PTAC
Alberta Upstream Petroleum
Research Fund

Project Summary, Milestones, Payment Schedule and Quarterly Update Reports

Report Date: July 1 – September 30, 2024

Project Summary

Project Title:	Towards Net-Zero Emissions: Mechanics, Processes and Materials to Support Risk-Based Well Decommissioning
Lead Investigator:	Ian Frigaard (UBC). Co-investigators: Ida Karimfazli (Concordia University) and Seyed Mohammad Taghavi (Université Laval)
AUPRF Managed Funds Award Amount:	$197,800 x 4 years, currently in year 2
PTAC Technical Champion:	Leah Davies, Wade Hartzell, James Ireland
GL #:	AUPRF2022 – 000124
Project Total Cost (all years)	$791,200
Leveraged Cash Funding (all years)	$1,200,000
Leveraged In-Kind Funding (all years)	$209,000
Start Date:	November 15th, 2022
Completion Date:	November 14th, 2026
Final Report Due Date:	3 months after completion date

Provide a brief description of the challenges this project aims to address and how industry and others will benefit, including what the anticipated impact is. (i.e., cost reductions, improved environmental performance, impact on regulation, enhanced access to resources). (Maximum 150 words or less)

The goal is to develop and deliver science-based knowledge to support engineering decisions on well integrity and abandonment. Knowledge will be developed at 3 Canadian universities by a research team of 3 faculty members, 1 research manager and >10 researchers, conducted in partnership with PTAC champions and collaborators at other universities and research institutes. The project (Phase II) builds on the success of Phase I (17-WARI-02/20-WARI-02) and is aligned with knowledge gaps and policy issues identified by consensus between industrial and regulatory players, documented fully in the project proposals to PTAC and NSERC.
The project utilizes infrastructure from Phase I and addresses sub-projects in 5 complementary areas: (i) dump bailing and off-bottom plug placement, (ii) cleaning behind casing and squeeze cementing, (iii) well leakage, (iv) mechanics and materials, and (v) societal impacts and abandonment alternatives. Our team will conduct these interlinked studies, addressing knowledge gaps while also providing fundamental advances using combined experimental, analytical and computational methodologies, along with field survey work and data modelling where appropriate.

List scope key milestones with invoicing schedule. Include quarterly estimates.

Milestone	Planned Expenditures[1]	Actual Expenditures	Status
Q2 (Jul 1 – Sep 30) 2024 (Yr 2)			
1 Salaries	$ 35,000	$ 35,000	
2 Equipment, materials & supplies	$ 9,955	$ 9,955	
Total Year 2, Qrt 4 milestones	$ 44,955	$ 44,955	
10% Overhead	$ 4,945	$ 4,945	
Q3 (Oct 1 – Dec 31) 2023 (Yr 2)			
1. Salaries	$ 30,000	$ 30,000	
2. Forum organization & travel	$ 14,950	$ 14,950	
10% Overhead	$ 4,945	$ 4,945	
Total Year 2, Qrt 1 milestones	$ 44,950	$ 44,950	
Q4 (Jan 1 – Mar 31) 2024 (Yr 2)			
1. Salaries	$ 35,000	$ 35,000	
2. Equipment, materials & supplies	$ 9,955	$ 9,955	
10% Overhead	$ 4,945	$ 4,945	
Total Year 2, Qrt 2 milestones	$ 44,950	$ 44,950	
Q1 (Apr 1 – Jun 30) 2024 (Yr 2)			
1. Salaries	$ 35,000	$ 35,000	
2. Equipment, materials & supplies	$ 9,955	$ 9,955	
Total Year 2, Qrt 3 milestones	$ 44,950	$ 44,950	
10% Overhead	$ 4,945	$ 4,945	
Total	$197,800	$197,800	All subprojects are ongoing

[1] All expenditures in Canadian dollars and must exclude GST and other applicable taxes.

Quarterly Update

Exception Highlight for the Quarter:
(any exceptions to the original project scope, timelines, payment schedule / amount(s) OR early significant findings) – this can be left blank if no changes are needed, and do not include exceptions already reported.

1.
2.
3.

Update on scope, key questions, gap analysis and work performed this quarter (include any requests for assistance to PTAC or the committees)

- Scott Charabin (UBC) completed his MSc work and graduated in July 2024. Not longer in the project.
- Hossein Hassanzadeh (Laval) completed his PhD work in August 2024. He will continue in the project as a Postdoctoral Fellow.
- Hossein Rahmani (UBC) will join the project in a 50 % capacity to work on squeeze cementing.
- Hedayat Moosavi (Laval) completed his MSc work and graduated in August 2024. Not longer in the project.
- Abdallah Ghazal (Concordia) concluded his work in the project as a postdoctoral fellow in August 2024.

