P a r t 3

ASH AND SLAG HANDLING

3.2. Ash and slag handling systems at TPPs

3.2.6. Integral indicators of ash and slag removal systems

3.2.6.1. Estimation of the basic integral indicators of new and reconstructed ash and slag removal systems at TPPs of Russia by the example of Reftinskaya SDPP of the JSC "WGC-5"

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ABSTRACT

Brief estimation of ecological indicators of ash and slag removal systems of the Russian Thermal Power Plants is given. Main principles of creation and reconstruction of the operating ash and slag removal systems at TPPs are presented. Block diagrams of the traditional and possible alternative ash removal systems by example of Reftinskaya SDPP are shown. Some aspects of implementing ecologically sound ash and slag removal technologies at reconstruction of coal-fired power plants are considered. An algorithm of decision making, considering the issues on ash removal arrangement in the case of coal-fired power plants retrofitting, is described.

BRIEF CHARACTERISTIC OF ASH AND SLAG REMOVAL SYSTEMS AT THE RUSSIAN TPPS

In 2000 - 2005 annual production of ash and slag at TPPs and boiler-houses of the Russian JSC "UES of Russia" changed from 22 to 25 million t. The relative volume of processing ash and slag from TPPs during this period made 12,4 … 16,7 % of their annual production. In table 1 data on annual volumes of production, beneficial use (processing) and disposing of ash and slag at disposal sites of Russia in 1990-2007 are resulted.

Table 1. **Volumes of production, processing and disposing of ash and slag at disposal sites of Russia in 1990-2007**

Indicators	Years						
	1990	1995	2000	2002	2005	2006	2007
Coal consumption, million t natural fuel/year	182,0	128,0	120,1	106,0	102,6	125,4	114,8
Average ash content, %	27,5	26,3	20,8	21,4	21,8	21,1	21,2
Volumes of ash and slag production, million t/year	50,0	33,7	25,0	22,7	22,4	26,5	24,3
Volume of ash and slag processing, million t/year	4,5	1,9	3,1	3,3	4,0*		
Volume of ash and slag disposal, million t/year	45,5	31,8	21,9	19,4	18,4		
Total relative volume of ash and slag utilization, % of the annual output	9,0	5,6	12,4	14,5	17,9		

*- expert estimation

About 85 % of ashes and slags are transported by hydraulic ash removal (HAR) systems in the form of slurries of low concentration for landfilling them at hydraulic ash disposals (HAD) being one of the key sources of environmental contamination at energy generation. The total area of hydraulic ash disposals makes more than 20 thousand ha.

The basic scheme of the traditional HAR system is presented in fig.1, and influence of hydraulic ash disposals on environment is shown in fig.2.

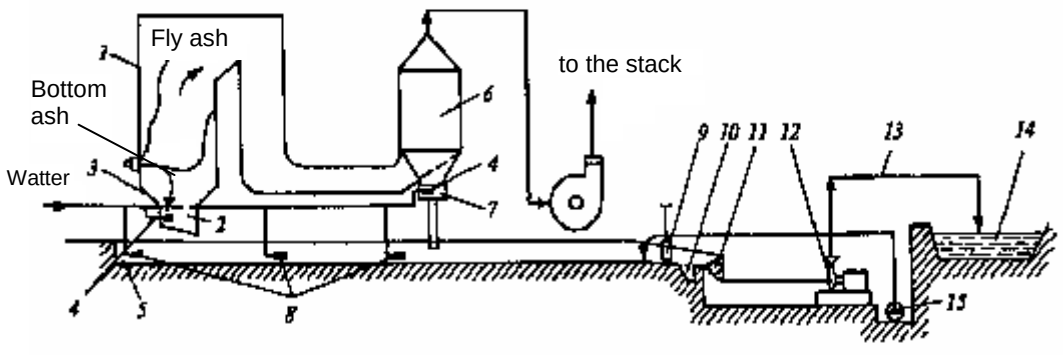

Fig.1. Basic scheme of traditional hydraulic ash disposal system
1 – boiler; 2- bottom ash bath; 3 – furnace tap; 4 – flush nozzle; 5 – gravity canal; 6 – fly-ash collector; 7 – ash flushing device; 8 – driving nozzles; 9 – stop log; 10 – catch pit; 11 – bottom ash crusher; 12 – slurry pump; 13 – bottom ash pipeline to the disposal; 14 – ash disposal; 15 – drainage pump.

