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**А. А. Новиков, А. А. Кучиерская, Д. Г. Карпов, В. С. Сеглюк**

РГУ нефти и газа (НИУ) имени И. М. Губкина

novikov.a@gubkin.ru

### **Фазовые равновесия жидкость — жидкость**

#### **в системе вода — этанол — циклогексан**

*В работе определено положение границы расслоения, измерены межфазное натяжение и плотности равновесных фаз в тройной системе вода – этанол – циклогексан при температуре 277,15 и 293,15 К. Проведено моделирование фазовых равновесий для этих условий методом молекулярной динамики. Установлено, что молекулярная динамика хорошо воспроизводит начальное падение межфазного натяжения, однако плохо согласуется с экспериментальными данными по плотности и составам водной фазы. Наблюдаемая кристаллизация органической фазы при температуре 277,15 К может быть полезна для быстрого разделения фаз при экстракции липидов.*

**Ключевые слова:** равновесие жидкость — жидкость, адсорбция, межфазное натяжение, растворимость.

**A. A. Novikov, A. A. Kuchierskaya, D. G. Karpov, V. S. Seglyuk.**

Gubkin University

### **Liquid-Liquid Phase Equilibria in the Water – Ethanol – Cyclohexane System**

*The studies determined the position of the separation boundary, measured the interfacial tension and densities of equilibrium phases in the ternary system water – ethanol – cyclohexane at temperatures of 277.15 K and 293.15 K. The phase equilibria for these conditions were simulated by the molecular dynamics method. It has been established that molecular dynamics reproduces well the initial decrease in interfacial tension, but does not agree well with experimental data on the density and composition of the aqueous phase. The observed crystallization of the organic phase at 277.15 K may be useful for rapid phase separation in lipid extraction.*

**Key words:** liquid-liquid equilibrium, adsorption, interfacial tension, solubility.

**М. Б. Ярахмедов<sup>1,2</sup>, Д. В. Сергеева<sup>1</sup>**

<sup>1</sup>Сколковский институт науки и технологий,

<sup>2</sup>РГУ нефти и газа (НИУ) имени И. М. Губкина,

d.sergeeva@skoltech.ru

### **Влияние аллилового и пропаргилового спиртов на равновесные условия образования гидрата метана**

*В работе изучена стабильность гидрата метана в 20%-ных водных растворах аллилового и пропаргилового спиртов, определено положение трехфазного равновесия раствор спирта – гидрат – газ в диапазоне давления от 3,68 до 9,53 МПа. Сравнение полученных данных показало, что в нижней части изученного диапазона давлений равновесные условия гидратообразования для обоих спиртов идентичны, тогда как в верхней части кривая для аллилового спирта отклоняется в область низких температур на 0,6°С. Установлено, что данные спирты являются термодинамическими ингибиторами гидратообразования. С прикладной точки зрения рассматриваемые системы могут использоваться в газовой промышленности для предотвращения гидратообразования и ликвидации сформированных гидратных осложнений.*

**Ключевые слова:** гидрат метана, спирты, фазовые равновесия, термодинамический ингибитор гидратообразования

*M. B. Yarakhmedov<sup>1,2</sup>, D. V. Sergeeva<sup>1</sup>.*

<sup>1</sup>Skolkovo Institute of Science and Technology,

<sup>2</sup>Gubkin University

### **Influence of Allyl and Propargyl Alcohols on Equilibrium Conditions for Methane Hydrate Formation**

*This study examined the stability of methane hydrate at a concentration of 20 mass% in aqueous solutions of allyl and propargyl alcohols. The research determined the position of the three-phase equilibrium "alcohol solution - hydrate - gas" in the pressure range of 3.68 to 9.53 MPa. A comparison of the data revealed that the equilibrium conditions for hydrate formation for both alcohols are the same at lower pressures. However, at higher pressures, the curve for allyl alcohol deviates towards lower temperatures by 0.6°C. The study found that these alcohols act as thermodynamic inhibitors of hydrate formation. From a practical standpoint, these systems can be used in the gas industry to prevent hydrate formation and address issues related to formed hydrates.*

**Key words:** methane hydrate, alcohols, phase equilibria, thermodynamic hydrate inhibitor.

*Л. Н. Корнева<sup>1</sup>, А. А. Кибкало<sup>1</sup>, А. О. Драчук<sup>1</sup>, К. А. Плетнева<sup>1</sup>,*

*П. А. Жингель<sup>1</sup>, Г. Пандей<sup>1,2</sup>, Н. С. Молокитина<sup>1</sup>*

<sup>1</sup>Институт криосферы Земли Тюменский научный центр Сибирского отделения РАН,

<sup>2</sup>Университет нефтяных и энергетических исследований, Дехрадун, Индия

gaurav.pandey@ddn.upes.ac.in, molokitina.nadya@yandex.ru

### **Исследование гидратов углекислого газа в дисперсной системе «сухая вода»**

*В работе исследованы кинетика и равновесные условия образования гидрата углекислого газа в дисперсной системе «сухая вода» с использованием разных типов гидрофобных наночастиц диоксида кремния в изохорных условиях при температуре 273,15 К и начальном давлении около 3 МПа. Исследовано влияние «сухой воды» на кинетику разложения гидратов углекислого газа при давлении ниже равновесного и температуре 268,15 К.*

**Ключевые слова:** газовые гидраты, газогидратные технологии, углекислый газ, утилизация углекислого газа, «сухая вода».

*L.N. Korneva<sup>1</sup>, A.A. Kibkalo<sup>1</sup>, A.O. Drachuk<sup>1</sup>, K.A. Pletneva<sup>1</sup>, P.A. Zhingel<sup>1</sup>, G. Pandey<sup>1,2</sup>, N.S. Molokitina<sup>1</sup>*

<sup>1</sup> Earth Cryosphere Institute, Tyumen Scientific Centre, Siberian Branch of the Russian Academy of Science,

<sup>2</sup> University of Petroleum & Energy Studies (UPES), Dehradun, India

### **Study of Carbon Dioxide Hydrates in the “Dry Water” Dispersed System**

*In this paper, the kinetics and equilibrium conditions of the formation of carbon dioxide hydrate in a dispersed "dry water" system using different types of hydrophobic silicon dioxide nanoparticles under isochoric conditions at a temperature of 273.15 K and an initial pressure of about 3 MPa are studied. The effect of "dry water" on the kinetics of decomposition of carbon dioxide hydrates at a pressure below equilibrium and a temperature of 268.15 K has been studied.*

**Key words:** *gas hydrates, gas hydrate technologies, carbon dioxide, carbon dioxide utilization, dry water.*

*К. А. Плетнева<sup>1</sup>, П. А. Жингель<sup>1</sup>, К. А. Илюшников<sup>1</sup>, А. О. Драчук<sup>1</sup>, Г. Пандей<sup>1,2</sup>, Н. С. Молокитина<sup>1</sup>*

<sup>1</sup>Институт криосферы Земли Тюменский научный центр Сибирского отделения РАН,

<sup>2</sup>Университет нефтяных и энергетических исследований, Дехрадун, Индия

pletnevaklavdia@yandex.ru

### **Влияние хлорида натрия на кинетику гидратообразования метана**

#### **в объемных растворах соевого лецитина**

*В работе представлены результаты исследований термобарических условий и кинетики образования гидрата метана в объемных растворах с концентрацией соевого лецитина 0,5% мас., полученных в дистиллированной и минерализованной воде (содержание NaCl 1 и 3% мас.) при температуре 273,2 К и движущей силе 4 МПа без перемешивания. Определено, что добавка соевого лецитина не приводит к смещению кривой фазового равновесия вода–гидрат–метан. Установлено, что присутствие NaCl приводит к уменьшению поглощения метана в гидрат в два раза в сравнении с раствором соевого лецитина без NaCl, что может быть следствием выпадения соевого лецитина в осадок в солевых растворах.*

**Ключевые слова:** природный газ, транспорт и хранение природного газа, газогидратные технологии, образование газового гидрата, соевый лецитин, растворы NaCl.

*К.А. Pletneva<sup>1</sup>, P.A. Zhingel<sup>1</sup>, К.А. Ilyushnikov<sup>1</sup>, А. О. Drachuk<sup>1</sup>, G. Pandey<sup>1,2</sup>, N. S. Molokitina<sup>1</sup>*

<sup>1</sup> Earth Cryosphere Institute, Tyumen Scientific Centre, Siberian Branch of the Russian Academy of Science,

<sup>2</sup> University of Petroleum & Energy Studies (UPES), Dehradun, India

### **Influence of Sodium Chloride on the Kinetics of Methane Hydrate Formation**

#### **in Bulk Soy Lecithin Solutions**

*This article presents the results of experimental studies of thermobaric conditions and the kinetics of methane hydrate formation in bulk soy lecithin solutions (concentration 0.5 mass%), obtained in distilled and mineralized water at a temperature of 273.2 K and driving force 4 MPa without stirring. It was observed that the addition of soy lecithin does not lead to a shift in the water-methane hydrate-methane equilibrium curve. It was established that the presence of NaCl leads to a 2-fold decrease in the absorption of methane into the hydrate in comparison with a soy lecithin solution without NaCl, which may be a consequence of the precipitation of soy lecithin in mineralized solutions.*

**Key words:** *natural gas, gas transport, gas hydrate technology, methane hydrate formation, soy lecithin, NaCl solution.*

*А. А. Кибкало<sup>1</sup>, Л. Н. Корнева<sup>1</sup>, К. А. Плетнева<sup>1</sup>, П. А. Жингель<sup>1</sup>,*

*А. О. Драчук<sup>1</sup>, Г. Пандей<sup>1,2</sup>, Н. С. Молокитина<sup>1</sup>*

<sup>1</sup>Институт криосферы Земли, Тюменский научный центр Сибирского отделения РАН,

<sup>2</sup>Университет нефтяных и энергетических исследований, Дехрадун, Индия

alexkibkal@gmail.com

### **Влияние поверхностно-активных веществ на кинетику гидратообразования**

#### **в порошковых гидрогелевых системах**

*В работе исследована кинетика гидратообразования в порошковых гидрогелевых системах, насыщенных водными растворами поверхностно-активных веществ и стабилизированных гидрофобными наночастицами. Также было проведено исследование систем на стабильность в многократных циклах образования и диссоциации гидрата, то есть на их способность сохранять изначальную скорость и степень конверсии воды в гидрат во втором и последующих циклах.*

**Ключевые слова:** транспортировка и хранение газа, газовые гидраты, гидратообразование метана, кинетика гидратообразования, многократное гидратообразование, поверхностно-активные вещества, гидрогель.

