

DOI 10.25689/NP.2018.4.1-17

УДК 622.276.1/.4(470.41)

**ON PROGRAM OF DEVELOPMENT OF PRIORITY RESEARCH STUDIES IN
GEOLOGICAL PROSPECTING AND RESERVOIR ENGINEERING BY
INDEPENDENT OIL COMPANIES FOR THE PERIOD 2016-2015**

Muslimov R.Kh.

Kazan Federal University

E-mail: davkaeva@mail.ru

Abstract: The paper presents the Program of Development of Priority Research Studies in Geological Prospecting, Reservoir Engineering, Oil Production, and Refining in Republic of Tatarstan for the Period 2016-2025 worked out by the Academy of Sciences of the Republic of Tatarstan in compliance with the updated Energy Strategy of the Republic of Tatarstan up to 2013, by order of President of the Republic of Tatarstan R.N. Minnikhanov.

Key words: *development program, marginal fields, hard-to-recover reserves, unconventional reservoir, unconventional reserves, high-viscosity oil, carbonate reservoir, sandstone reservoir, oil recovery factor, enhanced oil recovery methods (EOR), hydraulic fracturing, water flooding, TEOR, steam flooding, in-situ combustion, horizontal wells, multilateral wells, branched wells, horizontal sidetracks, bottomhole zone treatment.*

**THE PRESENT AND THE FUTURE OF SMALL OIL COMPANIES
IN REPUBLIC OF TATARSTAN**

Muslimov R.Kh.

Kazan Federal University

E-mail: davkaeva@mail.ru

Abstract. Transition to market economy conditions after collapse of the Soviet Union brought about creation of private-owned small- and medium-sized oil companies. Tatarstan led the list and in a rather short period, thirty-four small oil companies, or using the Western term, independent oil companies, were set up in the Republic of Tatarstan. Owing to the support provided by the Republic's Government and the TATNEFT Company, small oil companies successfully developed and have attained the planned oil production levels, contributing, thus, significantly to the economic development of the Republic of Tatarstan.

For more than two decades, the small oil companies have gained a vast hands-on experience in development of fields with troublesome geological settings and in production of unconventional reserves.

The accumulated successful oil production experience and the in-house commercially used innovation technologies suggest a long-term (up to 2050s and longer) sustainable development of small oil fields with complicated subsurface geology. This invaluable experience is worth a particular attention, examining, and extension.

Key words: *marginal fields, hard-to-recover reserves, oil recovery factor, enhanced oil recovery methods (EOR), physico-chemical EOR, physical EOR, TEOR, gas flooding, horizontal wells, multilateral wells, branched wells, horizontal sidetracks, hydraulic fracturing, well spacing pattern, replacement of reserves*

SEDIMENTARY ENVIRONMENTS OF WEST-SIBERIAN UPPER CRETACEOUS CAMPANIAN DEPOSITS REVISITED

Kudamanov A.I., Agalakov S.E., Marinov V.A., Novoselova M.Yu., Glukhov T.V.

Tyumen Petroleum Research Center

E-mail: aikudamanov@tnnc.rosneft.ru

Abstract. Sedimentary cover of West Siberia is represented by intervals composed predominantly of either terrigenous (allochthonous; for example, Middle Jurassic deposits, the Neocomian) or chemical-biogenic (autochthonous; for example, Bazhenovskian, Slavgorodskian, Lulinvorian horizons) sediments. Various types of sediments are characterized by various mechanisms and rates of sedimentation and reflect certain geologic events in the history of Earth's crust formation. Division of Earth's history into natural periods not only based on trace fossils but also with due account of changes in sediment types is crucial for modern historic geology science. Integrated analysis of large amount of geological and geophysical data (seismic, well logging, core data) yielded details of sedimentation environments for the Upper Cretaceous and provided a novel version of the conceptual model of the structure and formation history of Upper Cretaceous reservoirs of Western Siberian Plate. Seismic data obtained for sediments above the Senomanian suggest presence of four seismic zones (from bottom to top): Kuznetsovian (Turonian-Lower Coniacian), Lower Berezovian (Middle Coniacian-Santonian), Upper Berezovian (Campanian), and Gankinskian (Upper Campanian-Maastrichtian). Interpretation of integrated well logging data allowed to further subdivide these four seismic zones into thinner stratigraphic units and construct schematic distribution maps using the latest core and paleontological analysis data. Based on acquired data and contemporary concepts, an original version of regressive-transgressive sea-level fluctuations is proposed for Upper Cretaceous sediments on the territory of West Siberia. Evidence of repeated subaerial exposure and development of erosion processes (probably, only within islands) is provided. The paper presents a brief description of Upper Berezovian siliceous-argillaceous deposits and their distribution within West Siberia.

