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**UTILIZATION OF HIGH CALCIUM OXIDE  
AND ALKALI METAL CONTENT FUEL  
AT THE THERMAL POWER PLANTS\***

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**ИСПОЛЬЗОВАНИЕ ТОПЛИВ С ВЫСОКИМ СОДЕРЖАНИЕМ  
ОКСИДА КАЛЬЦИЯ И ЩЕЛОЧНЫХ МЕТАЛЛОВ  
НА ТЕПЛОВЫХ ЭЛЕКТРОСТАНЦИЯХ**

**Introduction**

The role of solid fuels on producing electric power at the thermal power plants has been strongly affected by oil prices in the world market. Despite this fact, the importance of solid fuels in power engineering has continuously risen. At the same time, the role of low-grade fuels in total fuel balance is remarkable and has a tendency to rise. The utilization conditions and combustion methods of low-grade fuels in power plants boilers are often determined by inorganic matter properties of the fuel. One type of solid fuel are fuels of high calcium and alkali metal content, which determine their utilization.

Such a class of solid fuels includes many kinds of brown coals, oil shales and also some type of coals. Utilization of these fuels at the thermal power plants is usually connected with the influence of the fuel inorganic matter on the design and running of the boilers that would be less sensitive to fouling of heating surfaces and corrosion. Also ash utilization in national economy as well as environmental protection must be considered.

The fouling intensity by ash deposits and corrosion of boilers heating surfaces can't always be determined by the high ash content of the fuel, but by its chemical and mineralogical composition. Physico-chemical characteristics of ash are decisive in fouling and corrosive wear of boilers heating surfaces in the furnace by complicated processes. The main factors that affect the behaviour of the fuel's inorganic matter in the furnace are: combustion temperature, residence time of ash particles in furnaces and gas passes, the composition of the surrounding gaseous medium, and the probability of contact between ash particles.

Combustion temperature, in the first place, affects the decomposition of initial minerals, the formation of new compounds and the volatilization of alkali metals.

The behaviour of inorganic matter in combustion processes, the fouling and corrosion of boilers heating surfaces, ash utilization in national economy and desulphurization of flue gas by using high calcium oxide and alkali metal content fuels at power plants are discussed in this paper.

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## Inorganic Matter of Solid Fuels and its Behaviour When Burning

**Inorganic Matter.** The inorganic matter in fuels occurs as inherent mineral matter and extraneous mineral matter. The ratio of inherent/extraneous mineral matter quantity determines the mechanism of distribution of the mineral matter components during preparing the fuel for burning, which affects the physico-chemical nature of the ash formed during combustion processes.

The inorganic matter in solid fuels consists of numerous mineral formations, the most wide-spread of which are clay minerals, mica of different composition, quartz, pyrite or marcasite, carbonate minerals, sulphates and some others. Sometimes the formation of the properties of ash during combustion is greatly affected by the chlorine compound existing in fuel ash chlorides of sodium, potassium, calcium and magnesium.

In many brown coals the organic matter often exists as constituents of organic compounds including calcium and magnesium salts of huminous acids and various compounds of chlorine and alkali metals.

The ash properties are determined by the ratio of basic and acid components in fuel inorganic matter B/A (base/acid ratio), where  $B = \text{CaO} + \text{MgO} + \text{Fe}_2\text{O}_3 + \text{Na}_2\text{O} + \text{K}_2\text{O}$  and  $A = \text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{TiO}_2$ . For different types of fuel the ratio A/B may change in wide ranges. In this paper we shall examine only the fuels with a high B/A ratio. This kind of coal and oil shale deposits are located in many countries, such as U.S.A., U.S.S.R., Yugoslavia, Germany and others. The chemical compositions of some fly ashes of high calcium oxide content fuel are given in Table.

