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Part 3

ASH AND SLAG HANDLING

3.4. Beneficiation and ash management

3.4.3. Prospects of producing high-quality ash and cenosperes from ashes of power coals having high L.O.I. on the basis of nanotechnologies

V.Y. Putilov[1], K.V. Eremin[2]
Moscow Power Engineering Institute (Technical University), Russia (1)
Omega Minerals Group, Germany (2)

ABSTRACT

Main stages of *fly ash light fraction* processing are listed. Main branches which use *hollow ash cenospheres* for the manufacturing of different types of high-technology products are presented. Estimations of the volumes of potential and existing world sales market of *hollow ash cenospheres* are given. Main factors influencing on physical and mechanical properties, chemical and mineralogical as well as particle size distribution of *hollow ash cenospheres* from coal combustion in power boilers are indicated.

Main reasons preventing from effective solving the problem on ash handling in power companies on up-to-date level taking into account the best world experience are indicated. Some conditions necessary for effective solving the ash problem are formulated.

Possible technology for complex solution of the issues of receiving quality ashes and production of cenospheres with required characteristics at coal-fired power plants is presented. Estimation of changes in economic and ecological indicators of power plants after implementation of the suggested technology is made.

1. ABOUT FLY ASH CENOSPHERES

As it is known ashes from different power coals have different characteristics. But if solving the problem on utilization of dry bottom ash removal seems to be clear enough, then effective utilization of fly ash is not as obvious as it may seem at first sight. In connection with that, systematic researches of the features of different fractions and creation of high-performance technologies of fly ash separation into fractions required by the customers are the paramount objective today. Solution of this task will allow processing various coal ashes in the most optimal way (according to the ratio of expecting profits to planned expenses for processing).

Alongside with a demand for ashes for large-tonnage ash-processing areas there is a demand for separate fly ash fractions for low-tonnage technologies of manufacturing high-technology products by different fields of industry. *Light fly ash fraction* may be referred to such narrow fractions.

Light fly ash fraction is a raw material for production of *hollow ash cenospheres*. *Hollow ash cenospheres* are extracted out of *light fly ash fraction* (Fig. 1) by means of its stage-by-stage processing with the use of various technologies.

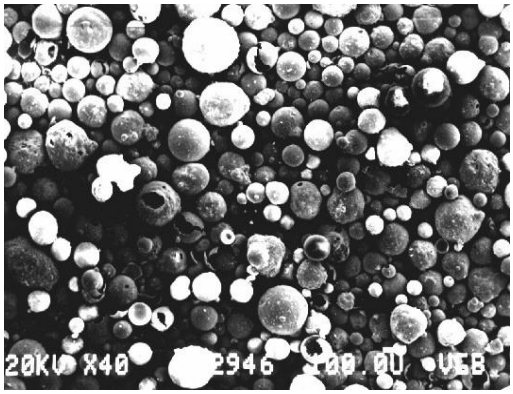

Fig. 1. Light fly ash fraction containing cenospheres

1.1. Light fly ash fraction processing

Characteristics of ash processing are determined by the conditions of further use of hollow ash cenospheres, i.e. by the requirements for physical and chemical features and particle size distribution of cenospheres from the side of the customers (Fig. 2). It is the aspect that defines a true rule for handing any ashes and slags: "Study of ash and slag characteristics → ***study and shaping of the market →working out and fulfillment of technical solutions for processing".***

Fig. 2. Classified *hollow ash cenospheres* and initial raw materials

Realization of this rule has resulted in business-processes of *hollow ash cenospheres* production and sale, which were created and fulfilled in practice.

The first stage of the *hollow ash cenospheres* processing is separation of *light fly ash fractions*. Numerous attempts to create effective technologies of *light fly ash fraction* extraction out of dry ash removal haven't led to the construction of industrial plants yet.

Foam flotation method widely promoted by Rock-Tron Company (Great Britain), of course, allows solving the task of fractionating the disposed ash from ash disposal, however prime cost of received products is tightly connected with the possibility of sale of main large-tonnage amount of processed ash. Fly ash from ash-collectors contains only up to 3 % of ash cenospheres by mass, and in some cases content of cenospheres is less than 1 %. Otherwise, prime cost of light fly ash fraction and other separated fractions (magnetite, carbon and others) appears to be unacceptably high.

