue gas circulation fan B was on, circulation fan A was off for NO<sub>x</sub> reduction.

## 5. REPAIR EFFICIENCY

### 5.1. As compared with the tests data before repair with true steam load 253 t/h (heat load was 150):

5.1.1. Air leakage into furnace and gas path before steam superheater outlet normalized to boiler output = 320 t/h was less by 10% (7% instead of 17%).

5.1.2 Air leakage into gas path from steam superheater outlet to smoke exhauster outlet normalized to boiler output = 320 t/h was 7% less (44% instead of 51%).

5.1.3. Flue gas temperature normalized to  $t_{\text{air heater}}^{\text{before}} = 30 \text{ }^{\circ}\text{C}$ ,  $t_{\text{feed water}} = 230 \text{ }^{\circ}\text{C}$  was 42 °C less (137 instead of 179 °C)

5.1.4. Air surplus coefficient behind steam super heater was less by 0.04 (1.09 instead of 1.13).

5.1.5. Boiler gross efficiency normalized to  $t_{\text{cool water}} = 30 \text{ }^{\circ}\text{C}$  and  $t_{\text{feed water}} = 230 \text{ }^{\circ}\text{C}$  was 2.4% higher (92.61 instead of 90.21%) – due to the reduction of flue gas temperature, air leakage into furnace and gas path of the boiler.

5.1.6. Specific power consumption for draft and blast was less by 0.03 kWh-hour/Gcal (5.74 instead of 5.77 kWh-hour/Gcal)

### 5.2 As compared with data of previous midlife repair in 2006 with true steam load 253 t/h (heat load 150 Gcal/h):

5.2.1 Air leakage into furnace and gas path before steam superheater outlet normalized to boiler output = 320 t/h was 9 % less (7 instead of 16 %)

5.2.2. Air leakage into gas path from steam superheater outlet to smoke exhauster outlet normalized to boiler output = 320 t/h was 8 % higher (44 instead of 36 %)

5.2.3. Flue gas temperature normalized to  $t_{\text{air heater}}^{\text{before}} = 30 \text{ }^{\circ}\text{C}$ ,  $t_{\text{feed water}} = 230 \text{ }^{\circ}\text{C}$  was less by 35 °C (137 instead of 172 °C).

5.2.4. Air surplus coefficient behind steam super heater was less by 0.02 (1.09 instead of 1.11).

5.2.5. Boiler gross efficiency normalized to  $t_{\text{cool water}} = 30 \text{ }^{\circ}\text{C}$  and  $t_{\text{feed water}} = 230 \text{ }^{\circ}\text{C}$  was 1.3% higher (92.61 instead of 91.31%) – due to the reduction of flue gas temperature, air leakage into furnace.

5.2.6. Specific power consumption for draft and blast was less by 0.34 kWh-hour/Gcal (5.74 instead of 5.4 kWh-hour/Gcal)

### 5.3. As compared with data of normative parameters with true steam load 253 t/h (heat load 150 Gcal/h):

5.3.1. Flue gas temperature normalized to  $t_{\text{air heater}}^{\text{before}} = 30 \text{ }^{\circ}\text{C}$ ,  $t_{\text{feed water}} = 230 \text{ }^{\circ}\text{C}$  was 37 °C less (137 instead of 174 °C).

5.3.2. Air surplus coefficient behind steam super heater was less by 0.02 (1.09 instead of 1.11).

5.3.3. Air leakage into gas path from steam superheater outlet to smoke exhauster outlet was 11 % higher (49 instead of 38 %).

5.3.4. Boiler gross efficiency normalized to  $t_{\text{cool water}} = 30 \text{ }^{\circ}\text{C}$  and  $t_{\text{feed water}} = 230 \text{ }^{\circ}\text{C}$  was 1.71% higher (92.61 instead of 90.9%).

5.3.5. Specific power consumption for draft and blast was less than standard one by 1.65 kWh-hour/Gcal (5.74 and 7.39 kWh-hour/Gcal).

## 6. EFFICIENCY OF NEW HEAT EXCHANGE ELEMENTS

As compared with test data before repair, the replacement of hot and cold end baskets of air heater ПБП 6А and 6Б (100 %) for intensified heat exchange elements produced by Northern Interindustry Company “Alternative” Ltd resulted in the reduction of flue gas temperature by 42 °C. As compared with standard – by 36-34 °C (boiler output = 259-310 t/h).