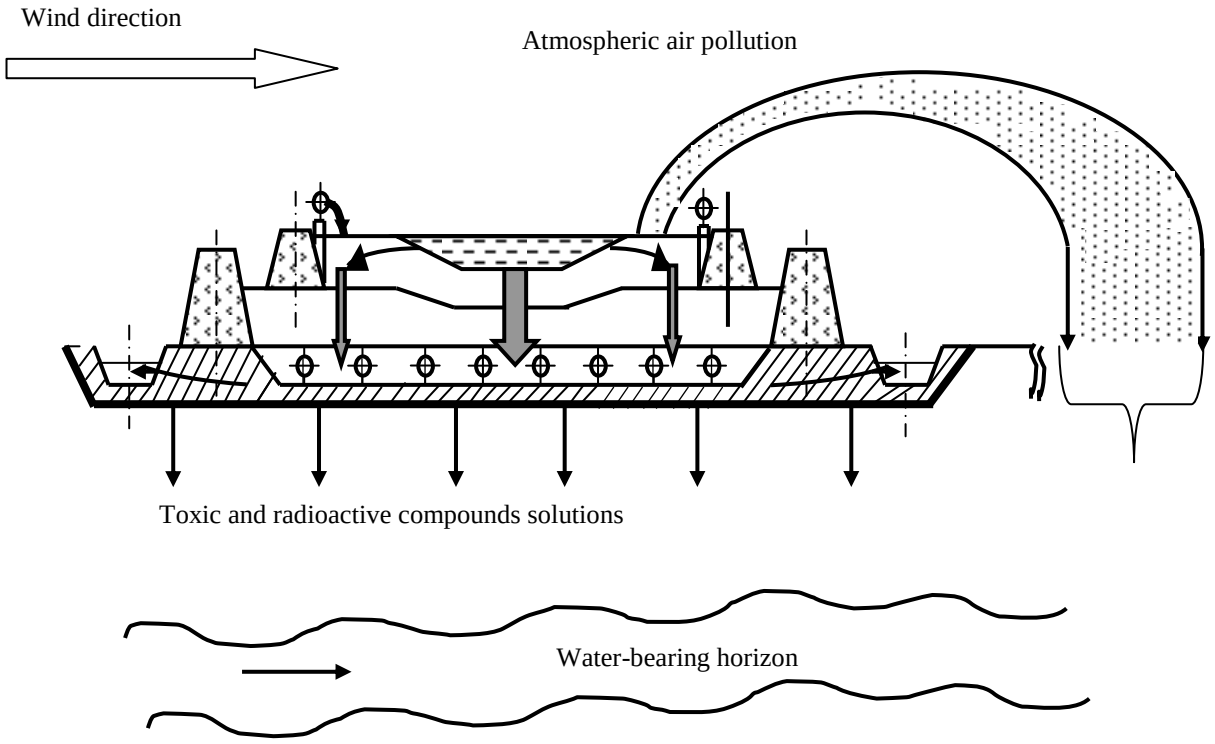

Fig.2. Influence of hydraulic ash and slag disposals of TPPs on environment

Analyzing technical, economic and ecological parameters of traditional HAR systems their following basic disadvantages have been established:

- formation of firm deposits in hydraulic ash pipelines resulting in its failure.
- 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;
- large specific water consumption - up to 50 m^3 of water for 1 ash ton;
- rather frequent replacement of pressure ash pipelines due to their erosion and corrosion;
- significant investments and rather long period for modernizing of technological configuration of ash removal system at change of the combusted coal ranks and/or technical requirements for consumer properties of ashes shipped to users;
- additional expenses for ash beneficiation at its shipment from ash disposals according to the technical requirements of users for their delivery;
- worsening of consumer properties of ashes at their interacting with water;
- necessity of clearing the circulating water of HAR systrems from the dissolved compounds in order to prevent formation of deposits in pipelines of the clarified water return;
- 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;
- frequent enough use of HAR systems both directly and for sanitary piping of TPP industrial sewages, amount of which can be sometimes more then amount of water required for reliable transportation of the removed ashes.

MAIN PRINCIPLES OF CREATING AND RETROFFITING ASH AND SLAG REMOVAL SYSTEMS AT TPPS

As a result of analyzing the parameters of ash removal systems in Russia and trends of their development in the industrially developed countries of the world in view of more and more toughening of requirements for ecological characteristics in various manufactures, the main principles have been formulated. They are to be guided at creation of new and modernization of the operating ash and slag removal systems at TPPs.

