# HYDROCARBON RESTRUCTURING

A Welcome, dear readers! Scientific research work, which is offered to your attention, is uncommon on one side and rather challenging on the other. A huge part of the raw materials used by mankind makes hydrocarbons, and therefore extremely acute are the problems of their processing, especially of processing "heavy" hydrocarbons produced in Canada, in the Mexico Gulf field, in the Russian Federation, Kazakhstan and in many Arab and Far East countries. Converting these oils into automobile fuel is very difficult and often merely impossible. The following situation turns out: there are a lot of raw materials, roads are built, there are cars and planes but we faced a problem of fuel shortage. Researchers have long been trying to find a solution of the problem but the current level of hydrocarbons conversion into distillate is not more than 10%. The results are noticeable but they are too far from the mankind needs. The intrigues evolved from the beginning around the phenomenon of cavitation in the liquid, and the prospects of its practical use deserve dramatic and detective stories and anecdotes, but we omit them. This review reflects only technical aspects of restructuring of the petrochemical production residues, oil mixtures uncomfortable for distillation, "heavy" and other oils and motor fuels. Together and at once using some thermodynamic effects we carried out hydrocarbon restructuring by a method called "cavitation hydrogenation". We made sure that the method allows cheap and safe converting heavy crude oils and other hydrocarbon feedstocks from arbitrary fields into light distillates (gasoline, diesel and jet fuels) with unprecedented performance: the distillate output several times higher than existing traditional refining methods. This technology is revolutionary in its own fashion. It allows a few times reducing the refining costs and significant rebuilding the entire industry.

**TECHNOLOGY OF CAVITATION HYDROGENATION (2007 - 2015).**

This technology originated from our previous developments and based on the complex of hydrodynamic and physico-chemical phenomena in the liquid hydrocarbon feedstock. The first phenomenon is cavitation. More precisely, it should be noted that we use cavitation only with a utilitarian aim: to boil up the part of fluid in multiple cavitation bubbles by mechanical or other effects rather than by heating. Cavitation in the liquid can be provoked by different power sources. These are thermal, electromagnetic, radiation and … mechanical sources. The last one is most studied and therefore most applicable for the technology of cavitation hydrogenation. It is the energy of interaction of moving masses actuated in the liquid by means of special vibration transducers which convert the input energy into vibrations of liquid inside closed contents or pipes. The most effective and adapted to this process conditions are transducers of magnetostrictive and pezostrictive types. They use electric energy and generate vibrations of their radiating surfaces in a liquid. Do not forget about the development of the converters of jet energy in sloshing that causes local boiling in the liquid. It is a large family of converters called “hydrodynamic cavitators”. Not less interesting and practical are devices that convert the energy of electric motor rotation into the energy of liquid boiling up in a local area of the reactor or the pipeline. These are hydrodynamic rotary converters. If electric, heat, luminance and radiation devices are so far not used in the oil refining, then a huge number of magnetostrictive and pezostrictive devices have taken this technological niche, and they successfully solve practical problems.

A basis for the existence of combustible materials that fill our world is the energy of interatomic bonds. Change of It will generate tangible metamorphosis. Thermal converters up to now were used to convert


*Fig.1. Appearance of some installations of the series "Potok."*

hydrocarbon compounds constituting the oil mixtures. These are well known furnaces, columns, heat exchangers, etc. But we have made an attempt to break interatomic bonds in feedstocks molecules using unconventional means. Therewith new molecules (usually distillates) are born which are easier than huge initial ones and possess the properties of fuels. To attain such changes we used modern principles of hydrocarbon transformation and appropriate equipment.

A basic particle capable of changing the properties of traditional natural materials (in this case, oil stock and its products) is a hydride-ion alias nucleon that is the most active particle of the universe. We learned how to get proportioned streams of these particles, without resorting to devices and methods of the high energy physics. Alongside with that, in our devices we used techniques of reducing the energy of intramolecular forces in the phenomenon of cavitation. Combined action of these two phenomena allowed quickly converting the said oil stock into fuel fractions, and in the future to restructure many liquids, not only hydrocarbons. To form a new stage of refining processes knowledge we have come a long way of theoretical and experimental study of the mentioned phenomena. It is practically almost completed. Already we know how a possibility emerges to realize the hydrocarbon conversion. We have learned and acquired sufficient knowledge and skills in order to increase, at least twice, the content of fuel fractions in oil as early as at the time of its preparation to evaporation. We learned to hydrogenate heavy oils and thus turn them into light low-boiling fractions. By way of processing a fuel blend of poor quality we have significantly raised its quality. Of particular note is a method of nucleon desulfurization, which will radically transform the technology of sulfur recovery. Not less important and promising is a process of gasification of raw hydrocarbons and off-spec hydrocarbon mixtures. It is hard to overestimate its potential applications.

