Influence of Water Vapor Pressure on Oil Shale Product Recovery

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Background

Previous work

- **Anhydrous non-isothermal evaluation**
  - **Fisher Assay, RockEval pyrolysis, ThermoGravimetric Analysis (TGA)**
- **Hydrous isothermal evaluation**
- **Sweep gas variation**
  - **1 atm, varying temperature and sweep rate**

    improves quantity

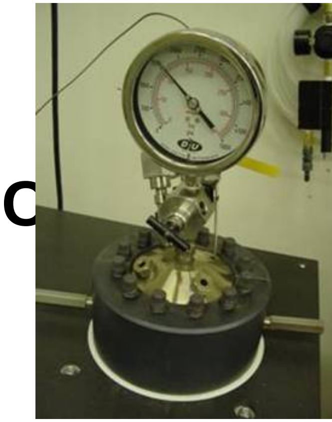
    generally lighter compound
- **Reaction kinetics**

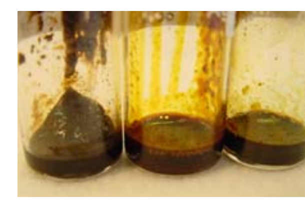
Objective

- Main objective
  - Develop a fundamental understanding of oil recovery from in situ oil shale production and it's environmental impact on the groundwater resource.
- Objective of this effort
  - Assess how addition of water effects the quality and quantity of products recovered from oil shale retorting processes

Experimental method

- **Add known amount of water and shale**
- **Pre-pressurize to obtain ~2,600 psi at 350°C**
- **Heat to 350°C for 72 hours**
- **Cool ~24 hrs to ambient temperature**
- **Collect**
  - **gas**
  - **floating oil**
  - **water**
  - **shale**

