Part 3

ASH AND SLAG HANDLING

3.7. Analytics

3.7.15. Specific operational expenses for handling ash and slag from thermal power plants by example of Kashirskaya SDPP

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Ashes and slags from thermal power plants (TPPs) are high on the list on production volume among other by-products from power generation. Increase in a coal share in the fuel balance of the Russian TPPs is in the long term predicted, including the respective raise of ash and slag production volumes, that results in deterioration of ecological conditions in a zone of TPP impact. In this connection there is a question on reconstruction of ash and slag removal systems in order to meet their ecological and economic characteristics.

It is technologically possible to allocate ash and slag removal system as the isolated complex of plants, constructions and technological units for evacuation of bottom ash/boiler slag from the boiler throat and fly ash from ESP hoppers and convection shafts of boiler plants with the subsequent solution of utilization issues [1]. At such a conceptual approach ash and slag removal system should be considered as the technologically allocated complex at TPP. In addition, the problems relating to optimization of costs for ash and slag handling are to be solved. In that case a correct choice of ash and slag removal system at designing and retrofitting TPP will result in significant cutting of the required investments and specific operational costs, leading to full recoupment of expenses for ash and slag removal system as a whole, or to their considerable decrease.

In 1998 the supervising document of the Russian JSC "UES of Russia" RD 34.02.103-98 "Procedure of estimation of technical and economic indicators of ash and slag removal systems of TPPs, considering ecological requirements" [1] has been approved. In this Procedure calculation of the integrated technical and economic indicators of ash and slag removal systems as a whole is considered. In this standard document, estimation of specific operational costs only for bottom ash/boiler slag removal wasn't considered. Accordingly, there is no a procedure of estimating economic and ecological indicators separately for bottom ash/boiler slag removal plants at TPP, though it is possible to execute cost estimation for bottom ash/boiler slag handling using the specified Procedure. It should be noted that power engineers do not practically use the mentioned RD 34.02.103-98, therefore, there are no actual data on specific operational costs for handling 1 ton of ash and slag mix, and 1 ton of ash or slag separately, including all expenses for their evacuation from boilers until selling them to customers or disposing at ash and slag disposal sites.

In market conditions of power industry functioning, more and more toughening requirements for ecological compatibility of TPP lead to additional growth of the cost price of electric and thermal energy generation due to increase in payment for withdrawal of land for constructing ash and slag disposal sites and plants of external ash and slag conveying, and also to growth of ecological payments.

Besides, the cost price of power generation strongly depends on operational costs for removal and disposing of ash and slag which are significantly influenced by the applied technologies [1].

For the analysis of specific operational costs for ash and slag handling, it is necessary to define significant factors and to estimate their influence on size of these costs. It allows to define directions of activity on decrease in the specific cost price for ash and slag handling at various operating modes of coal-fired power units for improvement of economic and ecological indicators of TPP as a whole.

It's well-known that specific operational costs of power plants considerably depend on operating modes of TPP as a whole, and separately of each power unit. Especially, it concerns those TPPs where both coal- and gas-fired power units are operated. Therefore, a question of analyzing specific operational costs for such a TPP is very actual, since at some operating modes of the power plant only one power unit out of several coal-fired ones, with the minimum loading, is in operation.

Analyzing technical, economic and ecological indicators of traditional wet ash and slag removal systems it has been established that the size of specific operational costs is caused, first of all, by technological features, namely — disadvantages of wet systems. In 1974 the following basic drawbacks of wet ash and slag removal systems [2] were marked:

- considerable labour inputs for maintenance of external hydraulic ash removal constructions, ash lagoons, escalating of dams and protecting disposals;
- need in treating of sewages from wet ash removal systems, containing harmful soluble substances, before their dump in reservoirs of the general using;
- high expenses for repair of pumps, free-flow channels and pipelines of external wet ash removal;

A rather complete analysis of drawbacks of traditional wet ash removal systems is resulted in [3]. To the disadvantages mentioned before, the following essential drawbacks are to be noted:

- formation of firm deposits in pressure head lines of hydraulic ash removal that can result in the system failure.
- necessity of clearing the circulating water of wet ash removal systems from the dissolved compounds in order to prevent formation of deposits in pipelines of the clarified water return;
- rather frequent replacement of pressure ash pipelines due to their erosion and corrosion;
- unjustified high power inputs for external ash hydrotransport because of practical noncontrollability of productivity of external hydraulic ash removal installations depending on mass of the transported ashes;