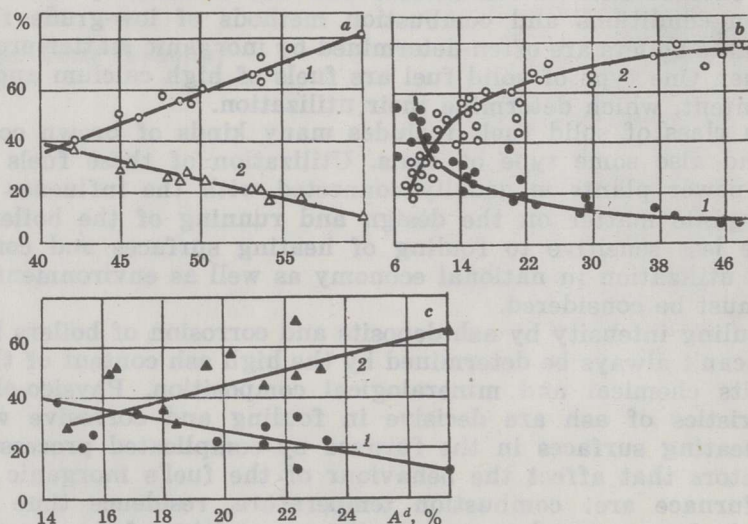


Fig. 1. Dependence of CaO (1) and SiO<sub>2</sub> (2) in laboratory ash on the ash content of high calcium oxide fuel (dry mass): a — Estonian oil shale, b — Kansk-Achinsk brown coal, c — Leipzig brown coal

Рис. 2. Зависимость содержания CaO (1) и SiO<sub>2</sub> (2) в лабораторной золе от содержания этой золе в топливе с высоким содержанием оксида кальция (на сухую массу): a — эстонский горючий сланец, b — канско-ачинский бурый уголь, c — лейпцигский бурый уголь

## Chemical Composition of High Calcium Oxide Content Fuel Fly Ash, %

Химический состав летучей золы топлив с высоким содержанием оксида кальция, %

Basin, fuel	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	CaO	MgO	Na <sub>2</sub> O	K <sub>2</sub> O	SO <sub>3</sub>	Cl
Estonian oil shale	26.6	7.2	4.2	48.3	5.2	0.1	3.4	6.9	0.4
Kansk-Achinsk basin (U.S.S.R.):									
Nazarovo brown coal	37.7	13.4	11.4	32.1	0.6	1.0	1.0	3.2	—
Berjozovo brown coal	13.8	9.2	11.1	43.6	8.1	1.1	0.5	12.2	—
Lignite ND (U.S.A.)	20.0	9.5	10.3	22.4	6.4	5.0	0.5	21.9	—
Kosovo coal (Yugoslavia)	33.2	8.5	9.7	33.9	4.7	0.8	0.3	9.0	—
Leipzig brown coal (Germany)	33.6	13.4	7.5	28.0	3.9	0.3	0.4	12.4	—

The dependence of CaO and SiO<sub>2</sub> in ash on the content of fuel ash is determined by the inherent/extraneous quantity ratio of mineral matter and also by its chemical and mineralogical composition (Fig. 1). Like Estonian oil shale, the brown coals of the Kansk-Achinsk and Leipzig basins have a high content of CaO in ash. However, despite the fact they considerably differ in mineral matter structure. As the amount of ash of Estonian oil shale rises, the percentage of SiO<sub>2</sub> in the ash decreases, while the CaO quantity grows. In Kansk-Achinsk and Leipzig brown coals, on the contrary, the CaO content decreases and SiO<sub>2</sub> rises by a rising ash percentage in dry mass of coal. This kind of dependence of SiO<sub>2</sub> and CaO in ash upon the ash quantity of the fuel is caused by their different origin. Thus, the calcium contained in Kansk-Achinsk and Leipzig brown coals mainly originates from the organic matter of the coal as calcium humates, while quartz is brought in the extraneous mineral contaminants. At the same time the ash content of oil shale grows, because the calcite in oil shale exists as extraneous mineral matter.

