

FUEL CONSUMPTION ANALYSIS IN COOPER MELTING AND REFINING PLANTS

ANALIZA POTROŠNJE ENERGENATA U POGONIMA ZA TOPLJENJE I RAFINACIJU BAKRA

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ABSTRACT

Cathode cooper production and refining include significant consumption of almost all-conventional fuel types. The given consumption is high in specific and in nominal way.

Especially high fuel value content is on Cathode cooper production line within Melting and Electrolyze plants. In this paper fuel consumption analysis is done in concrete case of Melting and Refining cooper plants in Bor. For consumption analysis purposes all fuels are calculated as prime energy. In order to complete picture of equivalent used energies the equivalent fuel (Equivalent coal) calculations are done. For Electrical energy equivalent as Equivalent energy Serbian Energy system efficiency grade 0.53997 is used and for fuel as Equivalent energy is equal to working mass Lower Heating Value.

The four fuels (electricity, coal in power plant, flame furnace coal and crude oil) have had the biggest participation in equivalent fuel consumption in Melting and Refining plants for the years 1996, 1997, 2000, 2001 and 2002 which is confirmed by given analysis. The Electricity consumption has decreased from 50858,9 t (28,9%) in year 1996 to 31 490,1 t (23,9%) in year 2002. The coal consumption in power plants has increased from 43272,2 t (24,6%) in year 1996, to 61872,4 t (46,9%) in year 2002. The coal consumption in flame furnaces has small reduction tendency and in equivalent fuel was 37405,4 t (21,2%) in year 1996, whilst in year 2002 was 33271,1 t (25,2%). The crude oil consumption has decreased drastically from 35997,1 t (20,4%) in year 1996, to 1694,8 t (1,3%) in year 2002, due to the its substitution by other fuels because of the very high price.

Key words: cathode cooper production, cooper refining, fuels consumption, rationalization

APSTRAKT

Topljenje i rafinacija bakra podrazumeva potrošnju znatnih količina skoro svih vrsta konvencionalnih energenata. Data potrošnja visoka je kako u nominalnom tako i u specifičnom obliku. Posebno visoko učešće u potrošnji energenata zastupljeno je u pogonima Topionice i Elektrolize. U ovom radu izvršena je analiza potrošnje energenata

na konkretnom primeru Topionice i rafinacije bakra u Boru. Radi detaljnije analize svi energenti svedeni su na primarnu energiju. U cilju kompletiranja slike o potrošnji energenata, izvršeno je još i svodenje na uslovno gorivo (ekvivalentni ugalj). Za svodenje električne energije na ekvivalent energije uzet je stepen iskorišćenja energetskog sistema Republike Srbije koji iznosi 0,53997, dok je kao ekvivalent energije goriva uzeto da je je jednak donjoj toplotnoj moći radne mase. Analiza potrošnje energenata u pogonima TIR-a za 1996, 1997, 2000, 2001 i 2002 godinu ukazuje da najveće učešće u potrošnji, izraženo u jedinicama uslovnog goriva, imaju četiri energenta: električna energija, ugalj u termoelektrani, ugalj u plamenim pećima i mazut. Potrošnja električne energije ima tendenciju pada i smanjena je sa 50858,9t(28,9%) u 1996. na 31 490,1t (23,9%) u 2002.godini. Potrošnja uglja u termoelektranama povećala se od 43272,2t (24,6%) u 1996, na 61872,4t (46,9%) u 2002. godini. Potrošnja uglja u plamenim pećima ima tendenciju blagog smanjenja i u jedinicama uslovnog goriva iznosila je 37405,4t (21,2%) 1996, dok je 2002. iznosila 33271,1t (25,2%). Potrošnja mazuta drastično je opala sa 35997,1t (20,4%) u 1996, na 1694,8t (1,3%) u 2002. godini, što je posledica supstitucije ovog energenta drugim vrstama goriva zbog njegove visoke cene.