- huge amount of specific water consumption - up to 50 m^3 of water for 1 ash ton (in some cases to 80 m^3 of water for 1 ash ton);
- withdrawal from rational land use of large areas for ash disposals and pipelines of external ash removal;
- pollution of an atmospheric air due to ash disposal dusting;
- underwater pollution by solutions of toxic and heavy metals compounds filtrated through a bed of an ash disposal;
- soil degradation in a zone of the ash disposal impact;

To analyze ecological and economic efficiency of operation of traditionally applied wet ash removal systems, the hydraulic ash and slag removal system of Kashirskaya SDPP (fig. 1) has been considered.

At Kashirskaya SDPP in 1966-1968 three coal-fired power units of 300 MW each were put into operation. Today one of them is under reconstruction. Besides, three gas- and oil-fired power units of 300 MW each and one gas- and oil-fired power unit of 80 MW are under operation. They all were commisioned in 1974-1975.

To estimate specific operational costs for ash and slag handling, actual data of Kashirskaya SDPP operation during 2004-2006 were used. In order to estimate an impact of the basic significant factors on specific operational costs, the alternative option of ash and slag removal system arrangement was considered [5]. The point is that all fly ash caught in ESPs dry, is shipped to cunstomers or disposded at dry ash landfill, and bottom ash is evacuated by pneumomechanical technology, eliminating use of water as the bearing medium (fig. 2). For the analysis, data on efficiency of applying pneumomechanical bottom ash removal technology *MAC* (firm Magaldi Power S.p.A, Italy), described in details in [4], were used.