We carried out a huge amount of theoretical (from 1998), experimental (from 2002) and laboratory (from 2007) research on the processing of various raw materials: fuel oil, heavy oil, pyrolyzed carbohydrates, conventional oil, light oil, stable condensate, as well as diesel fuel and gasoline. For this, we have constructed seven laboratory benches. All plants use piezoceramic transducers.The results of tests with these benches have proved to be unusually high. We had to sell some benches. To date three benches have been sold. From

2014 we are designing pilot-plant units, and soon they will be put into operation at least at two plants. Initially, we shall process the accumulated heavy fuel oil from the tanks of one of the Baltic terminals, the oils of Shebelynka plant (Ukraine) and from other origins.

Investigation of properties of the feedstocks processed by this technology (see Tabl. 1) showed that content of distillates for example in fuel oil M100 (from some plants) after cavitation hydrogenation increased from 5.6% to 41.9%, at that these distillates were overwhelmingly a diesel fuel. Altogether, processing of oils increases the content of distillates at least twice. Pyrolyzed feedstock loses radicals and unpleasant odors, and the amount of additional distillates is increased by more than 50%. Sure, the results are unusual.

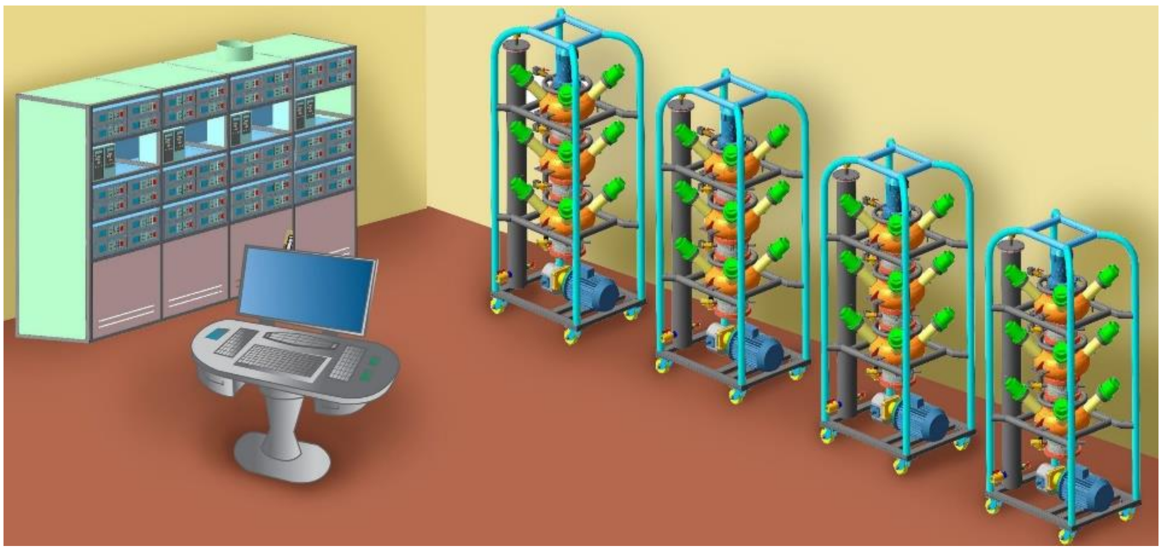

*Fig. 2. Appearance of the facilities for cavitation hydrogenation of hydrocarbon feedstocks "Potok-7MI-200". They are based on toroidal-type reactors and 48 emitters of a pezostriktive type. The facilities are equipped with a system of monitoring and control over the pumps and sensors.*

Now we are completing the design of benches "Potok-6MI-60" and "Potok-7MI-200" based on our latest and most productive versions of the given technology. According to our calculations, these benches will be able to efficiently process from 60 to 180-200 m$^3$ feedstocks per day. Calculations also show that the manufacturing cost of benches will make from $0.45 to $0.54 million, the expenditures for consumables and salaries will not exceed $50/m$^3$ and the income from their experimental and industrial use will exceed $17.5 million per year. This is an average cost of the distillates obtained additionally. Our experts have now been prepared all information for patenting five previous and the latest version of the technology. There are more than 20 innovative versions of the devices that implement the base technology. They enable to realise:

- feedstock **lightening** and obtaining additional lighter fuel fractions (more than twice);
- i**Isomerization** – rise in the gasoline octane number (at least by 14 units);
- i**mprovement in quality** of the random motor fuel (reducing the content of high-molecular compounds by 15-21%);
- r**emoval of sulfur** (targeted to at least 10 ppm);
- g**asification** of any hydrocarbon feedstocks with a ratio of 1:1500 or 1:1600.
- d**iversification** of motor fuels through its gasification in a hood device.

The first of these technologies is practically ready for application, while others processing capabilities of cavitation hydrogenation need to be further developed through experimental studies on appropriate laboratory facilities. It concerns the gasification, sulfur removal, time-stable iIsomerization, hood device et al.

Summing up the said above and based on the recent experimental data we compared the final results and brought them in Table 1. The third column shows the results of distillation of initial crude products, and the next column shows the analysis of the raw materials processed in Potok-5, Potok-6 and Potok-7. Analysis of other physical and chemical parameters of the processed raw materials and products was performed on common laboratory equipment according to effectual and common GOSTs and other standards.

Table 1

| *№* | *Feedstocks* | *Refining coefficient* **Initial** | *Refining coefficient* **Processed** | *Difference* |
|---|---|---|---|---|
| *1.* | *Heavy fuel oil M100* | *5,6%* | *41.9%* | *7-8 times larger* |
| *2.* | *High-viscosity oil* | *12%* | *122 - 158%* | *More than twice* |
| *3.* | *Heavy crude oil* | *22,6%* | *122%* | *122% more* |
| *4.* | *Pyrolysis oil* | *23,6%* | *161%* | *More than twice* |
| *5.* | *Middle oil* | *34%* | *71,9%* | *Two times larger* |
| *6.* | *Gas-condensate* | *77%* | *98%* | *21% more* |
| *7.* | *Diesel fuel* | *76%* | *97%* | *21% more* |
| *8.* | *Gasoline* | *72 (ON)* | *86 (ON)* | *14 units more* |

These are the indicators of our technology. Please note that in my understanding it is far yet from perfect. Experimental work should be urgently prolonged. But even these data allow confirming that in the worst cases we have got significant results. I am convinced that involving creditors or partners we could organize a rapid business making use of these technologies in continuous processing trains, mini- and makro-installations. The development of cavitation hydrogenation in other fields of applied science will enable to effectively process other raw materials.

For the sake of objectivity, let us go back in time and look at the appearance, state of being and prospects of solving this problem. Here one can find an extensive bibliography [1] of works indirectly and directly related to the problem. The publications [*] of the section "**Chemical Processes**" adequately justify the chemistry of the processes that occur during cavitation refining: type of reactions, their specificity, properties of products obtained by the impact of "cold boiling" (cavitation) on hydrocarbon mixture, thermodynamics and other guidance materials. Note that under this technological trend we have tried to combine the main problems (their vision and methods of their solutions) in terms of the system theory. Dedicate to this are publications [*] of the section "**Theory of Complex Systems Control**". The method itself, and rather tools for solution of most common problems of refining are given in [*] and the work in this direction is illustrated in publications [*]. Wanting information contains in the papers on analysis of particular issues of the problem, presented in other sections of the bibliography. The papers of the section "**Cavitation and energy exchange processes in hydrocarbons**" describe the basic cavitation application methods for solving various problems of acoustic field impact on liquid, gas-liquid systems and systems with solid inclusions (slurries), as well as examples of indirect analogues of the described technology. This section and two next ones concern a problem of oil refining with application of cavitation. It should be noted that along with the task of deepening the refining with the aid of cavitation hydrogenation we decided parallel tasks on up-grading hydrocarbon mixtures by gasoline hydrocarbon isomerization. The main focus in this section was given to the publications parallel to our methodology and aimed at active desulfurization of fuels by cavitation and other methods. Therefore, some of our methodological and technological solutions are based on the analysis of the publications of the sections "**Cavitation, sonochemistry and desulfurization**" and "**Cavitation in hydrocarbons for its desulfurization**". These sections contain publications [*] which describe a set of techniques and attempts to find a solution to