*A. A. Kibkalo, L. N. Korneva, K. A. Pletneva, P. A. Zhingel, A. O. Drachuk, G. Pandey, N. S. Molokitina.*

<sup>1</sup> Earth Cryosphere Institute, Tyumen Scientific Centre, Siberian Branch of the Russian Academy of Science,

<sup>2</sup> University of Petroleum & Energy Studies (UPES), Dehradun, India

### **Influence of Surfactants on Kinetics of Hydrate Formation**

#### **in Powder Hydrogel Systems**

*In this work, the kinetics of hydrate formation in powder hydrogel systems saturated with aqueous solutions of surfactants and stabilized with hydrophobic nanoparticles was studied. The systems were also studied for stability in multiple cycles of hydrate formation and dissociation, that is, for their ability to maintain the initial rate and degree of conversion of water to hydrate in the second and subsequent cycles.*

**Key words:** gas transportation and storage, gas hydrates, methane hydrate formation, hydrate formation kinetics, multiple hydrate formation, surfactants, hydrogel.

*M. E. Семенов<sup>1</sup>, А. Ю. Манаков<sup>1,2</sup>, А. С. Стопоров<sup>1,2,3</sup>, У. Ж. Мирзакимов<sup>1</sup>, М. А. Варфоломеев<sup>1</sup>*

<sup>1</sup>Казанский федеральный университет,

<sup>2</sup>Институт неорганической химии им. А. В. Николаева Сибирского отделения РАН, г. Новосибирск,

<sup>3</sup>РГУ нефти и газа (НИУ) имени И. М. Губкина,

xotoy\_82@mail.ru

### **Лабораторная установка по получению и прессованию газовых гидратов**

*В данной работе представлена лабораторная установка по получению газового гидрата в статических условиях и прессованию гидратных пеллет непосредственно в самом реакторе. Данная установка предназначена для разработки эффективных методик получения, формования и последующего хранения полученных газовых гидратов. В работе описаны конструкционные особенности установки, последовательность операций по получению гидрата метана и гранул из него, а также приведены примеры экспериментальных данных по ускоренному получению и прессованию гидрата метана из раствора кинетического промотора.*

**Ключевые слова:** газовый гидрат, лабораторная установка, гидратные пеллеты, промотор.

*M.E. Semenov<sup>1</sup>, A.Yu. Manakov<sup>1,2</sup>, A.S. Stoporev<sup>1,2,3</sup>, U.J. Mirzakimov<sup>1</sup>, M.A. Varfolomeev<sup>1</sup>*

<sup>1</sup>Department of Petroleum Engineering, Kazan Federal University,

<sup>2</sup>Nikolaev Institute of Inorganic Chemistry SB RAS,

<sup>3</sup>Gubkin University,

## Laboratory Unit for Producing and Pelletizing Gas Hydrates

*This paper introduces a laboratory setup designed to produce gas hydrate under static conditions and to compress hydrate pellets directly within the reactor. The installation is intended to facilitate the development of effective methods for obtaining and storing gas hydrates. The paper discusses the design specifics of the installation, outlines the sequence of operations for producing methane hydrate and granules from it, and provides examples of experimental data related to the accelerated production and compression of methane hydrate from a kinetic promoter solution.*

**Key words:** gas hydrate, laboratory installation, pellets, promoter.

*Ш. Э. Гайнуллин<sup>1,2</sup>, П. Ю. Казакова<sup>1</sup>, Р. С. Павельев<sup>1,2</sup>,  
Ю. Ф. Чиркова<sup>1</sup>, М. Е. Семенов<sup>1,3</sup>, М. А. Варфоломеев<sup>1</sup>*

<sup>1</sup>Казанский федеральный университет,

<sup>2</sup>Казанский национальный исследовательский технологический университет,

<sup>3</sup>Институт проблем нефти и газа Сибирского отделения РАН, г. Якутск,  
gravelyev@gmail.com

### **Новые промоторы на основе аминокислот и лимонной кислоты для эффективного хранения метана в виде газовых гидратов**

*В работе разработаны новые производные некоторых аминокислот на основе лимонной кислоты, которые улучшают кинетику образования гидрата метана при низких концентрациях. Эти соединения могут стать потенциальными эффективными промоторами гидратообразования, не образующими пены при извлечении газа из гидратов. Показано, что модификация аминокислот лимонной кислотой повышает их эффективность в качестве кинетических промоторов образования гидрата метана по сравнению с чистыми аминокислотами. Это проявляется в снижении времени индукции, времени достижения максимальной конверсии воды в гидрат и увеличении поглощения метана. Модификация норлейцина с образованием амида норлейцина и лимонной кислоты способствует увеличению конверсии воды в гидрат. Для растворов с концентрацией 0,05% мас. конверсия увеличилась на 5% до 89%, что соответствует поглощению 0,148 моль метана на 1 моль воды. Также при модификации норлейцина снижается время индукции в 1,6 раз, а время достижения максимальной конверсии в 2,8 раз по сравнению с немодифицированным норлейцином.*

**Ключевые слова:** газовые гидраты, гидрат метана, хранение природного газа, промотирование гидратообразования, аминокислоты, лимонная кислота, кинетические промоторы, промоторы образования гидратов метана.

*Sh.E. Gainullin<sup>1,2</sup>, P.Yu. Kazakova<sup>1</sup>, R.S. Pavelyev<sup>1,2</sup>, Yu.F. Chirkova<sup>1</sup>, M.E. Semenov<sup>1,3</sup>, M.A. Varfolomeev<sup>1</sup>*

<sup>1</sup> Kazan Federal University,

<sup>2</sup> Kazan National Research Technological University,

<sup>3</sup> Institute of Oil and Gas Problems, Siberian Branch of the Russian Academy of Sciences, Yakutsk

### **New Promoters Based on Amino Acids and Citric Acid for Efficient Storage of Methane as Gas Hydrates**

*In this study, new derivatives of some amino acids based on citric acid were developed that improve the kinetics of methane hydrate formation at low concentrations. These compounds could be potential effective hydrate formation promoters that do not form foam during gas extraction from hydrates. Modification of amino acids with citric acid has been shown to increase their effectiveness as kinetic promoters of methane hydrate formation compared to pure amino acids. This is manifested by decreased induction time, time to reach maximum water to hydrate conversion, and increased methane uptake. For example, modification of norleucine to form the amide of norleucine and citric acid (promotes an increase in the conversion of water to hydrate. Thus for solutions with 0.05 mass% concentration, the conversion increased by 5% to reach a level of 89%, which corresponds to an uptake of 0.148 mol of methane per 1 mol of water. Also, for CTR+Nle, the induction time decreased 1.6-fold to 27 min and the time to reach the maximum conversion 2.8-fold to 120 min compared to unmodified norleucine.*

**Key words:** *gas hydrates, methane hydrates, natural gas storage, promotion of hydrate formation, amino acids, citric acid, kinetic promoters, methane hydrate promoters.*

**A. С. Портнягин<sup>1</sup>, И. К. Иванова<sup>1</sup>, Л. П. Калачева<sup>1</sup>, В. К. Иванов<sup>1</sup>, В. В. Портнягина<sup>2</sup>**

<sup>1</sup> Институт проблем нефти и газа Сибирского отделения РАН – обособленное подразделение ФИЦ ЯНИЦ СО РАН, г. Якутск,

<sup>2</sup>Северо-Восточный Федеральный университет им. М. К. Аммосова, г. Якутск, al220282@mail.ru

### **Особенности термодинамических условий образования и состав газа в гидратах природного газа, полученных в засоленной хлоридом кальция дисперсной среде**

*В работе приведены результаты изучения термодинамических условий образования гидратов природного газа в дисперсной среде, насыщенной водой, растворами полимеров и их смесями с раствором CaCl<sub>2</sub>, а также состава газа в получаемых в гидратах. Установлено, что природный газ во всех исследованных системах образует смесь гидратов метана (гидрат кубической структуры I; первая ступень) и природного газа (гидрат кубической структуры II; вторая ступень). Равновесные условия образования гидратов второй ступени смещены по термической шкале в область высоких температур на 0,5–1°С относительно расчетной равновесной кривой для исходного природного газа, вероятно это вызвано концентрированием в составе гидрата гомологов метана C<sub>2</sub>–C<sub>4</sub>. Наличие соли CaCl<sub>2</sub> приводит к смещению равновесных условий образования гидратов второй ступени по сравнению с расчетными кривыми в область высоких температур и низких давлений, с увеличением доли компонентов C<sub>2</sub>–C<sub>4</sub> в гидратах. Особенностей влияния соли CaCl<sub>2</sub> на термодинамические условия образования гидратов природного газа в дисперсной среде в смеси с растворами полимеров не выявлено, так как полученные данные равновесных условий образования гидратов природного газа совпадают с данными, полученными при образовании гидратов в растворах CaCl<sub>2</sub> и воды.*

Ключевые слова: газы гидраты, природный газ, дисперсная среда, растворы полимеров, хлорид кальция.