Key words: *Upper Berezovian series, Lower Berezovian series, the Santonian, the Campanian, terrigenous material, chemical and biogenic sediments, autochthonous and allochthonous type, diatoms, transgression, regression, erosion.*

DOI 10.25689/NP.2018.4.55-72

УДК 553.98(571.1)

**IDENTIFICATION OF POTENTIAL PAY ZONES IN BAZHENOVSKIAN-
ABALAKSKIAN SERIES OF SEVERO-DEMYANSKOYE FIELD BASED ON CORE,
WELL LOGGING AND SEISMIC DATA**

Bozhenok A.D., Sorokina A.V., Bumagina V.A.

Tyumen Petroleum Research Center

E-mail: adbozhenok@tnnc.rosneft.ru

Abstract. Potential reservoir intervals of the Bazhenovskian-Abalakskian series have been predicted based on integrated geological, field, core analysis, well logging and seismic data. Diagnostic criteria for identification of lithotypes encountered within Bazhenovskian-Abalakskian series have been developed. The Bazhenovskian formation has been cut down into strata based on detailed core description. An algorithm for identification of pay zones in the Bazhenovskian-Abalakskian sediments of Severo-Demyanskoye field has been worked out.

Key words: *Bazhenovskian series, Abalakskian series, thermal conductivity, brittleness, fracture network, organic matter, basement rocks, production rate, abnormally high formation pressure, seismic attribute.*

**CONCEPTUAL MODEL OF LOWER PERMIAN ORGANOGENIC STRUCTURES
OF PECHORA LPG PROJECT**

Mameeva Yu.R., Borovkina E.E., Vanin V.A.

Tyumen Petroleum Research Center

E-mail: vavanin@tnnc.rosneft.ru

Abstract. Pechora LPG project involves a wide range of operations including development of two gas-condensate fields (Korovinskoye and Kumzhinskoye) located on the territory of the Nenets Autonomous District, development of gas transport infrastructure, construction of central gas processing facility as well as LPG plant. Implementation of this project requires significant capital investments into infrastructure, drilling and transportation. Successful production of recoverable reserves and achievement of desired production rates is critical for getting return on investments. Economic well production requires a better understanding of reservoir geology and hydrocarbon potential.

In view of the above, a comprehensive analysis of available geological and geophysical data, well test results and regional geological study data was conducted in 2017-2018 in Tyumen Petroleum Research Center. One of the main outcomes of that research effort was refinement of conceptual geological model of Lower Permian sediments of Korovinskoye field. A new understanding of the structure of Asselian-Sakmarian deposits will enable making more accurate decisions on selection of pilot sites and will optimize the processes of reservoir engineering and management.

Key words: *Timan-Pechora oil and gas province, Lower Permian sediments, organogenic structures, carbonate ramp.*

DOI 10.25689/NP.2018.4.86-108

УДК 553.98(571.1)

**STRUCTURE AND SEDIMENTATION ENVIRONMENT OF THE BAZHENOVSKIAN-
ABALAKSKIAN SERIES WITHIN THE KRASNOLENINSKY DOME**

**¹Bumagina V.A., ¹Potapova A.S., ¹Kudamanov A.I., ¹Marinov V.A., ²Akhmadishin A. T.,
³Alifirov A.S.**

¹Tyumen Petroleum Research Center

²RN-Nyagan'neftegaz

³Institute of Petroleum Geology and Geophysics, Siberian Branch of the Russian Academy of
Sciences

E-mail: vabumagina@tnnc.rosneft.ru

Abstract. Core data has been used to determine lithological types of rocks and define biostratigraphic units that provided the basis for division of the Bazhenovskian-Abalakskian series into members. The paper highlights unique features and areal correlation of members. Stability of these properties within the Krasnoleninsky Dome has been confirmed.

