Gas Retention and Release Tests for Low Yield Stress Non-Newtonian Fluids

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Background

•The Waste Treatment Plant & Immobilization Plant (WTP) design calls for the use of pulse jet mixer (PJM) technology in tanks that require mixing of the process fluids and release of hydrogen gas from radiolysis.

•During normal operation, the mixing systems in the WTP vessels must achieve safe, controllable release of flammable gases including hydrogen.

•During loss-of-power events, PJMs may be operated intermittently on backup power for extended periods, which can result in gelling of the slurry and accumulation of hydrogen or other flammable gases in the gelled slurry.

•Upon restart of the PJMs, the mass of released hydrogen gas and rate of release must not create flammable conditions in the vessel headspace.

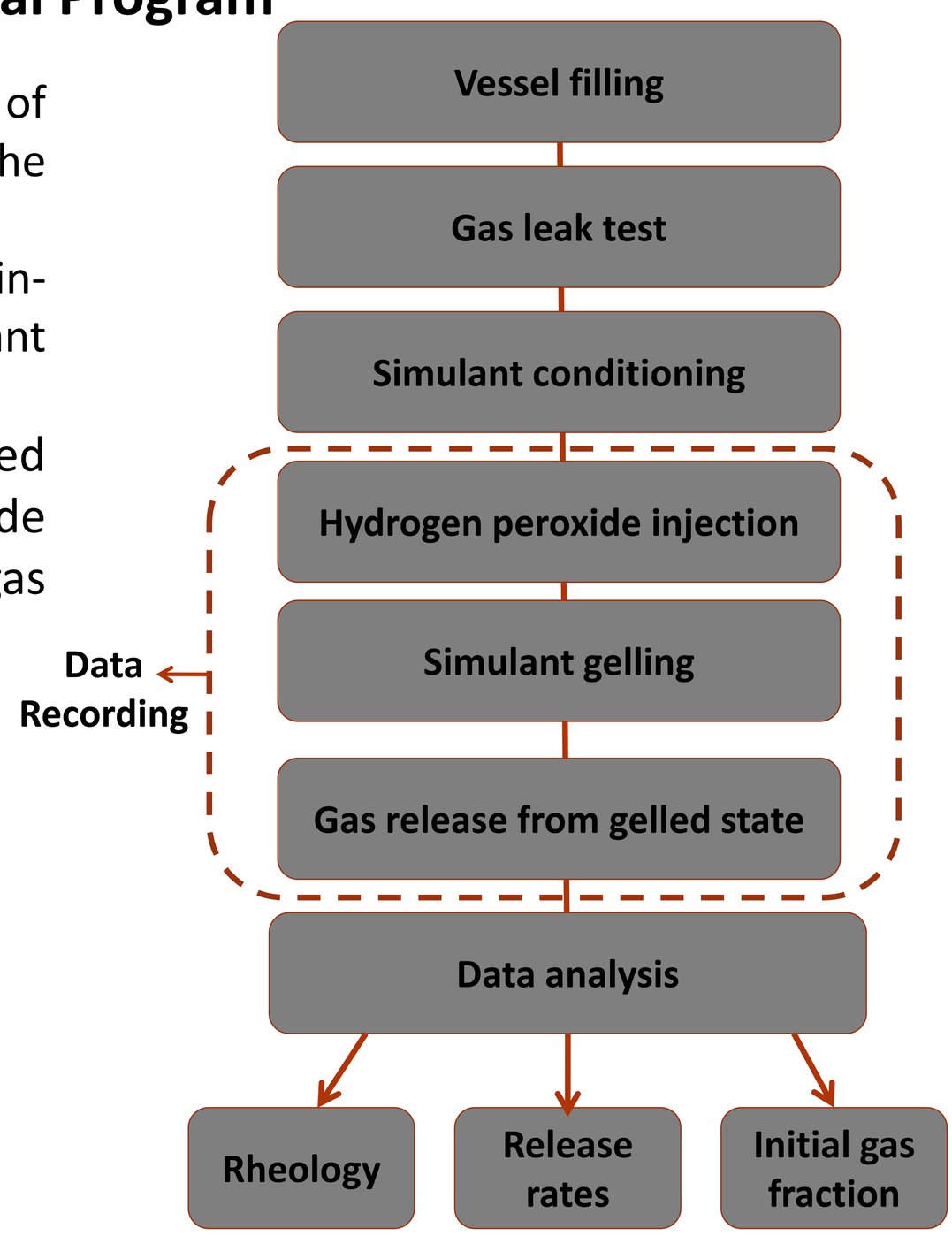
•A test program was established at Florida International University to quantify the gas retention and release characteristics of low yield stress non-Newtonian fluids of varying rheology with yield stress range of 0-10 Pa in the loss of power events.