[1] Bibliography includes a list of over three thousand works, reports, patents and others. It will be published separately.

the problems mentioned above involving and without involving cavitation processes. Cavitation processes, technics of their generation, various features of cavitation effects on raw materials and processed products play an important and at times hard-to-explain role. This can be seen in different works of this list. Information in these works is capacious and extensive. Particular attention should be paid to the pioneers and enthusiasts of pre-cracking of hydrocarbons processing. They are known for. The papers [*] contains the publications of tireless A.K. Kurochkin who hold a long way from theoretical justification of hydrocarbon splitting by ultrasonic treatment to creation of industrial equipment. Theoretical and experimental substantiation of cavitation effect on the quality of liquid fuel hydrocarbons subjected to cavitation treatment in changing conditions is given in the works of the school headed by V.G. Sister [*]. The specialists under the guidance of Gridneva I.I. [*] work in this direction parallel with that school. Causing cavitation in liquid hydrocarbons by means of rotary-impulsive devices [*], M.I. Promtov with his workfellows develops and implements a method for hydrocarbon pre-processing in rotary machines.

Note that a special role in the creation of methods and means of oil feedstock processing with cavitation belongs to the Soviet, and later Russian and Ukrainian scientific and engineering potential. Such was the decree of fate before and after the collapse of the USSR. Then, in the early '90s, many defense organizations plotted, offered and praised their formerly closed technologies, in particular, "cold boiling" in hydrocarbons as one of the conversional whilst effective technologies. But time has shown that over the past 25 years the efforts to use this method have been spent in vain. All such dreamy solutions led to naive mistakes. The methods and apparatus for converting oil in fuel indicated in many statements proved to be only groundless declaration, for example see. [*]. Using only cavitation does not transform hydrocarbons. They do not disintegrate into fragments and do not convert into other ones. The results of hours-long cavitation treatments showed extremely low possibility of cracking of the tested pure organic substances in the range of 1 - 2 %.

If from the early '90s there was a competition in the manufacturing "cold cracking" installations, and also with selecting design of emitting devices and using now water then gas etc., then in 2010 a group of experts of unquestioned authority in thermal physics, catalysis and organic chemistry from three institutes of the Novosibirsk branch of Russian Academy of Sciences[2] reported that they working together analyzed the results and finally found out that the cavitation impact on chemically pure hydrocarbons are not effective. I responded to their information, and advised at least to "spit" into reactor (in the sense to try to add something therein) when performing experiments.They ignored. And how wrong they were!
Refiners have long ago given up the information of possible cavitation "blessings" of civilization. However many enthusiasts continue to assail traditional values still ongoing to work in this direction. Some researchers having lost faith in the cavitation treatment possibilities stopped this work, while others increased their efforts. Significantly, the highest results of increasing the oil refining depth in Russia belong to FSUE "Center Keldyshev"[3]. The footnote mentions two articles in in which the authors report on the positive results of brand oil cavitation treatment with increasing the processing depth within ten percent. Confine oneself to the sufficient bibliography of information sources about the search for the "miracle", that is magical changes of the hydrocarbon mixture properties by cavitation impact. Note that the "miracle" does not occur just because it is. Using only cavitation, which all relied upon, does not help. The whole history of research in this direction persuades us of this. Money spent on seemingly simple technology, has not brought the expected results. No cracking occurred. But instead the researchers have learned to make powerful and good cavitators. Obviously, the studies were carried out only partially and only to perfect cavitation devices. Experience shows that to

[2] Yakovlev V.A., Zavaruhyn S.G., Kuzavov V.T., Malykh N.V., Maltsev L.I. and Parmon V.N. Study of chemical transformation of organic compounds under the influence of cavitation impact. *Chemical physics, 2010, Vol. 29, № 3, pp. 43-51*.
[3] V. Yakovlev, S.G. Zavaruhyn, Kuzavov V.T. Malykh N.V., L.I. Maltsev and V.N. Parmon. Study of chemical transformation of organic compounds under the influence of cavitation impact. *Chemical physics, 2010, Vol. 29, № 3, pp. 43-51.*

achieve the purpose in view one should focus the efforts of task teams on developing this theory but rather on elaboration of decisions on various issues anyhow associated with it.
Not less interesting and even intriguing are the reports published in the US during the past two years on the work with the use of QVI hydrodynamic cavitation reactor (a reactor with introduction of the cross-voltage). These American researchers[4] used a heavy-duty rotary machine, which enabled to partially solve the problem of conversion of "heavy" hydrocarbon mixtures of Canadian feedstocks into the "light" ones. Due to deep analysis of the cavitation phenomena they substantiated the processes taking place in the cavity of the rotary unit (Pat. US6016798), and they plan to develop in every way the work in this direction. We countenance amerikan researchers and hope that they will succeed in expanding the volume of cavitation zones compared with the use of piezoceramic radiators.

