# DEVELOPMENT OF RADIATION TECHNOLOGIES ON VNIIEF LU-10-20 LINAC

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For recent 5 years the VNIIEF specialists have been searching for new technologies whose application provides a significant economical effect [1].

As compared to the common thermal and chemical methods of action, the radiation technologies have significant economic and engineering advantages and are ecologically pure technology processes.

Application of electron accelerators has a number of obvious advantages, as compared to the sources of ionizing radiation of other types. A possibility of regulating (in a wide range) the power and geometry of a beam provides great possibilities both from the point of view of technology and of safety of works performed.

For radiation study and development of new production technologies at VNIIEF there was created a linear resonance electron accelerator LU-10-20 [2], possessing the following parameters:

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| accelerated electrons energy | 7-9 MeV; |
| electron beam power | 12-15 kW; |
| current pulse duration | 2...5 μs; |
| beam diameter | 25 mm; |
| current pulse repetition rate | 1-1000 Hz; |
| electron beam diameter | 20 mm; |
| irregularity of radiation fields on width of 500 mm | <10%; |
| power supply | 150 kW. |

In the present article there is given a review of a number of last works conducted at VNIIEF with the use of this accelerator.

## EXPERIENCE OF RADIATION HIGH-VISCOUS RESIDUAL FUEL OIL PROCESSING

Growth of oil products consumption in the whole world calls the necessity of creating principally new technologies of oil processing, differing in high production, final products quality, high ecology and relatively low energy consumption. For example, it is forecasted that summary world consumption of one of basic chemical products – olefin raw material- will rise from 190 million tons in 1997 to 350 million tons by 2010. Oil remains the main raw material source (65%) [3].

Destructive processing of oil raw material, as a result of radiation-thermal action, is one of the most important and promising areas when creating the modern petrochemical technologies; these technologies allow to provide a purposeful change of the petrochemical synthesis products composition, to raise a degree of the used raw material processing, to diminish energy consumption of technology process performance, as well as the ecology load on the surrounding medium. The increase of the required fractions output or diminishing of energy consumption even by several percents provides a significant economical effect for the large-tonnage production including oil processing.

At present the main ways of oil processing are catalytic processes: catalytic cracking, catalytic pyrolysis and catalytic oil reforming. These processes allow one to obtain from oil raw material a whole number of products.

Application of catalysts requires additional time and technology efforts. Here refer: catalysts production, preliminary refining of raw material from matters which can deactivate the catalyst: sulphur compounds, heavy metals, resin-asphalt matters and the necessity of regenerating the spent catalysts.

To overcome the pointed flaws there allow radiation thermal ways of oil raw material processing, in particular the radiation thermal cracking.

The process of radiation-thermal oil cracking (RTC) and its individual fractions was investigated by Soviet scientists and these data are presented in literature [4,5,6,7]. In paper[4] there are considered the possibilities for carrying out radiation thermal processes in oil processing on the example of RTC n-hexane. Irradiation was conducted on γ-facility K-300000 at MEPCI of Karpov. The dose rate changed from 7.8 up to 16.7 Gy/s, the maximally absorbed dose constituted 20 kGy. The autoclave pressure depended on temperature and conditions of the experiment and did not exceed 10 MPa. The experiments were conducted at temperatures from 573 K to 723 K.

In the result of the performed experiments there was shown that in conditions, when thermal cracking practically did not occur, the G value of radiation-chemical output of n-hexane decomposition at 720K was equal approximately to 1000mol/100eV. In the paper there is made a conclusion on the possibility of conducting RTC within a production scale with the aid of uranium in-pile loop, created on the basis of high-temperature nuclear reactors.

According to [5] gasoil was subject to the radiation thermal cracking at temperatures of $573 \div 673$ K in the dose range $(0.5 \div 2) \cdot 10^5$ Gy, the dose rate from the γ-quanta source $^{60}$Co 5.1 Gy/s, the process was performed in the autoclave. It was shown that at equal conditions of conducting the process at radiation thermal cracking there was reached the depth of conversion by $1.5 \div 2$ times exceeding the product output at thermal process. Radiation also contributes to the process of sulphur removal of light oil products obtained. As in paper [4], for practical use there is considered a possibility for applying heat and radiation of nuclear reactor.

In paper [6] there are presented the results of studying the main regularities of RTC fuel oil of Atyrausskii petroleum processing plant, representing a mixture of heavy oil fractions with boiling point of

Tb>673 K. As a source of high-energy electrons, there was used ELU-4 electron acelerator with average electron energy 4 MeV. The dose rate changed from 1 kGy/s up to 4 kGy and the absorbed dose - from 1 up to 40 kGy. Experiments were performed in two different modes of electron beam action on fuel oil: a stationary mode and a running one. It was demonstrated that optimal RTC temperature was 673÷683 K. The output of gasoline fractions with Tb<473K was 1.5 times higher than that at thermal cracking. The gasoline fraction obtained was characterized by high octane numbers 76÷80 and low sulphur content (by 35 times lower as compared to the initial product). The content of aromatic and naphthenes hydrocarbon in RTC products was much higher than at the common thermal cracking.