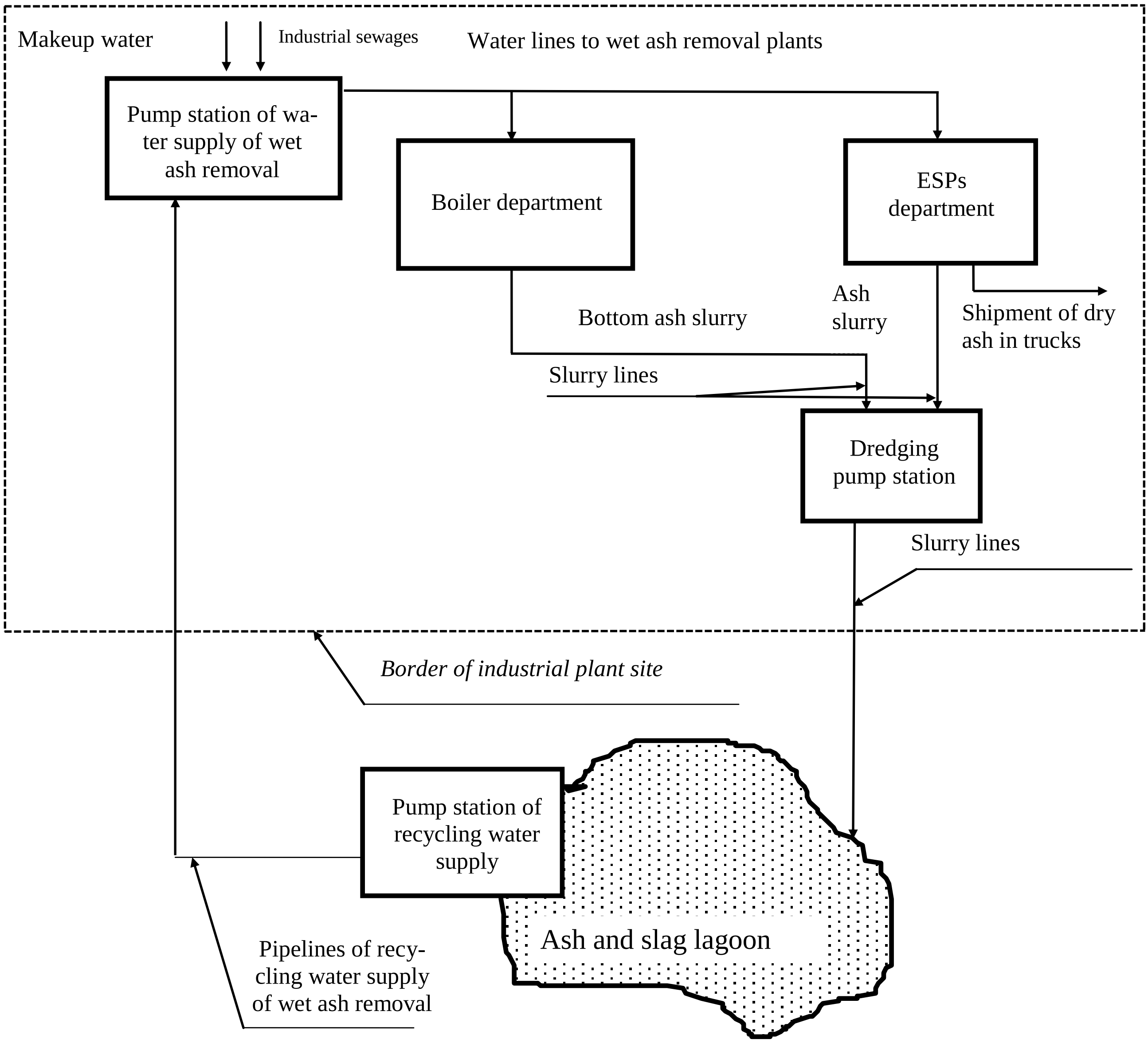

Fig. 1. Block diagram of wet ash removal system of Kashirskaya SDPP

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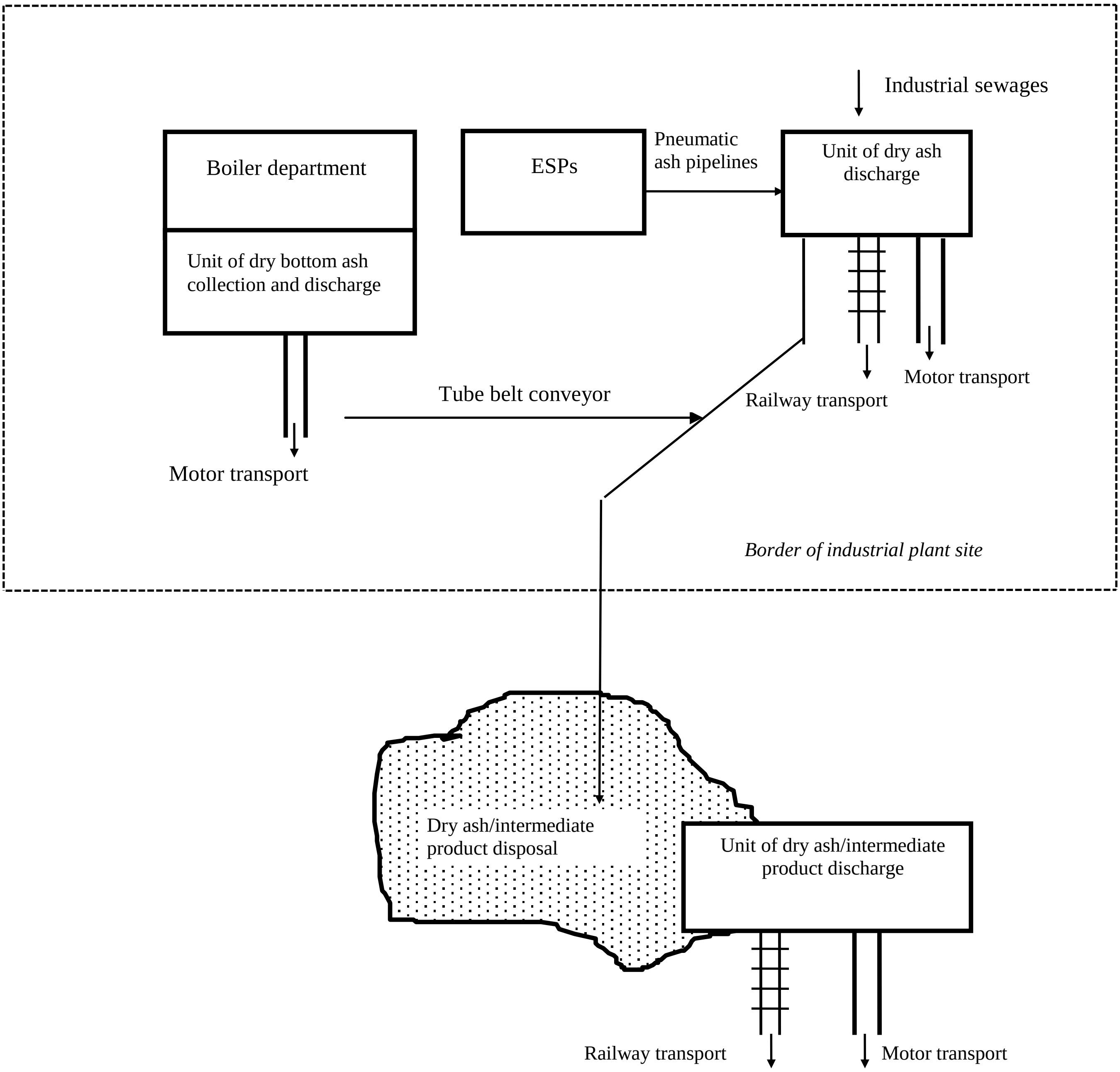