Due to in-depth understanding of the processes occurring in the hydrocarbons and the ability to correctly choose and use the necessary resources and make optimal design decisions we have obtained surprisingly good results. This is certainly not the limit but just the beginning of a long way.
An interesting fact: at the time when attempts were made to benefit from cavitation in the energy sector some foreign experts mastered the possibility of cavitational transformations when developing a process of "cold fusion hydrogen" in spherical reactors. A large number of reports also deal with a more commercial direction. Other employment of ultrasound technique was all at once developing in medicine, pharmacology, and biology and food industry. Adherents of biomedical research achieved a particular success. Widely known are the results of sonochemical catalysis of hydrocarbons and carbohydrates of various origins including proteins, obtained by Kenneth Suslick, an enthusiast and unquestioned leader of this trend, and his follower [*] and by other researchers [*].
I would like to add the general list by Ukrainian patents whouse authors investigated in various forms, created, stated and applied cavitation devices. It is at least 108 patents. Honor them and praise! I would like to sincerely wish them success. The patents describe the hydrodynamic devices in the form of pipes and nozzles, the vortex and rotary devices, as well as those using magnetostrictive and piezostrictiv radiators. Researchers in one way or another accumulated experimental data and formalized the functional dependencies between the parameters and properties of the treated hydrocarbon mixtures. Unfortunately, the limited scope of this article does not permit to reflect the whole diversity of approaches.
Due to the lack of experience in the experimental data planning and processing we decided to make optimal plans of experiments based on the best known planning theory algorithms. Patent [*] and the section "**Design of Experiments**" [*] describe possibilities of reducing the number of experiments for creation and identification of polynomial models. Note that the solution of the methodological problems of the identification of cavitation process models and experimental data processing algorithms are based, to some extent, on the methodology described in classical and amateur works of the section "**Design of Experiments**”.
We believe that to implement new methods of hydrocarbon mixture treatment not less important are the methods of standardization of parameters of feedstocks and processed products (normative literature of the section "**Standards**"). This is certainly not a complete list of the standards referred to in [*] yet it contains many useful references[5] that need to be taken into account at all stages of research and especially in decision-making. Presented there information on the numerous ways of solving the main problem and its particular issues is incomplete but sufficient for an objective assessment. It confirms that we made a correct choice of the ways to solve the problem.

[4]Fomitchev-Zamilov, M.I., 2014. Fluid Hammers, Hydrodynamic Sirens, Stream Reactors, Implementation of Same, and Methods for Treatment of Fluids, PCT Application #13/869,017. Fomitchev-Zamilov, M.I., 2013. Hydrodynamic Siren Theory, 2013, http://www.quantumvortex.com/Hydrodynamic%20Siren%20Theory.pdf.

[5] Bibliography includes a list of over three thousand works, reports, patents and others.

It is clear that to move from the laboratory plants to industrial ones is an expensive but already not so long process. Once a comprehensive analysis has shown the ability to convert hydrocarbons by the forced hydrogenation, we began intensive research. If the first bench (of the "glass") was built in 2006, then within the past 7 years seven benchs have been built and tested. And the development and manufacturing of each subsequent installation took lesser time. Laboratory-based work was carried out in such a way that it was possible to extend the technology on the contiguous technological problems. Available experience and ability allowed to quickly dealing with these problems. But a risen financial break was not conducive to commercialization. Planning of a deterministic trend of this business development requires particular actions. Income will depend on a sale strategy adopted and accorded with a partner. The strategy options are proposed to be selected and combined from the following

Table 2.

