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EDITOR'S PAGE

ESTONIAN OIL SHALE ENERGY, WHEN WILL IT COME TO AN END?

Standing at the threshold of the next millennium, all of mankind has reason to ask what could serve as a substitute for conventional energy resources, especially for crude oil which is utilized more and more intensively. In some countries, the question may be reduced to the rational exploitation of great oil shale resources which have not been used before.

In Estonia, the situation is quite different. Oil shale resources are diminishing, and, in addition to that, the state has to exert its influence in the short in order to catch up with the train of progress which we missed as a result of the windings and turnings of history.

To stay free, a country has to own an independent energy resource. Estonia is poor with regard to treasures of the soil, the only possible valuable resource being oil shale. In 1996, Estonia celebrates the 80th anniversary of oil shale mining. Estonia won her freedom in the beginning of this century and then the expert exploitation of such a low-calorific fuel as oil shale secured the independence. During the years after World War II, under the soviet empire, Estonia developed its oil shale industry into a mammoth undertaking. For a small country, such an accomplishment could only be of interest to the compilers of the Guinness Record Book. Neither the state, nor general economic requirements, needed such an enormous oil shale industry.

In August, 1996, Estonian scientists from all over the world assembled in Tallinn to take part in the World Congress of Estonian Scientists to discuss how to set the new-born state on its feet again. The future of the Estonian energy industry was one of the topics discussed at the Congress.

Professor Enno Reinsalu, Head of the Mining Institute at Tallinn Technical University, reported about the utilization of Estonian oil shale:

> "Estonian kukersite oil shale was already known in the 10th century. Industrial use of oil shale was started as a result of the fuel crisis during World War I, using Russian capital. The most intensive development of oil shale processing occurred in the 1930's when the processes for producing oil and other chemical products were put into operation. Supported by the state industrial policy in effect at the time, the average growth in oil shale industry was 23 % per year. Since 1933, private investments, mainly from foreign states, especially Germany, dominated in the oil shale industry. In

1939, Estonia derived 7.9 % of its export profit from shale oil, Germany being the main customer. In 1940, the oil shale industry was nationalized.

Until the middle of the 1950's, oil shale was used mainly as the raw material for oil, gas and the chemical industry. The post-war oil shale policy resulted mainly from soviet military and economic interests. Shale oil was used as fuel for the Baltic navy and merchant marine, and gas as a fuel for the City of Leningrad (now St.-Petersburg).

In the middle of the 1950's, an intensive utilization of oil shale for producing electric power was started. Two big oil shale-fired power plants were erected as a result of a shortage of energy resources in the north-western part of the Soviet Union. Retorting receded into the background and, since the middle of the 1960's, it gradually began to disappear. The Russian oil boom added to this effect. However, oil shale mining and consumption in the power industry continued to grow until 1980, when the maximums of production (31.3 million tonnes of mined shale per year), and consumption (just under 30 million tonnes per year) were reached.

As a consequence of over-production, 9 million tonnes of oil shale was placed into storage. Since the beginning of the 1980's, production levels in the oil shale industry, especially in power generation, began to decline. This lasted until 1995. In the 1990's, the state stopped supporting the oil shale industry. Now the first steps are being taken towards its privatization.

According to today's estimates, the Estonian oil shale industry, at least the power production part of it, will die out within the coming twenty-five years. Up to now, ca 880 million tonnes of oil shale have been mined. It looks like the total amount of mined and utilized shale will exceed one billion tonnes by the time the oil shale industry will probably go out of existence. When one includes mining losses, about two billion tonnes of the best shale reserves will be exhausted by that time. Approximately the same quantity of Estonian oil shale resources will remain unexploited since they are of significantly lower quality. Mining and utilization of these resources cannot stand the competition with other natural energy resource."

Prof. H. Käär

Academy Member Harry Käär, Director of the Institute of Energy Research, also spoke about the Estonian energy industry and cast his look in the future:

"The development of energy, which is one of the most important branches of an independent state's infrastructure, needs the scientific approach to find and implement a sufficiently stable and practical scenario for its development and application.

In the field of energy, the time period between a decision and its implementation is very long (usually 10-15 years). Capital investments for its actualization are very large for society and, because of that, the accuracy of the forecasts upon which the implementation decision was based has to be periodically reconfirmed.

Estonian energy is based on the burning of a low quality solid fuel: oil shale. This presently accounts for 67 % of the Country's primary energy. Oil shale resources are projected to last for 30-50 years, after which the share of domestic fuel rapidly decreases as imported fuels increase. An earlier shortfall of oil shale energy may be precipitated by any number of reasons, such as: a desire for preservation of this natural resource, a poor economic climate, excessive taxes for environment protection, opposition by society to the use of this resource, etc.