Key words: *Bazhenovskian series, Abalakskian series, Krasnoleninsky Dome, biostratigraphy, West Siberia, Upper Jurassic, Lower Cretaceous.*

DOI 10.25689/NP.2018.4.109-118

УДК 553.98(571.1)

**NEW GAS PROSPECTS IDENTIFIED IN WEST SUBERIAN UPPER CRETACEOUS
ARGILLACEOUS-SILICEOUS FORMATION**

**Nassonova N.V., Gordeev A.O., Distanova L.R., Kudamanov A.I., Kalabin A.A.,
Kuzovkov A.A.**

Tyumen Petroleum Research Center

E-mail: aakuzovkov@tnnc.rosneft.ru

Abstract. The paper considers regional criteria of hydrocarbon potential for unconventional reservoirs of the Berezovskian series, Coniacian-Santonian-Campanian stages. Lithological characteristics of the sediments are summarized. Preliminary criteria of the most promising zones on local structure are defined, particularly: clay content, gas saturation factor, net thickness, specific resistivity, and fracture network. Rock studies are currently underway.

Key words: *unconventional reservoirs of Berezovskian series, potentially productive zone*

USE OF SEISMIC DATA TO CALIBRATE GEOMECHANICAL PARAMETERS

¹Salimov O.V., ²Nasybullin A.V., ³Salimov V.G.

¹RN-UfaNIPIneft,

²TatNIPIneft Institute

³Volga-Kama Regional Branch of the Russian Academy of Natural Sciences

E-mail: arslan@tatnipi.ru

Abstract. Methods of calibration of geomechanical parameters used for the design of hydraulic fracturing have been analyzed. It was found that vertical seismic profiling data (VSP) can be effectively used for calibration of geomechanical parameters.

The paper presents examples of calibrated curves of density and horizontal in-situ stress based on VSP data for oil fields in Tatarstan. Matching with the Brocher's and Ludwig's empirical fits has been carried out. The authors present recommendations on calibration of in-situ stresses in FracPRO simulator. Stress distribution in the shallow part of the section has been characterized.

The carried out research allowed the following conclusions:

1. The empirical formulae provide higher accuracy once their coefficients have been adjusted to actual geological setting.
2. In presence of VSP data, the empirical formulae can be used as a reliable reference for calibration.
3. The stress contrast in the near-surface section is practically null.

Key words: *calibration, vertical seismic profiling, geomechanical parameters, hydraulic fracturing design, FracPRO simulation package, near-surface section.*

**FORECAST OF SEAL ROCKS AREAL EXTENT IN UPPER DEVONIAN
CARBONATES IN ORENBURG REGION**

**¹Shakirov V.A., ¹Miropoltsev K.F., ¹Vilesov A.P.,
²Maksimova I.A., ³Sobolev V.I.**

¹Tyumen Petroleum Research Center

²SamaraNIPIneft

³Orenburgneft

E-mail: vashakirov@tnnc.rosneft.ru

Abstract. In the Orenburg region, the cap rocks of Upper Devonian carbonates are characterized by facies variation, both vertically and laterally. Eustatic falls and rugged topography of Frasnian-Fammenian age contributed to epigenetic transformation of potential seal rocks, which resulted in deterioration of their sealing properties. Integral analysis of seal rocks has been carried out to define their properties, as well as facies have been identified and evaluation criteria have been developed for such important parameters as thickness and impermeability of seals. The studies performed allow for general assessment of geologic characteristics of major Upper Devonian cap rocks, their sealing properties, quality and areal extent. To verify sealing properties of cap rocks, it is advisable to integrate the presented approach with other types of studies.

Key words: *seal rock, Upper Devonian, carbonates, Orenburg region*

DOI 10.25689/NP.2018.4.154-162

УДК 550.832:622.243.24

**EFFECT OF INHIBITED DRILLING MUD ON LOG DATA INTERPRETATION
FOR HORIZONTAL WELLS OF PJSC TATNEFT**

Khuzina L.B., Golub S.I., Karimova R.M.

Almetyevsk State Petroleum Institute

E-mail: bngs_agni@mail.ru

Abstract. This paper discusses mud systems used for drilling through Kynovian clays confined to Devonian terrigenous formation. Drill mud is a medium where virtually all processes related to well drilling occur; therefore, it can potentially cause various problems, including loss of clay stability, poor quality of geologic and geophysical data, and others. Various inhibiting systems are used when drilling through the Kynovian horizon composed of swelling clays.