Fig. 2. Block diagram of ash removal system at separate removal, shipment, transportation and disposal of fly and bottom ash

Introduction at TPP of pneumomechanical bottom ash removal systems replacing wet ones results in the following [4]:

- raise reliability of operation both of bottom ash removal systems, and TPP as a whole;
- cut the cost price of energy generation;
- raise boiler efficiency;
- discharge bottom ash to customers according to their technical requirements;
- significantly improve ecological indicators of TPP;
- reduce greenhouse gas emissions (CO_2) due to decrease in specific fuel consumption at energy generation and use of bottom ash as a valuable material of a man-made origin at different applications at enterprises of various branches of economy.

ESTIMATION AND ANALYSIS OF SPECIFIC OPERATIONAL COSTS FOR ASH HANDLING

For estimation and analysis of specific operational costs for ash handling at Kashirskaya SDPP, the data resulted in tab. 1 were used. Specific operational costs for ash handling are presented in tab. 2. All expenses are resulted without VAT. For the analysis of costs for ash handling the year of 2006 was accepted as the base one.

Table 1. **Initial data for estimating specific operational costs for ash handling at Kashirskaya SDPP**

№ of item	Indicator	2004	2005	2006
1.	Number of hours in operation of coal-fired power units, h/year	5230+5802 = 11032	7510+2615 = 10125	7929+3061 = 10990
2.	Electricity generated at SDPP, totally, million kW·h/year	5803,2	6197,7	6337,5
3.	Electricity generated at coal-fired power units, million kW·h/year	2595,6	2457,9	2820,4
4.	Cost price of electricity generation, cop/(kW·h)	71,6	67,6	74,5
5.	Specific coal consumption at coal-fired power units, g ref. fuel/(kW·h)	355,1	354,2	355,9
6.	Fuel			
6.1.	Kuznetsky lean coal: - amount of coal combusted, t/year - % of the total amount of fuel (according to the heat balance) - calorific value Q_H^P, kcal/kg - ash content A^p, %	650483 28 5901 16,84	508793 21,8 6032 16,95	832332 31,8 6001 16,67
6.2.	Oil: - amount of oil combusted, t/year - % of the total amount of fuel (according to the heat balance) - calorific value Q_H^P, kcal/kg - ash content A^p, % - sulfur content S^p, %	271936 17 8696 0,06 1,9	46222 2,6 8126 0,06 1,86	179857 10,1 8799 0,06 2,37
6.3.	Natural gas: - amount of gas combusted, m^3/year - % of the total amount of fuel (according to the heat balance) - - calorific value Q_H^P, kcal/nm^3	945987 55 7964	1400180 76,5 8014	1138865 58,1 8017
6.4.	Fuel costs totally, million rub/year including: Kuznetsky lean coal oil natural gas	2321,6 527,5 684,8 1109,3	2656,1 503,1 128,0 2025,0	3486,2 874,4 811,5 1800,3