Experimental Program

•Investigate the gas retention and release properties of selected non-Newtonian fluids of low yield stress in the gelled state relevant to Hanford waste streams.

•Gas was introduced into the gelled simulant through in-situ decomposition of hydrogen peroxide and simulant was left to gel overnight.

•The composition of released gas which was purged from the headspace was measured to provide information about the rates and volumes of gas retention and release in the gelled simulant.



Simulant Properties

Simulant	Bingham Plastic Yield Stress, Pa	Bingham Plastic Consistency, cP
Clay	2	5
Clay	4	10
Clay	6	13
Clay	8	17

• The retention potential of each simulant and the signature of the released gas (such as total volume, shape, and peak intensity) were determined.

• The experimental data was correlated with the physicochemical and colloidal properties of the selected simulants.

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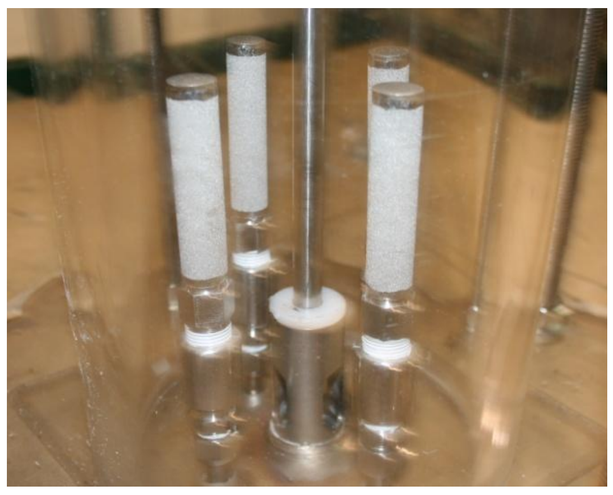
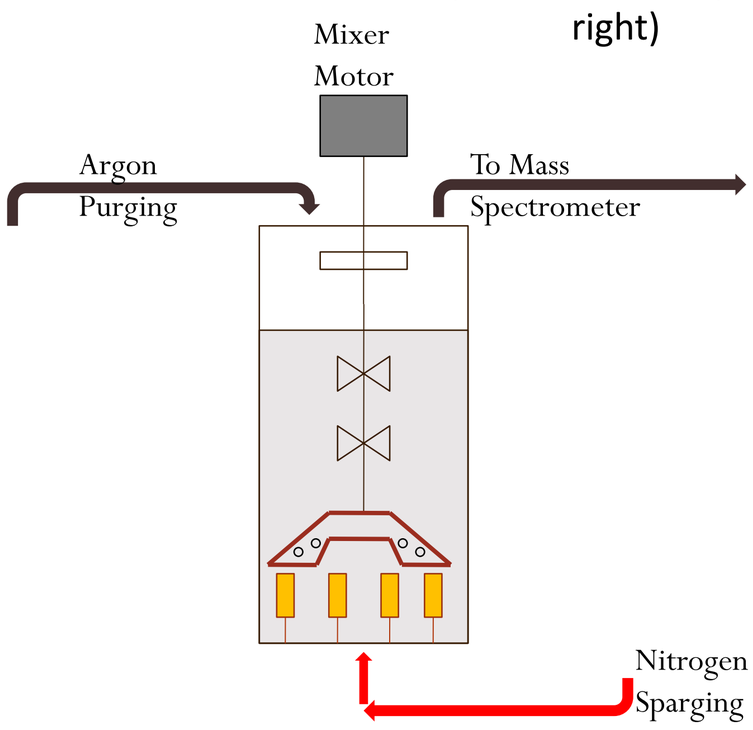
Experimental Set-up