Probably, technology developing by *Omega Minerals Group* together with RFNC - VNIIEF will be promising; however the terms of its industrial introduction are not determined yet. That is why gathering of *light fly ash fraction* from the surface of *ash disposal lagoon* is made both in manual and mechanized way now. When using manual way it is rather difficult to observe the safety and labour protection requirements, we are not even talking about low effectiveness of this method and quality of the product.

The most effective technology of mechanized gathering of *light fly ash fraction* from the surface of *ash disposal lagoons* first was worked out and introduced by *Omega Minerals Group* in 2001. Russian and international patents protect both the method and equipment. With the use of this technology it is possible to gather from 100 up to 5000 t of *light fly ash fraction* per month from one *ash disposal lagoon* (Fig. 3).

Fig. 3. Loading of *fly light fly ash fraction* gathered from *ash disposal lagoon* with the use of technology of *Omega Minerals Group*

The quality of *light fly ash fraction* influences greatly the further processing cost and consumer characteristics of quality hollow ash cenospheres. In some cases *hollow ash cenospheres* separated from *light fly ash fraction* appears to have either unacceptable price or improper consumer characteristics.

Light fly ash fraction gathered from the lagoons is packed in accordance with the transportation requirements and is carried out to the processing plants for its further treatment.

Processing of *light fly ash fraction* into *hollow ash cenospheres* includes several partially combining stages:

- removal of organic impurities and underburning;
- non-destructive drying and rubbish separation;
- material classification in accordance with size, density, strength of the particles;
- magnetic separation of the product, removal of iron-containing particles;
- ignition of the material (if necessary);
- dehydration of the material to the moisture level of 0,25 % and achieving free fluidity of the material;
- regulation of acid-base characteristics of the material (pH-level);
- sterilization of the material (if necessary – for the manufacturers of lacquers and paints).

At present there are several technological schemes of *light fly ash fraction* processing, which are based on different technical approaches.

Technology of separation of *hollow ash cenospheres* from *light fly ash fraction* developed and introduced by *Omega Minerals Group* is the most effective one. International patents protect above-mentioned technology as well. This technology allows to process up to 10 thousand tons of *light fly ash fraction* per year by one module and to achieve the lowest for today prime cost of processing. The quantity of modules is determined by the quantity of processed raw materials (Fig. 4).

Fig. 4. *Light fly ash fraction* processing plant

The most crucial part of the processing is classification/blending of intermediate product aiming at the receiving *the hollow ash cenospheres* of different grades which fully correspond to the consumers' demands.

It is necessary to mention particularly about *hollow ash cenospheres* post-processing, which includes different ways of their modification. Joint elaboration of RFNC - VNIIEF and *Omega Minerals Group* allows obtaining *hollow ash cenospheres* with unique characteristics, which meets the demands of the most highly technological and highly costing segment of the market.

1.2. Main fields which use hollow ash cenospheres

At present *Omega Minerals Group* produces more than 20 various grades of *hollow ash cenospheres* under its own international registered trademark *"Omegaspheres"*. Volume of produced goods allows to satisfy the demand of more than a half of the European market of *hollow ash cenospheres* consumers (Fig. 5 and 6).

Fig. 5. Preparation for the shipment of *hollow ash microspheres*

Fig. 6. Shipment of conditioned *hollow ash microspheres*

The only guarantee of long-term successful presence on the market is stable quality of the goods, i.e. full and constant conformity of the characteristics of produced goods to the announced technical conditions. The quantity of parameters for quality control of different grades of *"Omega spheres"* may reach 12, that is why quality management system plays a special role in the process. Companies – the members of *Omega Minerals Group* are certified in accordance with ISO 9001:2000 standard; that allows them to keep and increase annually the number of their customers.

Regarding geographic distribution of the market of *hollow ash cenospheres* we have to ascertain its correlation with the level of development of innovative component in different branches of the economy of a state. Main consuming branches are (in order of increasing the demands for the quality of *hollow ash cenospheres* and the quantity of control parameters):

- oil-producing and oil-servicing companies;
- manufacturers of dry masonry mixtures and building materials (DMM and BM);
- manufacturers of composites;
- manufacturers of refractory materials;
- manufacturers of goods for automobile industry;
- manufacturers of lacquers and paints;
- manufacturers of composite materials for microelectronics;
- manufacturers of emulsion explosives.

Correspondingly, the lower is demands for the quality, the lower is price which the customer is ready to pay.