**A. S. Portnyagin<sup>1</sup>, I. K. Ivanova<sup>1</sup>, L. P. Kalacheva<sup>1</sup>, V. K. Ivanov<sup>1</sup>, V. V. Portnyagina<sup>2</sup>**

<sup>1</sup>Federal Research Center "Yakut Scientific Center of Siberian Branch of the Russian Academy of Sciences", a Separate Division Institute of Oil and Gas Problems SB RAS, Yakutsk, Russia

<sup>2</sup>M. K. Ammosov North-Eastern Federal University, Yakutsk, Russia



## **Features of Thermodynamic Conditions of Formation and Gas Composition in Natural Gas Hydrates Obtained in a Dispersed Medium Salted with Calcium Chloride**

*Results are given for a study of the thermodynamic conditions of the natural gas hydrates formation in a dispersed medium saturated with water, polymer solutions and their mixtures with a  $\text{CaCl}_2$  solution, as well as the composition of the gas in the obtained hydrates. It has been established that natural gas in all studied systems forms a mixture of methane hydrates (first-stage hydrate) and natural gas (second-stage hydrate). The equilibrium conditions of the second-stage hydrates formation are shifted along the thermal scale to the region of high temperatures by  $0.5\text{--}1^\circ\text{C}$  relative to the calculated equilibrium curve for the initial natural gas, this is probably caused by the concentration of  $\text{C}_2\text{--C}_4$  methane homologues in the hydrate. The presence of salt  $\text{CaCl}_2$  leads to a shift in the equilibrium conditions of the second-stage hydrates formation compared to the calculated curves to the region of high temperatures and low pressures, with an increase of the content of  $\text{C}_2\text{--C}_4$  components in the hydrates. No specific influence of the  $\text{CaCl}_2$  salt on the thermodynamic conditions of the natural gas hydrates formation in a dispersed medium with a mixture with polymer solutions was revealed, since the obtained data on the equilibrium conditions of the natural gas hydrates formation coincide with the data obtained for the formation of hydrates in solutions of  $\text{CaCl}_2$  and water.*

**Key words:** gas hydrates, natural gas, gas composition in the hydrate, dispersed medium, polymer solutions, calcium chloride.

**Л. П. Калачева, И. К. Иванова, А. С. Портнягин, В. К. Иванов, А. Р. Бубнова, К. К. Аргунова**

Институт проблем нефти и газа Сибирского отделения РАН –  
обособленное подразделение ФИЦ ЯНЦ СО РАН, г. Якутск,  
lpko@mail.ru

### **Экспериментальное изучение влияния ионов $\text{HCO}_3^-$ и $\text{Cl}^-$ на гидратообразование природного газа в пористой среде**

*В работе изучены процессы образования и разложения гидратов в системах природный газ – песок – 5% мас. раствор  $\text{NaHCO}_3$  и природный газ – песок – 5% мас. раствор  $\text{NaCl}$  методом дифференциального термического анализа при начальных давлениях газа от 3 до 9 МПа. Определены равновесные условия, энтальпии диссоциации и кинетические параметры процесса образования гидратов.*

*Процесс гидратообразования в системе, содержащей раствор гидрокарбоната натрия, характеризуется более высокими температурами и низкими давлениями, а также более высокими кинетическими характеристиками по сравнению с системой с хлоридом натрия при одинаковой концентрации растворов. Показано, что одним из факторов, влияющих на образование гидратов в исследованных системах, является состав растворов. Установлено более сильное структурообразующее действие иона  $\text{HCO}_3^-$  по сравнению с ионом  $\text{Cl}^-$ , что и вызывает разницу в термодинамических условиях и кинетических параметрах гидратообразования природного газа в пористой среде.*

**Ключевые слова:** гидраты природного газа, кварцевый песок, гидрокарбонат и хлорид натрия, кинетические параметры образования гидратов, структура воды, структурообразователь, структуроразрушитель.

**L. P. Kalacheva, I. K. Ivanova, A. S. Portnyagin, V. K. Ivanov, A. R. Bubnova, K. K. Argunova**

Federal Research Center Yakut Scientific Center SB RAS - a separate division of the Institute of Oil and Gas Problems SB RAS, Yakutsk, Russia

## **Experimental Study of the Influence of $\text{HCO}_3^-$ and $\text{Cl}^-$ Ions on Natural Gas Hydrate Formation in a Porous Medium**

*The processes of hydrate formation and decomposition in natural gas – sand – 5% wt.  $\text{NaHCO}_3$  solution and natural gas – sand – 5% wt.  $\text{NaCl}$  solution systems were studied by differential thermal analysis at initial gas pressures ranging from 3 to 9 MPa. Equilibrium conditions, the enthalpy of dissociation and the kinetic parameters of the hydrate formation were determined. It was found that the process of hydrate formation in a system containing sodium bicarbonate solution is characterized by lower pressures, higher temperatures and kinetic characteristics compared to systems with sodium chloride solutions at the same solution concentrations. This suggests that the composition of the solution has a significant effect on hydrate formation within the studied systems. A stronger structure-making effect of the  $\text{HCO}_3^-$  ion has been established compared to the  $\text{Cl}^-$  ion, which causes a difference in thermodynamic conditions and kinetic parameters of the natural gas hydrate formation in a porous medium.*

**Key words:** *natural gas hydrate, quartz sand, bicarbonate and sodium chloride, kinetic parameters of hydrate formation, water structure, structure maker, structure breaker.*

***M. E. Семенов<sup>1,2</sup>, У. Ж. Мирзакимов<sup>1</sup>, М. Б. Ярахмедов<sup>3</sup>, А. С. Стопоров<sup>1,3</sup>***

<sup>1</sup>Казанский федеральный университет,

<sup>2</sup>Институт проблем нефти и газа Сибирского отделения РАН, Якутск,

<sup>3</sup>РГУ нефти и газа (НИУ) имени И. М. Губкина,

hotoy\_82@mail.ru

## **Изучение влияния промоторов на процесс образования гидрата попутного нефтяного газа в статических условиях**

*В этой работе экспериментально исследован процесс образования гидрата попутного нефтяного газа (ПНГ) из замороженных растворов в присутствии промоторов (додецилсульфат натрия и три-сульфированное касторовое масло) в статических условиях. Изучение проводилось с помощью метода дифференциальной сканирующей калориметрии. Анализ фазовых изменений (кристаллизация льда и/или гидрата, совместное плавление льда и образование гидрата) и визуализация процесса формирования гидрата способствовали определению факторов, влияющих на интенсивность роста гидрата ПНГ в изучаемых условиях. Показано, что в случае гидрата ПНГ наличие и тип промотора оказывают решающее влияние на скорость роста гидратов, тогда как протокол их получения больше влияет на воспроизводимость процесса.*

**Ключевые слова:** газоды гидраты, плавление льда, попутный нефтяной газ, промоторы, дифференциальная сканирующая калориметрия.

***M.E. Semenov<sup>1,2</sup>, U.Z. Mirzakimov<sup>1</sup>, M.B. Yarakhmedov<sup>3</sup>, A.S. Stoporev<sup>1,3</sup>***

<sup>1</sup>Kazan Federal University,

<sup>2</sup>Institute of Oil and Gas Problems SB RAS, Yakutsk,

<sup>3</sup>Gubkin University

## **Effect of Promoters on the Formation of Associated Petroleum Gas Hydrate under Static Conditions**

*This study investigated the formation of associated petroleum gas (APG) hydrate from frozen solutions of promoters (sodium dodecyl sulfate and trisulfonated castor oil) under static conditions. The experiment utilized differential scanning calorimetry to analyze phase changes, such as ice crystallization, hydrate formation, and joint ice melting and hydrate formation. The visualization of the hydrate formation process helped identify factors that influence APG hydrates' growth under the given conditions. The study concluded that the type and presence of promoters significantly affect the growth rate of hydrates, while the preparation protocol has a greater impact on the reproducibility of the process.*

**Key words:** gas hydrates, ice melting, associated petroleum gas, promoters, differential scanning calorimetry.

***П. Ю. Казакова, Р. С. Павельев, Д. О. Гнездилов, Ю. Ф. Чиркова, Е. Р. Сон, М. А. Варфоломеев***

Казанский федеральный университет,

pravelyev@gmail.com

**Низкодозируемые ингибиторы гидратообразования на основе сополимеров малеинового ангидрида**

**с изопропилакриламидом, амидированные дибутиламинопропиламином**

*Изучено влияние сополимеров на основе малеинового ангидрида и изопропилакриламида на процесс образования гидрата метан-пропановой смеси. Реакцию полимеризации проводили в петролейном эфире и диметилформамиде, затем цикл малеинового ангидрида раскрывали дибутиламинопропиламином. Часть полученных полимеров при концентрации 0,5% мас. продемонстрировала понижение температуры начала гидратообразования и конверсию газа в гидрат на уровне коммерческих кинетических ингибиторов гидратообразования Luvicap EG и PNIPAM. Наилучшие результаты по переохлаждению показал образец с повышенным содержанием фрагмента изопропилакриламида. Наименьшая конверсия газа в гидрат наблюдалась для системы, содержащей гомополимер малеинового ангидрида, модифицированного дибутиламинопропиламином*

**Ключевые слова:** газовые гидраты, природный газ, кинетические ингибиторы гидратообразования, полималеаты.

***P. Yu. Kazakova, R. S. Pavelyev, D. O. Gnezdilov, Yu. F. Chirkova, E. R. Son, M. A. Varfolomeev***

Kazan Federal University

**Low-Dose Hydrate Formation Inhibitors Derived from Copolymers of Maleic Anhydride and Isopropylacrylamide Amidated by Dibutylaminopropylamine**

*The effect of copolymers based on maleic anhydride and isopropylacrylamide on the formation of methane-propane hydrate was studied. The polymerization reaction was carried out in petroleum ether and dimethylformamide, then maleic anhydride cycle was opened by dibutylaminopropylamine. Some of the obtained polymers at a concentration of 0.5% wt. demonstrated a decrease in the temperature of hydration onset and gas to hydrate conversion at the level of commercial kinetic hydrate inhibitors such as Luvicap EG and PNIPAM. The sample with higher isopropylacrylamide fragment content showed the best supercooling results. The lowest gas to hydrate conversion was observed for the system containing maleic anhydride homopolymer modified with dibutylaminopropylamine.*

**Key words:** gas hydrates, natural gas, kinetic inhibitors of hydrate formation, polymaleates.

**E. V. Grokhotova**<sup>1✉</sup>, **I. F. Idiatullina**<sup>2</sup>

<sup>1</sup> Ufa State Petroleum Technological University; <sup>2</sup> Transneft Ural, Subkhankulovo Linear Production and Dispatch Station.

ketrin2306@yandex.ru

### **Processing of the Arctic Shelf Oil**

*This article presents the results of studies into the physicochemical properties of Arctic crude oil and its fractions. According to its characteristics and group composition, the Arctic shelf oil is a bituminous, high-sulfur, and low-paraffin oil with the content of light fractions less than 50 wt %. Approaches to its refining are proposed.*

**Keywords:** Arctic shelf oil, diesel fuel, marine fuel, petroleum bitumen, fractional composition, hydrocarbon composition.