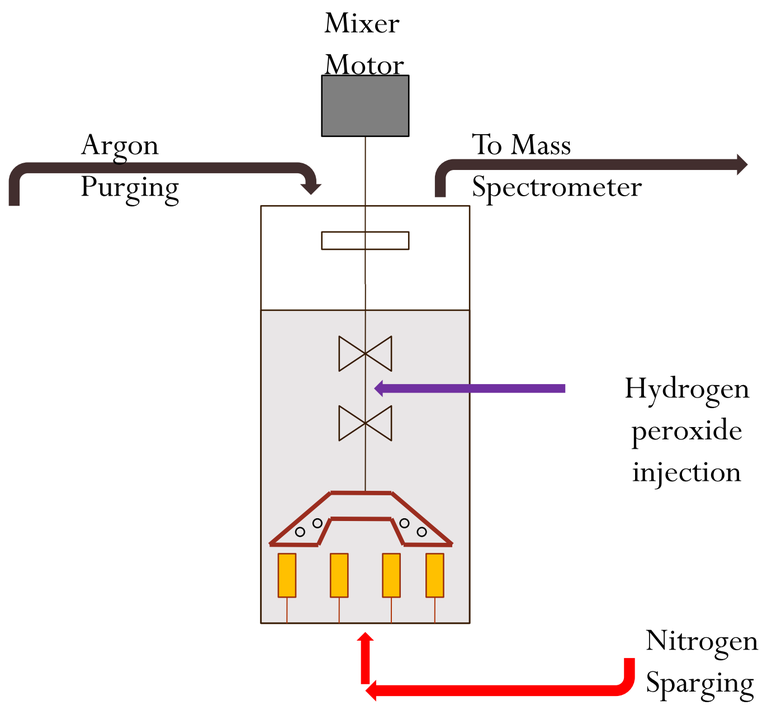


Test column (left), Mass Spectrometer (top right) and Spargers (bottom right)

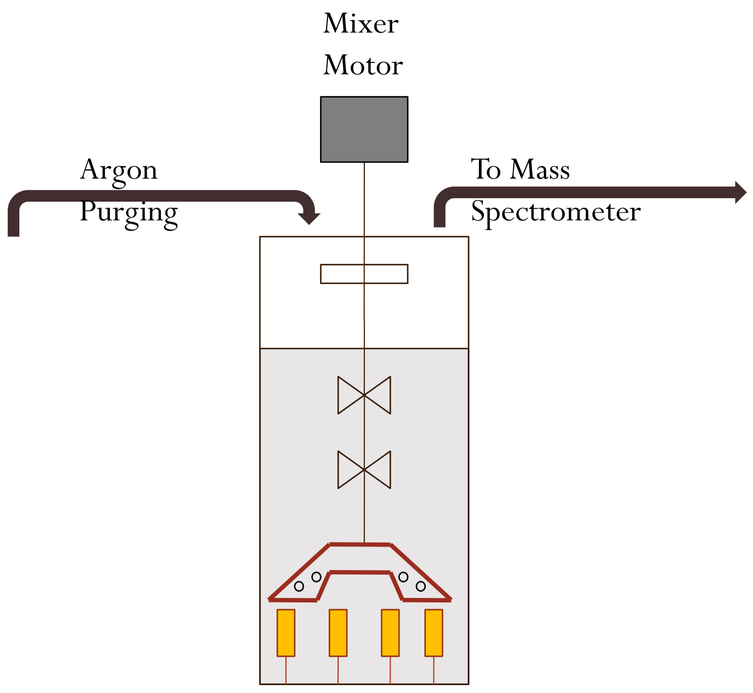
- Mechanically mixed vessel (impellers and spargers) of about 22 liters of simulant inventory.
- Four clay simulants were tested with varying rheology (<10 Pa).
- Gas was introduced into the gelled simulant through in-situ decomposition of hydrogen peroxide.
- Simulant was left to gel overnight (18 hours).
- Gas was released by restarting the mixing system and the concentration of gases was measured by the mass spectrometer.