In paper [7] there was investigated liquid and gas-phase radiation-thermal cracking of n-hexane at 573÷673K and irradiation by γ-source $^{60}$Co, dose rate 150÷460 Gy/h for liquid-phase and 240÷560 Gy/h for gas-phase process. It was shown that irradiation abruptly increased the process rate, not affecting the set of final carboniferous cracking products. A large amount of molecular hydrogen was formed at radiation thermal cracking.

In spite of good results of studying RTC of oil and oil products, there have been yet created no technology of radiation-chemical processing of oil raw material [8, 9, 10]. At VNIIEF there have been started works on studying a possibility of creating the production technology of fuel oil RTC.

The experiments were conducted on bremsstrahlung radiation in the stationary mode. The reactor represented a closed system of 650 cm$^3$ excluding the mass transfer with the environment. The reactor was designed and tested with ultimate pressure of 40 kgf/cm$^2$. In the experiments the maximum excess pressure did not exceed 11 kgf/cm$^2$. The fuel oil volume in the reactor was 120 cm$^3$.

After irradiating the gas phase was analyzed by the chromatography method. Viscosity was determined for liquid phase according to All-Union State Standard 33-82, as well as the fraction composition - according to All-Union State Standard 2177-82.

The experimental data analysis allows to make a conclusion that the results obtained correspond basically to literature data in the temperature range 250÷350 C°. It should be also noted that:

additional output of light petrol fractions up to 5% vol. was obtained;

abrupt lowering of viscosity up to 28 cSt at initial fuel oil viscosity of 1200 cSt, measured at 20 C°, was observed;

a large amount of hydrogen, saturated and unsaturated hydrocarbons, being valuable raw material for chemical production, was obtained;

an intense fuel oil sulphur remove was observed (hydrogen sulphide formation).

For production technology it is necessary to develop the running irradiation mode with rise of dose rate up to tens kGy/s, for this purpose it is planned to continue a study of accelerated electron beam action on oil raw material.

## PROCESSING OF SLIDING SKI SURFACE

The technology of special radiation treatment of the ski sliding surface is developed in RFNC-VNIIEF in collaboration with VISTI (All-Russian Institute of Sport Technics and Equipment).

The treatment technology basis is the irradiation of the ski surface with accelerated electron beam. This leads to the modification of the chemical structure of the irradiated polymer system. The break of some chemical bonds and the creation of new ones result in irreversible modifications of physical and mechanical properties of the polymer material.

Laboratory tests show a decrease of the coefficient of sliding friction by 10÷12%.

The first activities performed allowed to our Russian Team to ski successfully at the XVIII Olympic Games in Nagano, and during the final laps of World Cup in 1998. Olympic champions Galina Kukleva and Juliya Chepalova as well as the bronze prizeman Vladimir Drachev used the processed skis during the competition. We have got an approval from A.I.Tikhonov, president of the Union of biathlonists.

The worked out technology, as sport specialists say, is very promising and should be given a further development.

No foreign analogues of technology are known by this time.

## RADIATION DECOMPOSITION OF SPENT BUTYL RUBBERS

The problems of nature resources economy through the use of production and consumption wastes acquire greater importance with each year, as they allow to solve also ecology problems together with the economic ones. It is more acute in relation to polymeric systems based on saturated rubbers, for example, butyl rubber, used in tire industry, as due to their high resistance to the action of oxygen, ozone, sole radiation and bacteria they contaminate the surrounding media for rather a long period. At the same time these systems represent valuable raw material for reuse.

Radiation destruction of polymers containing a quaternary carbon atom is the most promising method, as due to high penetrating capability of ionizing radiation it is characterized by the absence of expensive destruction agents, contaminated sewage and gaseous effluents.

The known methods of radiation destruction of spent butyl rubber with accelerated electrons energy use implies a preliminary material grinding (bits of 1 mm size) followed by its formation into a sheet and irradiation. Such an approach does not give an opportunity to implement the method within production scale due to low process production, limited by the grinding operation [11]. Application of plane sources of γ-radiation Co$^{60}$ allows us to perform destruction of large material pieces, but for providing even irradiation it is required to increase the source surface or make the material turn around the source [12]. Besides, the danger of contaminating production areas with radioactive materials also limits the volumes of butyl rubber production processing.

Together with the Center on development of elastomers at Kazanskii State Polytechnic University there were conducted the first experiments on application of electron beams for decomposition spent rubber what will allow to:

- provide even irradiation of material along the whole volume;
- exclude additional operations of grinding the material;
- raise the production of technology facility for utilizing polymeric wastes;
- diminish a danger of ecology contamination of the surrounding area.

Irradiation of the pilot waste batch on butyl rubber base was carried out. Preliminary laboratory investigations of physics-chemical properties of a destructant demonstrated a possibility for its reuse in production without lowering of item quality.

It is planned to develop a technology of production radiation utilization of wastes on butyl rubber base up to 800tn/year.

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