Sooner or later the Country must choose the kind of imported fuel which is to replace oil shale. Such a decision must guarantee the fulfilment of consumer needs within the limits of acceptable prices to society and restrictions for environmental protection.

In the case of strict environmental protection limits (where CO_2 emissions are taxed), one scenario which is acceptable is the use of nuclear power units for meeting base load requirements and gas-fired power plants, in which both electrical and thermal energy are produced, for peak loads.

The use of nuclear power certainly needs the support of the population. The share of renewable energy resources would be markedly increased but does not become determinative.

Expectations concerning new technologies for producing power are also on hand but such optimism must be held in check."

Consequently, according to various estimates, Estonian oil shale resources will last for 30-50 years. Which are the most reasonable ways for utilization of these resources and how should one compensate for and prevent damage to the environment?

Academy Member Arvo Ots, Head of the Thermal Engineering Department at Tallinn Technical University, presented the recent achievements in the field of oil shale pressurized burning. This technology enables one to raise the efficiency of combustion equipment about one and a half times. His report was titled "Possibilities for the Use of Advanced Combustion Technology Devices in Oil Shale-Fired Power Plants":

"In current oil shale-fired power plants pulverized fuel is burned at atmospheric pressure. The efficiency of energy conversion - which is a measure of the energy present in fuel which is converted into electric power - in conventional steam units is determined solely by steam characteristics. The efficiency is independent of the combustion technology. In the case of atmospheric combustion, the temperature of both primary and secondary steam depends on the maximum operating temperature allowed for the steam tube metals. The allowable operating temperature, in turn, strongly steam tube metals. The allowable operating temperature, in turn, strongly depends on the characteristics of combusted fuel. Since the ash from burning pulverized oil shale has a highly corrosive nature, the temperature of superheated steam in conventional power plants is relatively low. The average thermal efficiency of oil shale-fired power plants lies between 28-29 %. This index cannot be improved even by taking into account new technologies as long as combustion is performed at atmospheric pressure.

The thermal efficiency coefficient of an oil shale fired power plant can be raised noticeably, up to 42-44 %, by raising the combustion pressure. The technology for burning solid fuels under pressure has gained a foothold throughout the world during the last five years, and the number of power plants using it is growing continuously.

Burning oil shale under pressure has some specific features discussed below.

Oil shale minerals, unlike those of numerous other fossil fuels, consist of two types of components - carbonates and sandy clay. As a result of the presence of carbonates, and a correspondingly suitable temperature in the furnace, there is no need to use some complicated systems for preparing and adding SO_2-binding absorbents, along with associated feeders. As shown by tests, carbonate compounds present in oil shale completely bind sulphur without preceding dissociation.

In case of oil shale pressurized combustion in a furnace, the process is mainly influenced by the CO_2 partial pressure in the combustion gas (which is on the level of 0.12-0.15 MPa). Such a back pressure prevents direct destruction of carbonates to the corresponding oxides and CO_2. As a result, the chemical processes in which the shale minerals are involved, occur with the direct participation of carbonates. This aspect represents the main difference between oil shale combustion processes in a furnace under atmospheric and pressurized conditions.

Consequently, the quantity of CO_2 emitted into the air diminishes when oil shale is burned under pressure, and the calorific value of the oil shale increases. This latter effect results from the fact that the carbonates remain intact. Theoretical calculations show a decrease in CO_2 emissions to be about 20 % and an increase in oil shale calorific value of 8-10 %. These problems are currently being studied in the Thermal Engineering Department of the Tallinn Technical University."

The oil shale chemistry research undertaken at the Institute of Chemistry is well known. An overview was given by Doctors H. Luik (Head of the Department of Oil Shale and Shale Oil), K. Urov and J. Bondar:

"The Department of Oil Shale Chemistry of the Institute of Chemistry was established in 1950, and was originally guided by the Academician P. Kogerman. The same year, studies on kukersite genesis and the chemical structure of kerogen were started, as supervised by Professor A. Fomina. Oxidative destruction was the main method for the research. The results provided the basis for developing an original technology to produce dicarboxylic acids and their methyl esters from kerogen.

In subsequent research, this method was applied to study numerous other shales. The UN Symposium on oil shales, held in Tallinn in 1968, became the starting point for international co-operation between the Institute of

Chemistry and other foreign research organizations in the field of oil shale research.