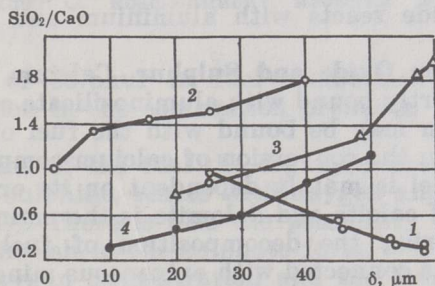


Fig. 2. Dependence of SiO<sub>2</sub>/CaO ratio of fly ash particles on their sizes: 1 — Estonian oil shale, 2, 3 — Kansk-Achinsk brown coal, 4 — Leipzig brown coal

Рис. 2. Зависимость отношения SiO<sub>2</sub>/CaO в частицах летучей золы от их размеров: 1 — эстонский горючий сланец, 2 — канско-ачинский бурый уголь, 3 — лейпцигский бурый уголь

If the calcium in the fuel is bound with inherent mineral matter as in Kansk-Achinsk and Leipzig brown coals, then by increasing the sizes of particles the content of CaO in these particles decreases and the amount of SiO<sub>2</sub> grows. In Estonian oil shale, as was mentioned above, the content of calcium oxide is connected with the growth of the particle sizes, and the quantity of SiO<sub>2</sub> falls (Fig. 2).

This major difference between these kinds of fuels finally leads to the decrease of CaO content of the fly ash formed during the combustion of the fuel, when CaO was bound with extraneous mineral matter and to the enrichment of fly ash of fuel with CaO, if calcium was connected with inherent mineral matter. Quartz is distributed between the fly ash and bottom ash contrary to calcium oxide.

**Conversion of Minerals When Heated.** During combustion the inorganic matter of fuel is subjected to the influence of high temperature and flue gas. Due to conversion process, the ash formed in the furnace during combustion is different from the initial chemical and mineralogical composition of the mineral matter of the fuel. The processes involved in the conversion of fuel mineral matter during combustion may be divided into the following groups:

- the decomposition of initial minerals into simple compounds;
- the formation of new minerals under the influence of temperature and the gaseous medium during contacts between separate minerals and the particles themselves or between separate particles and the gaseous medium;
- the volatilization of some components of the fuel inorganic matter and the formation of fine dispersed minerals;
- the conversion of separate particles or of the whole mass of fuel inorganic matter into plastic or liquid state.

One of the most active components of ash formed in the decomposition of carbonates or the combustion of organic matter containing calcium is calcium oxide. Reacting with quartz, calcium oxide forms bi-calcium silicate  $2\text{CaO} \cdot \text{SiO}_2$  (belite). Belite is an important mineral in ashes with a high content of calcium oxide. There is also the possibility of tri-calcium bi-silicate  $3\text{CaO} \cdot 2\text{SiO}_2$  and tri-calcium silicate  $3\text{CaO} \cdot \text{SiO}_2$  formation simultaneously with belite. These reactions occur, if the temperature in the furnace is higher than 1300—1350 °C, and they play an important part in cement clinker mineral forming processes. Also some part of calcium oxide reacts with aluminium and iron oxides.

**Behaviour of Calcium Oxide and Sulphur.** Calcium occurs in fuels as carbonate, or it is partly bound with aluminosilicate compounds. In some type of fuels calcium may be bound with the fuel organic matter.

During combustion, the conversion of calcium compounds in the mineral matter of the fuel is mainly dependent on its original form.

The dissociation of calcite and dolomite is the main source of calcium oxide formation during the decomposition of fuel inorganic matter when calcium oxide is connected with extraneous mineral matter. A part of calcium oxide transforms into cement clinker minerals, reacts with sulphur or remains in the free form. Hence, the calcium oxide in the ash is divided into the following three parts: CaO combined with carbonates —  $\text{CaO}_k$ ; CaO combined with cement clinker minerals and sulphur —  $\text{CaO}_b$ ; CaO that remains in the free form —  $\text{CaO}_f$ . Marking  $K_k = \text{CaO}_k/\text{CaO}$ ,  $K_b = \text{CaO}_b/\text{CaO}$ ,  $K_f = \text{CaO}_f/\text{CaO}$  ( $\text{CaO} = \text{CaO}_k + \text{CaO}_b + \text{CaO}_f$  — total calcium oxide content in ash), then  $K_k + K_b + K_f = 1$ .