№	Indicator	2004	2005	2006
7.	Ashes			
7.1.	Production of ashes, totally, t/year: including: fly ash bottom ash	123881 99104,8 24776,2	93913 75130,4 18782,6	157832 126265,6 31566,4
7.2.	Selling of ashes, totally, t/year including: ash mix from disposal site dry fly ash bottom ash	3050 — 3050 —	2727 — 2727 —	1927 — 1927 —
7.3.	Landfilling of ashes, totally, t/year: including: fly ash bottom ash	120831,0 96054,8 24776,2	91186,0 72403,4 18782,6	155905,0 124338,6 31566,4
7.4.	Cost for landfilling 1 ash t, rub/t	12,3	8,6	9,0
8.	Area of land allotted for ash landfill, ha	97,3	97,9	97,9
9.	Land fee rate, rub/(m^2·year)	22,5	16,4	4,4
10.	Number of personnel involved in operation and maintenance of ash removal system, men	31,4	31,4	31,4
11.	Average salary of one man involved in operation of ash removal system including unified social tax, rub/month	23953	26756	30073
12.	Consumption of electricity by ash removal system, million kW·h/year	5,242	4,541	4,967
13.	Water consumption in ash removal system	оборотное	оборотное	оборотное
13.1.	Industrial waste waters in wet ash removal system, m^3/year	462500	414000	475340
13.2.	Discharge of sewages from wet ash removal system, m^3/year	462500	414000	475340
13.3.	Water pumped by wet ash removal system, m^3/year	4800000	4800000	4800000
14.	Metal consumption by ash removal system, t	1930	1930	1930
15.	Materials consumption by ash removal system, m^3 of steel concrete	5720	5720	5720

Table 2. **Specific operational costs for ash handling**

№ of item	Indicator	2004	2005	2006
1.	Salary costs including unified social tax, thous. rub/year	9025,4	10081,5	11331,7
2.	Expenses for wet ash removal maintenance, totally, thous. rub/year	8359,3	16564,7	9935,2
2.1.	Expenses for dam maintenance, thous. rub/year	4000,0	6440,7	6628,2
2.2.	Costs for maintaining the clarified water channels, thous. rub/year	206,0	4950,0	1500,0
2.3.	Costs for capital repairs of channel of wet ash removal, thous. rub/year	3743,3	4804,0	1387,0
2.4.	Costs for collecting the samples from dams, thous. rub/year	410,0	370,0	420,0
3.	Payment for nature resources usage, totally, thous. rub/year	23737,2	17147,8	6058,3
3.1.	Land fee, thous. rub/year	21885,7	16093,8	4342,8
3.2.	Ecological payments, totally, thous. rub/year	1851,5	1054,1	1715,5
3.2.1.	Payment for ash landfilling, totally, thous. rub/year including: fly ash bottom ash	1487,4 1190,0 297,5	788,4 630,7 157,7	1407,7 1126,2 281,5
3.2.2.	Payment for air pollution by ash particles, thous. rub/year	210,2	122,7	178,8
3.2.3.	Payment for water pollution, thous. rub/year	153,9	143,0	129,0
4.	Costs for electricity, thous. rub/year	3754,8	3071,1	3700,9
5.	Total operational costs for ash handling, thous. rub/year (sum of it.1 — it. 4)	44876,7	46865,1	31026,1
6.	Revenue from ash selling, totally, thous. rub/year including: ash mix from landfill dry ash bottom ash	305,0 — 305,0 —	327,2 — 327,2 —	758,0 — 758,0 —
7	Operational costs for ash handling, thous. rub, including revenue from ash selling (it.5 – it. 6)	44571,7	46537,9	30268,1
8	Specific operational costs for ash handling, rub/ash ton	359,8	495,5	191,8

Salary costs are greatest of operational costs (36,5 % of total operational costs) and have a steady tendency to growth. Salary growth on operation of ash removal systems from 2004 to 2006 is connected with its indexation according to inflation.

Expenses for maintenance of wet ash removal systems are second-large (32,0 % of total operational costs). The basic part of costs for wet ash removal systems is made by costs for maintenance of dams (21,4 % of total operational costs), constantly growing from 4,0 in 2004 to 6,6 million rubles in 2006. Costs for capital repairs of channels of wet ash removal (4,5 % of total operational costs) and maintenance of channels of the clarified water (4,8 % of total operational costs) are rather high; they are essentially different by years and have no any constant dynamics. Expenses connected with sampling from dams are rather small and have no steady tendency to change.

Payment for use of natural resources is the third on size group of expenses which makes 19,5 % of total operational costs. In this group of expenses the fee for land (14 % of total operational costs), allotted for ash removal system out of TPP territory, is the highest. By this, in 2004 this payment was the biggest component of operational expenses (52,9 %). But in connection with revision of a cadastral estimation of land, the land fee rate decreased from 22,5 rub/(m^2·year) in 2004 to 4,4 rub/(m^2·year) in 2006 (more than in 5 times). Thereof, land fee in total operational costs didn't become so significant as earlier.