In late 1960's, Professor I. Klesment took the lead on oil shale research and then the studies in oil shale organic geochemistry were started. The variety of shales under study was enlarged. Until then, kukersite had been the main and only object of interest. Subsequently, the majority of shales occurring in the Soviet Union (from over 40 deposits) and numerous analogous resources from abroad were studied. The chemical structure of kerogen and the mechanism of its destruction were studied as well.

L. Mölder, along with his co-workers, is carrying on research in the field of physical chemistry of solutions. This includes chemistry and technology of oil shale-derived alkyl resorcinols. This work was started at Tallinn Technical University.

A great contribution made by Academician A. Aarna, during his tenure at the Institute of Chemistry, was the establishment of the *Oil Shale* journal in 1984. It enabled communication between researchers engaged in oil shale and the improvement of information interchange on a world-wide scale.

Now the researchers of the Department of Oil Shales and Shale Oil are fulfilling the program of oil shale chemistry and technology which includes plans through 2000, as drawn up by the present head of the Department, H. Luik. The aim of this program has several features: the rational and complex use of Estonian oil shale, further development of the processes in current use and establishment of new ones, production of valuable products from shale oil, extension of contacts with the Estonian chemical industry, and guarantee of both a needed theoretical basis for the oil shale industry and continuity of scientific staff.

This program includes studies of geochemical and technogenic alterations in oil shale, elaboration of scientific bases for optimization of thermal treatment processes, for refinement of shale oil, and utilization of alkyl resorcinols."

The shale oil industry is the most important branch of current Estonian industry. Unfortunately, it is also the greatest polluter of the environment, as stated in the report of L. Mölder, V. Yefimov, and K. Urov (Institute of Chemistry, Tallinn; Oil Shale Research Institute, Kohtla-Järve). In their report "Oil Shale Science as the Basis for the Estonian Oil Shale Industry" the achievements in the field of oil shale chemistry and technology research were discussed:

"Research into the structure and thermolysis of oil shale kerogen has shown that the redistribution of hydrogen is one of the most important processes during thermal destruction of kerogen, which has mainly an alicyclic structure. High oxygen content is characteristic of kerogen and that is why large quantities of oxygen compounds, carbon oxides and water are formed (the latter also acting as a thermolytic reagent). Oil shale is abundant in mineral matter, which also plays an essential part during thermal destruction.

Shale oil (which has a Fischer assay oil yield 66-67 %, on organic matter basis) is far from a state of thermodynamic equilibrium under its formation conditions. The composition of the oil clearly reflects kerogen structure. Oxygen compounds prevail in the oil, including mono- and dihydric phenols, ketones and ethers. Dihydric phenols are represented by resorcinol alkyl derivatives, mainly by 5-substituted compounds. The carbonyl group is preferably located in position 2. Oil hydrocarbons, especially those present in light fractions, are characterized by a preponderance of 1-alkenes.

Retorts of various type and capacity have been designed for processing large-particle shale (the Kiviter process, retorts with the throughput rate of 65-1000 tonnes per day are in operation now, with an oil yield of 150-170 kg/t). Pulverized oil shale is processed in units with a solid heat carrier (the Galoter process, with a nominal throughput rate of 3000 tonnes per day, with an oil yield of 120-130 kg/t).

All oil shale-derived chemical products are made from two feedstocks: crude shale oil and water-soluble phenols (alkyl resorcinols). Oil shale processing flow sheets provide for the production of fuel oil, oil liquifiers, wood impregnation oil, rubber softeners, etc., from oil distillate fractions. Coke is made from (distillation) residual oil. Alkyl resorcinols are used for synthesis of epoxy resins, DFK resins and other similar compounds, and after separation, for pure 5-methylresorcinol."

Phenols are special pollutants accompanying our oil shale industry. In the report made by I. Johannes, Ph. D., and L. Tiikma (Institute of Chemistry) a new method for determination of resorcinol-series phenols was presented. The basic principle for this new method is the easy nitrosation of resorcinol-series phenols. This method is described in detail in *Oil Shale* Vol. 13, No. 1, P. 21-27.

Dr. I. Johannes

"The method is very necessary for estimating the potential for pollution of surface waters in Estonia with phenols from kukersite shale processing. Of these water-soluble phenols (over 50 individual compounds) about 90 % are 1,3-benzenediol (i.e. resorcinol) alkyl derivatives (AR) and only 10 % are phenol-series compounds (AF). Based on guidelines laid down by other countries, only AF-pollution of waters has been systematically checked in Estonia. The possible pollution with AR has generally been left unmeasured since there has not been a suitable method for its determination. Until there is no easy and selective method to determine AR, one cannot prescribe legal limits for concentrations of such compounds and establish pollution compensation taxes for those compounds."