The changes of  $K_k$ ,  $K_b$  and  $K_f$  along the length of the flame (in time) in burning pulverized Estonian oil shale is given in Fig. 3. It is evident that the dissociation of carbonates and the reaction between forming free calcium oxide and other constituents in the mineral matter of fuel, as well as in the gaseous medium, begin within a very short time after inserting pulverized fuel into the furnace. The amount of combined

CaO in carbonates continuously diminishes, but bounded CaO increases. The free calcium oxide content of ash at first grows and then slowly diminishes. Therefore, the intensity of calcium carbonates dissociation does not limit the reactions between free CaO and other ash constituents.

If calcium is combined with the organic matter of fuel, then obviously calcium oxide separates during the combustion of the organic matter of the coal. In this case free CaO is formed only after the combustion of volatile matter, when the intensive burning of residual coke begins. Part of formed free calcium oxide reacts with minerals of extraneous mineral matter and gives, for instance, cement clinker minerals.

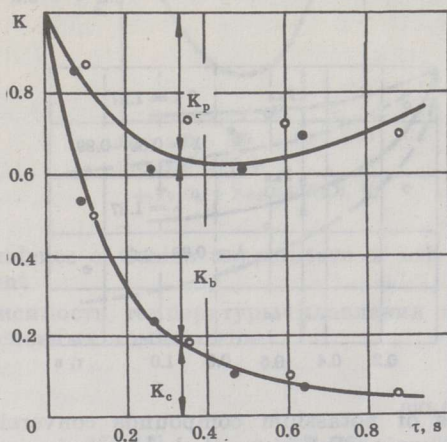


Fig. 3. Dynamics of CaO conversion along the flame length by burning Estonian oil shale (maximum furnace temperature 1450—1500 °C, excess air factor 1.27—1.41)

Рис. 3. Динамика превращения CaO по длине факела при сжигании эстонского горючего сланца (максимальная температура топки 1450—1500 °C, коэффициент избытка воздуха в топке 1,27—1,41)

The conversion of sulphur in fuel combustion depends mainly on oxygen concentration in the combustion products, as well as on temperature.

During combustion of the fuel the organic sulphur separates in pure form as hydrogen sulphide, reacts with oxygen and goes over into flue gas as SO<sub>2</sub> and SO<sub>3</sub>. There is also the possibility that part of organic sulphur may rest in ash in the sulphate form.

Depending on oxygen concentration and the temperature of the flue gas, compounds like SO<sub>2</sub>, SO<sub>3</sub>, Fe<sub>2</sub>O<sub>3</sub> and FeO can finally form from pyrite.

The conversion of sulphur depends on the existence of components in the fuel ash which are able to react with sulphur. When burning fuels with a high content of basic components in ash, a large part of sulphur will be combined into sulphates and its share going into gases diminishes.

**Behaviour of Alkali Metals.** The volatilization intensity of alkali metals from fuel particles depends significantly on the temperature, on the composition of the surrounding medium and on the form of alkali metal in the fuel. For instance, when alkali metals occur as the constituents of feldspars and micas, they can volatilize only after the decomposition of minerals or after their chemical reactions with other ash components.

One quantity, by means of which we can characterize the behaviour of alkali metal compounds during combustion, is their solubility in boiling water. Alkali metal compounds which are subjected to deeper changes during fuel burning, are also more soluble in water. Proceeding from that, alkali metal compounds can be divided into the following three groups: compounds which dissolve in boiling water within two hours (easily soluble) —  $M_{s,e}$ ; compounds which dissolve in boiling water within more than two hours (hard soluble) —  $M_{s,h}$ ; compounds insoluble in boiling water —  $M_{s,n}$ . Denoting:  $P_{s,e} = M_{s,e}/M$ ,  $P_{s,h} = M_{s,h}/M$  and  $P_{s,n} = M_{s,n}/M$  ( $M = M_{s,e} + M_{s,h} + M_{s,n}$  — total quantity of alkali metals in fuel), then  $P_{s,e} + P_{s,h} + P_{s,n} = 1$ .