Gljučne reči: proizvodnja katodnog bakra, rafinacija bakra, potrošnja energenata, racionalizacija

1. FUEL NOMINAL CONSUMPTION ANALYSIS

Fuel costs in process of cooper melting and refining have significant content in general cost structure. In order to notice fuel consumption characteristics process analysis for certain periods is done. In particular case, analysis for following years 1996, 1997, 2000, 2001 i 2002 is made. During the years 1996. i 1997. the average amount of energy consumption calculated as equivalent fuel (e.f.) was 179 172,7 t e.f. (equivalent fuel is 29 308 KJ/kg). The Consumption structure was: electricity 28,3%; heavy oil, coke, poling of green wood and coal in Melting plant 46%; coal in Thermal power plant 22,7% and others (light liquid fuel, liquefied petroleum gas, distilled coal and gasoline) 2, 54%.

During the years 2000, 2001 and 2002. average fuel consumption calculated as equivalent fuel was 118 350,8 t e. f. The particular fuel type content percentage in the consumption structure was: electricity 28,8 %; heavy oil, poling of green wood, coal in Melting plant 32,2%; coal in Thermal power plant 36,0% and others (light liquid fuel, liquefied petroleum gas, distilled coal and gasoline) 2, 54%.

We can notice that coal in Thermal power plant has increased its content in consumption structure from 22,7% to 36,0%, while heavy oil, coke, poling of wood and coal in Melting plant have decreased their content from 46% to 32,2%.

In Tables 1-5 the nominal and fuel consumption structure data per Melting and Refining plants for observed years are given.

Table 1. Fuel Nominal Consumption in Melting and Refining plants in year 1996

No	Plant	Electri city kWh	Coal t	Coke t	Heavy oil t	Diesel m ³	Propan butane gas t	Wood m ³	Gasoline m ³	Cooling water m ³	Demin. water m	Decarb. water m ³	Drinking Water m ³
1.	Smelter	105.764.479	39.914	2.059	25.329	415,020		4.962		1.545.773	191.702		
2.	Electrolyze	48.157.652				289,493				396.257	311	1.946	
3.	Power plant & Water supply	13.485.267	79.254			41,049				656.985	11.071	327.202	
4.	Sulfuric acid factory	31.105.886				900,977				514.092	288		
5.	Cooper alloy foundry	8.627.095	62.500			139,884	526.710			2.423			
6.	Valve Foundry	1.072.833					0.980						
7.	Wire factory	13.692.458	82.747				128.900			21.495			
8.	FOŽ - Žagubica	1.244.634				15,193							
9.	Transport	20.681				839,311			51,627	12.000			
10.	Common services	171.914											
11.	Quarry	230.357				60,628							
	Total:	223.573.256	119.313	2.059	25.329	2.286,535	656,590	4.962	51,627	3.149,025	203,372	329,148	806,055

Table 2. Fuel Nominal Consumption in Melting and Refining plants in year 1997

No	Plant	Electricity kWh	Coal t	Coke t	Heavy oil t	Diesel m ³	Propane-butane gas t	Wood m ³	Gasoline m ³	Cooling water m ³	Denim. Water m	Decarb. water m ³	Drinking water m ³
1.	Smelter	115.608.669	35.725	6.765	32.796	560,57		4.135		1.917.350	178.533		415.906
2.	Electrolyze	45.323.668				324.068				368.335	738	12.682	40.313
3.	Power plant & Water supply	12.756.718	63.384,4			28.105				513.184	7.842	275.534	29.356
4.	Sulfuric acid factory	23.129.002				1.404.79				398.813	293		76.775
5.	Cooper alloy foundry	2.920.107	130.948			164.006	75.830			3.767			89.688
6.	Valve Foundry	1.022.142					0.210						
7.	Wire factory	13.492.480	84.060				105.350			26.580			
8.	FOŽ- Žagubica	751.399				17.072							
9.	Transport	24.370				824.424			47,96	12.000			24.519
10.	Common services	201.263											
11.	Quarry	255.530				63.370							
	Total:	221.855.348	99.324,4	6.765	32.796	3.386,4	821.390	4.135	47,96	3.240.299	187.406	288.216	676.557

