Modern Approach to the Problem of Utilization of Fly Ash and Bottom Ash from Power Plants in Russia

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Abstract. Data on annual formation and utilization volumes of fly ash and bottom ash of TPPs in 1990-2005 are resulted. Main ash disposal systems, that are used at TPPs nowadays are described. Problem of pneumatic transportation installations reliability for ash disposal systems and coal-pulverizing systems of TPPs is considered. Analysis of an opportunity of significant increase of useful utilization volumes of power engineering ash is executed. Main branch documents of Russian JSC "UES of Russia" on a problem of fly ash and bottom ash for the last 10 years are resulted. Basic directions of ash utilization and requirements to fly ashes for concrete in Russia and abroad are considered.

Utilization of power generation wastes is one of the major problems of modern TPPs, especially for solid-fuel power plants burning coal, peat and slates as alongside with nitrogen oxides and/or sulfur oxides, as for gas or oil TPPs, fly and bottom ashes are formed. Average ashes output at TPPs and boiler-houses of Russian JSC "UES of Russia" in 2000 - 2005 makes about 25 million t per year. Relative volume of TPPs ashes useful utilization for the same years makes about 18-20 % from an annual output. In table 1 data on annual volumes of TPPs ashes formation and utilization for the period 1990-2005 are presented.

Table 1. Volumes of generation, utilization and disposal of ashes from TPPs of RF

Name/years	1990	1995	2000	2002	2005
Coal consumption, million t natural fuel/year	182,0	128,0	120,1	106,0	132,8 - 145,6
Average ash content, %	27,5	26,3	20,8	21,4	21,0
Volumes of ash generation, million t/year	50,0	33,7	25,0	22,7	27,9 - 30,6
Volume of ash utilization without station service, million t/year	4,5	1,9	3,1	3,3	4,5 – 5,6*
Volume of ash disposal, million t/year	43,0	30,1	20,7	18,3	22,4 – 24,0
Total relative volume of ash utilization, % from the annual output	9,4	5,9	16,0	19,1	19,6– 21,5

* - prognosis data

As a whole on branch about 85 % of ashes are transported as pulp of low concentration for storage at the hydraulic ash disposals which are one of the basic sources of environmental contamination by energy generation. The basic scheme of traditional hydraulic ash disposal system is presented in fig.1.

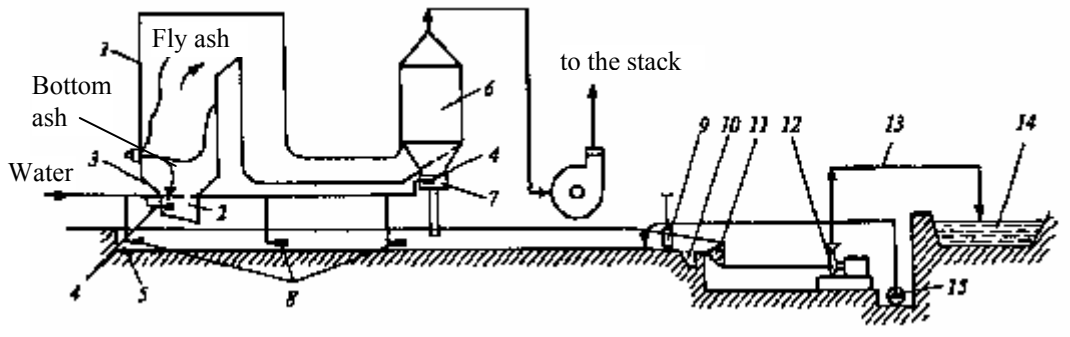

Fig.1. Basic scheme of traditional hydraulic ash disposal system
1 – boiler; 2- bottom ash bath; 3 – furnace tap; 4 – flush nozzle; 5 – gravity canal; 6 – fly-ash collector; 7 – ash flushing device; 8 – driving nozzles; 9 – stop log; 10 – catch pit; 11 – bottom ash crusher; 12 – slurry pump; 13 – bottom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

Basic disadvantages of hydraulic ash disposal systems are the following:

- great specific water charges on pumping ash pulps (water-ash ratio up to 50:1);
- negative influence on air (ash disposal dusting) and water (pollution of underground and superficial waters by recirculating and filtration water of ash disposal);
- chemical and mineralogical soil content change;
- ash disposal failures;
- withdrawal from rational land tenure of the areas for hydraulic ash disposals;
- worsening of consumers ash properties;
- formation of firm deposits in hydraulic ash pipelines at high-calcium ash transportation.