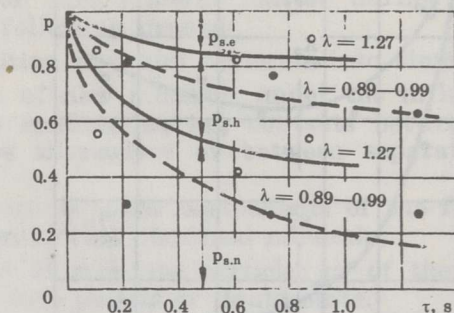


Fig. 4. Dynamics of potassium compounds conversion along the flame length by burning Estonian oil shale (maximum furnace temperature 1450—1500 °C,  $\lambda$  — excess air factor in the furnace)

Рис. 4. Динамика превращения соединений калия по длине факела при сжигании эстонского горючего сланца (максимальная температура топки 1450—1500 °C,  $\lambda$  — коэффициент избытка воздуха в топке)

The changes of  $P_{s,e}$ ,  $P_{s,h}$  and  $P_{s,n}$  along the length (in time) of pulverized Estonian oil shale flame is given in Fig. 4 by different excess air factor.

With the increase of oxygen concentration in the combustion products, the quantity of easily and poorly dissolving parts of alkali metals increase with a simultaneous decrease of the insoluble part of alkali metals of ash. Such characteristic dependence of the dissolution of alkali metals in boiling water on the excess air factor shows a very great significance of the air regime in burning coals with a high content of alkali metals.

**Fusion Characteristic of Ash.** For fuels with a high content of calcium oxide, the fusibility of ash was often considered to be dependent on the quantity of the sum of basic component in ash (Fig. 5). The fusibility temperatures of ash are minimum for ash containing 30—50 % basic components. For a high acid oxide ash content (the region of low basic component content), calcium oxide causes a decrease in ash fusibility. With the increase of the calcium oxide quantity, the ash becomes basic, calcium oxide leads to the discontinuance of the melting effect and the latter acts as a component increasing the fusion temperatures.

The fusion temperatures of ash also depend on quartz/aluminium oxide ratio  $\text{SiO}_2/\text{Al}_2\text{O}_3$  and iron oxide/calcium oxide ratio  $\text{Fe}_2\text{O}_3/\text{CaO}$ . In general, with the increasing  $\text{SiO}_2/\text{Al}_2\text{O}_3$  ratio, the fusibility of ash falls. The quartz/calcium oxide ratio influence on fusion characteristics

of ash for different base/acid ratio region is not the same. Based on many investigations, the iron oxide/calcium oxide ratio has a marked effect on lowering the fusibility temperatures of fuel ash.

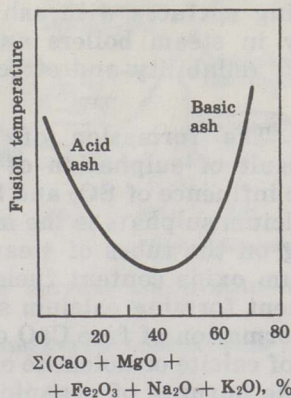


Fig. 5. Dependence of fusion temperature of ash on the basic component content

Рис. 5. Зависимость температуры плавления золы от содержания в ней основных компонентов

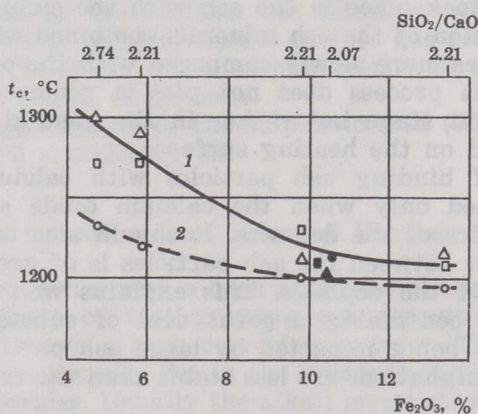


Fig. 6. Dependence of fluid temperature of ash on the  $\text{Fe}_2\text{O}_3$  content: 1 — oxidizing atmosphere, 2 — reducing atmosphere

Рис. 6. Зависимость температуры плавления золы от содержания  $\text{Fe}_2\text{O}_3$ : 1 — окислительная атмосфера, 2 — восстановительная атмосфера

In reducing atmosphere, the melting point of ash is usually lower than in an oxidizing one. The influence of the surrounding medium on the fusion temperatures of ash is ordinarily connected with the process occurring with iron (Fig. 6). Since the components of inorganic matter of the fuel during coal pulverization are distributed usually in various fractions of pulverized coal, the ash of certain fraction must have also unequal melting points.