1. Coal-fired TPP is not only a source of electric and thermal energy, but also a source of valuable mineral raw material of the man-made origin in the form of ash and slag.
2. Reliability, profitability and ecological compatibility are the basic requirements which ash and slag removal systems should meet.
3. Ash and slag removal system is a unique technological complex within the limits of TPP simultaneously solving technological and nature protection problems on removal of ash and slag from boilers, that can make profit while any other nature protection technology costs money.
4. Use of ash and slag at producing commodity output by internal and external users leads to raise of economic efficiency of electric and thermal energy generation and decrease in harmful impact of TPP on environment.
5. Separate removal of fly ash and bottom ash/boiler slag in connection with essential difference of their consumer properties promotes increase in volumes of their shipment for their using at commodity output production.
6. Collecting, transporting and shipment of the collected dry ashes for their processing on fractions promotes decrease in costs and expenses at their shipment to users according to the contracts on delivery.

7. The realized opportunity in ash and slag removal system of ash and slag shipment for their processing in the volume up to 100 % of the current production allows to load out ash and slag under users' demand without any additional investments and time expenses or with the part of them.
8. Minimal technically achievable impact of ash removal systems on environment is possible at the maximum shipment of ash and slag for their processing and landfilling of the unclaimed part at the disposal using ecologically sound ways.
9. The greatest possible application of technologies of landfilling the unclaimed part of ash and slag at the disposals in the form of products of a pent-up demand or with initial properties allows not only to reduce harmful affecting of the landfill on environment, but also to ship ash and slag according to demand of the users at the minimal expenses of means and time.
10. Opportunity of further technical improvement of equipment and configurations of separate units, installations and ash removal system as a whole, is one of the parameters showing a quality of the project on ash and slag removal system.
11. Maximum mechanization and automation of technological processes without the unjustified application of hand work is one of parameters of technical perfection of the project on ash and slag removal system.

BASIC METHODICAL REGULATIONS

For practical implementation of the main principles for creating ash and slag removal systems with optimum technical, economic and sound ecological indices it is necessary to be guided by the basic methodical regulations specified below.

1. Proceeding from that a TPP combusting solid fuel is not only a source of energy, but also a source of valuable mineral raw material of a man-made origin in the form of ash and slag, removal systems should meet the following primary goals:
   - reliable removal of coal ash and slag in all range of operational loadings of boilers;
   - providing maximum discharge of ash and slag with initial and changed properties for use as substituents of natural raw material by manufacture of a commodity output at the factories at various branches of economy;
   - landfilling the unclaimed part of ash and slag using ecologically sound ways.
2. Proceeding from that fly ash and bottom ash/boiler slag mix has the least consumers' demand, removal of fly ash and bottom ash/boiler slag should be separate, unless there is a secured and long-term commodity market of all volume of the mix.
3. For expansion of an opportunity of dry ash discharge to the existing and potential users in case of different quality requirements for the delivered materials, mentioned in specifications on its delivery, in comparison with initial ash, in units and plants of dry ash discharge, devices for discharging ash mixtures with different particle sizes from hoppers or silos should be provided. Such mixers are simple in design, and expenses for creation and costs on their maintenance are very small in comparison with the total cost of pneumatic ash removal system.
4. For meeting special users' requirements for ash delivery, units (manufactures) for beneficiation (superficial processing) of ash with initial properties, and also for essential changes of its properties (extraction of separate fractions, intermediate product production, etc.) can be created. In this case an expediency of creating special manufactures should be defined in compliance with change of technical and economic indices of the whole ash and slag removal system in view of ecological requirements according to [2], instead of compliance with economic efficiency of the separately considered manufacture [3].
5. The best known way of raising reliability of internal ash removal systems now is implementation of pneumotransport installations having in case of their qualified creation much greater operating flexibility in comparison with HAR systems. Besides, they have much wider control range of ash flow rates, and easier change of operating modes.
2. The most effective way of improving economic parameters of ash removal systems is the greatest possible selling of ash to users in the volume up to 100 % of its current production. Hence, one of the key issues is both permanent research of the existing and possible ash market and also its formation due to conducting a complex of provisions:
   - ash beneficiation;
   - creation of the own (being a property of TPPs) manufactures for commodity output production in the form of intermediate product and finished products;
   - creation of coproductions on share terms for processing of ash in a commodity output;
   - fixing of the reduced rates for all types of the consumed energy for the period of developing a technology of commodity output production using ash, etc.
3. From the world practice it is known, that use of ash and slag from TPPs in the amount of 100 % occurs very seldom. Hence, the unclaimed part of ash and slag should be landfilled. For maximum decrease in specific cost of ash removal by ash and slag removal system as a whole and for minimal environmental pollution by ash disposals, it is necessary to follow the regulations:
   - creating the new hydraulic ash disposals does not allow to achieve the objects in view;
   - maximum part of the unclaimed ash at ash disposals should be landfilled in a form of products of seasonal demand (storage less than one year to provide seasonal consumption by operating factories) or a pent-up demand (storage for the period before starting up the factories being under construction or design);
   - a part of ash meeting no seasonal or a pent-up demand on estimation, should be landfilled only by ecologically sound ways preferably in the form of products of superficial processing (gravel, crushed rock, etc.) with a minimal production cost or should be landfilled at dry ash disposals;
   - decision-making on types, ways and technologies of landfilling of the unclaimed ash part should be carried out on the basis of analysis of technical and economic indices of ash removal systems as a whole according to [2].
4. For achievement of the best project and average operation indices on reliability and profitability of technological units of internal and external pneumatic ash removal, the preference should be given to the automated pneumotransport installations at other equal parameters.
5. For the best adaptability of ash and slag removal systems for expansion of the ash commodity market, change of