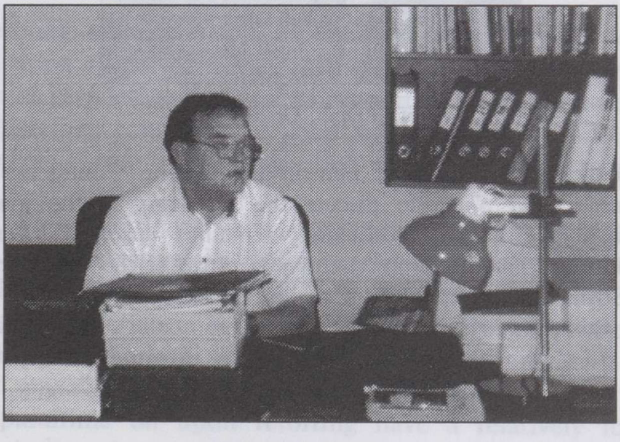
Professor V. Fainberg from Technion, the Israel Institute of Technology, an oil shale chemist educated in Estonia, gave a survey of the Israeli oil shale programs:

"Oil shale is the only source of energy and prime organic matter in Israel. There are about 12 billion tonnes of reserves. They will be enough to meet that Country's requirements for about 80 years. The heating value of the oil shale is 1150 kcal/kg, with an oil yield of 6 %, and sulfur content of 5-7 % in the oil. The shale beds overlie phosphate-rich rocks. The thickness of the shale ranges from 35 to 80 m. The average organic content is 14-18 % and the oil yield is 60-71 l/t. Economically, the low-cost, large-scale, open pit mining techniques may compensate for the relatively low grade of the shale.

A 25 MW demonstration plant for power generation has been successfully operated in Israel since 1989. Oil shale consumption at this plant is about 50 t/h. A few large-scale oil shale power plant projects with capacities of 75-450 MW are now being developed by the government and private companies.

A prospective process for oil shale retorting is being developed by the PAMA Co. The process is based on heating fine-grained oil shale by mixing it with circulating hot ash.

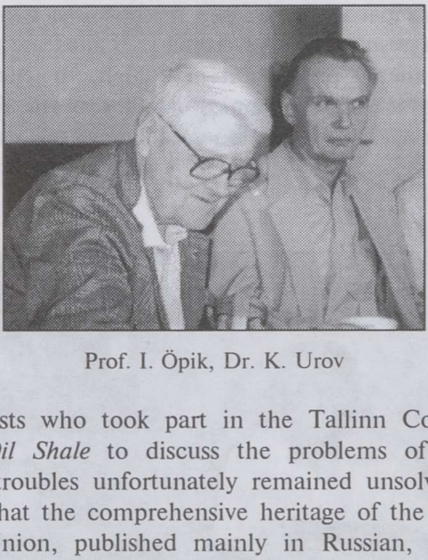
A new method for integrated oil shale processing, providing an exhaustive utilization of its energy and chemical potential is being developed at Technion. The principal feature of the method is a two-stage pyrolysis of the oil shale. As a result, gas and aromatic liquids are obtained. The gas may be used for energy production in a high-efficiency combined-cycle power unit, or as a source for chemical syntheses. The liquid products can be an excellent source for production of chemicals. This proposed method for oil shale processing has a number of advantages as compared to traditional methods."



Prof. J. Kann,
Editor in Chief

High-level oil shale research carried out in Estonia gave the occasion for the foundation of the journal *Oil Shale*. The journal was founded in 1984 by Academicians Ilmar Öpik and Agu Aarna and it is the only scientific-technical journal in the world specializing in oil shale problems. The journal is international. It is internationally reviewed and is sent into 30 countries.

Dr. T. Purre
Prof. V. Fainberg
Prof. V. Yefimov



Prof. I. Öpik, Dr. K. Urov

The oil shale scientists who took part in the Tallinn Conference met in the editorial office of *Oil Shale* to discuss the problems of the journal's future existence. Financial troubles unfortunately remained unsolved. Even in light of this, it was decided that the comprehensive heritage of the oil shale scientists of the former Soviet Union, published mainly in Russian, must be revised and republished - this time in English. The editors are of the opinion that now is the optimal time to start with such an effort, so as to avoid the repetition of this historic high-level research somewhere else.

Aili KOGERMAN
Executive Editor of *Oil Shale*