The authors analyze properties of clay stabilizing muds, their effect on quality of well logging data while drilling horizontal wells in PJSC Tatneft's fields.

Key words: *well logging, interpretation, Kynovian clays, inhibited drilling mud*

**OPTIMIZATION OF PROJECT WELLS' PLACEMENT USING SOFTWARE
MODULE FOR OIL PRODUCTION AND ECONOMIC ANALYSIS**

**Nasybullin A.V., Razzhivin D.A., Latifullin F.M., Sattarov Ram.Z., Smirnov S.V.,
Khafizov R.R., Sharifullina M.A.**

TatNIPIneft Institute

E-mail: arslan@tatnipi.ru

Abstract. A software module for production and economic analysis can be a useful tool to optimize placement of project wells. The paper considers different options of computerized placement of project wells to achieve the best possible economic performance under predetermined production and economic constraints for fields under development.

The authors have developed a procedure for a stage-wise placement of project wells by irregular well spacing pattern with maximum density that satisfies all predetermined operational and economic constraints. The procedure has found its realization in a software module.

The software module for production and economic analysis was used to perform calculations for 208 development targets of PJSC TATNEFT, including placement of project wells, calculation of basic performance data, and production and economic efficiency of the planned production enhancement operations.

Key words: *forecast of reservoir performance without production enhancement operations, production and economic analysis, production enhancement operations, optimization, project well spacing pattern, developed reserves, recoverable reserves, NPV, profitability index*

MONITORING THE PROCESS OF WELL START UP USING A NUMERICAL MODEL OF UNSTEADY-STATE OPERATION OF RESERVOIR/WELL/PUMP SYSTEM

Balandin L.N., Gribennikov O.A., Melnikov A.A.

Samara State Technical University

E-mail: gribennikov.oa@samgtu.ru

Abstract. This paper considers the procedure for monitoring the process of well operation, particularly start-up of well production. This is one of the main production stages, which requires adequate control. Monitoring of well start-up process involves such parameters as the position of dynamic fluid level in the annular space and presence of reservoir fluid inflow. This information is required to prevent overheating of submersible electric motor or pump underload due to level drop below pump suction screen. The monitoring process will rely on a numerical model to estimate certain parameters described in this paper.

The present research effort aims to increase the amount of data on well behavior to mitigate potential problems in the course of well operation.

The objective of this research is to use this data for numerical modeling followed by interpretation of the results and comparative analysis of the estimates with actual field data to evaluate applicability of the proposed procedure in the future.

The paper also presents screening criteria for the numerical model under analysis that are important for understanding the conditions under which this procedure can be applied.

The proposed procedure was used to estimate well parameters and plot well performance curves in the process of starting up a well operated by Samaraneftegaz. Analysis of uncertainties experienced during numerical modeling and data interpretation has also been conducted.

Key words: *bring a well into stable production; numerical model; well operation; bottomhole pressure; dynamic level.*

FORMULATION OF ACID CORROSION INHIBITORS

Nabiev M.S., Mingazova L.R., Mingazov R.R., Bashkirtseva N.Yu.

Kazan National Research Technical University

E-mail: aminkhon.260595@yandex.ru

Abstract. Matrix acidizing technology is based on the acid ability to dissolve oil-bearing carbonate rocks. This method provides increase or restoration of rock permeability in the near-wellbore area. Permeability is increased through removal of skin damage caused by plugging of pores during drilling and production operations. Acid treatments result in enlargement of constricted pore channels, thus providing improved permeability. Degree of production enhancement depends on the wellbore damage and reservoir pressure. Operational benefit is usually observed for several months after treatment.

Use of hydrochloric acid during acidizing results in significant metal corrosion and hydrogen-induced and chloride-induced delayed cracking of tubing strings. This paper discusses formulation of acid corrosion inhibitors and studies the inhibiting properties of these mixtures.

Surfactants were used as the base of the inhibiting systems, including alkyltrimethylammonium chloride and alkyldimethylbenzylammonium chloride. Hexamethylenamine and potassium iodide were used as modifying agents in corrosion inhibitors.

Maximum inhibiting effect is 95.4% when using potassium iodide and 89.7% when using hexamethylenamine. VNPP-2V was used as a model inhibitor having maximum inhibiting effect of 94% at 93°C.

