Oil Shale, Vol. 16, No. 3
pp. 273-282
ISSN 0208-189X

https://doi.org/10.3176/oil.1999.3.08

THE FEATURES OF OIL SHALE BURNT AT ESTONIAN POWER PLANTS IN 1959-1997

L. ÕISPUU, R. RANDMANN
R. ROOTAMM, K. INGERMANN

Tallinn Technical University,
Thermal Engineering Department
Kopli St. 116, Tallinn
11712 Estonia

The paper provides the data about quality indicators of oil shale burnt at Estonian power plants. The main quality indicators of oil shale (lower heating value, and ash, moisture and carbonate CO_2 content) are presented and discussed. The analysis of changes in these indicators over decades is presented. A remarkable deterioration of quality of oil shale burnt at Estonian power plants has occurred over decades.

The Estonian oil shale (OS) fired power plants are being provided with OS from the mines and opencasts at the Baltic OS basin. The amount of fuel mined and consumed was permanently rising over the years 1960-1990. The mined amount of fuel rose up from the initial level of mining about 14 million to 37.5 million tons per year, staying at the high level for several years [1]. Afterwards the amount of yearly mined and consumed OS lessened and now this figure is about 15 million tons per year [2]. According to the investigations the OS resources will last at the shown level of OS mining up to 100 years [2].

The consumption of OS for power generation was also rising over the decades mentioned; especially rapid increase of consumption for power generation occurred during the years 1960-1975. The amount of OS yearly burnt for power generation rose from 2.5 million tons up to 26.2 million tons. Beginning from 1979, the OS consumption for power generation fell down and was at the level of 23.8 million tons in 1981 [1, 3], 17.6 million tons in 1992 [4], and 12.2 million tons in 1995.

OS is being used not only for power generation, but also for heat production. The heat produced on the basis of OS is being delivered from Baltic Power Plant, Kohtla-Järve Combined Heat and Power (CHP) Plant, from industrial power plants of the joint-stock companies *Kiviõli* and *Silmet*. OS has been used also for heating Kunda, for shale oil production, and for production of cement clinker.

The reduction of OS consumption in Estonia in 1980 and 1981 was caused by commissioning in 1973-1981 four nuclear power generation energy blocks (each having the power production capacity 1000 MW) at Leningrad Nuclear Power Plant. As the result of that, the OS-fired power plants in the north-western part of the former Soviet Union were forced to work as the semi-peak power plants. The further decrease in OS consumption at power plants was caused by commissioning of Ignalina Nuclear Power Plant (in Lithuania, 1500 MW energy blocks) that started in 1983. The decrease in OS consumption was caused also by overall reduction of power consumption due to some kind of economical crisis and decreasing the role of military industry in the former Soviet Union. Finally, the collapses of the former Soviet Union and regaining of independence by Estonia also were the factors that affected (reduced) the OS consumption at power plants.

Before 1991, approximately one half of energy produced by Estonian power plants was transported into Russia (Leningrad and Pskov districts) and Latvia and sold there by the production price (without any profit). The demand for power produced at OS-fired plants reduced after regaining of Estonia's independence and establishing the tentative market conditions between producers and consumers. The developing market conditions entail the reduction of wasting the resources, including OS and power. More attention has been paid on the conservation measures and the wasting of energy will be stopped or at least reduced.

As the old economical system collapsed, there disappeared also some factors affecting the quality and technical indicators of OS delivered (sold) to the customers [1, 3, 4]. The free market developing nowadays in Estonia essentially affects the indicators of OS consumed in the Estonia's power sector.

The data upon average values of quality indicators of OS (lower heating value, ash content, carbonate $(CO_2)^r{}_M$ content, moisture content) are presented in this article. The initial data for analyses were got from officials of OS mines and opencasts as well from the reports of power plants and Estonian power company *Eesti Energia* Ltd.

The fuel price has had almost no effect on the fuel quality indicators and probably will have no effect also in the nearest future. The OS price is the factor affecting the consumption. Russia is offering Estonia a comparatively cheap natural gas nowadays. It means that big CHP power plants working on the natural gas may become serious competitors to condensing-type OS-fired power plants.

If the OS price will arise 1.5 times as compared to the current price then electricity generated at small CHP plants working on natural gas will be serious competitor to that from OS-fired condensing-type power plants. Taking into consideration the inflation rate 10 %, the above mentioned situation will occur in the year 2003. The power generated at a nuclear power plant will be also an alternative (competitor) to OS-fired power plants.