Gas flow during purging and simulant conditioning



Gas flow during hydrogen peroxide injection

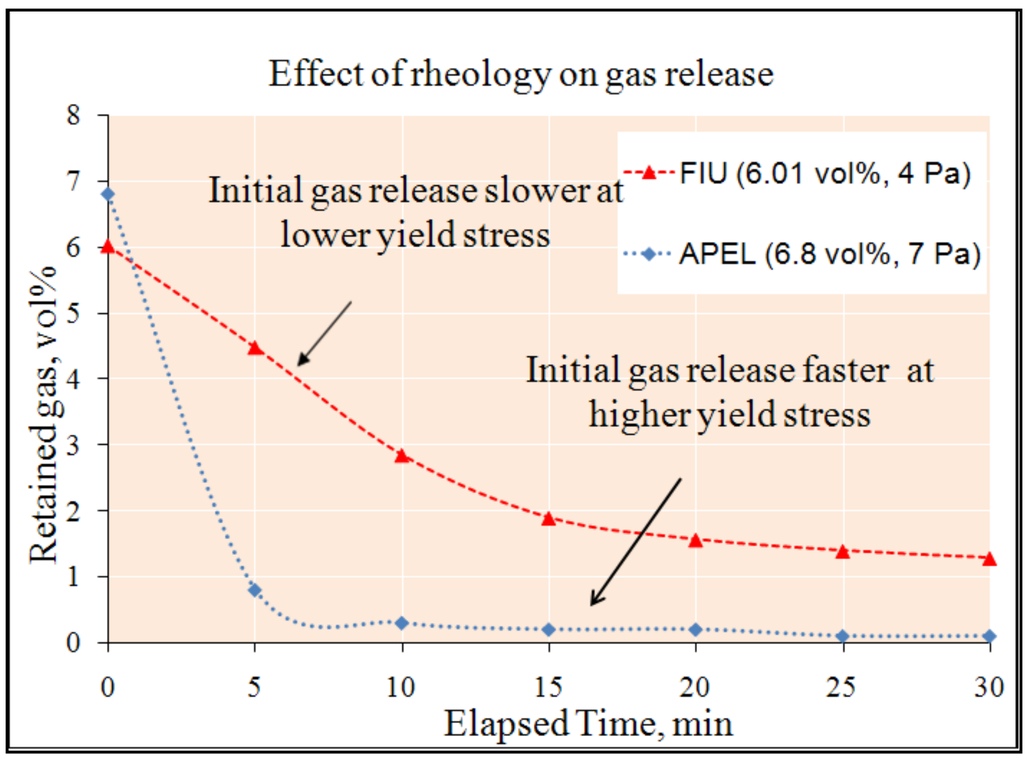


Gas flow during release of oxygen from gelled state

Results

Effect of Simulant Rheology

- In the first 10 mins, the 4 Pa releases about 56% of the total volume of gas compared to the 98% gas release by 7 Pa in 5 mins.
- This could be attributed to the formation of unmixed regions wherein the smaller bubbles are not able to coalescence to form larger bubbles and are unable to overcome the slurry yield stress and release gas.