Key words: well, acidizing, corrosion, corrosion inhibitor, surfactants

MONITORING ISSUES OF STRESS - CORROSION PROCESSES OF INTERNAL INDUSTRIAL PIPELINES IN COMPLEX CONDITIONS

¹Eremin N.A., ²Husnutdinov L.A.

¹Federal State Budgetary Institution of Science Oil and Gas Research Institute of Russian Academy of Sciences; Federal State Budgetary Educational Institution of Higher Education "Gubkin Russian State University of Oil and Gas (National Research University)";

²STS "Transcor-K»

E-mail: ermn@mail.ru; linya82@mail.ru

Abstract: The main purpose of the article is to improve the reliability of the in -field pipeline infrastructure on the basis of the early diagnosis of critical stress - corrosion manifestations in the metal of the pipe by the unique domestic method of magnetic tomography (MTM). The method of magnetic tomography has been successfully implemented into the technical practice of diagnosing ferrimagnetic pipelines on land and at sea in 27 countries of the world.

The total length of infield pipelines in Russia exceeds 0.35 million km. The metal of the infield pipeline infrastructure is monitored either upon the accident or selectively. The volume of sampling control does not exceed 2% of the total length of pipelines. There is a need to amend the Technical Regulations for the Safety of Pipeline Transport to the effect that the metal of all pipelines, including intra-field, must be monitored, and the quality of control of pipelines must be declared and checked.

The analysis of the traditional methods of the monitoring pipelines, such as the acoustic method of non-destructive testing "Echo"; distributed control systems with fiber optic cable along the object axis; and direct measurements during periodic surveys of the metal surface during inspections by pipeline walkers.

The article describes the method of magnetic tomography in the framework of the Risk Based Inspection, which proposes the inclusion of the registration of real mechanical stresses, stress-corrosion processes in the system of assessing the reliability of pipelines by the criterion of transition to the limiting state based on the registration of the degree of stress concentration or local loads. To date, many problems have been solved in the system for monitoring the technical condition of in-field pipelines. However, ensuring the reliability of in-field pipelines in difficult operating conditions at a late stage of development remains an urgent task.

Key words: *stress-corrosion processes; in - field oil and gas pipeline; diagnostics of oil and gas pipelines; magnetic tomography method; Villari effect; corrosion; stress corrosion cracking; biocorrosion; metal embrittlement; in-line inspection; stress-strain state; robotic systems; multikopter; water transitions.*

**ELECTRICAL SUBMERSIBLE CENTRIFUGAL PUMP FOR
LIFTING OF WELLSTREAM THROUGH PRODUCTION STRING**

¹Garifov K.M., ¹Kadyrov A.Kh., ¹Glukhoded A.V., ¹Rakhmanov I.N., ¹Archibasov P.S.,
²Ismagilov F.Z., ²Lyubetskiy S.V.

¹TatNIPIneft Institute,

²PJSC TATNEFT

E-mail: glukhodedav@tatnipi.ru

Abstract. This work presents a pumping unit for tubingless well operation developed by research engineers of TatNIPIneft – PJSC TATNEFT. The wellstream is lifted through the production string.

The electrical subsurface centrifugal pump is used for pumping. The technology for tubingless well operation using ESP was originally used in Well No. 38031 by LeninogorskNeft NGDU.

At the wellhead, a logging hoist for tripping of electric submersible pump and automatic winder for winding of ESP feeding cable are installed. A hoisting crane is used to install nipple and ESP. The assembled pumping unit is run in hole on a wireline and is set on a packer.

Among the advantages of the new technology are saving expenses on well servicing, replacement and repair of tubing strings, reduced risk of cable damage while tripping. All these result in OPEX reduction.

Because of water cut reduction oil production is increased. Economic performance of the oil production process is also improved.

Key words: *tubingless well operation, logging hoist, hoisting crane, wireline, cost reduction, decrease of water cut.*

SUBSTANTIATION OF PROCEDURE FOR EVALUATION OF CRITICAL STRESSES ACTING ON CEMENT SHEATH DURING WELL INTERVENTIONS

¹Agzamov F.A., ²Belousov A.O.