**L. L. Telyashov**<sup>1✉</sup>, **L. P. Trofimova**<sup>2</sup>

<sup>1</sup> SPC «SigmaTechPro» LLC, Nikolaev, Ukraine;

<sup>2</sup> Institute of Pulse Processes and Technologies of the National Academy of Sciences of Ukraine, Nikolaev, Ukraine.

cavitatijet40@gmail.com

### **Ignition Features of a High-Voltage Electric Discharge in Water under Conditions of Deep Oil Wells**

*Approaches to improving the electrode system of submersible electrohydropulse devices used for treating the bottom-hole zone of deep oil wells are analyzed with the purpose of increasing the oil flow rate at a hydrostatic pressure of up to 50 MPa and electric field strengths within the range of  $(0.5-1.5) \cdot 10^7$  V/m. The feasibility of increasing the voltage at the dielectric-liquid-metal interface up to  $E_{ign} = 3 \cdot 10^7$  V/m to ignite a discharge under high pressure conditions is demonstrated. The hysteresis of breakdown voltage in various liquids, such as an invert water-in-oil emulsion, formation water, and process water, is described and analyzed. Experiments are carried out at different values of hydrostatic pressure in the well. A possible mechanism for the appearance of hysteresis during repeated breakdowns of liquids during a decay and rise in operating voltage is explained. The necessity of taking the hysteresis effect into account when calculating the discharge ignition intensity in deep wells is shown. The efficiency of the impact of breakdown and corona discharges in water on the bottom-hole zone is compared. Options for using electrode systems with an increased electric field strength in the area of the pulse shaper in electrohydropulse devices for treating wells are shown. These include a dielectric patch with a small hole on the flat part of the working electrode. Types of plastic materials that could increase the level of electric field strength and carry out the required number of stable breakdown discharges for one hoisting operation, at least  $4.0 \cdot 10^4$  pulses, are described.*

**Keywords:** electrohydropulse device, high-voltage electric discharge, electrode system, intensification of oil production, hydrostatic pressure, breakdown voltage hysteresis.

**Pan Jie<sup>1</sup>, Guo Xiaochao<sup>2</sup>, Gu Tuan<sup>2</sup>, Yang Shugang<sup>2</sup>, Yang Rui<sup>3</sup>, Gong Hujun<sup>1</sup>**

<sup>1</sup> Department of Geology, Northwest University/State Key Laboratory of Continental Dynamics, Xi'an, Shaanxi, China;

<sup>2</sup> Liaohe Oilfield Exploration and Development Research Institute, Panjin, Liaoning, China;

<sup>3</sup> Civil Aviation Flight University of China, Guanghan, Sichuan, China.

15608106086@163.com

### **Characterization of Carbonate Reservoirs and Main Controlling Factors Research**

*This study deeply explores the characteristics of the dolomite reservoir and its controlling factors in the Ordovician Majiagou Formation in the southern Gaoqiao area of the Jingbian gas field in the Ordos Basin, aiming to provide a more accurate scientific basis for oil and gas exploration. The study reveals the petrological characteristics and reservoir properties of the reservoir through core analysis, thin-section observation and porosity and permeability testing. The results show that the reservoir in this area is dominated by mud-crystalline dolomite and crystalline dolomite, especially mud-crystalline dolomite shows excellent storage and permeability performance due to the development of pore-soluble pores. The porosity mainly ranges from 2% to 6%, with an average porosity of 3.03%, and the permeability mainly ranges from 0.01 to 5 mD, with an average of 2.14 mD. The analysis of the main controlling factors of the reservoir shows that karst plays a decisive role in the development of dolomite reservoirs, and especially the formation and distribution of the paste-solution pores have a significant influence on the storage and seepage performance. The depositional characteristics of gypsum nodules and their distribution pattern during the rock-forming process have an important influence on the porosity and permeability of the reservoir. Differences in the physical properties of the reservoir in the sedimentary microphase environment have a significant impact on the reservoir performance, in which the microphase reservoir containing gypsum cloud ping exhibits higher porosity and permeability. In addition, reservoir destructive primary control factors, such as compaction and pressure-solubilization effects and cementation and filling effects, negatively affected reservoir properties. Taken together, this study provides important scientific support for understanding the formation mechanism of dolomite reservoirs in the region, assessing the hydrocarbon resource potential, and guiding future exploration activities.*

**Keywords:** carbonate rocks, Jingbian gas field, Mawu<sub>1+2</sub>, reservoir characterization; main control factors.

**Jiang Guipu, Zhao Hui✉, Fu Bin, Hu Shuo**

The Fourth Oil Production Plant of Daqing Oil Field Co., Ltd., Daqing, Heilongjiang, China.

dongkangxing@163.com

### **Influence of Perforation on Fracture Initiation in Horizontal Wells and Parameter Optimization**

*Segmented multi-cluster fracturing is a key technology for unconventional reservoir development, and injection parameters have a significant impact on frictional resistance and fracture initiation pressure. A numerical model of dynamic fracking fracture propagation in horizontal wells was established by considering the flow distribution between the cluster perforations, the stress interference between the fractures, and the fluid-structure interaction, while the impact of various perforation parameters on the perforation friction and initiation pressure was investigated. The numerical simulation results showed that a more significant perforation density, aperture, and depth*

*decreased the hydraulic fracture initiation pressure. The initiation pressure displayed an initial decline at a higher perforation azimuth angle, followed by an increase while exhibiting a decreasing-increasing-decreasing fluctuation trend at a higher perforation phase angle. By extracting the influence of different apertures and hole numbers on the wellbore friction, The optimization template for perforation diameter and perforation quantity corresponding to different hole friction in flow limiting fracturing is provided. This provides theoretical support for optimizing the perforation parameters of segmented cluster fracturing in horizontal wells.*

**Keywords:** *perforation parameters, crack initiation pressure, multiple crack propagation, sensitivity, preferred template.*

**Xiaoping Gao<sup>1</sup>, Jingming Fan<sup>2</sup>, Miao Yu<sup>2</sup>, Zhanjun Chen<sup>3✉</sup>, Heng Zhang<sup>1</sup>, Feilong Gao<sup>1</sup>,**

**Zhenhua Li<sup>3</sup>, Yanju Li<sup>3</sup>**

<sup>1</sup> Yanchang Oilfield Co., Ltd., Yan'an, China;

<sup>2</sup> The No 3 Oil Production Plant of Daging Oilfield Limited Company, Daqing, China;

<sup>3</sup> Longdong University, Qingyang, China

*chenzhenqcfdc818@163.com*

### **Saturation Prediction of Specific Tight Sandstone Reservoirs Based on Experimental Analysis of Oil-Water Relative Permeability**

*The isotonic point of the Chang-6 tight oil reservoir in the Qilicun Oilfield in the Ordos Basin cannot be determined from experimental data on the waterflooding permeability. Furthermore, there are missing data near the isotonic point. Previous research on phase permeability trends has uncovered significant uncertainties in the application of data normalization, standardization, and interpolation processing. In current research, there is a consensus on the existence of a relationship between the relative permeability and saturation indices. However, since measurements contain relative permeabilities of 0, coefficient indices cannot be directly derived. Researchers have theorized that the first data number in the wet phase relative permeability must be changed from a 0 to non-0 minimum in order to directly establish the relationship between the relative permeability and the water saturation index. The missing intervals after the first data point are not interpolated. Not only does this method incorporate the knowledge of the permeability indices obtained by researchers, but it also eliminates the processes of normalization, standardization, and interpolation of missing data intervals for permeability data in order to avoid errors introduced by these processes. Without introducing new parameters, interference with raw data was reduced and the accuracy was improved. The results indicate that the relative permeability is highly correlated with the water saturation indices. Furthermore, the relationships between the water content and relative permeability and between the water saturation and water content were analyzed using the Leverett displacement function and percolation theory. The water saturation corresponding to the water content of 17 samples was calculated under the condition of displacement, and the relationship between the critical water saturation and water content was further established. These results provide support for studies on the relationship between phase permeability and oil-water saturation within this area.*

**Keywords:** *saturation prediction, waterflooding permeability, water content, tight sandstone.*

Xiaoyu Gu<sup>1,2✉</sup>, Weixuan Zhao<sup>3</sup>, Feng Jiang<sup>3</sup>, Xiaojun Cai<sup>3</sup>, Wei Zhao<sup>4</sup>, Feifei Huang<sup>5</sup>,