Table 3. Fuel Nominal Consumption in Melting and Refining plants in year 2000

No	Plant	Electricity kWh	Coal T	Coke t	Heavy oil t	Diesel m ³	Propane-butane gas t	Wood m ³	Gasoline m ³	Cooling water m ³	Demin. Water m	Decarb. water m ³	Drinking water m ³
1.	Smelter	92.744.597	42.844	1.785	1.510	396.40		2.490		1.718.827	170.807		
2.	Electrolyze	24.092.425								382.934	539	7.602	
3.	Power plant & Water supply	12.213.288	62.648			15.45				418.908	10.001	431.908	
4.	Sulfuric acid factory	13.716.547				229,19				161.846	151		
5.	Cooper alloy foundry	7.567.591	95.022			84.75	149,16			2.928			
6.	Valve Foundry	1.047.602					5,13						
7.	Wire factory	10.580.395	73.810				102,10			25.500			
8.	FOŽ-Žagubica	756.610				17,87							
9.	Transport	23.687				642,04			36,02	12.000			
10.	Common services	168.992											
11.	Quarry	223.839				48,68							
	Total:	163.428.656	105.661	1.785	1.510	1.387,65	256,39	2.490	36,02	2.732,665	181.498	439.510	698.448

Table 4. Fuel Nominal Consumption in Melting and Refining plants in year 2001

No.	Plant	Electricity kWh	Coal T	Heavy oil t	Diesel m ³	Propane - butane gas t	Wood m ³	Gasoline m ³	Cooling water m ³	Demin. Water m	Decarb. Water m ³	Drinking Water m ³
1.	Smelter	83.241.661	38.045	2.030	476.20		1.757		1.812.955	133.259		
2.	Electrolyze	19.212.069			109,86				354.757	749	11.231	
3.	Power plant & Water supply	14.205.354	69.327	1.098	17,86				457.580	10.554	350.358	
4.	Sulfuric acid factory.	10.058.865			640,48				122.923			
5.	Cooper alloy foundry	6.548.230	68,16		126,17	302,22			2.920			
6.	Valve Foundry	1.165.505				4,60						
7.	Wire factory	7.410.397	52,20			72			12.350			
8.	FOŽ- Žagubica	885.276			35,13							
9.	Transport	42.098			600,17			35,89	12.000			
10.	Common services	185.970										
11.	Quarry	234.708			51,19							
	Total:	143.190.133	107.492,3	3.128	2.057,06	378,80	1.757	35,89	2.775.485	144.562	361.589	682.585

Table 5. Fuel Nominal Consumption in Melting and Refining plants in year 2002

No.	Plant	Electricity kWh	Coal T	Heavy oil t	Diesel m ³	Propane butane gas t	Wood m ³	Gasoline m ³	Cooling water m ³	Demin. Water m ³	Decarb. water m ³	Drinking water m ³
1.	Smelter	80.072.600	35.407	1.192,5	470,2		1.880		1.812.955	165.000		
2.	Electrolyze	18.562.892			142,4				326.605	367		
3.	PP & Water supply	12.224.636	61.872,4	2.763	18,3				378.368	7.312	12.043	
4.	Sulfuric acid factory.	12.273.792			365,4				175.827			
5.	Cooper alloy foundry	5.778.124	69.212		105,2	252,4			2.920			
6.	Valve Foundry	917.414				4,6						
7.	Wire factory	7.473.215	46.912			74,6			12.350			
8.	FOŽ- Žagubica	659.955			13,1							
9.	Transport	73.626			656,1			32,79	12.000			
10.	Common services	175.768										
11.	Quarry	216.858			38,3							
	Total:	138.428.880	97.395,5	3.955,5	1.809	331,6	1.880	32,79	2.721.025	172.679	12.043	

During the observed period the consumption of some fuels have increased. The consumption growth for the same fuel was: electrical energy 84,76%, coal in flame furnace 185,1%, coke and fuel 59,56%, petrol 92,76% , coal in thermal power plant 196,37 %. Second fuel group registered the drop of average consumption per produced tone of cathode cooper: Crude oil for 84,89% and propane- butane gas for 2,40%.

