Part 3

ASH AND SLAG HANDLING

3.2. Ash and slag handling systems at TPPs

3.2.5. Ash and slag disposal sites

3.2.5.3. Dry ash landfills

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Significant reduction of lands intended for ash and slag disposal sites (ASDS) in a zone of TPP location; decrease in water consumption at TPP and harmful impact of ash and slag disposal sites on environment, and also cutting of power generation costs connected with ash and slag handling problem, are only possible in case of transfer from wet conveying method with disposing of ash and slag as low-concentration slurry to dry technologies of removal and landfilling which also create objective preconditions for processing of more ash and slag in a commodity output, used in various branches of economy.

The Russian experience of dry ash and slag landfilling

Dry ash and slag removal and landfilling were applied at boiler-houses and TPPs of Russia from the beginning of electric power industry development [5, 6]. However, dry ash landfills haven't received their wide use. There are some examples of construction and operation of dry ash and slag landfills. An experience in operation of dry ash and slag disposing systems at bulk disposal sites earlier limited itself to certain heating boilers and small TPPs, such as Barnaulskaya CHPP-1 and TPP of Krasnogorsk factory of artificial leather. At these power enterprises dry ash evacuated from boilers by mechanical or pneumatic conveying, was transported in open dump trucks and dumped in the nearest ravines, bogs or other invaluable ground areas without its subsequent consolidation and fastening of a surface of the disposal site. Such disposing of ash and slag doesn't correspond to the state-of-the-art requirements of environmental protection. Environmentally more sound ways of ash and slag landfilling are recently applied at dry ash disposals of Krasnoyarskaya CHPP-2 and boiler-house of "Krasmash" factory.

In order to check and work off dry technologies of collecting, conveying and landfilling of ash from ekibastuzsky coal in the conditions of the Urals, an industrial test [7] at Verhne-Tagilskaya SDPP from 1979 to 1985 was made. "UralORGRES" and the Ural branch of "Teploelektroproject" Institute developed and supported introduction of these technologies. Dry ash was delivered by dump trucks, leveled by bulldozers and rolled by road rollers. Maximum capacity of test plants of dry ash collection has made 8 t/h at hourly average operational capacity of 6 t/h.

It has been established that an optimum humidity of ash mix, at which there is no dusting at loading, conveying and unloading of dump trucks at the disposal site with their full discharge, made 20 … 25 %. At lower humidity a screw didn't provide homogeneous mixing, dusting at loading, conveying and unloading of ash was observed. At the same time at its higher humidity a body of the dump truck wasn't unloaded completely and its manual cleaning was required.

To the pilot dry disposal site ash was conveyed by dump trucks MAZ-5549 of load-carrying capacity of 7 t with not heated body. Time of truck loading made 8 … 12 minutes. Conveying route of about 4,5 km passed through a territory of SDPP and a concrete highway out of the building area. Average speed of the dump truck was 25 … 35 km/h, and time in a way made 10 … 15 minutes. The dump truck was unloaded at the disposal site during 3 … 5 mines at complete transportation cycle of 30 … 45 minutes.

In winter period ash temperature during the complete technological cycle was measured. Temperature of the humidified ash, loaded into dump truck, made 30 … 40°C, but during transportation it cooled down by 5°C at air temperature of –25°C, by 3°C at –15°C and by 2°C at –7°C. Rather fast decrease in ash temperature was observed at the disposal site. At outside air temperature, being lower than –25°C, a surface of the unloaded ash in 1 hour became covered with an ice crust of 3 … 5 sm thick, and temperature in a layer in this period decreased by 8 … 10°C. Hence, during winter period duration of the technological cycle of unloading-leveling-rolling is necessary to reduce as much as possible.

The pilot dry ash disposal site was chosen at the top of the completed preserved landfill of SDPP on a border of ash inwash so, that ground was a base for half of the site, and a surface of the stockpiled ash and slag of chelyabinsky coal was a base for another half. For superficial drainage from the landfilling site, water-diversion ditch of the disposal area, located at a distance of 50 m, was used. For water drainage from the landfilling site, a ditch with drainage capacity was dug along its perimeter. Exit from a highway to the landfilling site was made of rocky crushed stone from the local open-cast mine, and for the whole period of test works on ash laying it was in a satisfactory condition.

Ash in the amount of 25 thousand tons was laid in a pile with the sizes of 60×109 m and height of 5,5 m. At its laying and rolling dump trucks, bulldozer on the base of T-100 tractor, plain U-50 rollers of 6,5 tons and width of the compacted stripe of 1,8 m and a watering machine were used. The works were conducted within a year under any weather conditions with geotechnical control of each laid layer of ash and periodic control of its dispersion, density and chemical compound.

For ash landfilling it was collected only from the first stages of ash collecting plants — battery cyclones. In this connection its dispersion was slightly lower, than of the whole ash, collected from flue gases, owing to absence of small fractions, caught at the second stage of gas purification — in scrubbers. Therefore, physical and mechanical properties of the laid and rolled ash at the dry disposal site turned out to be lower, than expected at laying the whole amount of ash after ash collecting plants.