Shaofei Kang<sup>5</sup>, Xiaolong Hu<sup>6</sup>

<sup>1</sup> School of Petroleum Engineering in Xi'an Shiyou University, Xi'an, Shaanxi, China;

<sup>2</sup> Engineering Research Center of Development and Management for Low to Extra-Low Permeability Oil & Gas Reservoirs in West China, Ministry of Education, Xi'an, Shaanxi, China;

<sup>3</sup> No. 11 Oil Production Plant, Changqing Oilfield Company, Qingyang, Gansu, China;

<sup>4</sup> No. 5 Oil Production Plant, Changqing Oilfield Company, Xi'an, Shaanxi, China;

<sup>5</sup> School of Petroleum Engineering and Environmental Engineering, Yan'an University, Yan'an, Shaanxi, China;

<sup>6</sup> No. 2 Production of XinJiang OilField Company, Xinjiang, Karamay, China.

jk15100541199@163.com

### **Characterization of Pore Structure and Thermal Evolution of Shale**

*The porosity and pore structure of mud shales are crucial for shale oil and gas storage and transportation. Although the change of organic matter state in thermal evolution has a significant effect on pore formation, the mechanism and main controlling factors still need to be deeply explored. In this paper, we selected the shale of the Yanchang Formation in the southeastern Ordos Basin as an object, and used low-pressure N<sub>2</sub>/CO<sub>2</sub> adsorption, He density method, high-pressure mercury compression, and field FE-SEM to deeply investigate the relationship between thermal evolution and pore development in organic matter-rich shale. The experimental results show that FE-SEM observation reveals that the organic matter pores of the shale in the Long 7 section of the Extension Formation show four developmental states, in which the organic matter in the undeveloped pores is mainly of higher plant origin, solid asphalt and laminated organic matter. The organic matter with highly developed pores is nanofibrous, similar to extracellular polymers. Comparison of thermal simulation experiments shows that the high-pressure semi-closed system has stronger hydrocarbon drainage strength than the closed glass tube system. In the oil generation stage, the pore volume of both systems decreased, mainly due to oil filling; while the oil cracking stage was the main pore development period, especially in the high-pressure semi-closed system; Simulation experiments with different organic matter types and contents showed that the mud shale with better organic matter type and TOC content was more prone to hydrocarbon drainage and pore growth. Compared with type II/II mud shale, type I and II are more likely to form macropores, and compaction has an inhibitory effect on the formation of macropores. This study reveals the close relationship between the pore development of mud shale and its thermal evolution of organic matter, which provides an important reference for shale oil and gas exploration.*

**Keywords:** organic matter, pore structure, thermal evolution, hydrocarbon drainage, extension group.

Xiaolong Ma<sup>1</sup>, Ye Zhang<sup>2</sup>, Shigao Xu<sup>3</sup>, Qike Wang<sup>3</sup>, Shenglai Guo<sup>4✉</sup>, Feng Shi<sup>5</sup>, Wei Xu<sup>6</sup>

<sup>1</sup> Well Cementing Company, SINOPEC Zhongyuan Petroleum Engineering Co. Ltd., Puyang, China;

<sup>2</sup> The 1st Cementing Branch of CNPC Bohai Drilling Engineering Company Limited, Renqiu, China;

<sup>3</sup> The 2nd Cementing Branch of CNPC Bohai Drilling Engineering Company Limited, Tianjin, China;

<sup>4</sup> College of Petroleum Engineering, China University of Petroleum, Qingdao, China;

<sup>5</sup> Cementing Technology Service Center of Sinopec Shengli Petroleum Engineering Co., Ltd., Dongying, China;

<sup>6</sup> Management Center of Oil and Gas Exploraton, Shengli Oilfield Company, SINOPEC, Dongying, China.

guoshenglai@upc.edu.dn

## **Effect of pH of Synthetic Solution on the Performance of the Fluid Loss Control Additive Used in Oil Well Cement**

*The retarding side effect and the compatibility with other additives are the main problem to limit the field application of the fluid loss control additive (FLCA) synthesized. The effect of the pH of the synthetic solution, and the type of carboxylic acid group on the retarding side effect and the compatibility with the retarder AMPS-IA synthesized by 2-acrylamido-2-methyl propane sulfonic acid (AMPS) and itaconic acid (IA), and the influence mechanism was studied in this paper. The pH value of the synthetic solution has a significant impact on the performance of fluid loss agents containing different carboxylic acid groups. For fluid loss control additive containing maleic acid (MA), as the pH value of the synthesized solution gradually increases, the compatibility between the fluid loss agent and the retarder gradually deteriorates, but the side effects of the retarder gradually decrease. For water loss agents containing IA, as the pH value of the synthesized solution gradually increases, the compatibility between the fluid loss agent and the retarder first improves and then gradually deteriorates. The compatibility is best at pH 7, but the side effects of the retarder gradually decrease. For fluid loss agents containing acrylic acid (AA), as the pH value of the synthesized solution gradually increases, the compatibility between the fluid loss agent and the retarder first deteriorates and then gradually improves. The compatibility is best at pH 12. Overall, the fluid loss control additive containing MA has the best compatibility with the retarder, and the side effects of the retarder are not strong, resulting in the best overall performance.*

**Keywords:** fluid loss control additive, cement, retarder, carboxylic group, pH.

**Shujie Liu<sup>1,2,3</sup>, Haodong Chen<sup>1,2,3</sup>, Donglei Jiang<sup>1,2,3</sup>, Yanhui Wu<sup>1,2,3</sup>,  
Yupeng Yang<sup>1,2,3</sup>, Yu Gao<sup>1,2,3</sup>, Hongyu Wan<sup>4,5</sup>, Xun Zhang<sup>4,5</sup>✉**

<sup>1</sup> CNOOC China Limited, Hainan Branch, Haikou, China;

<sup>2</sup> CNOOC South China Sea Oil & Gas Energy Academician Workstation, Haikou, China;

<sup>3</sup> Key Laboratory of Deep Sea Deep Formation Energy Engineering of Hainan Province, Haikou, China;

<sup>4</sup> College of Safety and Ocean Engineering, China University of Petroleum-Beijing, Beijing, China;

<sup>5</sup> Key Laboratory of Oil and Gas Safety and Emergency Technology, Ministry of Emergency Management, Beijing, China.

wanhongyude@126.com

## **Numerical Simulation Investigation of Lateral Bearing Characteristics of Deepwater Expandable Conductors**

*Deep water poses challenges for conventional surface conductors due to soft seabed soil. The current installation methods are time-consuming and risky, leading to sinking and instability. A new high-bearing capacity surface conductor is essential. This study investigates lateral bearing characteristics of deepwater expandable surface conductors. A mechanical model was established based on fundamental mechanics principles. Three types of expandable conductors were designed, varying expansion material distribution. The study compares lateral bearing characteristics, analyzes changes in bearing capacity based on soil parameters and expansion material section, and demonstrates enhanced bearing capacity of the new conductors compared to traditional ones. This research supports expandable surface conductor design and numerical simulations in surface well construction.*

**Keywords:** drilling, deepwater drilling, surface conductor, expandable conductor, bearing characteristics.



**Xueni Yin<sup>1,2✉</sup>, Hongzhi Liu<sup>3</sup>, Chao Yang<sup>4</sup>**

<sup>1</sup> School of Foreign Languages, Mianyang Teachers' College, Mianyang, China;

<sup>2</sup> Research Center for China's Neighboring Countries, Mianyang, China;

<sup>3</sup> Mianyang Flight College of Civil Aviation Flight University of China, Mianyang, China;

<sup>4</sup> Technology Inspection Center of Shengli Oilfield, SINOPEC, Dongying, China.

*yx721@163.com*

### **Research Status and Prospect of Rheology of Waxy Crude Oil**

*In this paper, the rheological properties and viscosity reduction mechanism of waxy crude oil were reviewed. Firstly, the rheological behavior of waxy crude oil was introduced from the aspects of microscopic properties, viscosity, yield properties, thixotropy and viscoelasticity. Secondly, the effects of dissolved gas, light crude oil or alcohol on the rheological properties of crude oil were described respectively. Finally, the shortcomings and limitations of existing studies were further prospected. The future research will focus on exploring the mechanism of the effect of shear history on the microstructure of wax crystals, and establishing the constitutive model of crude oil considering the yield strain and yield stress based on the morphological and structural changes of wax crystals. Furthermore, to explore the mechanism and influence law of light component dissolution on crude oil rheology, and establish a reliable viscoelastic-thixotropic model of crude oil under the conditions of unsteady shear, wide range shear rate and ultra-low shear rate, will be the prerequisite and basis for the numerical calculation in restarting of gelled crude oil containing light component at low temperature.*

**Keywords:** *waxy crude oil, rheology, thixotropy, dissolved light component, restarting.*

**Zebo Yuan<sup>1</sup>, Xiangjuan Meng<sup>2</sup>, Yongcang Ren<sup>1</sup>, Changmin Zeng<sup>1</sup>, Yige Wu<sup>1</sup>, Jiani Li<sup>1</sup>, Shijun Chen<sup>3✉</sup>**

<sup>1</sup> Experimental and Testing Research Institute, Traim Oilfield Company, PetroChina, Korla, Xinjiang, China;

<sup>2</sup> Scientific and Technological Management Department, Traim Oilfield Company, PetroChina, Korla, Xinjiang, China;

<sup>3</sup> College of Chemistry and Chemical Engineering, Xi'an Shiyou University, Xi'an, Shaanxi, China.