Ecological payments (5,5 % of total operational costs) concern this group of operational expenses, namely payment for air and water pollution, and also for ash landfilling. Payment for ash landfilling is the most essential component of ecological payments and makes 4,5 % of total operational costs.

Costs for electricity consumed by ash removal system, make 12,0 % of total operational costs. Since pumps of wet ash removal system work in a constant mode within a year, regardless of loading of power units, these costs depend only on cost of the consumed electricity.

The operational costs for ash handling were considered above. The only revenue item at ash handling can be ash selling, that would either partially, or completely cover operational costs. However, the existing system of combined wet ash removal isn't technologically adapted for shipment of dry ash to consumers in considerable volumes that disables Kashirskaya SDPP to get essential incomes from ash selling. The existing plant of dry ash shipment can provide loading in car trucks of some thousands tons of dry ashes a year.

RESULTS OF ANALIZING SPECIFIC OPERATIONAL EXPENSES FOR ASH HANDLING

It has been established that specific operational costs for ash handling have made 359,8 rub/t in 2004. This fact is explained by a share of the combusted coal, which according to the heat balance made about 25 % at various loadings and a number of coal-fired power units in operation. In 2005 specific operational costs for ash handling made 495,5 rub/t. It is mainly explained by the total amount of the combusted coal making less, than in 2004, that accordingly resulted in less ash production. Besides, total operational costs have grown. In 2006 specific operational costs for ash handling made 191,8 rub/t. This results from the fact that a share of the combusted coal (by 63,6 % in comparison with 2005) has essentially grown, and the land fee rate has essentially decreased, resulting accordingly in considerable decrease in payment for use of natural resources.

Relative operational costs for ash handling in the cost price of electricity generation (according to data of 2006):

at 100 % loading of three power units, % ………..… 0,75
at 70 % loading of one power unit, % ……….……... 2,91
actual costs, % ……………………………………….1,44

At arrangement of discharging the whole volume of dry fly ashes to consumers for their processing, and bottom ash — by operational wet ash removal system to the existing ash lagoon, specific operational costs for bottom ash handling will essentially increase (tab. 3).

From tab. 3 one can seen that at a design loading of three power units and the minimum loading of one power unit, specific operational costs for bottom ash handling in case of wet ash removal system would make 310,0 and 1298,8 rub/t accordingly in 2006. Using pneumomechanical bottom ash removal technology (for example, technology of Magaldi) specific operational costs for bottom ash handling at design loading of three power units and the minimum loading of one power unit depend on a type of the shipped bottom ash: coarsed-crushed, fine crushed or bottom ash dust (tab. 4).

Table 3. **Influence of power units loading on specific operational costs for bottom ash handling in case of wet bottom ash removal system (according to data of 2006)**

№ of item	Indicator	Design loading of three power units	Minimal loading of one power unit
1.	Costs for maintenance of wet bottom ash removal	9935,2	9935,2
1.1.	Costs for maintenance of dams, thous. rub/year	6628,2	6628,2
1.2.	Costs for maintaining the clarified water channels, thous. rub/year	1500,0	1500,0
1.3.	Costs for capital repairs of channel of wet ash removal, thous. rub/year	1387,0	1387,0
1.4.	Costs for collecting the samples from dams, thous. rub/year	420,0	420,0
2.	Salary costs including unified social tax, thous. rub/year	9527,3	9527,3
3.	Payment for nature resources usage	5298,2	4664,6
3.1.	Land fee, thous. rub/year	4342,8	4342,8
3.2.	Ecological payments, totally, thous. rub/year	955,4	321,8
3.2.1.	Payment for bottom ash landfilling, thous. rub/year	826,4	192,8
3.2.2.	Payment for water pollution, thous. rub/year	129,0	129,0
4.	Coasts for electricity, thous. rub/year	3700,9	3700,9
5.	Total operational costs for bottom ash handling, thous. rub/year (sum of it.1 — it. 4)	28461,6	27828,0
6.	Specific operational costs for bottom ash handling, rub/bottom ash ton	310,0	1298,8

Таблица 4. **Specific operational expenses for bottom ash handling using pneumomechanical bottom ash removal technology *MAC***