specifications on ash delivery, toughening of the nature protection legislation and conditions of economic activities configurations of technological units (internal and external transport, devices and installations of ash discharge, manufactures for ash processing and ash disposals) should be provided with the opportunity of their change with minimal expenses.

In 1995-98 employees of MPEI developed the main principles and methodic regulations on creating ash and slag removal systems at TPPs with optimum technical, economic and sound ecological parameters, financed by the state budget and used them by development of the basic supervising documents of the Russian JSC "UES of Russia" on ash removal systems [1, 2].

Reconstruction of the operating ash and slag removal system by example of Reftinskaya SDPP. At Reftinskaya SDPP of the total capacity of 3800 MW 4 power units of 500 MW and 6 units of 300 MW are installed. Ekibastuzskiy coal of the design ash content of 42 % is combusted in boilers. Volumes of ash production are given in table 2.

An existing capacity of hydraulic ash disposal provides the power plant operation till 2010. At the expected increase in the coal share in the fuel balance of electric power industry of Russia, ecological problems become more sharp.

The problems became especially actual after acceptance of two Laws of the Russian Federation - "On atmospheric air protection" (1999) and "On environmental protection" (2002). According to the Concept of technical policy of the Russian JSC "UES of Russia" at development of projects on ash and slag removal systems in case of creating the new and modernization of the operating coal-fired TPPs, separate removal of ash and slag, maximum mechanization and automation of all technological processes at complete meeting of all requirements of nature protection legislation, should be provided. Thus, it is necessary to give special attention to development and introduction of the scientifically-proved, ecologically comprehensible and economically accessible technologies providing the minimum negative influence of power enterprises on environment. By developing the projects on ash and slag removal systems, it is necessary to provide a possibility of ash and slag shipment for their processing in a volume to 100 % of the current output and disposing of the unclaimed part of ash and slag by ecologically sound ways at disposal sites with maximum preservation of their consumer properties.

Table 2. **Volumes of ash production at Reftinskaya SDPP in 2005-2007**

Name of by-product	Volumes of ash production				
	Under the project		Report data, thous. t/year		
	t/h	thous. t/year	2005	2006	2007
Fly ash	608,3	5437,4	3752,5	3971,0	3558,7
Bottom ash	32,7	286,2	197,5	209,0	187,3
Fly and bottom ash, totally	641,0	5723,6	3950,0	4180,0	3746,0

At the expected annual ash production in the amount of 5 million tons by 2010 and in the future - of 6 million tons, the aim of reconstructing the ash removal system of Reftinskaya SDPP in accordance with requirements can be unlikely satisfactory solved at preservation of the existing technology of conveying and disposing of the main ash part in a form of low-concentration ash slurry. A block-diagram of the existing wet ash and slag removal system is given in fig.3.