*shay1579@126.com*

### **Experimental Study on the Synergistic Effect of «Dispersion-Chelation-Dissolution» on the Removal of Trithiane Blockages in Gas Wells**

*Natural gas has become an important replacement resource for conventional oil and gas resources. However, the generation of trithiane blockages during gas well development can affect the development efficiency and wellbore safety of the gas well. Unfortunately, the current research on the formation mechanism of blockages in wellbore and their removal processes is not yet complete, and cannot provide theoretical support for the removal of blockages in deep-water gas wells. In this study, based on the validation of the adaptability of the experimental system and methods, the composition of wellbore blockages during gas well development was analyzed. Then, the mechanism of dispersion chelation dissolution synergistic unblocking was explored, and the influence of factors such as wellbore temperature was studied. Research has found that blockages in the wellbore are mainly composed of calcium*

carbonate (accounting for up to 61.3%), and contain a certain amount of highly corrosive iron sulfide and calcium sulfate. Moreover, the dissolution rate of trithiane wellbore blockages by the unblocking system will significantly increase with the increase of temperature. However, when the wellbore temperature exceeds 140°C, the promotion effect of the increase in wellbore temperature on the accelerated dissolution rate of blockages is significantly weakened. At the same time, the dissolution rate of wellbore blockages will increase with the increase of chelating agent concentration within the low chelating agent concentration range. However, when the concentration of chelating agent is higher than 5.0 wt%, the dissolution rate of wellbore blockage will slowly decrease with the increase of chelating agent concentration. Finally, on-site application found that the wellhead pressure and gas production both returned to the level before the wellbore blockage after the removal of the trithiane blockage in the wellbore, and there were no repeated wellbore blockages in the following year.

**Keywords:** trithiane, collaborative unblocking, wellbore flow, chelating agent concentration.

**Jian Yang**<sup>✉</sup>

Guangzhou City University of Technology, Guangzhou, China.

yangjian@gcu.edu.cn

### **Some Approach to Active Disturbance Rejection Control in Fuel Cells Regarding Air Inlet Flow Control**

Air inlet flow control is critical for performance of Proton Exchange Membrane Fuel Cells (PEMFC). An essential gauge for air input flow is the oxygen excess ratio (OER). However, accurate controlling for OER is a huge challenge because of the erroneous modeling, imprecise parameter values, and disturbances. An Active Disturbance Rejection Control (ADRC) approach is suggested in this research as a means of resolving the issue of fuel cells' internal and exterior interference. Firstly, the total disturbance is obtained using an extended state observer. Secondly, the total disturbance is compensated before the control action to determine the control quantity for air supply, which is further controlled by modifying the air compressor's voltage. The performance comparison between the suggested approach and PID and fuzzy PID control shows that the proposed technique can achieve a higher reliability for managing the mechanical faults of the air compressor. In addition, the root mean square error (RMSE) of control time and overshoot is smaller.

**Keywords:** proton exchange membrane fuel cell, active disturbance rejection control, oxygen excess ratio, total disturbance.

**Ting Deng<sup>1</sup>, Weina Li<sup>2</sup>, Qing Hua<sup>1</sup>, Gang Wang<sup>2</sup>, Yang Xiang<sup>1</sup>, Shengfeng Yang<sup>2✉</sup>**

<sup>1</sup> Chongqing Gas Mine, PetroChina Southwest Oil & Gasfield Company, Chongqing, China;

<sup>2</sup> Beijing Sunshine GEO-Tech Co., Ltd., Beijing, China.

yanghongqcx15@126.com

### **Relationship of Reservoir Characteristics with Stability Parameters of Underground Gas Storage**

The geological reservoir characteristics and mechanical parameters of oil and gas fields exert significant influence on the stability and preliminary feasibility assessment of underground gas storage facilities, posing an urgent challenge

for petroleum engineers to address. This study, grounded in the geological conditions and fundamental characteristics of the Wanshunchang gas field, explores the effects of various factors on stability parameters of gas storage facilities and analyzes the reasons underlying differences in stability. The findings reveal that the geological and mechanical parameters of the Wanshunchang gas field meet the basic requirements for gas storage facilities and can withstand injection and extraction pressures of up to 80 MPa. Furthermore, an increase in reservoir elastic modulus and cohesive strength mitigates reservoir leakage and contributes to maintaining wellbore stability in underground gas storage. Additionally, the pressure and curvature of the overlying strata are important factors affecting the permeability characteristics and stability of gas storage facilities. However, at a reservoir depth of 3000 meters, low leakage rates (23 ml/h) and reservoir damage (8%) can be achieved, highlighting the potential for establishing gas storage facilities with minimal adverse effects. Through comprehensive analysis of the geological reservoir characteristics of the Wanshunchang gas field, optimal parameter configurations suitable for gas storage facilities can be identified, elucidating the stability mechanisms thereof. This study provides essential data support for the Wanshunchang gas field as a potential site for underground gas storage.

**Keywords:** geological reservoir characteristics, Wanshunchang gas field, gas storage stability, seepage coefficient, chemical mechanism analysis.

**Xianzheng Li**<sup>1✉</sup>, **Chunfu Pan**<sup>1</sup>, **Hao Chen**<sup>1</sup>, **Zheng Zhang**<sup>1</sup>, **Shengzhou Wang**<sup>1</sup>, **Kun Ning**<sup>2,3</sup>

<sup>1</sup> China National Oil and Gas Exploration and Development Company Ltd, Beijing, China;

<sup>2</sup> CNPC Engineering and Technology R&D Company Limited, Beijing, China;

<sup>3</sup> National Engineering Laboratory of Oil and Gas Drilling Technology, Beijing, China.

lv1511199@126.com

### **Experimental Study of Gas Drive Chemical Analysis and Enhanced Recovery in Tight Oil Reservoirs**

As an important unconventional oil and gas resource, tight oil reservoirs are difficult to achieve ideal recovery rates with conventional oil recovery methods. In this paper, the oil driving effect of different gases ( $\text{CO}_2$  and  $\text{N}_2$ ) in tight reservoirs was investigated, and the auxiliary roles of chemicals such as surfactants and polymers in the gas driving process were also discussed. An autoclave was used for the different gas drive experiments, with a set pressure range of 10 MPa to 30 MPa, a constant temperature of 60°C, and the gas injection rate was adjusted to evaluate the drive effect. In addition, the effects of surfactants SDBS and C12-14 Pareth-7, as well as polymers PAM and HPAM at different concentrations on the gas drive effect were investigated. The results showed that the oil driving effect of  $\text{CO}_2$  was better than that of  $\text{N}_2$ , and the oil recovery of  $\text{CO}_2$  drive was increased by more than 20% at 30 MPa and 20 mL/min. With the addition of surfactant, SDBS increased the recovery by 15% at 0.3% concentration, while PAM increased the recovery by 10% at 0.4% concentration. This study demonstrated the superiority of  $\text{CO}_2$  gas drive in tight reservoirs and elucidated the enhancement effect of chemical adjuvants in the gas drive process by analyzing detailed experimental data. These findings provide an important theoretical basis and technical support for optimizing the gas-drive development scheme in tight reservoirs, which improves the crude oil recovery and has important practical application value.

**Keywords:** tight reservoirs, gas drive,  $\text{CO}_2$  drive, surfactant, recovery.

Jiangjun Xi<sup>1</sup>, ZhuangWei Li<sup>1</sup>, Lin Tao<sup>1</sup>, Wenlong Li<sup>1</sup>, Nan Jin<sup>1</sup>, Yufeng Wang<sup>2</sup>✉

<sup>1</sup> CNOOC China Limited, Tianjin Branch, China;

<sup>2</sup> China University of Petroleum-Beijing, China.

beijingwyf@126.com

### **A New Method for Solving Three Moment Equation in Well Trajectory Control**

*Considering the assembly as a multi-span, continuous beam-column, a system of “three moment equations” can be derived to compute side force components as well as all reactive forces, deflection, bending moment, and slope. Solving high-order nonlinear equations involves programming and debugging, which can be time-consuming. Moreover, many methods for solving such equations may not necessarily yield correct results. However, the Python open-source library “sympy” simplifies this process by eliminating the need for complex programming and debugging. It only requires the necessary equation information to quickly solve the high-order nonlinear equations. Additionally, C# provides the capability to rapidly create graphical user interfaces, enhancing the solution’s usability. By utilizing Python.NET to call Python code, it reduces the programming workload and effectively addresses the problem of solving a system of three moment equations.*

**Keywords:** three-moment equations, trajectory control, C#, Python, Pythonnet, Python.net, sympy.

Jianqiang Chen<sup>1</sup>, Haiyan Qiu<sup>1</sup>✉, Zhiyi Chen<sup>1</sup>, Guihong Lan<sup>1</sup>, Qi Xiao<sup>2</sup>,

Songsong Xue<sup>3</sup>, Tianxiong Ou<sup>3</sup>, Bo Xu<sup>1</sup>, Tianyi Wang<sup>4</sup>

<sup>1</sup> Laboratory of Green Oilfield Chemicals & Microbial Technology, School of Chemistry and Chemical Engineering, Southwest Petroleum University, Chengdu, China;

<sup>2</sup> Panzhihua China Resources Gas Co., Ltd, Sichuan, China;

<sup>3</sup> Sinopec Group Zhongyuan Petroleum Exploration Bureau Co., Henan, China;

<sup>4</sup> China National Complete Engineering Corporation, Beijing, China.

windqq2002@163.com

### **Temporal Changes of Sulfate-Reducing Microbial Communities Based on Functional Gene Sequencing in Production Water of Shale Gas Reservoir**

*Microbial sulfate reduction is a crucial metabolic process in shale gas reservoirs and a major contributor to microbiologically influenced corrosion (MIC). To better understand and control the corrosion of sulfate-reducing bacteria (SRB) during repetitive fracturing in produced water. In this paper, dissimilatory sulfite reductase (dsrB) gene sequencing and quantitative real-time PCR (qPCR) techniques were used to compare SRB communities in flowback and produced water from two shale gas wells (QS: fracturing with fresh water, FP: fracturing with produced water) in the Changning area of the southern Sichuan Basin at multiple time points. A total of 10 samples from the QS and FP wells were analyzed, revealing a shared core species distribution of Archaeoglobus (28.12%), Desulfomicrobium (10.75%), and unclassified\_d\_bacteria (18.97%). The dominant genus in well QS was Archaeoglobus, while well FP was unclassified\_d\_bacteria. The number of SRB was consistently higher in well QS compared to well FP throughout the production process. Direct gradient analysis indicated that  $SO_4^{2-}$  and pH ( $P <$*

0.05) were significantly correlated with the community composition of SRB. These findings offer valuable insights into the temporal trajectory of SRB communities in different hydraulic fracturing habitats and have important implications for understanding the enrichment of microorganisms that may pose a potential corrosion threat to gas well infrastructure during this process.