## The Fouling of Steam Boiler Heating Surfaces

One of the main problems concerning the burning of low-grade fuels in steam boilers is the intense formation of ash deposits on heating surfaces. The fouling of heating surfaces with ash deposits causes a considerable loss of efficiency in steam boilers and generally leads to a significant decrease in their reliability and effectiveness.

**Calcium Oxide Influence.** The formation of bounded ash deposits based on calcium is the result of sulphation of the numerous calcium compounds in ash under the influence of  $\text{SO}_2$  and  $\text{SO}_3$  in flue gas with the formation of  $\text{CaSO}_4$ . The calcium sulphate is the main binding component in the ash deposits forming on the tubes of steam boilers heating surfaces in burning high calcium oxide content fuels.

The essential ash component forming calcium sulphate in ash deposits is free calcium oxide. The formation of free  $\text{CaO}$  occurs either as a result of the thermal dissociation of calcite or dolomite existing in the inorganic matter of fuel, or during the burning of organic compounds of the fuel containing calcium. However, such compounds as calcium sulphide and calcium chloride and other numerous calcium silicates, aluminates and ferrites have the ability to sulphation as well. This trend of the calcium oxide bond with quartz, aluminium and iron oxides towards sulphation is demonstrated in the results obtained by the laboratory studies of some fly ash sulphation. It was established that the reduction of the vitreous substance content took place in the ash with the simultaneous increase in  $\text{SO}_3$ . The sulphation of the ash minerals combined with calcium oxide proceeds many times more slowly compared with the sulphation of free calcium oxide. This process does not play a remarkable role in ash particles in the first stage but rather in the general consolidation of the deposits formed on the heating surfaces.

The processes of binding ash particles with calcium sulphate into deposits can proceed only when the calcium oxide sulphation occurs directly in the layers of the deposits. It should also be mentioned that a very close contact between the ash particles is of great importance in the consolidation of the deposits. This explains well enough why the back side deposits containing a great deal of substances inactive to sulphation and not being impacted by large ash particles, even with a similar degree of sulphation, are less stable than the front side deposits.

**Alkali Metal Influence.** Alkali metal compounds may also play a significant role as binding substances in ash deposits. These compounds are usually accumulated in the lower layers of the deposits. The penetration of the sulphates of alkali metals and chlorides into deposits during the fouling process of tubes may proceed in two ways, immediately during initial stages of deposit formation and gradually after such formation.

The temperature limits and the condensation intensity of the alkali metal compounds on the tubes of the heating surfaces depend mainly on the partial pressure of their vapours in flue gas. In this case, the determining factor is the dew point (the initial point of condensation) of the particular alkali metal compound. If the temperature of the heating surface is lower than the dew point of alkali metal compound the condensation of vapour occurs simultaneously with the formation of the deposit layer.

For instance, Fig. 7 illustrated the dependence of the heating surface tubes fouling intensity on the surface temperature, while burning Estonian oil shale. The alkali metal compounds in Estonian oil shale are connected with potassium. A direct condensation of the potassium



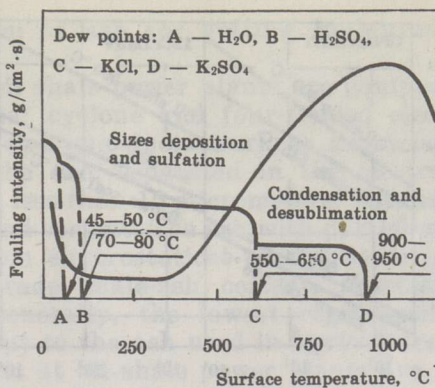


Fig. 7. Influence of surface temperature on the intensity of ash deposits formation

Рис. 7. Влияние температуры поверхности на интенсивность загрязнения

sulphate mostly occurs in the region of the temperature of flue gas over 900—950 °C. An intensive condensation of the potassium chloride vapour occurs, starting from the temperature of 550—650 °C. This appears to be the reason why lower layers of the deposits (where temperature conditions are more favourable) contain a higher quantity of potassium chloride than the upper ones.