Effect of low yield stress on the gas release behavior

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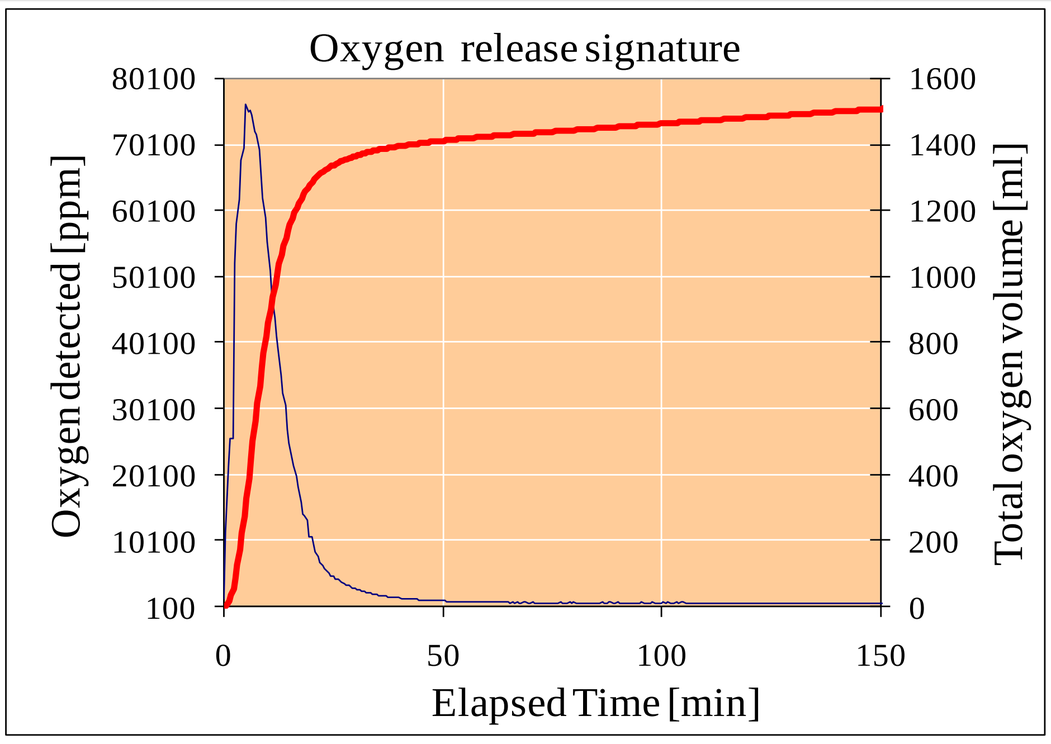
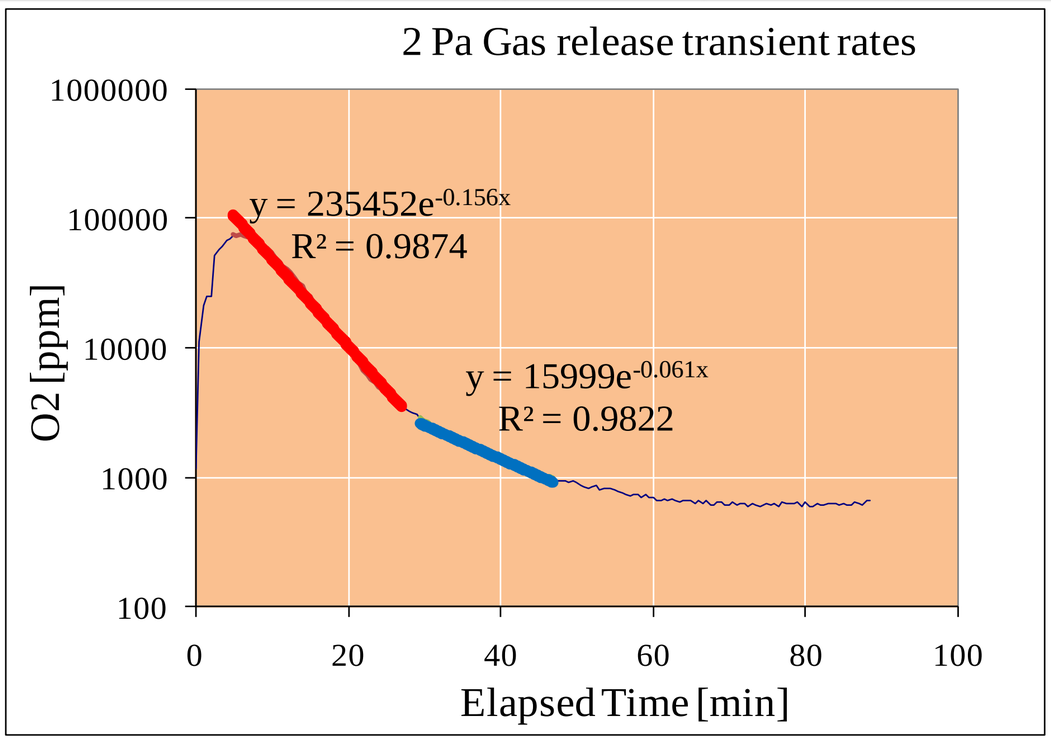
Initial rates of release