**Keywords:** sulfate-reducing bacteria, bacterial community structure, flowback and produced water, water quality.

**Li Yang<sup>1</sup>✉, Zhao Yining<sup>1</sup>, He Pei<sup>1</sup>, Dong Tao<sup>1</sup>, Xue Shaofei<sup>1</sup>, Li Zixin<sup>2</sup>, He Weijin<sup>2</sup>**

<sup>1</sup> Research Institute of Shaanxi Yanchang Petroleum (Group) Co., Ltd., Xi'an Shaanxi, China;

<sup>2</sup> College of Chemistry and Chemical Engineering, Xi'an Shiyou University, Xi'an, China.

472060143@qq.com

### **Evaluation of the Performance of New Surfactants and Study of Enhanced Recovery**

*In order to improve the efficiency of crude oil recovery, reduce the adhesion and adsorption of crude oil in the formation, reduce the interfacial tension of oil and water to form a stable emulsion, the performance evaluation of new surfactants and methods for improving oil recovery are studied. The esterification reaction is used to synthesize the raw material of glyceryl monooleate succinic acid monoester, and the raw material is neutralized with an alkaline solution to prepare a new surfactant. Through experiments, the surfactant's interfacial tension, salt resistance, temperature resistance, emulsification, viscosity reduction and other properties were evaluated, and the effect of changing the oil recovery rate after using the surfactant was studied. Test results show that this new surfactant can significantly reduce the water-oil interfacial tension, and can still reduce the water-oil interfacial tension even in saline environments and high temperature environments. After the temperature reaches 50°C, the temperature resistance is basically stable; When the surfactant concentration of the water-oil ratio is lower than 7:3 and higher than 700mg/L, it can reduce the viscosity of the water-oil mixture; the surfactant has good foam performance and emulsification, and can effectively improve crude oil recovery. Use 0.25% mass fraction surfactant, can effectively improve oil recovery, but abnormal low-pressure environment will affect the recovery effect.*

**Keywords:** surfactant, performance evaluation, recovery, water-oil interfacial tension.

**Guanghui Rong<sup>1</sup>✉, Yongtao Liu<sup>1</sup>, Weitao Xie<sup>1</sup>, Xingshuo Chen<sup>2</sup>**

<sup>1</sup> China Petroleum Changqing Oilfield Branch Ninth Oil Production Plant, Ningxia, China;

<sup>2</sup> China Petroleum Changqing Oilfield Third Oil Production Plant, Ningxia, China.

ubbcht@163.com

### **Oil Displacement Mechanism of a Novel Surfactant**

*China's low-permeability reservoirs possess abundant resources characterized by poor rock properties, strong heterogeneity, and fine pore throats, leading to low displacement efficiency. This study expands the concentration window for achieving ultra-low interfacial tension (ULT) by adding co-surfactants to the primary surfactant. Research indicates that the critical micelle concentration (cmc) and corresponding interfacial tension ( $\sigma_{cmc}$ ) of the compounded system are lower than those of individual components. When the molar ratio of M to Q is 1:1, the interaction parameter  $\chi_n$  reaches its minimum value, indicating the strongest synergistic effect within the system.*

*The compounded system achieves an oil-water interfacial tension as low as 0.0021 mN/m at 0.25% M + 0.025% Q, enhancing recovery efficiency by 0.88% compared to the single component M. Utilizing micro-etching microscopy and natural core physical model experiments, the compounded surfactant system's recovery efficiency increment reaches 19.7%, significantly surpassing water flooding effects. This provides robust support for the efficient development of the Jiyuan X reservoir.*

**Keywords:** *low-permeability reservoir, surfactant, performance evaluation, enhanced oil recovery.*

**Jiang Ping**<sup>1,2</sup>, **Zha Yuqiang**<sup>1,2✉</sup>, **Ye Qing**<sup>1,2</sup>, **Cao Bao**<sup>1,2</sup>, **Zhu Shaopeng**<sup>1,2</sup>, **Xiong Runfu**<sup>1,2</sup>, **Zhao Nan**<sup>1,2</sup>

<sup>1</sup> CNOOC China Limited, Hainan Branch, Haikou, China;

<sup>2</sup> CNOOC South China Sea Oil & Gas Energy Academician Workstation, Haikou, China.

zhayq@cnooc.com.cn

### **Investigation into the Dominant Factors of Gas Recovery in High-Temperature and High-Pressure Gas Reservoir**

*With the exploration and development of gas reservoirs moving into deeper formation, high temperature and high pressure (HTHP) gas reservoirs have gradually become one of the research focuses. However, there is still lack of enough experience and systematic understanding of the development principles of HTHP gas reservoirs with different petrophysical characteristics to clarify the development strategies. This paper established a model of HTHP gas reservoir to investigate the effects of the major development and geological factors on gas recovery factor and stable production period, such as reservoir permeability, water aquifer, stress sensitivity, and gas production rate, figuring out the sensitivity of each factor to gas recovery factor. Then a RBF neural network algorithm was employed to predict the gas recovery factors of HTHP gas reservoirs with different gas production rate in the Yinggehai Basin in the South China Sea, and then effective development approach for HTHP gas reservoirs was proposed. The research results showed that reservoir permeability had the highest impact on gas reservoir recovery, followed by water body multiples and permeability stress sensitivity, while gas production rate came in last. The development of medium and high permeability gas reservoirs was different from that of low and ultra-low permeability ones. As the permeability and stress sensitivity increased, the recovery factor of medium and high permeability gas reservoirs changed slightly, which was more affected by water aquifer. However, that was not the case in low and ultra-low permeability gas reservoirs. For medium and high permeability gas reservoirs with weak water aquifer, it was proposed to improve the gas production rate to enhance the development economics. For low and ultra-low permeability gas reservoirs with strong stress sensitivity, it was proposed to control the gas production rate to weaken the permeability damage and increase the stable production period in addition to the methods such as long horizontal wells, branch wells, and fracturing acidification. The research results could provide an effective guidance for the development of HTHP gas reservoirs.*

**Keywords:** *high-temperature and high-pressure gas reservoir, gas recovery factor, stress sensitivity, water aquifer, gas production rate, prediction model.*

Wang Xudong<sup>1</sup>, Li Zhaoting<sup>1</sup>, Xu Jingjing<sup>2</sup>, Zhang Gaofeng<sup>3</sup>, Song Xinwang<sup>4✉</sup>, Hou Guanqun<sup>5</sup>, Zhou Siyuan<sup>5</sup>

<sup>1</sup> School of Petroleum Engineering, Shandong Institute of Petroleum and Chemical Technology, Dongying, Shandong, China;

<sup>2</sup> Dongsheng Jinggong Petroleum Development Co., Ltd, Dongying, China;

<sup>3</sup> Bohai Drilling Company, SINOPEC Shengli Petroleum Engineering Corporation Limited, Dongying, Shandong, China;

<sup>4</sup> School of Chemical Engineering, Shandong Institute of Petroleum and Chemical Technology, Dongying, Shandong, China;

<sup>5</sup> Drilling Fluid Company, Great Wall Drilling Engineering Corporation Limited of CNPC, Panjin, China.

songxw625@126.com

### **Development and Application of a Oligomeric Emulsifier**

#### **with High-Temperature Resistant**

*The main technical challenge of drilling fluid in deep oil and gas drilling is that the treatment agent fails at high temperatures. The shortcomings of emulsifiers used in oil-based drilling fluids under high temperature conditions included high dosage and susceptibility to failure. An oligomeric emulsifier SSRH-1 with high temperature resistant was prepared through the reaction of organic acids and organic amines and the product yield exceeded 93%. Using SSRH-1, a high temperature oil base drilling fluid was formulated with organophilic clay, filter loss reducer and wetting agent etc. The density of this oil base drilling fluid was adjustable between 1.2 and 2.1 g/cm<sup>3</sup>. The oil base drilling fluid had the characteristics of good rheological performance and low filtration rate at 220°C.*

**Keywords:** oil base drilling fluid, tolerance to high temperature, amidation reaction, oligomeric surfactant.

Shiqi Yin<sup>1✉</sup>, Juhang Wei<sup>2</sup>, Wei Zhou<sup>3</sup>

<sup>1</sup> Jingzhou University, Jingzhou, Hubei, China;

<sup>2</sup> No.5 Gas Production Plant, PetroChina Changqing Oilfield Company, Xi'an, China;

<sup>3</sup> The Seventh Geological Exploration Institute of Heilongjiang Province, Suihua, Heilongjiang, China.