For successful ash utilization problem solution and minimal ecological damage to the environment it is necessary to apply ash pneumatic transportation systems. At TPPs various pneumatic ash disposal schemes are applied: pressure, vacuum, vacuum-pressure and a scheme of gravity ash shipment to the consumer's transport from the bunkers of electrostatic precipitators or their combinations. However, more often pressure systems of pneumatic ash disposal with transportation distance up to 1000 m are used. The scheme of pressure ash pneumatic transport from one power engineering unit of Ryazanskaya TPP with capacity 300 MW is showed in fig.2

One of the main disadvantages of pneumatic ash disposal systems is heightened erosion wear of horizontal and especially shaped elements of pneumatic transport pipelines.

Reliability and profitability of ash disposal systems appreciably depends on erosion wear of the pneumatic transportation equipment: pumps, pipelines (pneumatic transportation pipelines), shut-off and regulating armature and other elements of pneumatic transportation installations. In this connection erosion wear is one of the main problems of pneumatic transportation equipment of ash disposal systems and coal-pulverizing systems of TPP. Erosion wear of pipelines results in worsening technical and economic parameters of pneumatic transport installations of fine-dispersing loose materials with the increased erosive properties. Thus the following is observed:

- Decrease of pneumatic transport installations reliability because of delays caused by blowholes in pipelines;
- Deterioration of economic parameters owing to application of pipelines with the overestimated walls thickness;
- Increase of specific power imputs on materials pneumatic transport in connection with the air flow growth and pipelines aerodynamic resistance because of change of geometrical sizes and form of rectilinear and shaped pipelines sites flow area;
- Worsening of ecological parameters because of dust emergency emissions into environment at blowholes formation in pipelines.