Table 2. Release parameters for Kaolin-Bentonite tests

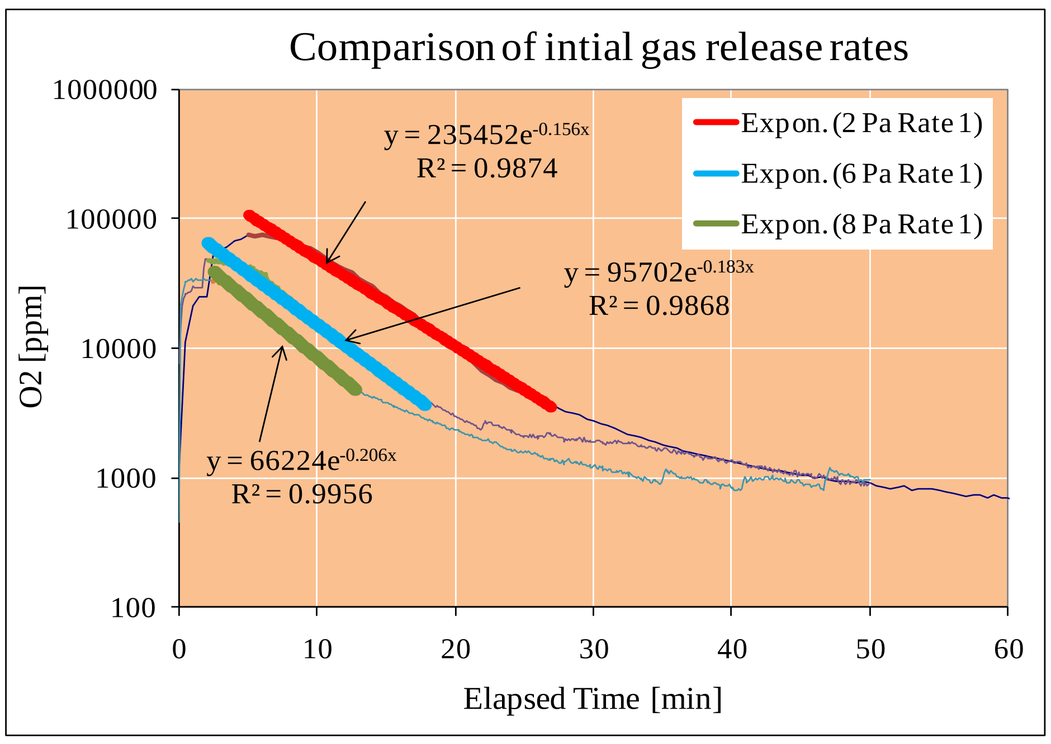
Test	Yield Stress	Test Mode	k_1	k_2	Simulant volume	Stoichiometric volume of oxygen generated insitu	Gel Hold	Fractional Retention	Estimated O2 volume released	Fraction Released
	Pascal		Min^{-1}	Min^{-1}	Liters	Liters	Liters	Percent	Liters	Percent
K01	2	H202 addition and gelling			22.23	2.36			0.85	
K01	2	Gel Release	0.156	0.061			1.51	6.79	1.50	99.34
K02	4	H202 addition and gelling			22.27	2.00			0.58	
K02	4	Gel Release	0.143	0.075			1.42	6.36	1.40	99.08
K03	6	H202 addition and gelling			22.33	2.28			0.87	
K03	6	Gel Release	0.183	0.033			1.41	6.31	1.41	99.93
K04	8	H202 addition and gelling			22.17	2.24			0.75	
K04	8	Gel Release	0.205	0.089			1.49	6.72	1.46	98.05