In 1981 control dumping of 700 ash tons in one layer of 1 m high without laying was conducted at outside air temperature of 7 … 12 °C. Humidity of the mix at dumping made 18 … 22 %. Average ash density was 675 … 720 kg/m^3, and filtration factor made 0,624 … 0,75 m/day. In July, 1984 after 2,5 years of storage the control ash layer settled by 0,2 … 0,3 m, its density increased to 840 kg/m^3.

At laying of ash in one layer with compaction it has been established that for normal work of dump trucks and rollers, a thickness of the not rolled ash layer shouldn't exceed 0,25 m. In this connection dumping was conducted by dump trucks evenly along the site with daily leveling of ash by bulldozer till the specified thickness. After that ash layer was

laid by three-five roller passes to density of 1350 … 1450 kg/m^3. To provide optimum humidity of ash at its laying, the ash was additionally moisture by a watering machine. Filtration factor of the ash layer made 0,20 … 0,45 m/day.

Afterwards at laying the main part of ash (23 thousand tons) from October, 1983 till December, 1984 a plain roller was applied to compact only the first five layers, and since the sixth layer ash was laid by the loaded dump trucks. After four-six passes of dump truck, the ash layer of 0,20 … 0,25 m high got density of 1300 … 1400 kg/m^3 and volume density of a skeleton of 870 … 980 kg/m^3. Further increase in a number of passes hasn't led to increase in density of its layer.

The rolled surface of the laid ash pile practically didn't raise dust. Only during the long periods of dry and windy weather intensive drying of a surface layer and some dust were observed. Slopes of the pile were not laid and fixed, therefore for a long time they remained friable and in this connection dusting in dry windy weather was observed. In all cases dusting was eliminated by humidifying of the surface layer by a watering machine. Thus, in hot and dry windy weather humidifying of the unfixed surfaces of dry disposal sites is required. At raining the dry disposal site intensively absorbs water. The surface layer becomes extra wet (humidity of 50 … 55 %) and swells a little, however it doesn't affect a passability of dump trucks. Slopes of the pile after rains are a little compacted and washed away, carrying out ash to the pile base.

In winter time snow from a surface of the ash pile was cleaned only once when the thickness of a layer of the dropped out snow has exceeded 15 sm, that made the work at the disposal site more complicated. In other cases ash was dumped on snow, it quickly froze together that worsened parameters of compaction.

At laying the ash by digging of the dumped pile, its monolithic samples have been received. Some geotechnical indicators of these samples have been defined:

- maximum density of the ash skeleton is 980 … 1100 kg/m^3;
- optimum ash humidity is 34 … 40 %;
- average density of the ash skeleton rolled by plain roller and dump truck is 960 and 920 kg/m^3 accordingly;
- compaction factor at ash laying by roller and dump truck is 1,25 … 1,43 and 1,24 … 1,40 accordingly;
- average filtration factor of the ash compacted by roller and dump truck is 0,31 and 0,35 m/day accordingly;

At optimum humidity and maximum density of ash the deformation module makes 15 MPa, coupling — 0,007 MPa, angle of internal friction — 32°, filtration factor — 0,1 … 0,2 m/day.

Researches of drain structure after water-to-ash contact have shown that at filtration through a layer it becomes polluted by harmful components and doesn't meet the norms of maximum concentration limit. For its prevention it's required to take away from the disposal site the superficial drains and atmospheric precipitation, filtered through ash, dropping out on the disposal area, and to prevent ingress of the polluted water from the disposal site into base grounds.

Thus, as a result of industrial test on laying of dry ash from ekibastuzsky coal the following has been established:

- dry ash removal is more beneficial and technically possible in climatic conditions of the Urals;
- compaction of the humidified ash by plain roller provides 20 % increase in ash disposal volume in comparison with the hydraulic inwash, and at rolling by dump trucks — by 15 %;
- dry ash and slag removal using motor transport is expediently for application at domestic TPPs, large and medium industrial boiler-houses;
- a choice of a method and scheme of ash and slag removal should be made on the basis of feasibility report taking into account ecological characteristics of the compared alternatives, prospects of ash and slag applications and other factors.

Experiment was stopped because, despite of the received positive results on dry ashes disposing, a share of the caught dry ash in of the total output at Verhne-Tagilskaya SDPP was small and a parallel operation of both ash and slag removal systems was economically inexpedient.

Foreign experience of dry ash and slag disposing

Special conditions of development of electric power industry in the U.S., Germany, Canada and some other countries, consisting in high cost of land, deficiency of water resources in areas of TPPs location, developed road and transport networks, rigid nature protection legislation stimulating replacement of natural raw materials by by-products from different industries, high degree of scientific, design and technical readiness of enterprises of the building industry to use ash and slag from TPPs, and also other specific technical, conjunctural and economic conditions have predetermined wide introduction of dry ash and slag removal and disposal in electric power industry of the industrially developed countries since 1950-ties. Basically efforts of experts were directed on perfection of the existing and creation of the new technologies, providing maximal reduction or practically a complete elimination of water for ash and slag removal, introduction of dry technologies of ash and slag landfilling, beneficiation and shipment to customers.