№ of item	Indicator	2006
1.	**Shipment of fly ash in a dry state for its processing and coarsed-crushed bottom ash**	
1.1	Specific operational costs for bottom ash handling at 100 % loading of three power units, rub/t	42,8
1.2.	Specific operational costs for bottom ash handling at 70 % loading of one power unit, rub/t	173,5
2.	**Shipment of fly ash in a dry state for its processing and fine crushed bottom ash**	
2.1.	Specific operational costs for bottom ash handling at 100 % loading of three power units, rub/t	54,4
2.2.	Specific operational costs for bottom ash handling at 70 % loading of one power unit, rub/t	189,9
3.	**Shipment of fly ash in a dry state for its processing and bottom ash dust to the silo**	
3.1.	Specific operational costs for bottom ash handling at 100 % loading of three power units, rub/t	64,6
3.2.	Specific operational costs for bottom ash handling at 70 % loading of one power unit, rub/t	204,6

Thus, it is possible to draw a conclusion that applying pneumomechanical bottom ash removal technology instead of the existing wet one, decrease in specific operational costs for bottom ash handling at design loading of three power units and the minimum loading of one power unit is expected, as follows:

- shipping the coarsed-crushed bottom ash to customers - approximately in 7,2 … 7,5 times;
- shipping the fine crushed bottom ash to customers - in 5,7 … 6,8 times;
- shipping bottom ash dust to customers - in 4,8 … 6,3 times.

Thus incomes from selling bottom ash to customers aren't considered that, by different estimations, allows to provide payback of investments in reconstruction of bottom ash removal system within 4-5 years. This, certainly, will lead to essential decrease in the cost price of electricity generation.

It should be noted that at Kashirskaya SDPP old slag-tap boiler P-50, which don't meet requirements for NOx emissions, are under operation. To apply pneumomechanical technology of bottom ash removal, dry bottom boilers are to be operated. In case of dry bottom boilers the maximum temperature of a flame in the furnace decreases, that leads to reduction of thermal nitrogen oxides and, accordingly, to decrease in harmful impact of boilers on environment and reduction of ecological payments.

BASIC CONCLUSIONS

Analyses of specific operational costs for bottom ash handling results in the following possible basic conclusions:

1. traditionally applied wet ash removal system of Kashirskaya SDPP is economically inexpedient owing to use of water as the bearing medium;

2. use of pneumomechanical bottom ash removal technology results in significant cutting the specific operational

costs from bottom ash handling, leading to decrease in the cost price of electricity generation;

3. relative operational costs for ash handling are rather small in the cost price electricity generation, but total costs for ash handling will be several times more due to account of an investment component and amortization expenses;

4. estimation, analysis and management of total specific costs for ash handling, considering operational costs, amortization charges and an investment component are almost impossible now in connection with absence of their separate account on ash removal systems at the majority of TPPs;

5. For introduction of progressive technology of pneumomechanical bottom ash removal dry bottom boilers are required and an estimation of investment attractiveness of introducing this technology is needed.

REFERENCES

1. **Методика** оценки технико-экономических показателей систем золошлакоудаления ТЭС с учетом экологических требований. РД 34.02.103-98. // Путилов В.Я., Автономов А.Б., Боричев К.П. и др. М.: НТФ "Энергопрогресс", 1998, 79 с.

2. **Рекомендации** по выбору системы удаления шлака и золы в котельных установках. М.: ГПИ Сантехпроект, 1974, 59 с.

3. **Путилов В.Я., Путилова И.В.** Анализ общемировых тенденций и перспектив решения проблемы золошлаков ТЭС в России. Междунар. научн. практ. семинара «Золошлаки ТЭС — удаление, транспорт, переработка, складирование», 23 марта 2007 г., Москва, М.: Издательство МЭИ, с.10-16

4. **Применение** технологии сухого шлакоудаления МАС — возможность значительного повышения надежности, экономичности и экологичности угольных электростанций / Коппола Д., Путилов В.Я., Путилова И.В., Савастано С. // Труды II Междунар. научн. практ. конф. и спец. выст. «Экология в энергетике – 2005», 19-21 октября 2005 г., Москва, Издательство МЭИ, - М. с.237-242

5. **Putilov V.Y., Gavlitin N.V.** Perspectives of creating ecologically sound ash removal systems at Russian TPPs by the example of Reftinskaya power plant. Monograph. „Ashes from Power Generation”, November 6-8, 2006, Cracow, (Poland), EKOTECH Sp.z.o.o., Szczecin, p.137-143.

Specific operational expenses for handling ash and slag from thermal power plants by example of Kashirskaya SDPP. Putilov V.Y., Lunkov A.M., Fatkullin R.M., etc. // Energy saving and water treatment, №3, 2008, P.35-38.