As a whole, analyzing technical, economic and ecological indicators of the existing ash removal system of Reftinskaya SDPP, in has been established that it has all the disadvantages of wet ash removal systems, mentioned before.

There have been developed several scripts of ash removal arrangement. A preliminary ecological and economic estimation of two basic of them has been carried on; they are the following:

1) the existing hydraulic ash removal system is remained and expanded,
2) the alternative dry ash removal system is created with disposing of the unclaimed by consumers ash part at dry ash landfill.

In a basis of developing the alternative ash removal system the main principle - application of the best available technologies, was considered.

To evacuate bottom ash from the boiler throat a pneumomechanical technology, widely enough applied at thermal power plants in industrially developed countries world-wide, was chosen. To estimate investments, required for retrofitting of bottom ash removal plants, the costs of capital equipment of the known firms - Magaldi (Magaldi Group, Italy) and Clyde Bergeman (Clyde Bergemann Power Group, Germany) were considered.

For transportation of an unclaimed ash part to the disposal site, a tube belt conveyor developed by the German firm Beumer was chosen.

For landfilling the unclaimed ash part at the disposal site, a technology of dry ash disposal site, providing level-by-level laying of the humidified ash with its subsequent compaction by rollers, was chosen. This technology is also widely enough applied at TPPs in many countries. In Russia the first industrial test on dry conveying and disposing of ash from ekibastuzsky coal was conducted from 1979 to 1985 at Verhne-Tagilskaya SDPP (the Urals). This project was developed and supported by the specialized enterprise on analysis, generalization and introduction of the advanced technologies in power industry – "URALORGRES" and Institute "URALVNIPIENERGOPROM". As a result of a long industrial test on dry ash laying, it has been established that:

- dry ash removal is technically possible in climate conditions of the Urals and it is economically effective;
- bulk (dry) ash disposal sites have large useful capacities at equal areas as due to compaction of the humidified ash, density of the ash massif increases by 25 … 40 % in comparison with inwash method.

It should be noted, that the mentioned firms Magaldi, Clyde Bergeman and Beumer aren't the confirmed suppliers of the corresponding equipment for Reftinskaya SDPP, but for a preliminary estimation of investments for retrofitting ash removal system it was necessary to know approximate cost of the required equipment. For that purpose corresponding inquiries were made and necessary preliminary information, sufficient for estimating the investments and impact of ash removal system on environment at the stage of draft business plan preparation, was received.

A business plan of the investment project "Building of ash disposal site and ash removal system at Reftinskaya SDPP with environmentally sound, economically and technologically expedient ways" according to the established procedure, firstly, has been considered and approved by Committee on Investments of the Open JSC RAO "UES of Russia", and then confirmed by Board of directors of WGC-5 in September, 2006. In tab. 3 integrated indicators of alternatives of reconstructing ash removal system, are resulted.