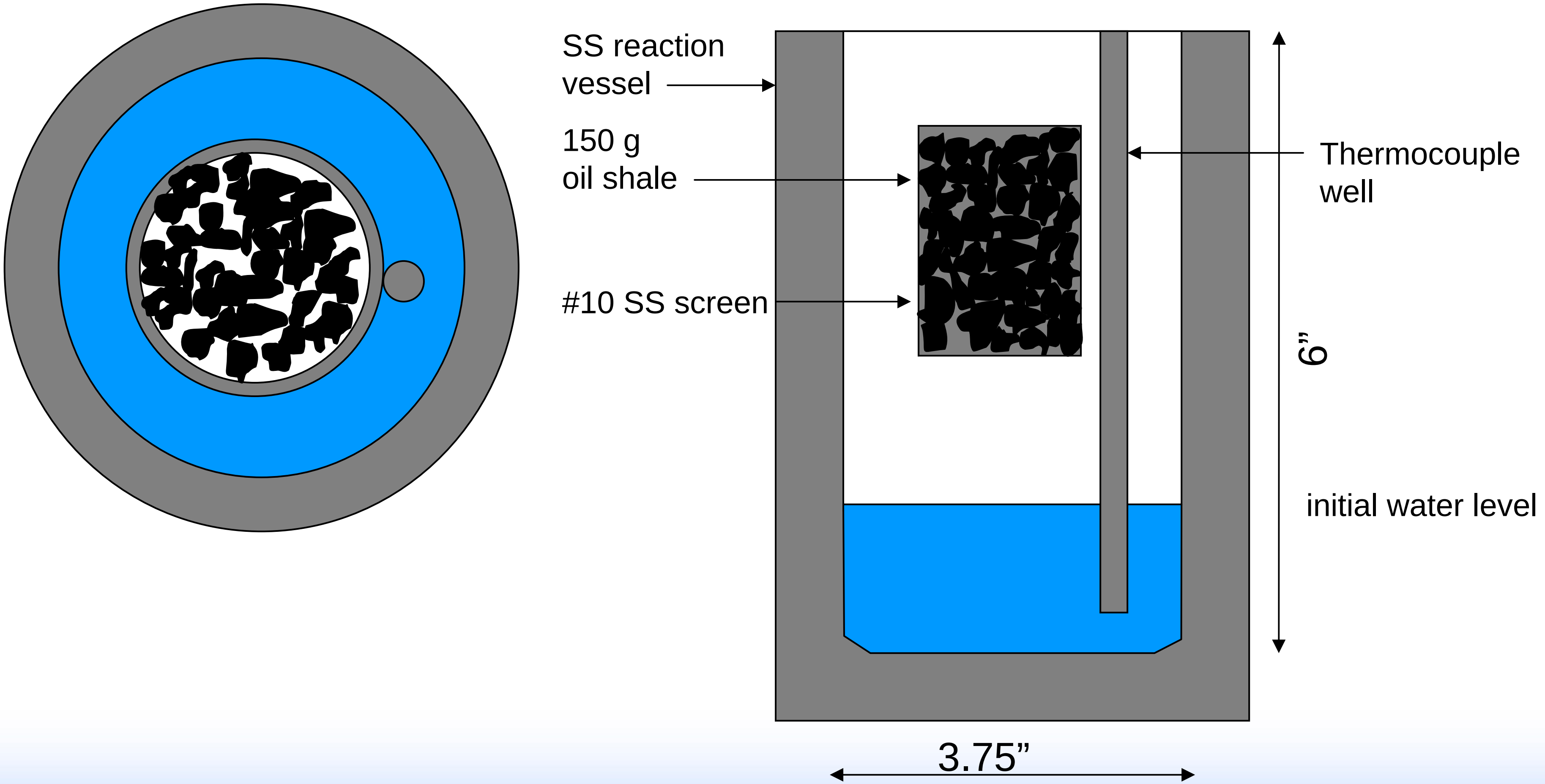




Experimental series

- Experiments conducted with
  - 0g 0%
  - 28g ~25%
  - 56g ~50%
  - 84g ~75%
  - 101g ~99%
  - 113g saturated
  - 250g hydrous
  - 300g hydrous