Since the average production in years 1996 and 1997 was 105.292 t cathode cooper from all row materials, and in years 2000, 2001 and 2002 was 37.965 t, that increased the average fuel consumption per produced tone of cathode cooper.

The significantly decreased average of fuel consumption per produced tone of cathode cooper could be noticed for crude oil. This is the consequence of coal consumption instead crude oil in Melting plant due to the high crude oil price.

Nominal amount of cooling water consumption in Smelter and Refining plants in the years 1996 and 1997 was in average 3.194.662 m³, while for years 2000, 2001 and 2002 was 2.743.059 m³. Actually, cooling water consumption is higher than quantity needed for units and machines cooling, i.e., for technogy needs. The causes for increased consumption are water losses due to the damaged instalations, water evaporation, bad tracking and measurements of water quantities and therefore, its consumption, as well as the lack of water recirculation system.

Cooling water used after Smelter, Power plant and Electrolyze plants should be transported back in circulation as it was done in Cooper and Cooper's alloys foundery plant or to be used in flotation and mines. As obvious example of big and irational cooling water consumption we can mention Smelter plant where water consumption is the same when line is not in operation and while working with full capacity.

Nominal Demineralized water consumption during the years 1996 and 1997 in Smelter and Refining plants in average was 195.389 m³, and in years 2000, 2001 and 2002 was 166.247m³. The biggest Demineralized water consumer comparing to others plants is Smelter plant. That means preventive action in melting process (utilization steam boiler) and converting process is needed.

2. COALS CONSUMPTION CHARACTERISTICS

In Smelter plant in years 1996 and 1997 the coals have been used for firing of flame furnace. The used coals have had the average Low Heating Value of 27.415 kJ/kg, while during the years 2000, 2001 and 2002 this value was 26.378 kJ/kg.

The Specific Coal consumption in flame furnaces in average during the years 1996 and 1997 was 400 kg/t cathode cooper, (0,374 t e.f./ t cathode

cooper), and for the years 2000, 2001 and 2002 was 1044 kg/t cathode cooper (0,940 t e.f./ t cathode cooper). This high fuel consumption for flame furnace firing for the period year 2000. – 2002. is due to the short usage of melting line, i.e. inconstant operation, maintaining furnace on hot stand by, as well as due to the poor concentrate quality.

Table 6 - Quantities and average Lower Heating Values of used coals in Smelter per year

No.	Year	Quantity, t	Low Heat Value, kJ/kg ²⁵
1.	1996	41.973	27.466
2.	1997	42.490	27.364
3.	2000	42.678	25.854
4.	2001	37.880	25.740
5.	2002	35.407	27.540

The coals wich were used for firming the boilers in this power plant had an average Low Heating Value of 16739 kJ/kg in the years 1996. and 1997, and a value of 15487 15487kJ/kg in the years 2001. and 2002.

Table 7 - Quantities and Average Low Heating Value of used coal in Power plant, years 1996-2002

No.	Year	Quantity, t	Low Heat Value, kJ/kg ²⁵
1.	1996	79.254	16.002
2.	1997	63.385	17.475
3.	2000	41.201	15.132
4.	2001	69.323	14.454
5.	2002	47.641	16.874

The nominal electricity consumption in Smelter and Refining plants in the years 1996 and 1997 was in average 222.714.302 kWh, and in the years 2000, 2001 and 2002 it was 148.326.151kWh. It is important to point out the Reactive Electricity consumption and Peak power (calculated power), have high content value that is shown in table 8. Smelter and Refining plant is huge consumer of almost all fuel types and especially electricity which participation percentage is 24 - 33 %, as shown in table 9.

