Review of the Scientific co-supervisor

for the dissertation Thesis submitted on the Requirements for the Degree of Doctor of Philosophy (Ph.D.) in the specialty 6D073900 - "Petrochemistry" at Satbayev University, Almaty, Republic of Kazakhstan

by Nurbatyr Mukhametgazy

entitled "Synthesis and characterization of acrylamide-based polyampholytes for EOR, drilling of wells and tracer applications"

The submitted Ph.D. dissertation of Nurbatyr Mukhametgazy entitled "Synthesis and characterization of acrylamide-based polyampholytes for EOR, drilling of wells and tracer applications" describes the fundamental aspects of acrylamide-based polyampholytes that potentially might be applied in enhanced oil recovery (EOR), as water based drilling fluids (WBDFs), and as tracer agent for monitoring of interwell connections between injection and production wells.

The present thesis is devoted to synthesis and characterization of specially designed polyampholyte terpolymers based on nonionic monomer – acrylamide (AAm), anionic monomer – 2-acrylamido-2-methyl-1-propanesulfonic acid (AMPS) and cationic monomer – (3-acrylamidopropyl) trimethylammonium chloride (APTAC) for application in EOR, which proves the relevance of the research to develop temperature- and salt-resistant polyampholytes for oil industry of Kazakhstan.

Nurbatyr's thesis is devoted to the synthesis of a novel high molecular weight ternary polyampholyte AAm-*co*-AMPS-*co*-APTAC with a composition of 80:10:10 mol.%. Which demonstrates a superior oil displacement capability compared to hydrolyzed polyacrylamide (HPAM) for Enhanced Oil Recovery (EOR), WBDFs and as tracer applications in high-saline reservoirs.

Personal contribution of Nurbatyr Mukhametgazy is demonstrated by the collection, analysis, and summarization of the available literature on polyampholytes, performing experiments, and interpreting and discussing the results. The author of the thesis presented the following basic scientific results:

1. The dynamic viscosity of ternary polyampholytes (AAm-*co*-AMPS-*co*-APTAC) in water depends on the composition of the terpolymers and increases in the following series: 80:10:10 > 60:20:20 > 70:15:15 > 50:25:25 > 90:5:5 mol%. In this regard, for the comprehensive study of the behavior of TPA in saline solutions, the optimal composition [AAm]:[AMPS]:[APTACH] = 80:10:10 mol% was chosen. Initially, injecting the low-molecular weight TPA solution during the core flooding tests resulted in a 4.8-5% increase in the oil recovery factor (ORF).

2. Rheological studies of high-molecular-weight TPA (AAm-*co*-AMPS-*co*-APTAC in an 80:10:10 ratio) solutions showed improved viscosifying behavior in high-salinity brine (200-300 $g \cdot L^{-1}$) at both 24 and 60 °C.

3. Injection of 0.25-0.5 wt.% of amphoteric terpolymer dissolved in 200-300 $g \cdot L^{-1}$ synthetic brine into high permeable sand pack model showed that the oil recovery factor (ORF) increases up to 23-28% in comparison with water flooding. The TPA allowed the

production of 2 times more oil at its maximum than did HPAM.

4. The addition of TPA not only improved rheological properties and reduced fluid loss of WBDFs but also increased salt resistance of the drilling fluids and gel strength, providing excellent performance in a wide range of high salinity brine and shear rate.

5. A novel ternary polyampholyte (AMPS-*co*-APTAC-*co*-ANB=50:49:1) in both water and saline solutions effectively reduces adsorption, resulting in a 90% polymer recovery factor when injecting a 0.1 wt.% solution into the core. Which suggests potential use as a polymer tracer agent.

The dissertation work was carried out at the Laboratory of Engineering Profile (LIP) of Kazakh National Research Technical University and the Institute of Polymer Materials and Technology (IPMT) within the framework of several grant projects funded by the Ministry of Science and Higher Education of the Republic of Kazakhstan. The results of the research are reflected in 12 publications.

The thesis is composed of six chapters. The introduction presents the general overview, relevance, objectives, hypotheses, and dissertation organization. Chapter I provides the literature survey on polyampholytes, especially in relation to petroleum industry. Chapter II describes the experimental part, including materials, methods and used instruments. Chapter III is devoted to synthesis and characterization of polyampholytes and rheological studies. Chapter IV presents results of core/sand pack flooding experiments with polyampholyte terpolymers and hydrolyzed polyacrylamide aqueous solutions. Chapter V describes the preparation protocol of drilling fluids. Chapter VI considers the synthesis and characterization of fluorescently labeled polyampholyte as well as core flooding experiments. Chapter VII is a conclusion.

In summary, Nurbatyr Mukhametgazy's dissertation titled "Synthesis and characterization of acrylamide-based polyampholytes for EOR, drilling of wells, and tracer applications" meets the criteria set by the Committee of Higher and Postgraduate Education of the Ministry of Science and Higher Education of the Republic of Kazakhstan, demonstrating its relevance and scientific merit. Consequently, Mukhametgazy is qualified for the award of a Doctor of Philosophy (Ph.D.) degree in the field of 6D073900-Petrochemistry.

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