1.3. Estimation of world *hollow ash cenospheres* sales market

Potential volume of world *hollow ash cenospheres* market (according to the estimation of the experts from American Coal Ash Association) makes up to 1 million tons per year; however, current consuming level does not exceed 100 thousand tons per year. It is connected with the peculiarities of the niche of *hollow ash cenospheres* in the common market of light fillers and the range of objectively existing factors.

As it is known, *hollow glass cenospheres* are the nearest by their characteristics *to hollow ash cenospheres*. However, difference in features (higher density and low strength) does not allow *hollow ash cenospheres* to fill in this highly costing niche (from 3000 up to 17000 Euro/ton, delivered to the customer). If to consider more available price niches, we can see that manufacturers of other spherical and non-spherical light fillers (artificially made, including *hollow glass cenospheres*) guarantee stable quality and production volume of their products. In contrast to above mentioned products initial physical and mechanical properties, chemical and mineralogical as well as particle size distribution of *hollow ash cenospheres* and their stability are sufficiently influenced by the following main factors:

- stability of the grades and quality of coals burnt in power boilers;
- stability of conditions of cenospheres formation in power boilers depending on their load;
- technologies of ash collecting and ash removal;
- technologies of *light fly ash fraction* separation out of dry fly ash on power stations or gathering of *light fly ash fraction* on *ash disposal lagoons* taking into account climate conditions, etc.

Besides, another significant factor is that the prices limit for *hollow ash cenospheres* either has reached or is approaching the upper limits of consuming demands in the most fields of use. Such situation leads to reformulation of component composition of the products by many *hollow ash cenospheres* consumers, who want to avoid risks of quality problems with raw materials and decrease prime cost of their goods; as a result they give their preference to other fillers and refuse from use of *hollow ash cenospheres*. As a rule, the customers who have once made such reformulation do not return to the use of *hollow ash cenospheres* any more by force of system limits.

The more highly technological the fields of use of light fillers are, the more demanding the potential consumers of *hollow ash cenospheres* are. These circumstances determine the rules of cooperation between the manufacturers and consumers of *hollow ash cenospheres* (some kind of Good Managing Practice): ***participation in the process of working out the formulas and technologies of hollow ash cenospheres use in the consumers' products; constant incoming quality control of hollow ash cenospheres; timely consulting and readiness for anticipating the new grades offer.***

As a result, we can ascertain that *hollow ash cenospheres* market is highly competitive; moreover, compe-

tition is determined not so much by the manufacturers' offers of *hollow ash cenospheres*, as by ***presence of alternative products of similar type***. This situation is aggravated by appearance of new production technologies of light (including hollow, monospherical) spherical fillers with determined properties and relatively low prime cost. Some of the technologies are in the stage of testing production now and will be ready for mass introduction into the market in the near 2—3 years.

1.4. Some necessary conditions for effective solving the ash problem on power stations

At such circumstances only the company with full business cycle from *light fly ash fraction* gathering to *hollow ash cenospheres* sale under its own trademark, corresponding technological potential for *hollow ash cenospheres* production and marketing potential for market development can be the most successful in this field.

At present *Omega Minerals Group* is the only *hollow ash cenospheres* manufacturer in Europe, which works according to such business cycle. It took more then 10 years of hard work and 15 million Euro of investments to achieve such position.

In 2005 according to the results of II International Science-Practical Conference and Specialized Exhibition "Ecology in Power Engineering" *Omega Minerals Group* was awarded the Diploma and Honourable prize "For the organization of ash utilization business".

Methodology of organization of light fly ash fraction utilization business-process on the example of *Omega Minerals Group* is presented in short above. This methodology is entirely acceptable for the utilization of any other fractions of fly ash as well. It is proved to be the experience of cooperation with range of leading centers and companies in the EU and RF. Period of organization of similar business-processes for each fraction may take from 3 to 7 years and will require from 1 to 10 million Euro for their realization in different fields. Complex solution of the task may reduce expenses owing to synergy in fulfilling technical solutions; however, considerable reduction of marketing expenses seems to be unlikely.

It is necessary to point out that experience of *Omega Minerals Group* is the part of world experience of power stations ash and slag utilization and, what is very important, it is the only successful experience of western company, which has passed all stages of formation and development of the project in the territory of the CIS-countries.