Table 8 - Electricity consumption per year through transformer Bor-3

No.	Title	Year 1996			
		Quantity	Price, din	Total, din	%
1.	Active higher tariff, kWh	187.135.104	0,057	10.666.701	44,16
2.	Active lower tariff, kWh	92.160.640	0,029	2.672.659	11,06
3.	Reactive higher tariff, kWh	164.648.555	0,005	823.243	3,41
4.	Peak Power, kW	434.700	22,988	9.992.884	41,37
	Total:			24.155.487	100,00

No.	Title	Year 1997			
		Quantity	Price, din	Total, din	%
1.	Active higher tariff, kWh	189.154.788	0,109	20.617.872	44,45
2.	Active lower tariff, kWh	93.099.664	0,054	5.027.382	10,84
3.	Reactive higher tariff, kWh	166.928.103	0,009	1.502.353	3,24
4.	Peak Power, kW	443.592	43,358	19.233.262	41,47
	Total:			46.380.869	100,00
No.	Title	Year 2000			
		Quantity	Price, din	Total, din	%
1.	Active higher tariff, kWh	117.253.479	0,196	22.981.682	38,21
2.	Active lower tariff, kWh	86.774.340	0,098	8.503.885	14,14
3.	Reactive higher tariff, kWh	43.948.944	0,075	3.296.171	5,48
4.	Peak Power, kW	323.105	78,482	25.357.927	42,17
	Total:			60139665	100,00
No.	Title	Year 2001			
		Quantity	Price, din	Total, din	%
1.	Active higher tariff, kWh	111.892.365	0,552	61.764.585	52,15
2.	Active lower tariff, kWh	63.075.284	0,188	11.858.153	10,01
3.	Reactive higher tariff, kWh	100.205.148	0,078	7.816.002	6,60
4.	Peak Power, kW	316.044	117,053	36.993.898	31,24
	Total:			118.432.638	100,00
No.	Title	Year 2002			
		Quantity	Price, din	Total, din	%
1.	Active higher tariff, kWh	118.584.827	0,985	116.806.055	57,52
2.	Active lower tariff, kWh	58.765.091	0,326	19.157.420	9,43
3.	Reactive higher tariff, kWh	130.327.903	0,090	11.729.511	5,78
4.	Peak Power, kW	312.356	177,321	55.387.278	27,27
	Total:			203.080.264	100,00

Table 9 - fuel consumption in Smelter and Refining plants for years 1996-2002 calculated as equivalent fuel and percentage participation for each year

No	Fuel	Year 1996		Year 1997		Year 2000		Year 2001		Year 2002	
		Equiv. Fuel, t	%Equiv. Fuel, t	Equiv. Fuel, t	% Equiv. Fuel	Equiv. Fuel, t	% Equiv. Fuel	Equiv. Fuel, t	% Equiv. Fuel	Equiv. Fuel, t	%Equiv. Fuel
1	Electricity, t	50.858,9	28,9	50.468,1	27,7	37.176,8	32,49	32.585,0	29,99	31.490,1	23,9
2	Heavy oil, t	35.997,1	20,4	46.609,1	25,6	2.146,0	1,89	2.910,5	2,68	1.694,8	1,3
3	Coal in flame furnaces, t	37.405,4	21,2	33.355,4	18,3	37.794,7	33,04	38.045	30,62	33.271,1	25,2
4	Coke in WJ furnaces, t	1.995,6	1,1	6.556,6	3,6	1.730,0	1,51	-	-	-	-
5	Propane - butane gas, t	1.293,7	0,7	1.618,4	0,9	505,0	0,44	378,82	0,69	653,5	0,5
6	Wooden & retortni coal, t	144,8	0,1	214,3	0,1	168,3	0,15	120,36	0,11	115,8	0,1
7	Coal in power plant, t	43.272,2	24,6	37.793,2	20,7	32.243,7	28,19	35.826,4	32,97	61.872,4	46,9
8	Cooling water, m ³	-	-	-	-	-	-	-	-	-	-
9	Drinking water, m ³	-	-	-	-	-	-	-	-	-	-
10	Demin. water, m ³	-	-	-	-	-	-	-	-	-	-
11	Decarb. water, m ³	-	-	-	-	-	-	-	-	-	-
12	Light liquid & diesel fuel, m ³	3.348,0	1,9	4.197	2,3	1.719,7	1,50	2.549,3	2,35	2.242,1	1,7
13	Gasoline in transport, m ³	52,4	0,030	48,6	0,027	36,1	0,032	35,9	0,033	33,3	0,025
14	Wood for polovanje, m ³	1699,9	1,0	1.416,6	0,8	853,0	0,75	601,9	0,55	644,0	0,5
	Total:	176.068,0	100,00	182.259,3	100,00	114.391,3	100,00	108.643,9	100,00	132.017,1	100,00