Being condensed on the surface, the alkali metal chlorides in time, under the influence of sulphur oxides in flue gas transform into alkali metal sulphates. The alkali metal sulphates as well as calcium sulphate are a binding substance of deposits.

In Fig. 7, the dew points of the sulphuric acid (70—80 °C) and water vapour (45—50 °C) are also given.

## High-temperature Corrosion and Wear of Heating Surfaces

**Corrosion.** The fuel ashes with a high alkali metal content not only often induce the formation of fast growing ash deposits on boiler heating surfaces, but also have a high corrosion activity. The main reason for such high corrosion activity lies in the presence of alkali metal complex sulphates and chlorides. Usually the alkali metal chlorides have a higher corrosion activity compared with complex sulphates.

The high-temperature corrosion intensity of metal depends mainly on the type of steel and temperature level by the same composition of ash deposits on tubes. In Fig. 8 we can see the comparative diagram of high-temperature corrosion intensity of two types of boilers steel under the influence of Estonian oil shale fly ash (K<sub>2</sub>O = 6.0 %, Cl = 0.5 %), Kansk-Achinsk brown coal fly ash (Na<sub>2</sub>O = 0.4 %, K<sub>2</sub>O = 0.6 %, Cl = 0 %), and in air medium depending on time. It becomes clear that both steels corrode with a greater intensity under the influence of oil shale ash than in the air atmosphere or when it happens due to the presence of the Kansk-Achinsk brown coal ash. The content of alkali metals in the latter is small and chlorine is absent.

A relative accelerating impact of the ash and ash deposits on chromonickel austenitic steel Cr18Ni12Ti is more vivid than on perlitic 12Cr1MoV ones, in spite of the fact that the absolute value of corrosion in the first case is lower. Such behaviour of the austenitic steel, if compared with perlitic one, is induced by an extremely strong action of the alkali metal chlorides exerted on chromium.

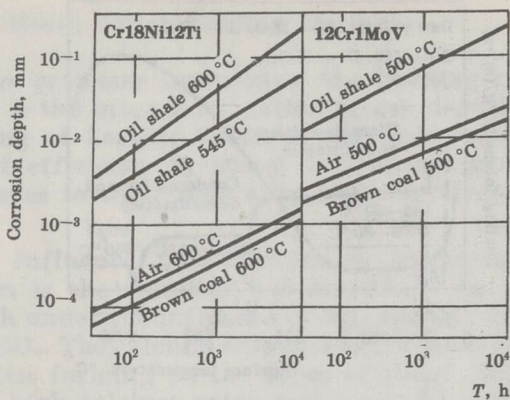


Fig. 8. Diagram of the depth of high-temperature corrosion of austenitic Cr18Ni12Ti and perlitic 12Cr1MoV steel

Рис. 8. Диаграмма глубины высокотемпературной коррозии аустенитной (X18H12T) и перлитной (12ХМФ) стали

**Wear.** To stabilize heat transfer in steam boiler heating surfaces, the modern boilers are equipped with a different type of cleaning systems. For boilers, which burn fuels with a high calcium oxide and alkali metal content, the problem of efficient cleaning of heating surfaces from ash deposits, due to their fast growth, is of paramount importance. The cleaning cycles serve not only to separate ash deposits from heating surfaces, but also to incur the destruction of protective oxide film on metals diminishing its diffusion resistance and inevitably bringing about the intensity of corrosion.

The decrease in corrosion-erosion wear of heating surfaces, due to the cleaning effect, can be achieved either by increasing the period between cleaning cycles or by decreasing cleaning force effect on the oxide film. Hence, it follows that by intensifying the cleaning of heating surfaces, the heat transfer is being also intensified, however, corrosion-erosion wear of heating surfaces tubes is accelerated as well. In this connection, there arises a problem of the choice of an optimal cleaning regime of heating surfaces from ash deposits, particularly the interaction between the intensity of cleaning and conditions of its implementation. The right resolution of the problem will be conclusive for design, operating conditions and economic parameters of the boiler.