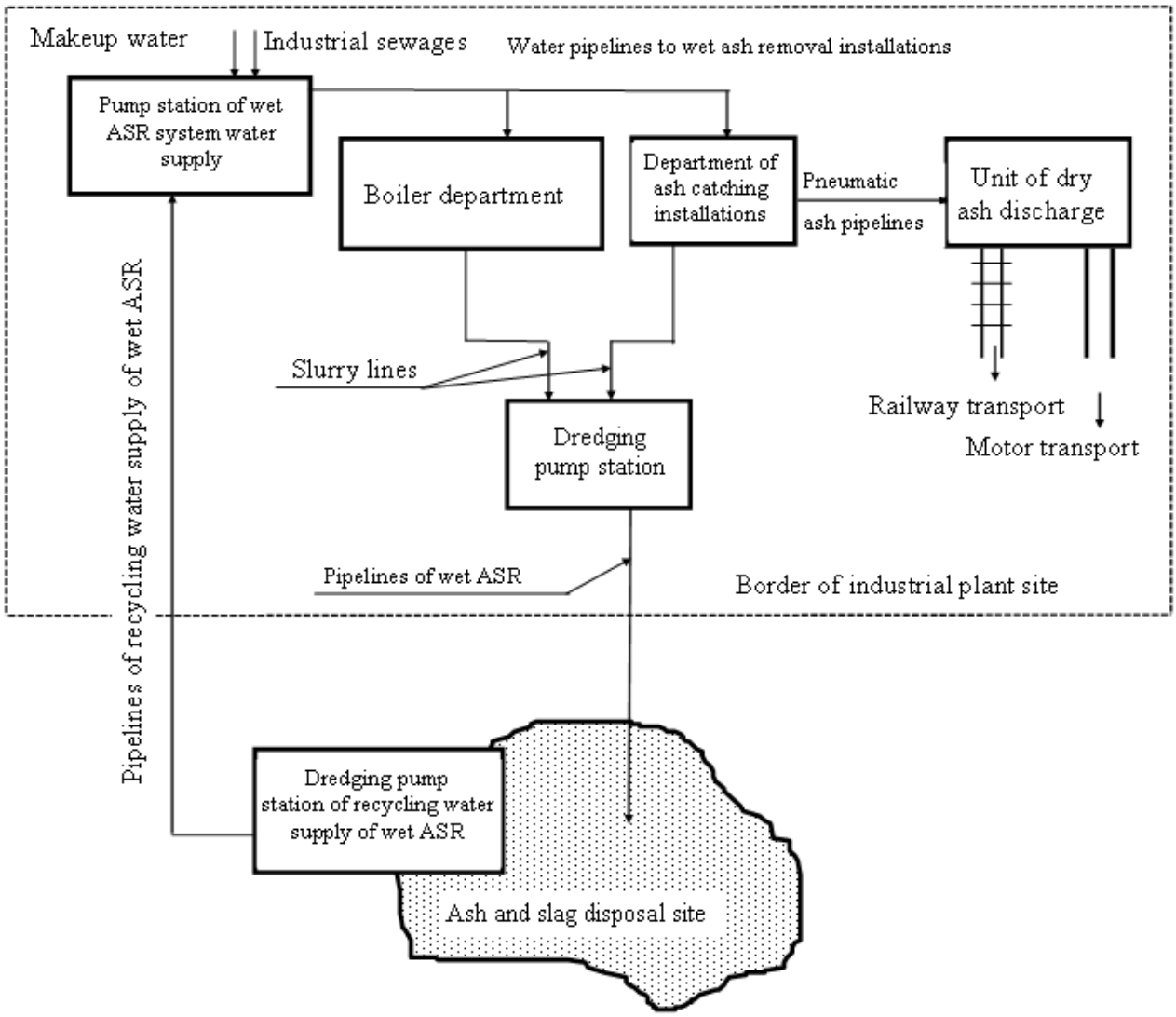

Fig. 3. Block diagram of the existing wet ash removal system at Reftinskaya SDPP

Table 3**. Integrated indicators of alternatives of reconstructing ash removal system at Reftinskaya SDPP**

Indicators	Wet ash removal	Dry ash removal
Area of ash disposal expansion, ha	456,0	–*
Total ash disposal site capacity, million m^3	137,2	185,3
Duration of ash disposal site filling, years	20,6	36,0
Length of protecting dams, km	49,4	–
Need in stones for dam construction, thousand m^3	4660,0	–
Dump cost (without VAT), million US $	269,0	
Costs estimation of ash removal system alternatives (without VAT), million US $	448,0	241,0
Payback period of the investment project	never	Depending on amount of dry ash selling

* — for construction of dry ash disposal site, the completed sections of ash lagoon are used.