If the price of Estonian OS will arise two times, the coal imported from Russia will become a real alternative to Estonian oil shale. That may occur probably in the year 2007. All it means that it will be reasonable to start to invest into the OS processing technology and into the OS power technology. That will be obligatory for securing the opportunity to produce cheap power at OS-fired power plants and competitiveness with the comparatively cheap (imported) energy from some nuclear power plant. If the OS price will continue to arise, it will be very soon necessary to subsidize the OS industry and OS power sector that are the strategic sectors of Estonia's economy.

The data on the quality indicators of fuel mix burnt at power plants of the state company *Eesti Energia* Ltd. are presented in figures below. The indicators of the fuel mix mined at Estonian and Leningrad district basins as well the data on OS mined and transported into Estonia from the Leningrad deposit are presented. OS from three mines at the Leningrad district basin was delivered mostly to Baltic Power Plant. It had always a lower quality compared with oil shale from the Estonian deposit (look at Fig. 1, *a* and *b*). That is mostly caused by the geological issues. The share of OS from Leningrad district (supply up to 2 million tons per year) in the fuel mix was in 1981 up to 18.9 % of the total OS consumption at Baltic Power Plant.

After 1991 the import and consumption of OS from Leningrad district remarkably lessened thus the production capacity of the state company *Eesti Põlevkivi* (*Estonian Oil Shale*) was underloaded. Since 1996 some amount of OS has been transported from Leningrad district OS basin into Estonia and its cost has been paid by power transported back into Russia. That secures the employment for the miners living in Slantsy and allows increasing the load of power generating units in Estonia.

The yearly average lower heating value (LHV) of the burnt OS mix (Fig. 1*a*) dropped down from the initial figure 10.72 to 8.76 MJ/kg over

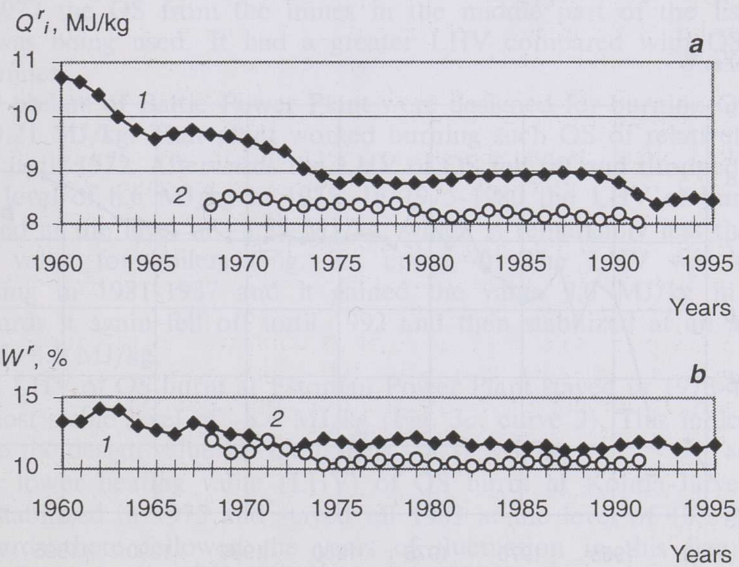

Fig. 1. The yearly average quality indicators of oil shale burnt at power plants of the state stock company *Eesti Energia* Ltd. in 1960-1997: *a* - lower heating value, MJ/kg; *b* - moisture content, %. Curves: *1* - oil shale mix burnt at Estonian power plants, *2* - oil shale from Leningrad district basin

the years 1960-1975. The lower heating value of OS was quite stable during the years 1975-1987, heaving within the interval of 8.96-8.97 MJ/kg.

Since 1988 until 1992 the figures of LHV fell down and stabilized at the level 8.5 MJ/kg. The figures of LHV of OS delivered from the mines of Leningrad district showed in 1963-1993 a slight decreasing trend within the interval of 8.5-8.0 MJ/kg (Fig. 1*a*, curve *2*).