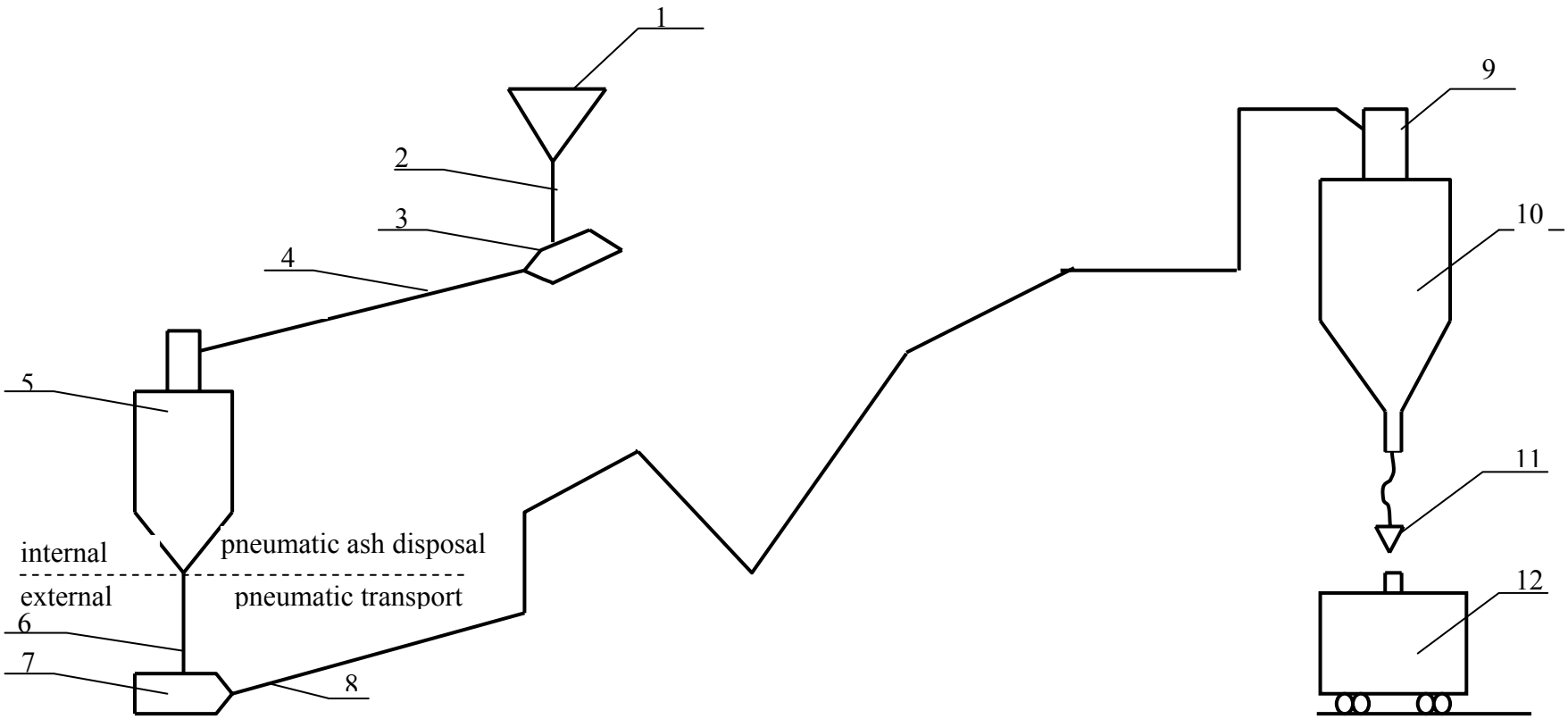

Fig.2. Scheme of pneumatic transport of prechamber ash of power unit № 1 with capacity 300 MW at Ryazanskaya TPP

1 – bunker of electrostatic precipitator prechamber; 2 – ash discharge; 3 – pneumatic jet pump; 4 – pneumatic ash pipeline of internal pneumatic transport installation; 5 – surge bin; 6 – feed jet of external ash pneumatic transport installation; 7 – pneumatic screw or chamber pump; 8 – pneumatic ash pipeline of external pneumatic transport installation; 9 – silo head; 10 - silo; 11 – charger; 12 – cement carrier.

Besides the raised erosion wear prevents from wide introduction of more acceptable ecological pneumatic ash disposal systems of TPPs, than hydraulic ones. It is necessary to emphasize, that satisfactory solution of erosion wear problem allows us to make higher reliability of pneumatic transport installations not only for power engineering enterprises, but also for pneumatic transport installations of any other erosive fine-dispersing loose materials (cement, coke, sand etc.). It should be mentioned that erosion wear is the one of the main factors playing a determining role at estimation of lifetime and reliability of the pneumatic transport equipment. For proper estimation of erosion wear and increase of pneumatic transport installations reliability under the order of Russian JSC “UES of Russia” in 2001 the group of the leading specialists of power engineering under scientific management of Putilov V.Ya. developed in Moscow power engineering institute the branch normative document “Methodical instructions for calculation and recommendations for erosion wear reduction of pneumotransport pipelines of ash disposal systems and coal-pulverizing systems of TPPs”. RD 153-34.1-27.512-2001.

Opportunity of significant increase of ash useful utilization volumes. A developed traditional method of solving the ash problem at TPPs is that the TPP is considered to be a separate business intended only for generation of thermal and electric energy. Thus it’s missed the fact, that ash disposal system is a unique technological complex in structure of TPP, which can be completely separated into independent manufacture. In the supervising document of Russian JSC "UES of Russia" "Technique of technical and economic parameters estimation of TPPs ash disposal systems in view of ecological requirements. RD 34.02.103-98" the following definition is established: “Ash disposal system is a complex of buildings, constructions, installations and equipment for evacuation of ashes from boilers, recycling and their shipment to the consumers and storage of not required ash part on ash dumps using ecologically acceptable ways”. If power engineers are interested in essential increase of economic indices of coal TPPs under all other equal conditions it can be made only at maximum possible useful ash utilization. So power engineers should face existing and potential consumers of ashes with the aim of problems discussion, search of ways and creation of conditions for adjustment of mutually advantageous cooperation on ash utilization. Thus ashes should be considered as valuable mineral raw material of technical processes needed for natural materials replacement, but not as inevitable useless wastes. The final type of delivered ashes (bottom ash, fly ash, fly and bottom ash mixture, intermediate product, cindery gravel or ash production) should be chosen on the basis of economic parameters estimation for ash disposal system as a whole. Ash disposal system at TPP should be constructed according to

the ash properties required by existing and potential consumers. A TPP is considered to be a part of power engineering and technological complex of the region. Only at such approach essential ash volumes increase can take place, that is for manufacture of various production types. Otherwise TPPs burning coal will continue affecting the environment with ash dumps.