paper20240113@163.com

### **Enrichment Mechanism for the Organic Matter in a Shale Gas Formation**

#### **Based on Its Geochemical Characteristics**

*In order to acknowledge the enrichment mechanism of organic matter in the black shale of the Middle Ordovician Yanxi Formation in central and southern Hunan area, the shale samples of the Yanxi Formation in the Maduqiao, Jinweixiang, Hejiadong and Mianhuaping are selected to test abundance of organic matter, major, trace and rare earth elements. The results show that the average total organic carbon (TOC) of black shale in study area is 2.03%, indicating the high abundance of organic matter in the Yanxi Formation. The CIA values and w(Sr)/w(Cu) ratios show that the Yanxi Formation had a warm and humid climate. The concentrations of Zn, V, Ni and Cu imply a medium primary productivity in the Yanxi Formation, whereas they have weak correlations with TOC. The element concentrations of V, Cr, Ni, and Mo reveal that the black shales were deposited in anoxic-euxinic conditions. The accumulation of organic matter is jointly affected by paleoclimate, primary productivity, redox conditions, sea level change and terrigenous debris. The organic matter enrichment model of the Yanxi Formation shales is a 'deepwater retention basin' controlled by anoxic conditions.*

**Keywords:** Yanxi Formation, black shale, organic matter, redox condition, enrichment mechanism.

**Qinxi Tang<sup>1</sup>, Kaibin Yu<sup>1</sup>, Zijia Liao<sup>2</sup>✉, Jie Yang<sup>1</sup>, Li Liao<sup>3</sup>, Yuwang Zhong<sup>3</sup>, Su Liu<sup>2</sup>, Renze Li<sup>4</sup>**

<sup>1</sup> Sulige Gas Field Branch of the Great Wall Drilling Company in CNPC, Panjin, China;

<sup>2</sup> Tianfu Yongxing Laboratory, Chengdu, China;

<sup>3</sup> Panzhuhua Bing Yang Technology Co.,Ltd., Panzhuhua, China;

<sup>4</sup> Southwest Petroleum University, Chengdu, China.

lzjfrac@foxmail.com

## **Numerical Study on Crushing Strength of Porous Proppant**

### **Using the Finite Element Method**

*Porous proppants are an important type of lightweight proppants, which can be transported to far fractures in hydraulic fracturing. The ideal proppants should have higher strength besides lower density. Usually, as the pores increases, the crushing strength of porous proppants will decrease, resulting in the difficulty propping more fractures. In this study, the three-dimensional finite element model(3D-FEM) was used to study crushing strength of single proppant. The effects of pore distribution, pore size and porosity on proppant crushing strength were analyzed. Weibull theory was used to describe the dispersion of crushing strength. The failure processes of solid proppant and porous proppant were studied. The results show that the solid proppant has obvious brittle fracture, while porous proppant has structural plasticity. With the increase of pore size and decrease of porosity, the distribution of crushing strength is more dispersed. The crushing strength decreases significantly when porosity is less than 7% and then decreases slowly as porosity continues to increase. The crushing strength will increase with the increase of pore size. When the pore size is larger than 0.1 mm ( $d/D < 1/6$ ), the crushing strength has no obvious change. These results can guide the preparation and application of porous proppants.*

**Keywords:** hydraulic fracturing, porous proppants, crushing strength, finite element model.

**Liu Liang<sup>✉</sup>, Ma Qingwei, Gao Biao, Ding Fei, Yang Jianli, Zhang Xueping**

Dingbian Oil Production Plant of Yanchang Oilfield Co., Ltd, Yulin, China.

452292209@qq.com

## **Research and Application of Temporary Blocking and Diversion Techniques for Fractures in Tight Oil Reservoir**

*The tight oil reservoirs in the western region of Yanchang Oilfield are characterized by low porosity, low permeability, low pressure, and strong heterogeneity. During the process of volumetric fracturing, there are issues such as low complexity of fracture extension within single clusters and the inability to fully open multiple clusters within the same section. To increase the complexity of single-cluster fractures and improve the efficiency of cluster activation, a field test of temporary blocking and diversion volumetric fracturing was conducted on the Chang 72 layer of Well Luoping 29 and the Chang 8 layer of Well Ding 4994DX-1 in the tight oil region. The optimal dosage of the temporary blocking agent and the parameters for temporary blocking operations were determined. It is recommended that the amount of the temporary blocking agent be 150-250 kg per segment, with a displacement rate of 4-5 m<sup>3</sup>/min, and a blocking pressure of 2-3 MPa. The amount of temporary blocking balls should be 1.3 times*



greater than the perforation holes, with a displacement rate of 5-6 m<sup>3</sup>/min and a blocking pressure of 3-14 MPa. This led to the development of a temporary blocking and diversion technology suitable for tight oil reservoirs. Through the analysis of fracture monitoring data and fracturing operation curves, the construction success rate of temporary blocking and diversion was found to be over 80%, achieving the re-opening of fractures after temporary blocking and diversion. Post-fracturing performance evaluation indicated that Well Luoping 29 had an initial monthly cumulative oil production of 1206 m<sup>3</sup> and an average daily oil production of 40 m<sup>3</sup>/d, which is 2.2 times the average daily oil production of neighboring wells at the same layer. Although the daily oil production of Well Ding 4994DX-1 was similar to that of neighboring wells, its daily fluid production and wellhead pressure were increased by 1.0 times compared to neighboring wells, showing better post-fracturing performance. The successful trial of the temporary blocking and diversion technology provides significant technical support for the thorough stimulation of tight oil reservoirs.

**Keywords:** volumetric fracturing, temporary blocking and diversion, blocking pressure.

**Yinghui Ren<sup>✉</sup>, Shifang Li<sup>2</sup>, Ke Wu<sup>3</sup>, Kangning He<sup>4</sup>, Nan Jiang<sup>1</sup>**

<sup>1</sup> School of Petroleum Engineering and Environmental Engineering, Yan'an University/Yan'an Engineering Technology Research Center of Efficient Pipeline Transportation of Oil and Gas and Flow Guarantee, Yan'an, Shaanxi, China;

<sup>2</sup> The 10th Oil Production Plant of Changqing Oilfield Branch Company, Qing Yang, China;

<sup>3</sup> Research Institute of Exploration and Development, PetroChina Changqing Oilfield Company / National Engineering Laboratory for Exploration and Development of Low Permeability Oil & Gas Field, Xian, Shaanxi, China, China;

<sup>4</sup> Xi'an Shiyou University, Xi'an, Shaanxi, China.

ys3931@126.com

### **High-Temperature Resistant and Environmentally Friendly Drilling Fluid Treatment Agent**

*During the drilling process, high-temperature environments can cause the performance of traditional drilling fluids to decline, affecting drilling efficiency and environmental protection. To address this issue, this study added polymetallic hydroxide to anti-temperature and environmentally protective drilling fluid treatment agents, verifying its performance through linear expansion experiments, anti-expansion experiments, mud ball experiments, and thermogravimetric analysis. The experimental results indicate that at 20 minutes, the expansion rate of bentonite is 44.2% in water and 22.3% in KCl, and at 120 minutes, the expansion rate is 70.4% in water and 50.4% in KCl. When mixing different polymetallic hydroxides with bentonite clay, M1-Fe exhibited the lowest swelling among Fe-doped polymetallic hydroxide samples, with rates of 13.3% at 20 minutes and 22.7% at 120 minutes. Among Cu-doped samples, M2-Cu showed the lowest expansion, at 15.9% at 20 minutes and 25.3% at 120 minutes. For Zn-doped samples, M3-Zn had the lowest expansion rates, at 16.5% at 20 minutes and 27.3% at 120 minutes. The results demonstrate that Fe-doped polymetallic hydroxide samples exhibit excellent swelling inhibition and thermal stability at high temperatures. These samples significantly improve the high-temperature stability and environmental performance of drilling fluids, showing great potential for widespread use in high-temperature drilling.*

**Keywords:** inhibitors, high temperature resistance, drilling fluids, linear expansion experiments, environmental protection.

**Li Hanqing<sup>✉</sup>, Chen Tianyu, Xu Peizhe, Wu Yuzeng, Fang Mingming**

Marine Design and Research Institute of China, Shanghai, China.

3130000170@zju.edu.cn

### **Typical Deterioration Process of Jet Fuel Quality during Maritime Storage and Transportation**

*Maritime transportation is one of the vital means delivering jet fuel from refineries to end-users. The possible deterioration of fuel quality during maritime transportation directly impacts the final performance of jet fuel and, in severe cases, may even compromise aviation safety. While numerous studies have delved into the deterioration of jet fuel quality during long-term storage on land, there is a notable lack of research reporting on its quality deterioration during maritime transportation. This paper summarizes the unique conditions faced by jet fuel during maritime storage and transportation. Based on these characteristics, experimental studies were conducted to investigate the effects of storage duration, atmosphere, impurities, water content, and fuel blending on the quality deterioration process of jet fuel. The results reveal the process and underlying causes of jet fuel quality deterioration during maritime transportation.*

**Keywords:** jet fuel, deterioration, maritime transportation, accelerated aging.

**Xu Meng<sup>1</sup>, Zhang Chengke<sup>2</sup>, Xu Jingjing<sup>3</sup>, Sheng Weijie<sup>4✉</sup>**

<sup>1</sup> School of Management, Guangdong University of Technology, Guangzhou, China;

<sup>2</sup> School of Economics, Guangdong University of Technology, Guangzhou, China;

<sup>3</sup> Dongsheng Jingong Petroleum Development Co., Ltd, Dongying, China;

<sup>4</sup> Guangdong branch, Bank of communications, Guangzhou, China.

skerr1102@163.com

### **Key Components of Energy Cooperation Based on the Game Analysis Between China and the Central Asian Region**

*Aiming at the real problems of energy cooperation negotiation between China and Central Asia, based on the bargaining game theory proposed by Nash and Rubinstein, we adopt the method of dynamic game analysis to establish the tri-stage bargaining game model of complete and incomplete information. Nash and Rubinstein, we adopt the method of dynamic game analysis to establish the tri-stage bargaining game model of complete and incomplete information, and use the inverse induction method to solve the equilibrium problem. information, and use the inverse induction method to solve the equilibrium, and get the equilibrium strategies of two players.*

**Keywords:** energy cooperation, tri-stages bargaining, pricing game.