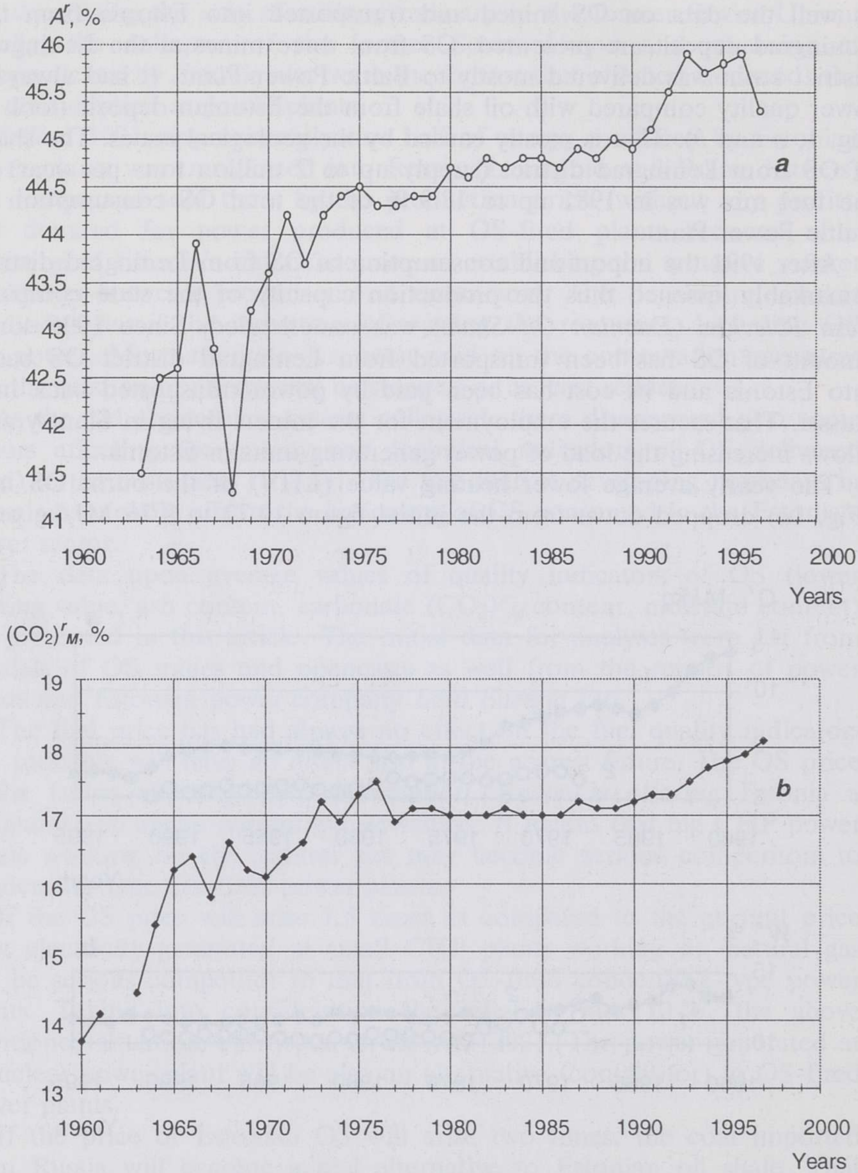

Fig. 2. The yearly average quality indicators of oil shale mix burnt at power plants of the state stock company *Eesti Energia* Ltd. in 1960-1997: *a* - ash content, %; *b* - carbonate $(CO_2)^r_M$ content, %

The yearly average moisture content of the OS mix W^r (Fig. 1*b*, curve *1*) shows a slight falling trend over the years 1962-1972 with some increase in 1967. Since 1971, that figure has more or less stabilized heaving within the interval of 12.0-11.5 %. The yearly average figures for the moisture content of OS from Leningrad district were decreasing to 10.3 % in 1974. Afterwards this indicator stabilized at the level of 10.2 % and since 1992 it fell down to 10 %. OS from the mines of Leningrad district is the OS with the smallest moisture content (Fig. 1*b*, curve *2*). According to this indicator, the OS from Leningrad district has a higher quality compared with OS from the Estonian basin.

The yearly average figures for the ash content of OS (as burnt) A^r showed a clear increasing trend in 1960-1997 - this figure increased from the initial 13.7 % up to 45.9 %. The ash content of burnt oil shale increased very rapidly up to 41.2-44.5 % during the years 1960-1975. The increase in ash content was quite slow in the years 1975-1989 (average values are 44.2-45 %) and more pronounced since 1990 (Fig. 2*a*).