According to Environmental Protection Agency of the U.S., 153 out of 320 coal-fired power plants (47 %) apply dry ash removal. About the same situation is observed in other developed western countries. However, at the most part of TPPs, hydraulic slag removal is applied and only 20 % of TPPs operate dry (mechanical or pneumatic) systems of slag removal. Dry ash and slag landfilling is also used in Poland, Hungary and Slovakia. In connection with essentially higher massif density at ash laying by a dry method in comparison with hydraulic inwash, some power companies take ash and slag from the filled inwash disposal sites and stack them on the same place with level-by-level compaction, that allows to raise a quantity of ash and slag disposed at the landfill by 40 % [5].

In connection with the obvious advantages of a dry method of ash landfilling (improvement of ecological characteristics of disposal sites, low water consumption for ash removal and landfilling, almost complete elimination of washing away harmful substances containing in ash and slag and corresponding prevention of ground waters pollution, essential reduction of territories intended for disposal sites) almost at all the U.S. power plants being under construction dry ash landfills are being built, and at the most part of the operating TPPs, combusting solid fuel, hydraulic ash and slag conveying is replaced by automobile transportation [6].

Typical for the foreign TPPs is dry ash and slag removal system of the U.S. power plant "Brig-Braun" of the Texas power company and an incorporated dry landfill of the power plant "Morgentau" and "Faulkner" of power company "Potomac" [5, 8]. "Brig-Braun" TPP has two units of 575 MW; lignite with the ash content of 11 % is combusted. Slag from boilers is evacuated by hydraulic method at a distance to 500 m to two-section sediment basin of a total area of 12 hectares. Slag basin is screened by the clay material, and slag slurry together with some other polluted drains from the TPP are dumped in it. The clarified water returns to the power plant for its reuse. For neutralization of calcium, potassium and sodium oxides, containing in slag, some amount of hy-

drochloric acid is added into water. One section of the sediment basin is under operation, another one is being drained at this time, slag is taken by an excavator and transported to the site of local roads construction, and also to special site— a temporary disposal area located near the power plant.

Cleaning of flue gases from ashes is realized in four-field ESPs with collecting efficiency of 98,4 %. From ESP hoppers ash is evacuated by the automated pressure head system of pneumatic conveying with chamber feeders set under each hopper, to the silos located at a distance of 700 … 800 m from ESPs. In the silo small ash particles are separated in the cyclone and feed to the hopper, from which they are taken by trucks to cement works for its use as a mineral additive at portlandcement grinding. Large ash particles are supplied to the silo, from which through the special mixer-humidifier with humidity of 14 … 16 %, sufficient for dust elimination at loading, conveying and unloading of ash, they are periodically unloaded in scrapers, transported to the dry disposal site which is located directly by the silos, and laid by layers of 0,25 … 0,30 m thick with compaction by vibrorollers.

Removal and landfilling of ash and slag at "Morgentau" and "Faulkner" TPPs is similarly realized. Ash and slag materials are laid by layers of 0,25 … 0,30 m thick and rolled by vibrorollers. The joint ash disposal site of both plants was located in the territory unsuitable for building and agricultural use. Its preparation for ash landfilling consisted in removal of the fertile ground layer, laying of a drainage cushion from the slag layer of about 0,30 m thick, construction of a drainage ditch round the site, lay-out of the disposal base before dumping of the drainage layer pitched to the ditch, erection of four consistently connected clearing pools and building of a bulk road from the asphalted highway to the site.

Ash from power plants is transported to the site by open dump trucks of a load-carrying capacity of 15 tons. The distance makes 11 km, but thus it is necessary to notice that in the U.S. there are dry ash disposal sites, located at a distance of 90 … 100 km from TPPs. On the site ash of 0,25 … 0,30 m thick is spread by bulldozer and compacted by vibrorollers of 20 tons by weight which pass four times. Therefore, the ash layer decreases to 0,01 m, and density of the ash massif raises to 1600 kg/m^3 that is approximately by 40 % more, than at hydraulic inwash. To prevent dusting, on the site and adjoining bulk roads, the ash is constantly humidified by means of a watering machine. For the surface water drainage, the ash is laid pitched to the drainage ditch. Superficial and underground waters from the disposal area through drainage system reach the clearing pools, where they are clarified and dumped into the river. A part of water is used for ash humidifying on the site and watering of roads.

During operation of dry ash disposal site a special attention is given to formation and strengthening of slopes. They are covered with a half-meter layer of ground and sown with long-term grasses. The ash settled in the clearing pools and soil, is periodically unloaded and transported by trucks to the disposal site. Using such a method up to 500 thousand tons of ash in a year, or 1300 tons per day are processed.