| № | **Sale strategies** | *Variants of business registration* |
|---|---|---|
| *1.* | *Selling of licenses for technology* | *Contract for license* |
| *2.* | *Selling of licenses for equipment* | *Contract for license* |
| *3.* | *Selling of equipment* | *Contract (Agreement) with Customer for equipment* |
| *4.* | *Services for designing, manufacture, commissioning* | *Contract, Project* |
| *5.* | *Joint running venture (50/50)?* | *Partnership contract* |
| *6.* | *Manufacture and installation of equipment on the Partner's site for a fixed share of the total product cost* | *Contract (Agreement) for the cost of production volume* |
| *7.* | *Independent expanding business on a particular field* | *Product sharing agreement* |

Here given is only my vision. Sales strategies may be discussed. Our next steps will depend on a business option chosen. After testing the first installation, an expansion of business can be planned for example by numerous replication of the installations (this will require patent protection in European countries, USA, Canada, South America, South-East region, the Middle East and Russia). Each of the strategies listed in the table is associated with risks which should be anticipated and methods of reducing them should be developed. Risks can be so striking that without our control over the technology utilization we may lose a good deal of buisiness. It concerns to nearly all strategies except the 7$^{th}$ one. I am inclined to place confidence in my partners and to rely on their caution and foresight. I am not so experienced as to figure out all the options of strategy employment, to evaluate and anticipate situations. Again, I rely on a partner. Income from the use of the innovative installations Potok-6 or Potok-7 makes the difference between the means coming to a company making use of the said installation and the ones when making use of the old (traditional) equipment. The income in this case is equal to the difference between the means spent on the project and the sale price of the installations. For a more or less accurate assessment of economic performance we need to have the bulks of situational assessments of the technology utilization, the algorithms of forward planning, the identification of probabilistic models of game situations, the methods of assessing situations, and then indicators of economic evaluation of the results. But we do not have all that. Therefore, heuristic evaluation methods can be used at the first stage, which could be offered by our partners or investors. And we will examine them together.

Dear readers, the result of our work is obvious. Now about 7 billion cubic meters of hydrocarbons is extracted in the world. Their processing is carried out by almost all countries. Refineries are located in all regions of the world. The project is relevant but requires support for industrial implementation, as well as for further research that will greatly increase the scope of its use. Making use of our technological devices at any refinery will bring undeniable advantages to owners of resources and plants in many countries. The advantages are obvious: lower fuel costs, higher fuel amount and quality, significantly lower energy intensity of enterprises, better environment, easy production of materials with predetermined properties, and this is not a complete list of the technology values. And yet, all markets of the world will be open for such technological devices.
Note that the project is a multibillion one. Please take it with understanding and seriousness. One should select an optimal strategy for its implementation. Depending upon the right strategy one could think of the prospects of its implementation in such countries as Canada or Venezuela. Namely there is an abundance of raw materials and lack of capacities of its processing.

Goals and objectives concerning the project implementation will be agreed upon with interested partners, and in the meantime the relationships will be legally documented and detailed answers to any questions will be prepared.

Testing and updating characteristics and parameters according to experimental data is a long and complex process. All this would have been impossible to commit and, especially, to get good results without the support of my wife, persons of the immediate environment, assistants (Wojtowich J.A., Morgunyuk B.V., Morgunyuk V.S., Pelyushok R.G., Katchura I.B., Dumik V.I., Kopylov E.V., Firsov V.N.), colleagues (Tsaturyants G.A., Jurin S.S., Khmelev V.N.), partners, unindifferent and/or interested people and organizations. The work continued 15 years in the period of 1999 – 2014. The active part of the development and especially the manufacturing laboratory facilities, providing experiments with raw, software and hardware, marketing and management of technologies were conducted during the last 8 years. This was attended by Dyachenko V.S., Pozdeev A.V., Konorezov V.V., Sigorskih S.V., A.A. Arkhipov., Zabiyvorota E.A., Sedad Peyam with financial and organizational support of the Presidium of the UAS (Onipko A.F.) and a number of foreign organizations: AK Party (M. Ihsan Arslan), AZERSUN (Abdolbari Goozal), TUROIL (Erol Seybol), Basis Ecotech LLP (Yuriy Golubyev), Turkche Petrollerum (management) and individuals such as: Raçabali Həsənzadə Əsgər oğlu, Dr. Rana Javadova, Abdülaziz Karakoç, Lembit Eespäev, Seyhmus ÖZKAN, Kareem R. Al-Saidi, Saad-K-Ibraheem, Salah M.Ali, M. Stec and A. Nenko. I offer heartfelt thanks to all these persons (some of them represent the listed organizations) for supporting the work on the technology.

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