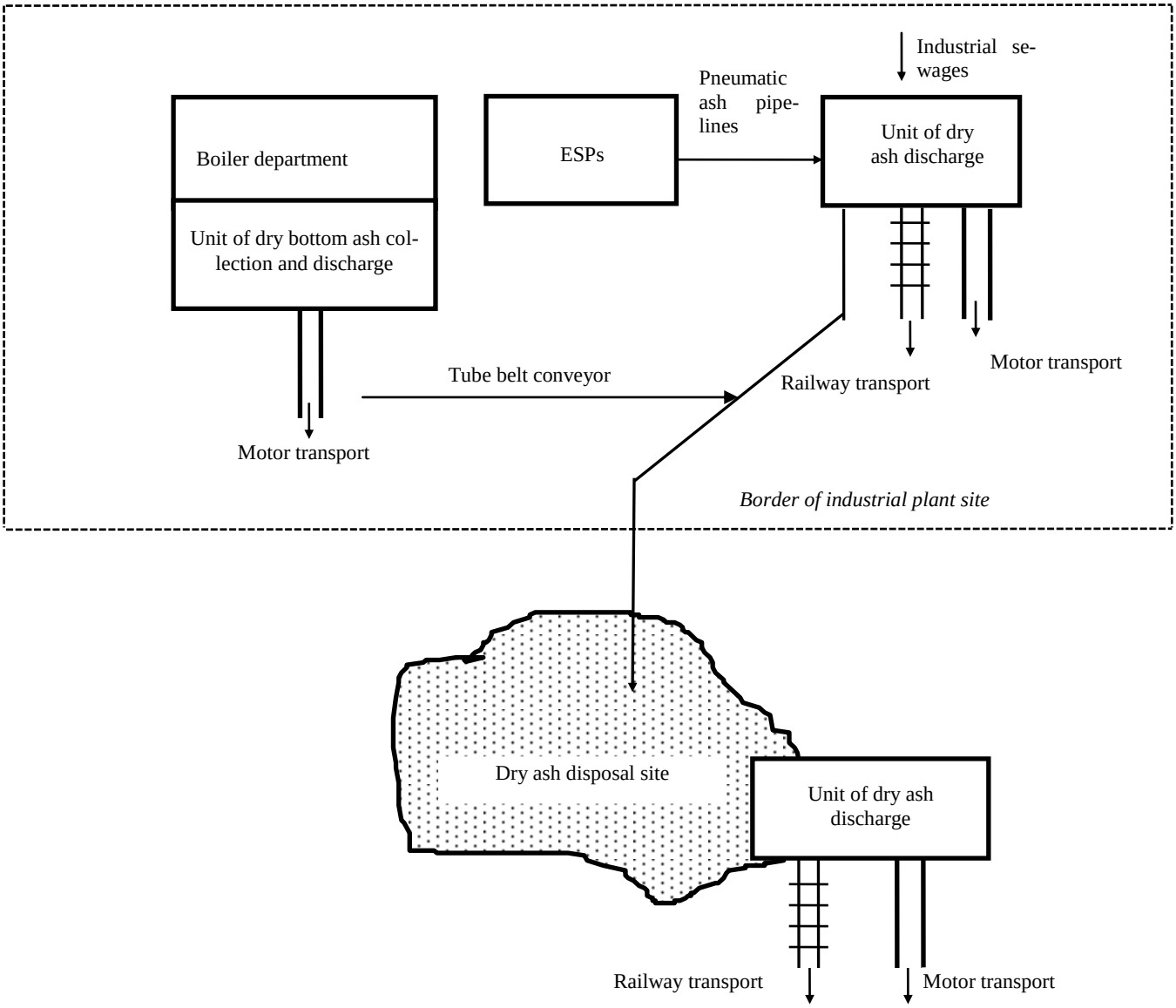

Fig. 4. **Block diagram oa alternative dry ash removal system at Reftinskaya SDPP**

The reconstructed ash removal system is planned to be put into operation in 2010.

Results of reconstruction of ash removal system at Reftinskaya SDPP with application of dry technologies are the following:

- improvement of ecological conditions around the power plant;
- no need for expansion of ash disposal site and according to that no need for cutting down 456 hectares of wood;
- decrease in water consumption by power plant as a whole;
- increase in duration of ash disposal filling in 1,8 times;
- decrease in the cost price of electricity generation due to considerable reduction of the specific cost price of ash removal;
- increase in volume of ash selling due to creation of possibility of dry ash shipment with the required consumer properties in demand volume.

For increase in volumes of selling ash to customers, management of WGC-5 with participation of management of the Reftinskaya SDPP conducted a number of meetings with the Government of Sverdlovsk Region. During these meetings questions relating to possible volumes of ash beneficial use and the rough schedule of ash deliveries by years, and also consumer properties for various applications of ash replacing natural resources, were discussed. It is expected that volume of beneficial use of ash from Reftinskaya SDPP by 2010 in comparison with 2005 will increase approximately in 10 times and will reach 2,0 million tons in a year.

There are no doubts that successful implementation of the project on complete reconstruction of ash removal system at Reftinskaya SDPP will serve a good example of a right solution of ash handling issues and will give a powerful impulse to essential increase in volumes of processing of ash in commodity output instead of poisoning the environment by traditional wet ash removal systems.