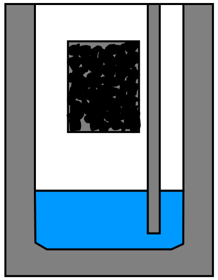
Low Water Fugacity Test Design

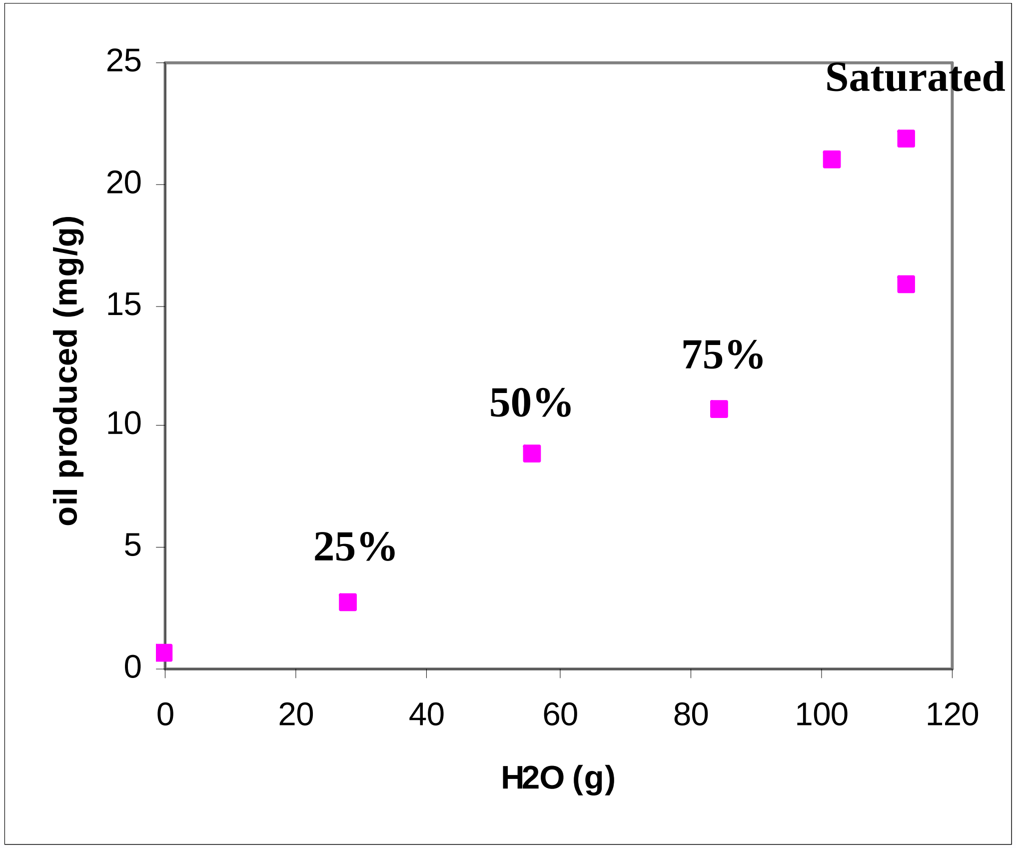


Experimental Design

Partial pressure results

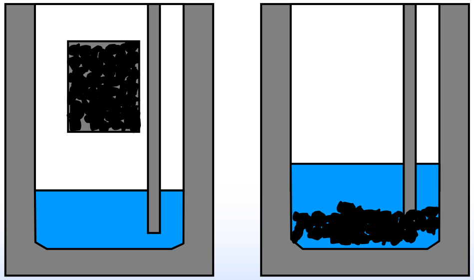
- **Fairly linear relationship of oil production as a function of water added.**