Technical activity summary:

(i) Dump bailing and off-bottom plug placement

M. Faramarzi (Laval): This quarter, he studied the injection of a heavy viscoplastic fluid (cement slurry) into a light Newtonian fluid (drilling mud) in a closed-end pipe. Using Carbopol solutions with varying yield stress, experiments at different injection rates were captured via high-speed imaging. The results showed that flow regimes depended on the yield stress, and release velocity affected the heavy fluid's front velocity, particularly at lower rates. These findings provide valuable insights into cement dynamics.

S. Akbari (UBC) is continuing the experimental studies on the stability of the cement plug in the off-bottom cement plug placement method. This involves placing a dense shear-thinning fluid (Xanthan solution) on top of a lighter fluid in an inclined pipe. The research focuses on detailed analyses of the fluid interface post-placement, examining aspects such as unstable interface dynamics, the extent of the mixing region, and the effects of the fluids' rheological and physical properties.

At Concordia University, A. Shakeri successfully passed his comprehensive exam in September and is continuing his work on numerical simulations of plug placement. He is now preparing his PhD proposal report, expanding 3D simulations, and drafting manuscripts for ASME OMAE 2025. A. Ghazal has completed his postdoc and is currently a Visiting Assistant Professor at the American University of Sharjah.

(ii) *Cleaning behind casing and squeeze cementing*

H. Hassanzadeh (Laval) has completed his PhD and is now a postdoc advancing research on jetting and cleaning processes for P&A applications. His recent experiments focus on Newtonian fluid jets in viscoplastic fluids, simulating in-well materials. Using high-speed imaging and tomographic PIV, he identified four jet flow patterns, providing insights that optimize well cleaning processes.

M. Izadi (UBC) is working on a parametric study examining the factors influencing microannulus gap thickness and variation, such as cement expansion, eccentricity, and the impact of cement particle size on squeeze cementing across different scenarios. He is also studying further the influence of capillarity on the squeeze cementing displacement process, i.e. wetting/non-wetting.

H. Rahmani (UBC) is developing a new network model to accelerate the simulation of squeeze cementing processes in micro annuli. The models' input includes the fluid rheological parameters, e.g. the cement yield stress, and the geometrical parameters, such as the gap size of micro annuli. The end goal is to develop models that can predict the critical pressure maps around perforations in a fast and accurate way, i.e. predicting how much pressure is needed to penetrate and fill between perforations.

(iii) *Well leakage*

In Concordia, A. RezkAllah was on medical leave. She has now fully recovered and is ready to resume the planned work as outlined in our previous report.

(iv) *Mechanics and materials*

Z. Rahmani (UBC) is developing an analytical model to predict stress distribution within eccentric annuli, incorporating the effects of early-age shrinkage. She has employed the equivalent perturbed domain solution to analyze wellbore stresses in an annulus with moderate eccentricity and has advanced the model to a third-order scheme for improved precision. Her next step involves integrating the shrinkage deformation of well cement during the curing process into the model to investigate stress distribution within the eccentric wellbore, aiming to predict potential failure modes throughout the hydration process.

(v) *Societal impacts and abandonment alternatives*

S. Akbari (UBC) is exploring the feasibility of geothermal energy for power generation and industrial use, with an emphasis on repurposing abandoned oil and gas wells in Northeastern British Columbia (NE-BC), Canada. The significance of pad-drilled wells in NE-BC, where 5 to 30 wells are drilled from the same surface location, is being investigated for geothermal energy generation. The availability of pad-drilled wells simplifies surface facility operations. The temperature, depth, and number of these wells are currently under investigation.

Dissemination of knowledge:

Journal articles:

- M. Faramarzi, S. Akbari and S. M. Taghavi. *Buoyant miscible viscoplastic injections*. Physical Review Fluids, 9, 073301, 2024.
- S. Charabin, and I.A. Frigaard, *Exchange flows and plug cementing*. Accepted in the J. of Fluid Mech., 2024.

Conference proceedings and presentations:

- I. Frigaard, *Let me tell you about my problems*. Workshop on non-Newtonian fluids in porous media, Banff, AB. July 15-19, 2024.
- M. Izadi and I. Frigaard, *Dynamics and Stoppage Mechanisms in Viscoplastic Suspensions: Modelling Capillary Forces, Pore Blockage, and Yield Stress Effects*. Workshop on non-Newtonian fluids in porous media, Banff, July 15-19, 2024.
- Z. Rahmani, I. Frigaard and S. Malek. *A numerical investigation of the evolution of tensile strength of oil well cement during curing process*. 16th World Congress on Computational Mechanics, Vancouver, BC. July 21-26, 2024.
- S. Akbari & S.M. Taghavi. *Buoyant miscible injection flows in an inclined closed-end pipe.* 16th World Congress on Computational Mechanics, Vancouver, BC. July 21-26, 2024.