SOME ASPECTS OF IMPLEMENTING ECOLOGICALLY SOUND ASH REMOVAL TECHNOLOGIES AT CONSTRUCTION OF NEW AND REDESIGN OF OPERATING COAL-FIRED POWER PLANTS

Organization of close interacting of administration of the power companies with regional authorities on a problem of beneficial use of ashes is one of the main directions of activity for reducing harmful environmental impact of coal-fired power plants, and also for cutting the cost price of electric and thermal energy generation. Such an effective interacting will also promote more intelligent use of natural resources due to decrease in water consumption by power plants and

replacement of nonmetallic materials with ashes/slags by factories of other economy branches. It is necessary to note, that such a correct approach to solution of the ash problem is formed for the present not in all heads of administration of power companies and coal-fired power plants, and regions of Russia.

Normative and legal documents of a federal level on promoting beneficial use of ashes and slags from TPPs are developed not systematically enough, resulting in a very low level of replacement of natural materials with ashes and slags. First of all, it is necessary, in our opinion, to develop "Rules of certifying sanitary-and-hygienic properties of the commodity output made from ashes and slags, and ashes and slags as a commodity output". We suppose, that availability of such Rules would allow to avoid many misunderstandings at solution of issues on beneficial use of ash and slag, and promote both essential growth of volumes of natural materials replacement with ashes/slags, and also environmental protection in a zone of the TPP impact.

Underestimation of importance of ash and slag problem at development of projects on reconstruction of coal-fired power plants by administration of the power companies leads to that at a stage of development of feasibility report on TPP reconstruction, not enough attention is often given to the problems of ash and slag use. Many heads of the power companies have a wrong opinion, that somebody else should be engaged in ash and slag problem solution, but not power engineers, who have only one aim - energy generation.

An algorithm of optimum solution of ash and slag problem is considered to be the following:

- **The state** through the matching legislative bodies provides financing of researches on ash and slag problem and a duly development of matching normative and legal documents, and through the bodies of control and nature protection supervision pursues a policy on promotion of intelligent use of natural resources and environmental protection;
- **power companies** with the purpose of cutting power generation costs and environmental protection, constantly finance studies of existing and potential commodity market of ashes and slags and arrange operation of ash and slag removal systems according to the main principles and methodical regulations on creating these systems with optimum economic and sound ecological parameters.

CONCLUSIONS

1. Coal-fired TPP is not only a source of electric and thermal energy, but also a source of valuable mineral raw material of the man-made origin in the form of ash and slag.
2. Ash and slag removal system is a unique technological complex within the limits of TPP simultaneously solving technological and nature protection problems on removal of ash and slag from boilers, that can and should make profit, but not losses, while any other nature protection technology costs money.
3. Use of ash and slag at commodity output manufacture leads to increase in competitiveness of the generating power enterprises due to decrease in the cost price of electric and thermal energy generation and reduction of the harmful impact of TPPs on environment.
4. Separate removal of ash and slag in connection with essential difference of their consumer properties promotes increase in volumes of their shipment for using at commodity output manufacture.
5. Minimum environmental impact of ash and slag removal systems of TPPs that could be technically achieved, is possible at the maximum ash and slag shipment for their processing and disposing the unclaimed ash and slag part at disposal sites by ecologically sound methods.
6. As much as possible application of technologies for disposing the unclaimed part of ash and slag at disposal sites in the form of products of a pent-up demand or with initial properties, allows not only to reduce harmful impact of ash disposal sites in environment, but also to provide shipment of ash and slag from disposal site at their increased consumption with the least expenses of means and time.
7. The effective state policy relating to ash and slag problem is only possible under condition of duly perfection of the existing and development of new standard-legal documents on the basis of results of state financing of corresponding interbranch system researches and focusing of activity of controls and nature protection supervision bodies of all levels at all-round stimulation of ash and slag use, replacing natural raw materials and elimination of application of wet ash and slag removal systems at building the new and reconstruction of the operating TPPs.
8. One of the key directions of power companies activity on decrease in costs of power generation and environmental protection is creation of ash and slag removal systems at TPPs with optimum economic and comprehensible ecological indicators on the basis of results of constant monitoring of existing and potential ash and slag markets.
9. Introduction of technologies on collecting, conveying, shipment and disposing of ash and slag from TPPs with zero consumption of water as a bearing environment will result not only in water consumption decrease, but also will compel management of power companies to be really engaged in solution of issues connected with sewages at TPPs,. being not technologically linked with ash and slag removal system.

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