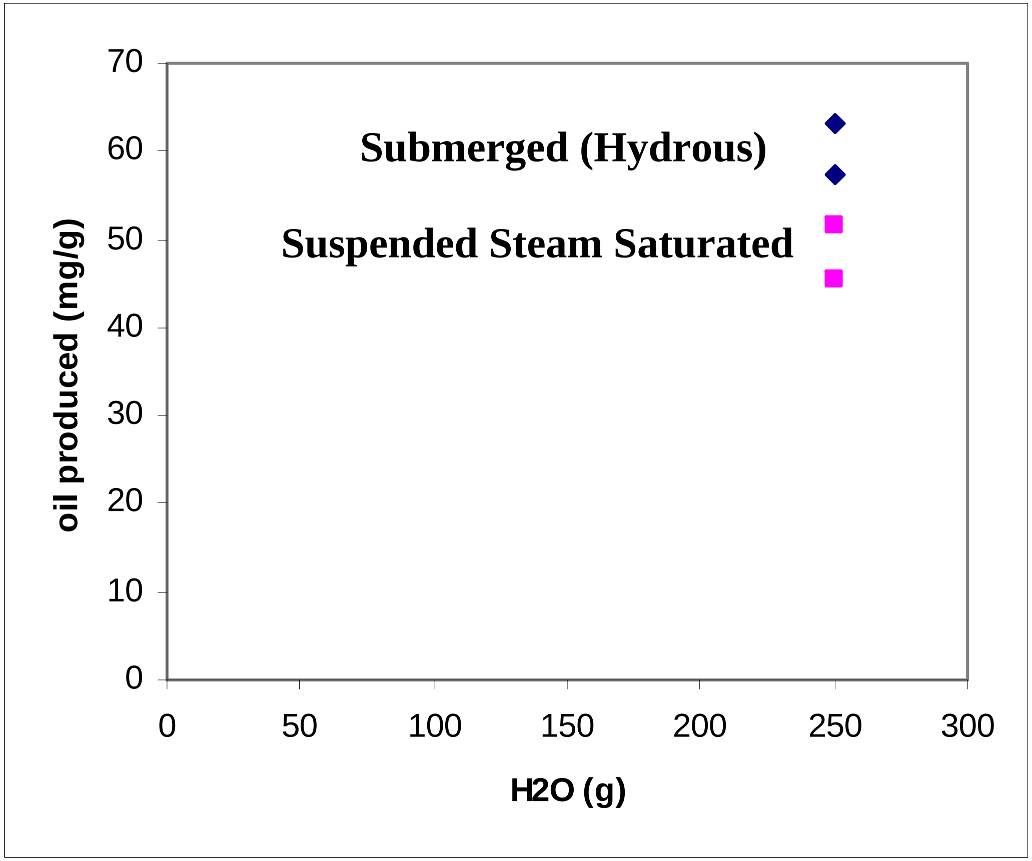




Submerged vs Suspended

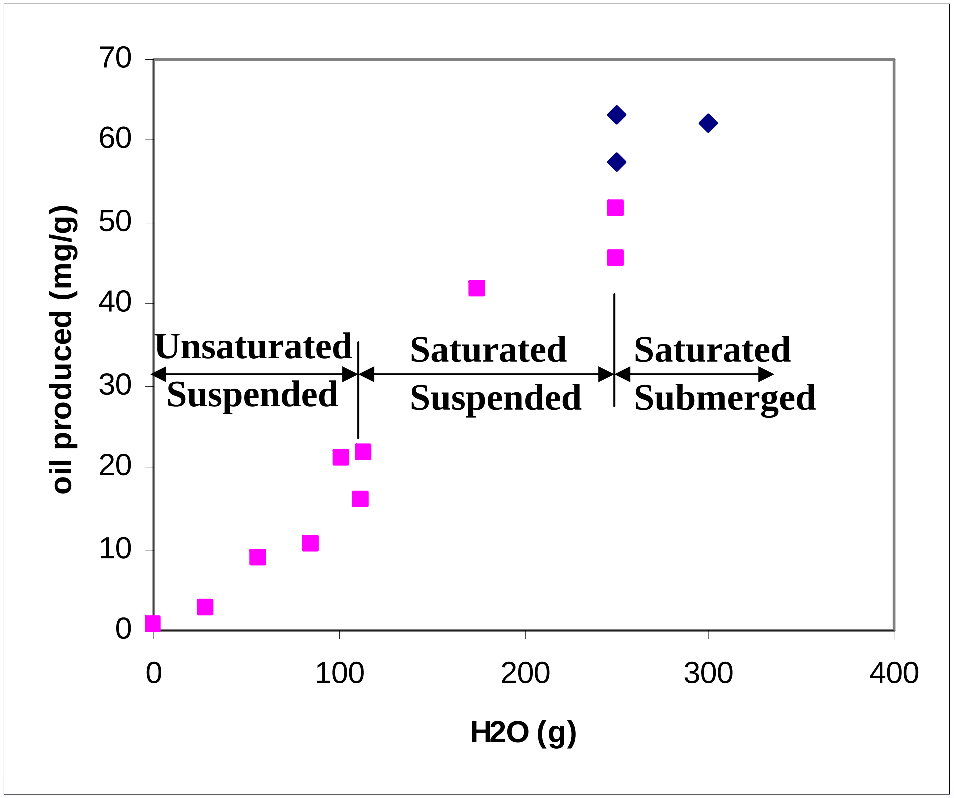
- **Submerged produces approximately 15% more liquid product.**
  - Pyrolysis
  - Expulsion
  - Migration





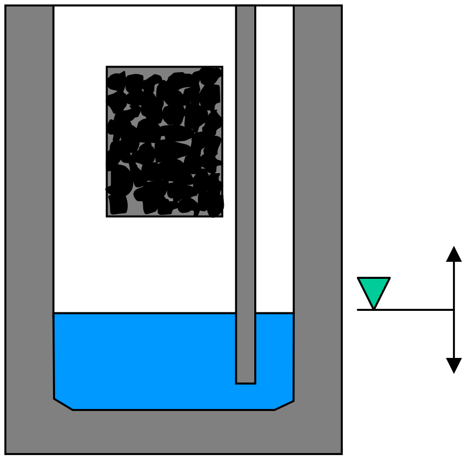
Anhydrous to Hydrous Results

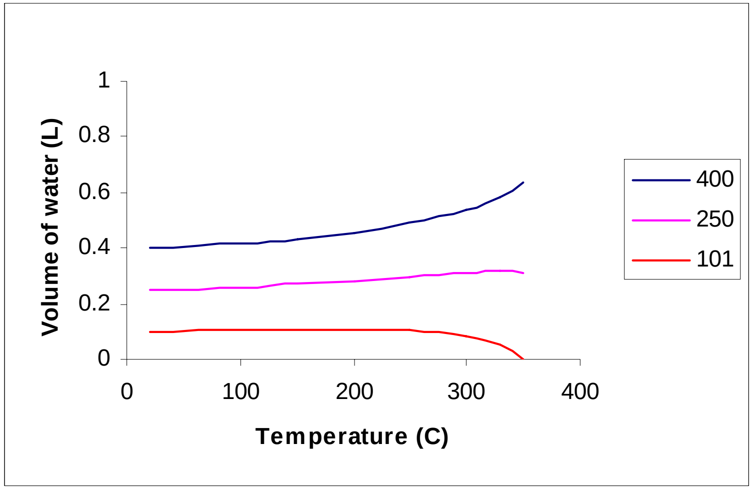
- **Shale exposed to steam – linear relationship with partial pressure**
- **Shale submerged in water – no correlation with water volume**
- **Shale exposed to saturated steam – linear relationship with water (???)**