Regarding Russian ash market in general and hollow ash cenospheres in particular, regretfully it is necessary to mention that overwhelming majority of the companies, which are trying to operate in this market, has neither qualified management and staff, nor technologies, nor understanding the kernel of the treatment process, nor marketing possibilities. We face dilettantism, total absence of strategic planning, sharp rejection of long-term investments of such kind of projects and inability to develop the market. Intellectual parasitism, reduced to trite use of someone's solutions without permission of the owners, is extremely developed. In authors' opinion (and to their great regret) the reason of appearance of these tendencies, which has already turned into practice, is that many top-managers of power engineering companies understand this business as means of prompt solution of their own financial problems and not the solution of the problem on ash and slag handling on up-to-date level aiming at economic effectiveness of power engineering production and reduction of its harmful influence on the environment.

How paradoxical it is, but building boom in 2005—2008 played negative part in development of ash and slag utilization process in the RF, many different "leading ash utilization companies" arose in the market. Main selling activity of these companies (during the peak of building boom) was reduced either to short-term large-tonnage one-time solutions only or to the sale of fly ash to negligent manufacturers of infringing cement and dry masonry mixtures. Acquaintance with sad consequences of these activities is still ahead. None distinct strategic solution was developed and introduced into practice in full by the management of power engineering companies. There are isolated examples of correct approach, which are, unfortunately, do not play leading part in general in the effective solution of ash handling problem in the Russian power engineering.

Prospective of effective ash and slag utilization in the RF depends directly on understanding of the owners of power engineering companies the weakness of the behavior of some hired top-managers and it will force them to switch from solving their own financial problems to working out and introducing in practice the purposeful and systematic solutions of ash and slag handling problem alongside with practical transferring of power stations to dry ash removal method. Also it is necessary to understand that creation of pocket "daughters", "granddaughters" and similar small companies does not assist the effective solution of ash and slag utilization problem aiming to reduction of prime cost of power engineering production and improvement of environmental conditions around power station.

One of the important conditions of successful realization of effective ash and slag utilization projects is the participation of companies and experts who have been professionally engaging in these issues in scientific, engineering, marketing and production directions for a long time and have shown certain results. Such companies recruited by the owners of power stations could help in solving not only scientific and technical, technological and organizational aspects of above mentioned problem, but also could assist in attraction of investments for realization of ash utilization projects. World experience shows that the most effective way of solving such problems is not in the strategy of "pocket companies", but in the strategy of outsourcing and partnership. Ignoring all issues mentioned above leads only to aggravation of the ash and slag handling problem right up to the stoppage of power station because of impossibility to use *ash disposal lagoons* as a result of

their project filling up. Let's assume that the owners of power engineering companies, who have understood all mentioned issues and the kernel of ash and slag handling problem, decided to find effective solution of the mentioned problem, but faced the question: "What should they do in technological aspect on power stations in order to move in this direction?" Below we shall consider one of possible variants of technological solution for obtaining coal ashes of high quality and managing production of cenospheres on power plants.

2. POSSIBLE TECHNOLOGY OF COMPLEX SOLUTION OF THE ISSUES OF RECEIVING HIGH QUALITY ASHES AND PRODUCTION OF CENOSPHERES

2.1. Brief characteristics of suggested technology

Principal scheme of experimental-industrial technological complex for obtaining high-quality coal ashes and production of cenospheres on the basis of nanotechnologies are presented on Fig. 7.