The yearly average carbonate $(CO_2)^r_M$ content of OS (as burnt) was permanently rising during 1960-1975, and it stabilized in 1977-1988 at the level of 17.0-17.2 %. Since 1989 this indicator has remarkably increased, and it reached 17.9 % in 1996 (Fig. 2*b*).

The Figures 3 and 4 represent the yearly average quality indicators of oil shale delivered to power plants in 1959-1997. It can be seen that a serious deterioration of fuel quality occurred in 1959-1975. This has been obviously caused by increasing the share of fuel amount from opencasts and decreasing the share of fuel from underground mines in fuel mix. Kohtla-Järve CHP Plant has been an exception as at this power plant until 1972 the OS from the mines in the middle part of the Estonian basin was being used. It had a greater LHV compared with OS from other mines.

The boilers of Baltic Power Plant were designed for burning OS with LHV 9.21 MJ/kg. That plant worked burning such OS of relatively high quality until 1972. Afterwards the LHV of OS fell off and dropped down to the level of 8.6 MJ/kg in 1975. In 1975-1980 the LHV of burnt OS stabilized at the level of ~8.55 MJ/kg, which is remarkably less than the design value for boilers (Fig. 3*a*, curve *4*). The LHV was slightly increasing in 1981-1987 and it gained the value 9.0 MJ/kg in 1987. Afterwards it again fell off until 1992 and then stabilized at an average level of ~8.6 MJ/kg.

The LHV of OS burnt at Estonian Power Plant stayed in 1973-1991 at an almost stable level of ~8.4 MJ/kg (Fig. 3*a*, curve 3). This indicator is close to the design value for the boilers - 8.37 MJ/kg.

The lower heating value (LHV) of OS burnt at Kohtla-Järve CHP Plant stabilized in 1975 and stayed till 1982 at the level of 10,2 MJ/kg. Afterwards there followed the years of fluctuation in this figure, the average for the years 1983-1997 being 9.94 MJ/kg.

In 1970-1990, at Ahtme CHP Plant the OS of a comparatively high quality has been burnt. Its LHV has been at the stable level of

9.45 MJ/kg. Since 1990 the LHV has been decreasing and in 1992-1997 it stabilized at the level of ~9 MJ/kg (Fig. 3*a*, curve *2*).

The yearly average ash content of OS shows the following changes. The ash content of OS burnt at Baltic Power Plant increased till 1974 and thereafter it stabilized in 1974-1990 at an average level of 45.1 % (Fig. 3*b*). Beginning from 1993 it is increasing and has reached ~46 % by 1997.

The yearly average ash content of the fuel at Estonian Power Plant has been stable within 1974-1975 being 43.7 %. Since 1981 the ash content has shown the tendency of increase being 46.1 % in 1996.