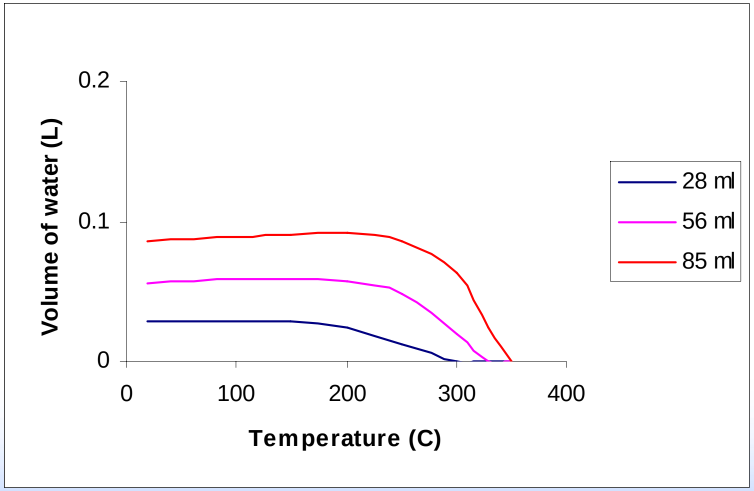


Water levels during heating

- Competition between water expansion and vaporization
- Mathcad modeling



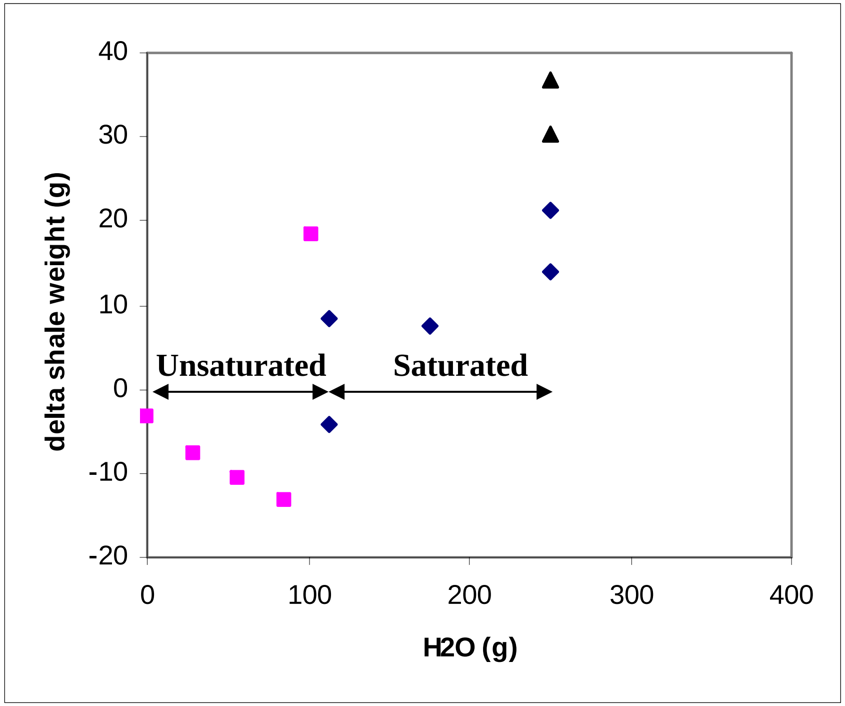




- Only over volumes of 250 ml is the water expanding significantly

Where is the liquid water?

- **Weight loss-gain of the shale suggests suspended water saturated samples may have been exposed to liquid water during testing**