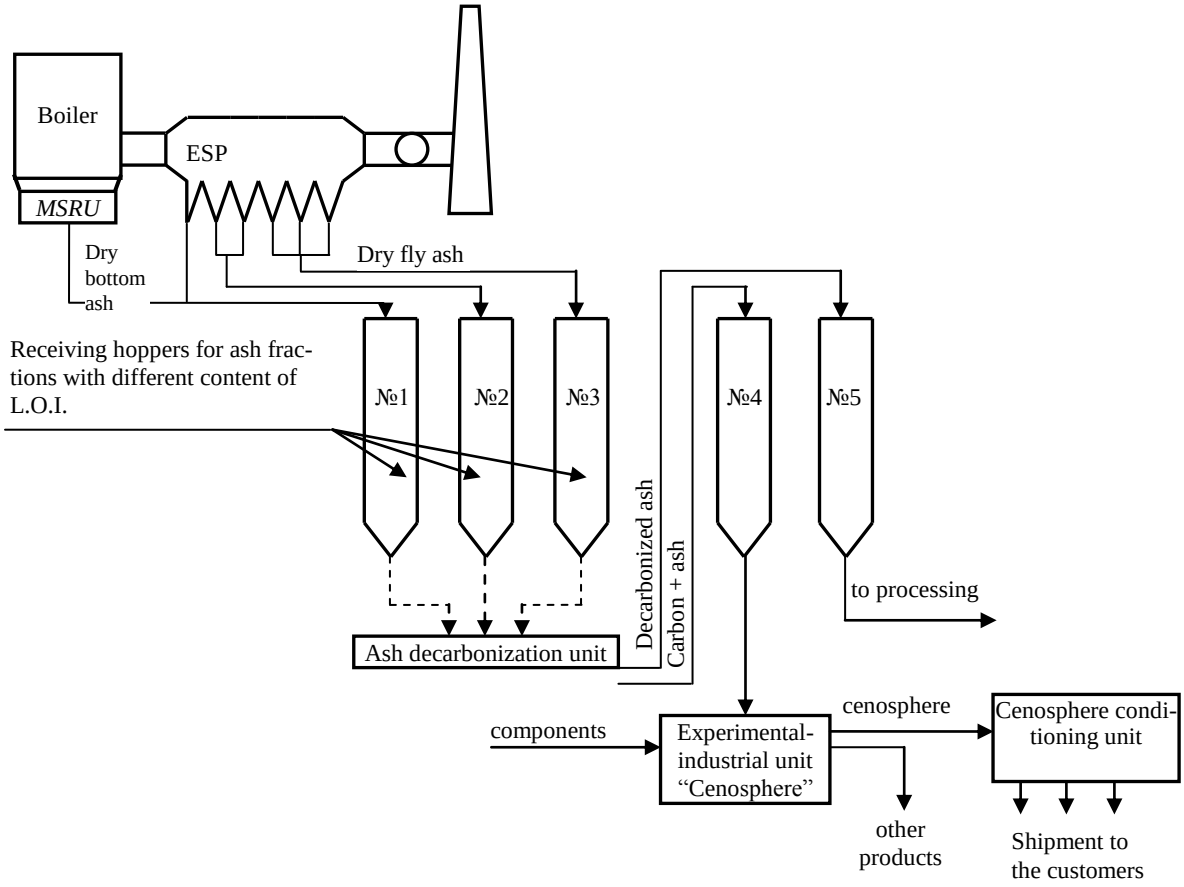

Fig. 7. Principal scheme of experimental-industrial technological complex for obtaining high-quality coal ashes and production of cenospheres on the basis of nanotechnologies

Content and brief characteristics of the main technological units of experimental-industrial technological complex are listed below.

1) Pneumo-mechanical bottom ash removal unit — unit for pneumo-mechanical bottom ash removal from the boiler throat, its grinding and air transportation to the receiving hopper №1. Rather detailed description of the technology of pneumo-mechanical bottom ash removal and its advantages in comparison with wet bottom ash removal are presented in [1,2] and other published works.
2) Air transporting units for ash feeding from convection pass and ESP hoppers into receiving ash hoppers №№1-3 with different L.O.I. They are not shown on the scheme because of complete clarity of their use.
3) Receiving ash hoppers №№1-3 are meant for feeding ash with different L.O.I. into decarbonization unit.
4) Decarbonization unit is meant for maximum separation of combustible substances out of fly ash and dust bottom ash. Description of technology introduced by STI company and experience of its industrial implementation are presented in [3]. On the output we have two products:

- Carbon-enriched fly ash containing ~ 50 % of combustible substances by mass feeding to supply hopper №4 of experimental-industrial unit for cenospheres production (Cenospheres);
- Decarbonized fly ash with L.O.I. less than 5 % by mass which is fed into supply hopper №5 for further shipment to the customers. If necessary, L.O.I may be reduced by means of several staged separation of combustible substances.

5) Experimental-industrial unit "Cenosphere" is meant for the production of cenospheres with characteristics required by the consumers, of carbon-enriched ash and corresponding components. On the output we have cenospheres and by-products. Cenospheres are fed into conditioning unit for their further shipment to the customers. Volume and field of use of by-products will become clear after receiving the pilot lots of cenospheres. Systematic researches and cenospheres formation processes modeling have been carrying out by V. Drozhzhin and other members of RFNC – VNIIEF during several years. As a result of theses studies we have got an understanding of existing processes that allowed producing cenospheres in laboratory conditions. The results have shown that it is impossible to have managing production of cenospheres with certain characteristics without use of nanotechnologies for preparation of components for formation of cenospheres, supplied into fire chamber of experimental-industrial unit "Cenosphere".
6) Cenospheres conditioning unit is meant for adjusting cenospheres in accordance with customers' demands and product shipment. Technology and experience of *Omega Minerals Group* will be used in this unit.
7) Supply hopper №5 is meant for the shipment of decarbonized fly ash to the customers. Absence of L.O.I. limits for the use of such ash is very important peculiarity of this product. Such ash will be very valuable component for the products of different use, including refractories.