Table 10. Fuel Consumption in Smelter and Refining plants calculated as equivalent fuel and content percentage per plant

No	Plant	Year 1996		Year 1997		Year 2000		Year 2001		Year 2002	
		Equiv. fuel, t	% plant content	Equiv. fuel, t	% plant content	Equiv. fuel, t	% plant content	Equiv. fuel, t	% plant content	Equiv. fuel, t	% plant content
1	Smelter	101.671,8	57,75	114.931,1	63,05	64.130,7	56,06	56.416,2	51,93	54.407,7	49,60
2	Electrolyze	11.313,8	6,43	10.711,9	5,88	5.493,4	4,80	4.506,5	4,15	4.399,3	4,01
3	Power plant & Water supply	46.390,8	26,35	40.729,9	22,35	35.041,2	30,63	39.017,4	35,91	42.353,2	38,61
4	Sulfuric acid factory	8.192,6	4,65	7.002,4	3,84	3.402,6	2,97	3.081,9	2,84	3.244,9	2,96
5	Cooper alloy foundry	3.235,9	1,84	3.857,5	2,12	2.213,2	1,93	2.274,9	2,09	2.011,1	1,83
6	Valve Foundry	246,0	0,14	232,9	0,13	248,4	0,22	274,2	0,25	217,8	0,20
7	Wire factory	3.451,2	1,96	3.360,7	1,84	2.681,5	2,34	1.879,5	1,73	1.893,9	1,73
8	FOŽ- Žagubica	302,0	0,17	192,1	0,11	194,2	0,17	244,9	0,23	166,4	0,15
9	Transport	1.097,2	0,62	1.075,9	0,59	837,2	0,73	789,3	0,73	863,1	0,79
10	Common services	39,1	0,02	45,8	0,03	38,4	0,03	42,3	0,04	40,0	0,04
11	Quarry	127,5	0,07	136,7	0,07	111,2	0,01	116,8	0,11	96,8	0,09
	Total:	176.067,8	100,00	182.276,8	100,00	114.391	100,00	108.643,9	100,00	109.694,2	100,00

From the given data it can be concluded that Smelter and Refining plant is a big consumer of almost all fuel types, electricity especially. The Electricity share of consumption was 24% - 33 % (Tables 9 and 10).

During the year 1997, comparing to the year 1996 specific fuel consumption increased for 6%. This is the consequence of much higher heavy oil consumption of line 2 and coke due to the work of Vateržaket furnace in Smelter plant.

CONCLUSION

The collected and worked out data analysis have given the following conclusions:

- The four fuels (electricity, coal in power plant, flame furnace coal and crude oil) have had the biggest participation in equivalent fuel consumption
- The consumption participation of almost all fuel have changed during the observed period of time
- The biggest fuel consumption in equivalent fuel was in the years 1996 and 1997, amounting 176 068 t, and 182 259 t.
- The biggest participation in fuel consumption in year 2002 have had: coal in the power plant – 46,9 %, coal in flame furnaces – 25,2 %, electricity – 23,9 %.
- The drop in Crude oil consumption from 25,6 % in year 1997 to 1,3 % in year 2002 was significant. This is the consequence of fuel change from crude oil to coal due to the very high crude oil price.
- The Melting plant (50 %) and the Power plant and water supply system (39 %) are the biggest fuel consumers.

The fuel consumption in Smelter and Refining plant are very high. Rationalization of its consumption is necessary in order to reduce fuel cost and to lower its participation in production price. In that way, firms business success will be higher.

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