¹ Ufa State Petroleum Technical University

²KogalymNIPIneft, Branch of LUKOIL-Engineering Company in Tyumen

E-mail: BelousovAO@tmn.lukoil.com

Abstract. Numerical, experimental and field studies have been conducted to determine parameters describing stress-strain performance of cement sheath required for prevention of cement structural integrity failures due to dynamic and shock loads.

Estimation of cement sheath strength required to resist dynamic loads and experimental study data indicate that adequate annulus integrity should be provided before any well intervention. Analysis of field data has demonstrated that cement bond integrity failures due to hydraulic fracturing treatments are not infrequent, resulting in losses of reservoir fluids through cross-flows along the cement sheath.

Experimental studies confirmed adverse impact of thermal corrosion on Portland cement sheath cured at temperatures of about 100 °C. Particularly, poor strength performance (compression, bending, tensile strength, and shock resistance), increased brittleness and circumferential stresses inside cement are observed. Ultimately, this translates into reduction of oil-well cement sheath resistance to dynamic loads.

On the basis of research findings, parameters required for evaluation of cement sheath stress-strain performance are proposed.

Key words: *Cement sheath, support load, bending strength, compression strength, shock resistance.*

**EVOLUTION AND STATE-OF-THE-ART OF GEOTHERMAL ENERGY
UTILIZATION ISSUE**

Gutorov Yu.A.

RKNTC Neftyanaya Dolina

E-mail: gutorov70@mail.ru

Abstract. The idea of geothermal energy industrial utilization has gone mainstream in many countries, mainly due to rise in the prices of conventional fuels, oil and gas. Thermal energy, generated and stored in the Earth, is huge. Therefore, comprehensive theoretical and practical studies of geothermal technologies are required. The heat flow from the earth interior averages 50 MW/m² and can vary from region to region. This paper reviews current state of geothermal industry worldwide based on published data analysis. Today, the Earth's heat produced at geothermal stations is used in many countries as the source of electric or thermal energy. Huge potential of geothermal energy shows promise for further development of this energy sector, for which reason it is necessary to perform basic research in this field.

Key words: *geothermal stations, conductive heat transfer, geothermal gradient, neutral layer, heat conductivity, thermal pump, numerically simulated model*

**FACILITY FOR CONVERTING GEOTHERMAL ENERGY INTO ELECTRIC
ENERGY FOR LOW-TEMPERATURE OIL WELLS**

¹Gutorov Yu.A., ²Gabdrakhmanova K.F., ²Izmailova G.R., ³Akhmadeev R.N.

¹RKNTC Neftyanaya Dolina

²Ufa State Petroleum Technical University, Oktyabrsky Branch

³Tekhnopromservis

E-mail: gulena-86@mail.ru

Abstract. This paper presents the equipment used for utilization of geothermal energy from a low-temperature oil well and conversion it into electric energy. Considering the prevailing share of unconventional oil reserves in the Russian fields, this provides significant reduction of oil production cost per one ton and increase of oil recovery factor in the least favorable conditions characterized by maximum reservoir pressure of 45-50°C, which is typical of the most oil fields in the Urals-Volga region.

Key words: *geothermal gradient, unconventional reserves, fuel cells, binary scheme of converting geothermal energy into electric energy*

**ON PROSPECTS OF ENERGY-EFFICIENT METHOD OF
CLEANING THE INNER SURFACE OF EXPORT PIPELINES**

¹Gutorov Yu.A., ²Gabdrakhmanova K.F., ²Izmailova G.R., ³Gimaev I.Kh.

¹RKNTC Neftyanaya Dolina

²Ufa State Petroleum Technical University, Oktyabrsky Branch

³Malta

E-mail: gulena-86@mail.ru

Abstract. This paper discusses various ways to solve the problem of cleaning the inner surface of export pipelines used for transporting Russian oil to the foreign customers. The majority of fields producing oil, which is exported out, are located in Western and Eastern Siberia where the climate is rigorous. Therefore, the authors propose an energy-efficient method of pipeline cleaning in the regions with harsh weather conditions where this problem is the most pressing. A device is offered comprising fuel cells that have a distinctive ability to generate heat by hydrogen recovery from the transported oil. These cells have virtually unlimited run life and do not need refueling, which is critical for their continuous operation in long sections under harsh weather conditions of the Russian North, thus reducing energy demands and cost price.

Key words: *export pipelines, energy efficiency, paraffin deposits, cleaning pig, weather conditions, fuel cells, cost price*