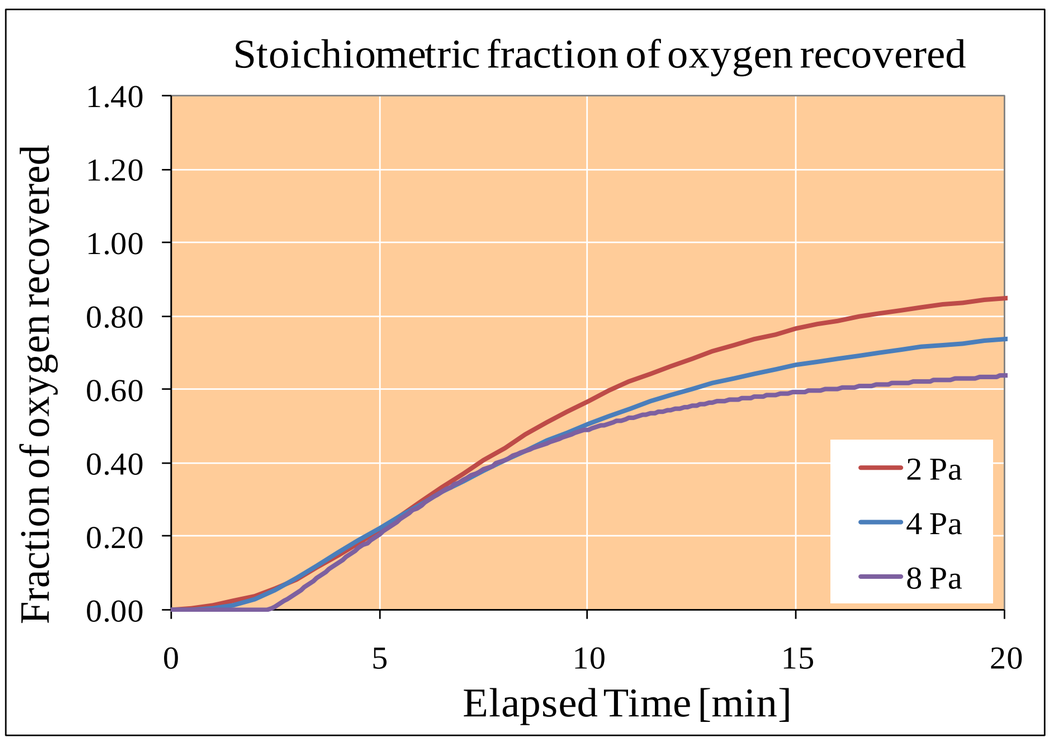
Oxygen release signature



Gas Release transients for 2 Pa clay



Comparison of initial release rates



Fraction of oxygen recovered in the first 15 minutes

Conclusion

•Release rate appears to be associated with 2 time constants:

➢The shorter time constant (5 – 15 min)may be related to the release of larger bubbles and is seen to increase with an increase in the yield stress (15 mins for 2 Pa, 10 mins for 6 Pa and 5 mins for 8 Pa).

➢The longer time constant (50 – 150 min) may be related to release of smaller bubbles and incomplete mobilization of slurry.

➢About 60-80 % of gas is released within the first 15 minutes and about 98% within 150 minutes.

Future Work

•**Effect of Anti Foaming Agents (AFA):** WTP currently has a cohesive research project underway that is heavily involved towards modeling. It could use experimental support. Identification of key variables and how they affect the behavior (mechanism) will be established to provide guidance to the experimental work.

• A correlation will be developed linking critical waste properties (particle size distribution, zeta potential, particle shape) to the simulant tests.

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