Due to the reduction of flue gas temperature, boiler gross efficiency normalized to  $t_{\text{cool water}} = 30\text{ °C}$  and  $t_{\text{feed water}} = 230\text{ °C}$  was 2.4% higher in comparison with the data before repair. As compared with the previous tests data – 1.2-1.7 % higher and 1.71-1.99% higher – as compared with standard (boiler output = 289- 310 t/h).

Air heating was 252-262 °C. It was 55 °C higher than before repair and 60-62°C higher as compared with previous tests data when boiler output was 259-310 t/h.

## 7. CONCLUSIONS

7.1. The boiler reliably works with steam load 259-310 t/h with superheated steam parameters:  $P = 129\text{ kgf/cm}^2$ ,  $t = 550\text{ °C}$  and  $t_{\text{feed water}} = 231- 239\text{ °C}$  when burning natural gas and associated gas from research and production association “Saratovneftegaz”.

7.2. The boiler load 310 t/h is restricted by station mode only.

7.3. Draft, blast and superheater margin is available.

7.4. Almost the full replacement of furnace setting allowed to reduce air leakage and provide the leakage into furnace and gas path before steam superheater outlet at the level of standard value 7% while according to maintenance rules it is 5%.

7.5. The usage of heat exchange elements produced by Northern Interindustry Company “The Alternative” Ltd in the air heater of БК3-320-140ГМ boiler unit No.6 allowed to sufficiently improve its technical and economical indexes – to reduce flue gas temperature in the whole range of steam load (259-310 t/h) by 35-42°C and increase boiler gross efficiency by 1.71-1.99%.

7.6. Air leakage into gas path from steam superheater outlet to smoke exhauster outlet normalized to steam load was 19% higher than standard value of maintenance rules (44% instead of 25%).

7.7. Metal temperature in the path didn't exceed maximum permissible values

7.8.  $\text{NO}_x$  concentration in the flue gases was 335-361  $\text{mg/m}^3$  and didn't exceed maximum permissible emissions. The load having been 310t/h, flue gas circulation fan B was on, flue gas circulation fan A was off with the purpose of  $\text{NO}_x$  reduction.

## 8. RECOMMENDATIONS

8.1. Seal gas path of the boiler from the steam superheater outlet to smoke exhauster outlet, make air leakage close to the standard values.

8.2. Carry out tests in the full range of loads to correct parameter chart.

Head of Tests  
Chief Engineer

Y.B.Antoshin

Enclosures:

1. Summary table of test results. БК3-320-140ГМ boiler unit No.6, power plant-3 after overhaul repair when burning natural gas.
2. List of technical and economical indexes of БК3-320-140ГМ boiler unit No.6, power plant-3.

**Summary table of test results.**

**БК3-320-140ГМ boiler unit No.6, power plant-3 after overhaul repair when burning the mixture of natural gas and associated gas.**

No.	Parameter	Test number					
		1	2	3	4	5	6
1	Test execution date	08.09.11		20.10.11			
2	Duration, hours	2		2			
3	Barometric pressure, mm of mercury	755		765			
4	Steam load, t/h	259		310			

**FUEL**

No.	Parameter		Test number					
			1	2	3	4	5	6
1	Mark		natural + associated gas					
2	Calorific efficiency, kcal/ m <sup>3</sup>		8166		8166			
3	Available heat, kcal/ m <sup>3</sup>		8193		8194			
4	Specific weight, kg/ m <sup>3</sup>		0.756		0.756			
5	Gas consumption per boiler, nm <sup>3</sup> / h	according to the indicator	18900		21800			
6		calculated	19935		23545			
7	Valve gas pressure, kgf/ cm <sup>2</sup>		0.49		0.58			
8	Quantity of burners in operation, pcs		6		6			
9	Pressure on burner No. 1, kg/ cm <sup>2</sup>		0.14		0.18			
10	Pressure on burner No. 2, kg/ cm <sup>2</sup>		0.14		0.18			
11	Pressure on burner No. 3, kg/ cm <sup>2</sup>		0.14		0.18			
12	Pressure on burner No. 4, kg/ cm <sup>2</sup>		0.11		0.16			
13	Pressure on burner No. 5, kg/ cm <sup>2</sup>		0.11		0.16			
14	Pressure on burner No. 6, kg/ cm <sup>2</sup>		0.11		0.16			
15	Gas pressure on burner (average), kg/ cm <sup>2</sup>		0.13		0.17			