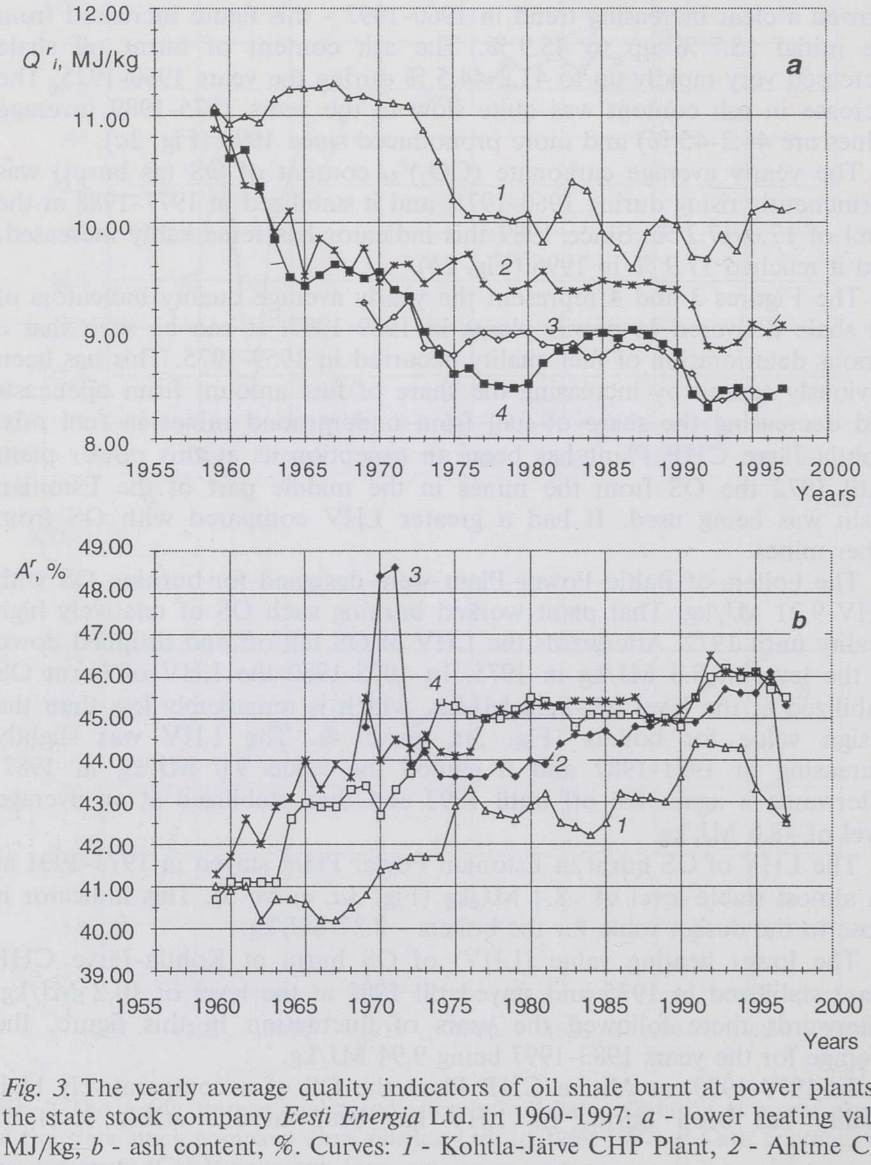

Fig. 3. The yearly average quality indicators of oil shale burnt at power plants of the state stock company *Eesti Energia* Ltd. in 1960-1997: *a* - lower heating value, MJ/kg; *b* - ash content, %. Curves: *1* - Kohtla-Järve CHP Plant, *2* - Ahtme CHP Plant, *3* - Estonian Power Plant, *4* - Baltic Power Plant