Major laws of the RF and branch normative documents of Russian JSC "UES of Russia" on ash disposal of TPPs and boiler-houses:

1. Law of the RF №89-FZ from 24.06.98 "On production and consumption wastes".
2. Law of the RF №7-FZ from 10.01.2002 "On environmental protection".
3. Law of the RF №184-ФЗ RF from 27.12.02 "On technical regulation".
4. Federal classification wastes catalogue. Order of Ministry of Nature Resources of Russia № 786 from 02.12.2002.
5. Branch standard. OST 34-70-542-2001. "Fly ash of thermal power plants. Normative characteristics".
6. RD 34.02.202-95. "Recommendations on revegetation of ash disposals of thermal power plants".
7. RD 153-34.02.202-95. Recommendations on revegetation of exhausted ash disposals of thermal power plants".
8. RD 34.27.109-97. Methodical directions on designing pneumatic ash disposal systems from TPPs boilers, installations of dry ash delivery to the consumers and its shipment to the poured ash disposals.
9. RD 34.02.103-98. Technique for technical and economic parameters estimation of TPPs ash disposal systems in view of ecological requirements.
10. RD 153-34.0-02.106-98. Technique for estimation of wind erosion and dusting of ash disposal.
11. RD 153-34.1-02. Time methodical recommendations for definition of ash hazard category of TPPs and boiler-houses.

Let's consider basic directions of ashes utilization and also requirement to the fly ash for concrete in Russia and abroad (tab. 2, 3).

Table 2. Basic directions and volumes of ashes utilization in Russia and some other countries

Countries	Ashes output, mill. t/year	Ashes utilization		Principal directions and ash utilization volumes, mill. t/year
		mill. t/year	% from output	
Russia	~ 25	~ 3,5	~ 19	All directions
Great Britain	~ 6,5	~ 3,2	~ 49	All directions
China	~ 41,0	~ 9,5	~ 25	Cement replacements, ceramic brick, bulk material, territory lay-out, mine filling
EU as a whole (without new members)	~ 48	~20,5	~ 43	All directions

Table 3. Requirements to the fly ash for concrete in Russia and states of EU

Parameter	Coal type	Value of parameter depending on ash type under GOST 25818-91 requirements, % on mass				Value of parameter under EN450 requirements, % on mass
		I	II	III	IV	
1. CaO content		<10				<1
- for acid ash	Any					
- for basic ash, free	Brown coal					
including: CaO_{free}:						
- for acid ash	Any	Not normalized				
- for basic ash	Brown coal	<5	<5	Not norm.	<2	
2. MgO content	Any	<5	<5	Not norm.	<5	Not normalized
3. SO_3 content						<3
- for acid ash	Any	<3	<5	<3	<3	
- for basic ash	Brown coal	<5	<5	<6	<3	
4. Na_2O content						<1,5
- for acid ash	Any	<3	<3	<3	<3	
- for basic ash	Brown coal	<1,5	<1,5	<3,5	<1,5	
5. Mass loss on ignition						<5
- for acid ash	Anthracite	<20	<25	<10	<10	
	Hard coal	<10	<15	<7	<5	
	Brown coal	<3	<5	<5	<2	
- for basic ash	Brown coal	<3	<5	<3	<3	
6. Specific surface, m^2/kg						Not normalized
- for acid ash	Any	>250	>150	>250	>300	
- for basic ash	Brown coal	>250	>200	>150	>300	
7. Sieve residue						
7.1. R_{45}	Any					<40
7.2. R_{80}						
- for acid ash	Any	<20	<30	<20	<15	
- for basic ash	Brown coal	<20	<20	<30	<15	
8. Cl content	Any	Not normalized				<0,1
9. Humidity	Any	<1,0				<1,5

By comparison of the basic requirements to the fly ash quality in Russia and European Committee on standardization it is possible to make the following basic conclusions:

standard EN450 establishes unified requirements to all kinds of fly ash formed after burning of various coal types;

practically all parameters under standard EN450 are more strict especially it concerns loss on ignition.

Unified and stricter requirements to the fly ash quality for all coal types are one of the principal reasons of its use in much bigger volumes abroad than in Russia by manufacturing various concrete as the best consumer ash properties allow to use it in wider range of building manufacture technologies.

CONCLUSIONS

1. In the nearest future essential growth of coal consumption and decrease in a gas part in electric power industry will be observed.
2. Essential increase in ash useful utilization volumes at traditional method of ash problem solution is impossible.
3. Shipment or processing of TPPs ashes in any quantities entails corresponding reduction of harmful influence of TPP on environment and decrease in costs by electric and thermal energy generation.
4. For creating objective conditions for increase of ashes utilization volumes in various branches of national economy it’s necessary first of all developing a complete complex of national standards and organization standards on a problem of ashes.