2.2. Estimation of changes in integral economic and ecological indicators of power stations after implementation of suggested technology

Let's consider the question of changes in economic and ecological indicators of power plants after implementation of the suggested technology on the example of every main technological assembly.

Pneumo-mechanical bottom ash removal unit. Implementation of pneumo-mechanical technology of bottom ash removal allows to increase efficiency coefficient of fuel use by 0,4 %, eliminate use of water for bottom ash transportation, and get necessary characteristics of bottom ash with L.O.I less then 5%. More detailed information about pneumo-mechanical bottom ash removal unit is presented in [1,2].

Fly ash decarbonization unit. "More than 50 % of power in the USA is produced by coal-fired power plants. Twenty of 25 power plants which produce power at the lowest prices are coal-fired." This information about the situation with ash and slag in the USA in 2005 is given in [4]. A level of utilization of ash from these power plants is very high, that is to a large degree due to the use of technology developed by STI company. Information about it is presented in [3] and other published works.

Experimental-industrial unit "Cenosphere". It does not exist yet, but the prime cost of cenospheres produced in such a way will be less than that of artificial cenospheres produced by other technologies at the expense of initial raw materials and energy costs. Besides, flue gases of experimental-industrial unit "Cenosphere" may be used for coal drying in coal-pulverizing plants of power stations. That also allows to reduce prime cost of *hollow ash cenospheres* at the expense of:

- use of the flue gases heat;
- there is no necessity to fulfill nature protection measures to clean flue gases.

It is also necessary to take into account the cost of steam, produced in fire chamber of experimental-industrial unit "Cenosphere".

Expenses on creation and mastering this unit will be reduced by the cost of scientific researches of mechanism of ash cenospheres formation which have been made by RFNC – VNIIEF previously.

Cenospheres conditioning unit. Construction costs and expenses for putting into operation of this unit will be minimum due to long-term positive experience and existing technologies of *Omega Minerals Group*. Besides, there is no need in the costs for full-scale sales market researches and cenospheres promotion not only in Russia but in other world countries as well.

Shipment of decarbonized ash. Presence of combustive substances in ash is a very serious limitation factor of its use in the majority of products of different purpose. L.O.I., as a rule, should not exceed 5 % by mass. Decarbonized ash, being the main part of coal ash, is an excellent product and in future will absolutely have larger demand than now. Therefore, losses from ash storage on ash disposal lagoons in case of implementation of suggested experimental-industrial technological complex will turn into profits from sale of high quality ash without restriction for their use.

From all mentioned above we can make a conclusion that with due organization the project on development of experimental-industrial technological complex for obtaining the high quality coal ash and production of cenospheres on the basis of nanotechnologies will be cost-beneficial. Estimation of the volume of investments and term of their return is possible only after development of technical proposals for the exact power station.

CONCLUSION

Hollow ash cenospheres are valuable components in production of high-technology products of different purpose. However, their production volume is not enough and quality does not always correspond to the requirements of the consumers that force the last ones to look for the substitution for *hollow ash cenospheres*.

Practical actions of the majority of top-managers of power engineering companies are not directed to effective solution of ash handling on the modern level aiming at growth of cost-effectiveness of production and reduction of harmful influence of power stations on environment.

Owners of the majority of power engineering companies underestimate the influence of effective solution of ash handling problem on ecological indicators of coal-fired power stations.

Owners and top-managers of the majority of the power engineering companies underestimate advantages of mutually beneficial cooperation with specialized Russian and foreign organizations and companies which have long-term positive experience in practical solution of the problem on ash handling.

Possible technology of complex solution of the questions of obtaining high quality ash with L.O.I less than standard and producing cenospheres with certain characteristics on coal-fired power plants is presented. As a result of creation of suggested experimental-industrial complex on coal-fired power plant, such power station will meet the stringent environmental requirements and have economic indicators not worse than indicators of gas power plants.

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