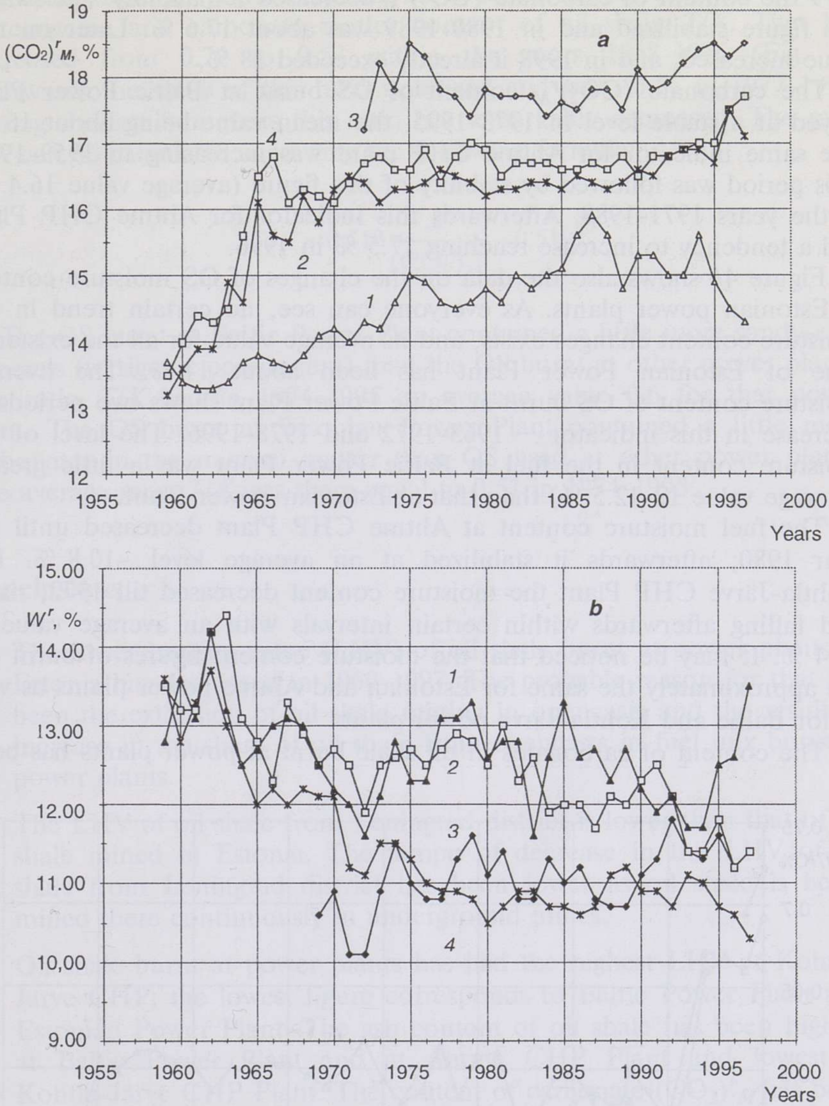

Fig. 4. The yearly average quality indicators of oil shale burnt at power plants of the state stock company *Eesti Energia* Ltd. in 1960-1997: *a* - carbonate $(CO_2)^r_M$ content, %; *b* - moisture content, %. Curves: *1* - Kohtla-Järve CHP Plant, *2* - Ahtme CHP Plant, *3* - Estonian Power Plant, *4* - Baltic Power Plant

The ash content of OS burnt at Kohtla-Järve and Ahtme CHP plants was stable in 1974-1975. Afterwards (till 1975) it fluctuated within the interval of 45-46 % for Ahtme CHP Plant and between 42.4-44.4 % for Kohtla-Järve CHP Plant with an average ash content of OS ~43 % that was the lowest value among OS mixes burnt at Estonian power plants.

Figure 4 shows that the content of carbonate $(CO_2)^r_M$ in OS has been biggest for OS burnt at Estonian Power Plant (Fig. 4*a*). During 1975-

1979 the content of carbonate $(CO_2)^r{}_M$ decreased remarkably. Afterwards this figure stabilized and in 1980-1989 was about 17.6 %. Later on this value increased, and in 1998 it already exceeded 18 %.

The carbonate $(CO_2)^r{}_M$ content of OS burnt at Baltic Power Plant stayed at a stable level in 1973-1995, the mean value being about 16 %. The same indicator for Ahtme CHP plant was increasing in 1959-1971. This period was followed by stability of this figure (average value 16.4 %) in the years 1971-1988. Afterwards this indicator for Ahtme CHP Plant had a tendency to increase reaching 17.5 % in 1996.

Figure 4*b* shows also the data on the changes of OS moisture content at Estonian power plants. As everyone can see, no certain trend in the moisture content changes exists, and its average value for all the existence time of Estonian Power Plant has been about 11 %. The average moisture content of OS burnt at Baltic Power Plant shows two periods of decrease in this indicator – 1963-1972 and 1978-1996. The level of the moisture content in the fuel at Baltic Power Plant was a little greater (average value 12-12.5 %) than that at Estonian Power Plant.

The fuel moisture content at Ahtme CHP Plant decreased until the year 1980; afterwards it stabilized at an average level ~10.8 %. For Kohtla-Järve CHP Plant the moisture content decreased till 1972, rising and falling afterwards within certain intervals with an average value of 12.4 %. It may be noticed that the moisture content figures of burnt OS are approximately the same for Estonian and Ahtme power plants as well as for Baltic and Kohtla-Järve power plants.