## AIR

No.	Parameter	Test number					
		1	2	3	4	5	6
1	Temperature at smoke exhauster suction, left side, °C	23		17			
2	Temperature at smoke exhauster suction, right side, °C	22		14			
3	Temperature behind calorifer, left side, °C	31		25			
4	Temperature behind calorifer, right side, °C	31		24			
5	Temperature behind air heater, left side, °C	245		256			
6	Temperature behind air heater, left side, °C	259		268			
7	Pressure in common duct, kgf/ m <sup>2</sup>	66		102			
8	Resistance, air heater A, kgf/ m <sup>2</sup>	56		74			
9	Resistance, air heater B, kgf/ m <sup>2</sup>	57		70			
10	Pressure before air heater A, kgf/ m <sup>2</sup>	122		176			
11	Pressure before air heater B, kgf/ m <sup>2</sup>	123		172			
12	Pressure on burner No. 1, kgf/ m <sup>2</sup>	52		80			
13	Pressure on burner No. 2, kgf/ m <sup>2</sup>	55		80			
14	Pressure on burner No. 3, kgf/ m <sup>2</sup>	51		80			
15	Pressure on burner No. 4, kgf/ m <sup>2</sup>	54		79			
16	Pressure on burner No. 5, kgf/ m <sup>2</sup>	53		80			
17	Pressure on burner No. 6, kgf/ m <sup>2</sup>	52		80			
18	Pressure on burners (average), kg/ cm <sup>2</sup>	53		80			
19	Air path resistance (burners including), kgf/ m <sup>2</sup>	A		174			
20		B		170			
21	Theoretical air volume, m <sup>3</sup>	9.06		9.06			
22	Air consumption per the boiler, m <sup>3</sup> /h	197.0		226.2			

## FLUE GASES

No.	Parameter		Test number					
			1	2	3	4	5	6
1	Temperature behind primary superheater, path A, °C		490		508			
2	Temperature behind steam superheater, path B, °C		493		519			
3	Temperature before air heater, path A, °C		299		309			
4	Temperature before air heater, path B, °C		286		315			
	Temperature behind air heater, path A, °C		134		135			
	Temperature behind air heater, path B, °C		149		156			
5	Flue gas temperature, path A, °C		137		137			
6	Flue gas temperature, path B, °C		136		140			
7	Flue gas temperature normalized to temperature before air heater and feed water temperature, °C	A	138		140			
8		B	137		143			
9	Furnace draft, left side, kgf/m <sup>2</sup>		1.5		2			
10	Furnace draft, right side, kgf/m <sup>2</sup>		1.5		2			
11	Draft before smoke exhaustor A, kgf/m <sup>2</sup>		150		180			
12	Draft before smoke exhaustor B, kgf/m <sup>2</sup>		145		170			
13	Gas path resistance, kgf/ m <sup>2</sup>	A	149		178			
14		B	144		168			
15	RO <sub>2</sub> content behind steam superheater, %		10.6		11.0			
16	O <sub>2</sub> content behind steam superheater, %		2.0		1.2			
17	CO content behind steam superheater, mg/ m <sup>3</sup>		0		0			
18	NO <sub>x</sub> content normalized to $\alpha = 1.4$ , mg/ m <sup>3</sup>		335		361			
19	Air excess coefficient behind steam superheater, left side		1.09		1.06			

20	Air excess coefficient behind steam superheater, right side	1.09		1.06			
21	Air leakage in the area “behind steam superheater – behind smoke exhauster ”	left	0.51		0.46		
22		right	0.48		0.44		
23	Air excess coefficient behind smoke exhauster, left side	1.60		1.52			
24	Air excess coefficient behind smoke exhauster, right side	1.57		1.50			
25	Leakage into furnace, %	8.7		7.3			
26	Water steam volume, m <sup>3</sup>	2.08		2.08			
27	Full gas volume, m <sup>3</sup>	15.50		14.82			
28	Flue gas volume , thousand m <sup>3</sup> /h	474.5		535.2			