### Ash Utilization and Environmental Protection

**Ash Utilization in National Economy.** The presence of calcium oxide and other appropriate mineral components makes it possible to utilize ash in national economy. A very good example of this kind is the utilization of ash formed from Estonian oil shale at power plants: in cement industry, building materials industry, agriculture, road construction, etc. Complex utilization possibilities of ash in national economy are determined, on the one hand, by an adequate burning process arrangement of the fuel, and on the other hand, by the ash separation system. In order to get cement clinker minerals in oil shale ash, the maximum temperature in the furnace should be at least 1350—1400 °C. Oil shale burning in low-temperature furnace (low-temperature vortex burning and fluidized bed combustion) probably excludes the formation of cement clinker minerals

and the utilization of ash for getting high-grade shale-ash Portland cement.

The boilers at oil shale power plants are equipped with two stage ash separation systems: cyclone and four-fielded electrostatical precipitators. The furnace and gas ducts work as ash separators too. The most valuable ash is the one, separated in the electrostatical precipitators with particle sizes less than 15 micrometers. It is used for manufacturing high-grade Portland cement. The ash with particles below 30 micrometers also separated from electrostatical precipitators and cyclone is used to produce middle-grade shale-ash cement, autoclave concrete and as lime fertilizer. Generally, the lowest requirements to the fractional composition are put to the ash used in agriculture. The bottom ash and ash from gas ducts at oil shale power plants are handled hydraulically and are not used in national economy.

**Ash Utilization for Desulphurization of Flue Gas.** While burning fuels with a high calcium oxide and alkali metal content, part of sulphur present in the fuel is bounded by their components in the furnace and gas passes of the boiler. The amount of sulphur bounded with basic components of ash may range within wide limits. While burning Estonian oil shale, depending on the type of boiler, its load and excess air factor, 75—85 % of sulphur reacts on ash. It is the reason why the temperature difference between the dew points of sulphuric acid and water vapour is relatively small (Fig. 7). In such conditions (sulphur binding factor is 0.75—0.85) the remainder sulphur oxide concentration at excess air factor 1.5 in oil shale flue gas is 1.2—1.6 gramm per cubic meter. While burning Kansk-Achinsk brown coal with a high calcium oxide content, the sulphur binding factor is lower, being within the limits of 0.5—0.6.

In spite of the large sulphur-binding effect of the high calcium oxide content ash, it does not guarantee a low enough sulphur oxides concentration in flue gas yet.

There are possibilities to use different units while burning acidic ash fuels in order to desulphurize flue gas. Despite of the difference in these units, supplied lime is used almost without exception. This makes the desulphurization units complicated in design and expensive in cost.

When burning fuels with a high calcium and alkali metal content, it is possible to use the fuel ash for desulphurization of flue gas. There we have got several possibilities.

One of them is cleaning the flue gas from sulphur oxides in scrubber by using clarified alkaline water from hydraulic ash removal system with  $\text{pH} = 12-13$ . It is also possible to use ash-soaking basin in order to obtain alkaline water.

## РЕЗЮМЕ

Механизм распределения минеральных составляющих между отдельными компонентами неорганической массы топлива во многом определен составом внутренней и внешней минеральной части. Во многих бурых углях оксид кальция в первичном виде связан с внутренней минеральной частью, а в карбонатных сланцах, наоборот — с внешней минеральной частью.

В результате высокотемпературных процессов в топках и газоходах котла образуется активная часть золы, которая является основной составляющей в процессах загрязнения и высокотемпературной коррозии поверхностей нагрева котла. Характеристика золы с точки зрения загрязнения и коррозии поверхностей нагрева котла во многом определена режимными параметрами горения топлива (температура, концентрация кислорода в продуктах сгорания и др.)

Высокое содержание в золе оксида кальция дает возможность использовать её как сырье во многих отраслях народного хозяйства.

Образующаяся при сжигании топлива с высоким содержанием оксида кальция и щелочных металлов зола способна связывать в топке и газоходах котла оксиды серы. Для дополнительного снижения концентрации оксидов серы в продуктах сгорания можно использовать и образующуюся в котле золу.

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