The content of carbonates in oil shale burnt at power plants has been

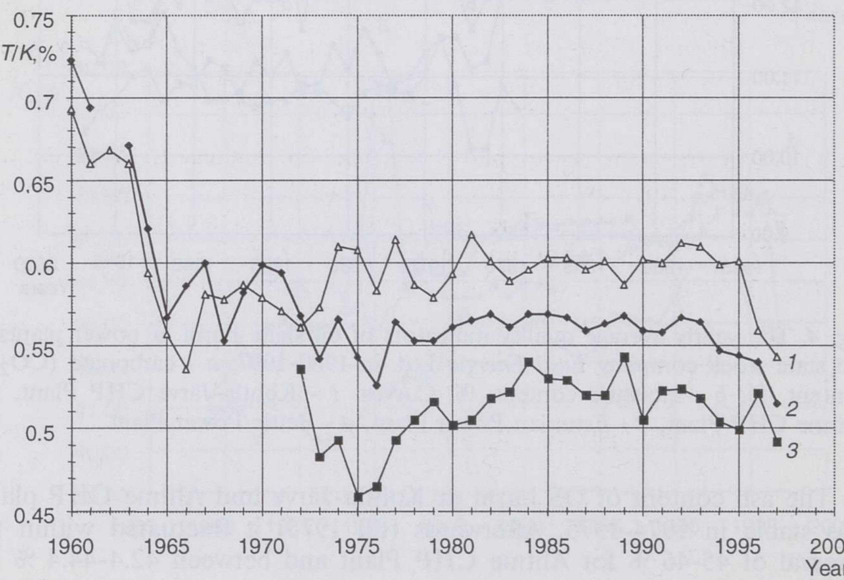

Fig. 5. The ratio of terrigenic (*T*) and carbonate matter (*K*) content of OS over the years. Curves: *1* - oil shale burnt at Baltic Power Plant, *2* - oil shale mix burnt at Estonian power plants, *3* - oil shale burnt at Estonian Power Plant

increasing over the years. That can be declared on the basis of the ratio of terrigenic and carbonate matter content of oil shale T/K. That has decreased from 0.72 to 0.53 within the years 1958-1976 (Fig. 5). Afterwards the value of this ratio stabilized and was ~0.56 in 1977-1992. During the last four years this ratio has remarkably decreased. The ratio T/K can be calculated according the following formula:

$$T/K = 0.413\frac{A^r}{(CO_2)^r_M} - 0.519$$

The OS burnt at Baltic Power Plant contained a little more sandy-clay minerals (terrigenic component) than the OS burnt at other power plants. The ratio T/K had in 1974-1995 an average value 0.6 for that power plant. The OS burnt at Estonian Power Plant contained a little more carbonates in the mineral matter than OS used at other power plants. The average ratio T/K was there equal to 0.51 in 1974-1995.

Conclusions

1. The lower heating value (LHV) of oil shale burnt at power plants in Estonia has decreased in 1960-1997. The probable reason for that has been the extension of oil shale mining in opencasts and the resulting increase in the share of oil shale from opencasts in fuel mix burnt at power plants.
2. The LHV of oil shale from Leningrad district is lower than that of oil shale mined in Estonia. The tempo of decrease in the LHV of oil shale from Leningrad district has been lower as oil shale is being mined there continuously in underground mines.
3. Oil shale burnt at power plants has had the highest LHV at Kohtla-Järve CHP; the lowest figure corresponds to Baltic Power Plant and Estonian Power Plant. The ash content of oil shale has been highest at Baltic Power Plant and at Ahtme CHP Plant and lowest at Kohtla-Järve CHP Plant. The content of carbonate $(CO_2)^r{}_M$ has been greatest at Estonian Power Plant and lowest at Kohtla-Järve CHP Plant. The moisture content has been greatest at Kohtla-Järve CHP Plant and lowest at Ahtme CHP Plant.
4. The yearly average ratio of sandy-clay and carbonate matter content of oil shale T/K has been decreasing in 1960-1973, and it has stabilized in 1974-1997. The greatest ratio corresponds to the oil shale burnt at Baltic Power Plant; the lowest corresponds to OS burnt at Estonian Power Plant.

REFERENCES

1. *Õispuu L. M., Reinsalu E. J., Rootamm R. E.* The dynamics of oil shale quality indicators at power plants over the years of 1960-1981 and up to 2005 // Transactions of Tallinn Polytechnic Institute. 1983. No. 547. P. 3-13 [in Russian].
2. *Reinsalu E.* Is Estonian oil shale beneficial in the future // Oil Shale. 1998. Vol.15, No 2. P. 97-101.
3. *Öpik I. P., Öispuu L. M., Sits H. I.* The reasons of falling down the lower heat value figures of oil shale used for power generation // Transactions of Tallinn Polytechnic Institute. 1978. No. 458.P. 3-14 [in Russian].
4. *Öispuu L., Randmann R., Rootamm R.* The oil shale ash components at ash fields, in flue gas and in ash consumed // Transactions of Tallinn Technical University. 1994. No. 739. P. 94-114 [in Estonian].

Presented by A. Ots
Received November 12, 1998