### FEED WATER

No.	Parameter	Test number					
		1	2	3	4	5	6
1	Consumption, t/h	254		305			
2	Pressure, kg/cm <sup>2</sup>	214		204			
3	Temperature, °C	231		239			
4	Enthalpy, kcal/kg	238.67		247.3			
5	Specific weight, calculated, kg/m <sup>3</sup>	840.6		840.6			
6	Specific weight, real, kg/m <sup>3</sup>	842.6		831.4			
7	Actual consumption, t/h	254.3		303.3			



### OVERHEATED STEAM

No.	Parameter	Test number					
		1	2	3	4	5	6
1	Consumption, t/h	259		310			
2	Pressure, kg/cm <sup>2</sup>	129		129			
3	Temperature, °C	550		550			
4	Enthalpy of overheated steam, kcal/kg	829.3		829.3			
5	Specific weight, calculated, kg/m <sup>3</sup>	38.27		38.27			
6	Specific weight, real, kg/m <sup>3</sup>	36.56		36.56			
7	Real consumption, t/h	253.1		303.0			
8	Imbalance of feed water consumption, t/h	-5.7		-8.8			
9	Drum pressure, kgf/cm <sup>2</sup>	146		151			
10	Enthalpy of saturated steam, kcal/kg	379.6		384.2			
11	Consumption of continuous blowdown, t/h	6.9		9.2			

### HEAT BALANCE

No.	Parameter	Test number					
		1	2	3	4	5	6
1	Heat loss with flue gases, %	7.20		7.39			
2	Heat loss with incomplete combustion, %	0.00		0.00			
3	Heat loss into environment, %	0.65		0.55			
4	Total heat loss	7.85		7.94			
5	Boiler gross efficiency, %	92.15		92.06			
6	Feed water temperature, standard value, °C	230		230			
7	Cold air temperature, standard value, °C	30		30			
8	Heat loss with flue gases, normalized, %	6.74		6.46			
9	Boiler gross efficiency, %	92.61		92.99			
10	Heat productivity	150.5		177.6			

**List of technical and economical indexes of БК3-320-140ГМ boiler unit No.6, power plant-3**

No.	Parameter	Dimension	Tests data			Standard values
			before repair	after repair		
				after the repair before the last one	after the last executed repair	
1	Test execution date		10.03.11	28.12.06	08.09.11	
2	Fuel type		natural gas + associated	natural gas + associated		natural gas
3	Real steam productivity	t/h	248	245	253	251
4	Heat load	Gcal/h	150	145	150	150
5	Pressure of overheated steam	kgf/cm <sup>2</sup>	127	128	129	135
6	Overheated steam temperature	°C	550	550	550	555
7	Feed water temperature	°C	221	234	231	230
8	Cold air temperature	°C	-1	14	23	30
9	Air temperature behind calorifer	°C	5	17	31	33
10	Air temperature behind air heater	°C	197	192	252	
11	Flue gas temperature	°C	179	172	137	174
12	normalized to standard temperature before air heater and feed water temp., °C					
13	Air excess coefficient behind steam superheater		1.13	1.11	1.09	1.11
14	Air excess coefficient behind smoke exhauster	%	1.70	1.52	1.585	1.49
15	Air leakage in the site "steam superheater – smoke exhauster"	%	57	41	49.5	38
16	Leakage into furnace (320 t/h)	%	17	16	7	
17	Heat loss with released gases, normalized	%	9.14	7.99	6.74	8.45
18	Heat loss with incomplete combustion	%	0.00	0	0.00	0
19	Boiler gross efficiency, normalized	kgf/m <sup>2</sup>	90.21	91.31	92.61	90.9
20	Total resistance of air path	kgf/m <sup>2</sup>	96	104	121	
21	Total resistance of gas path	kgf/m <sup>2</sup>	136	117	146	

22	Specific power consumption for draft and blast	kWh/Gcal	5.77	5.40	5.74	7.39
23	Specific power consumption for flue gas recirculation	kWh/Gcal	0.00	0.00	0.00	
24	Total power consumption	kWh/Gcal	5.77	5.40	5.74	7.39