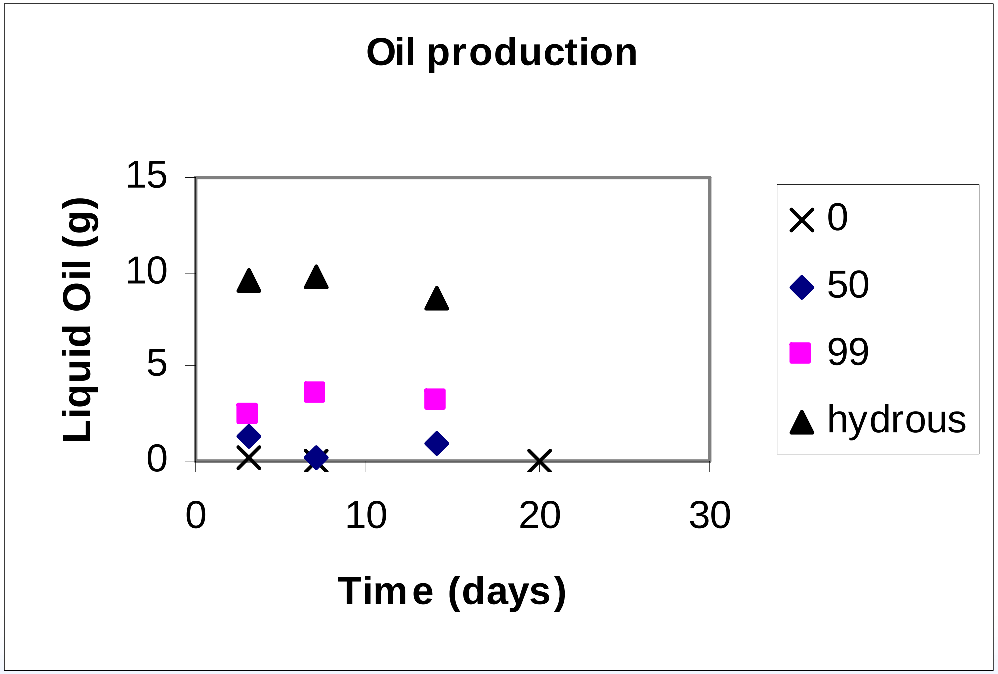


Longer Term Testing

- **What are the kinetics of the kerogen conversion of these tests?**
  - **Is three days sufficient?**
  - **When do the samples come to steady state?**
  - **How do these rates compare to those of heat transfer?**
- **Experimental conditions**
  - **3, 7, 14 (20) day tests**
  - **350°C, pre-pressurized, 4 fugacity conditions**

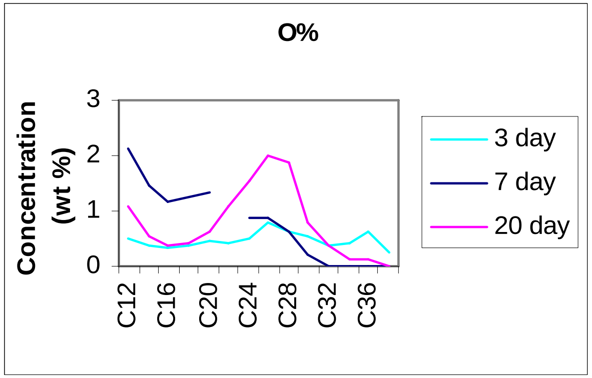
Longer Term Testing Results

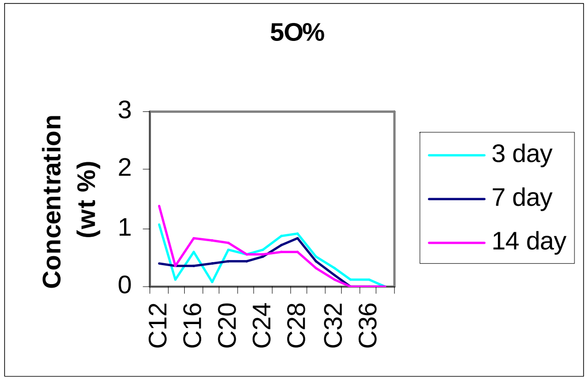
- **Liquid Oil Quantity**
  - **No significant changes with time**

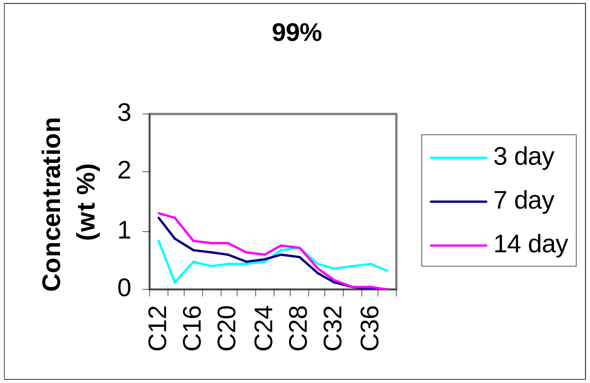


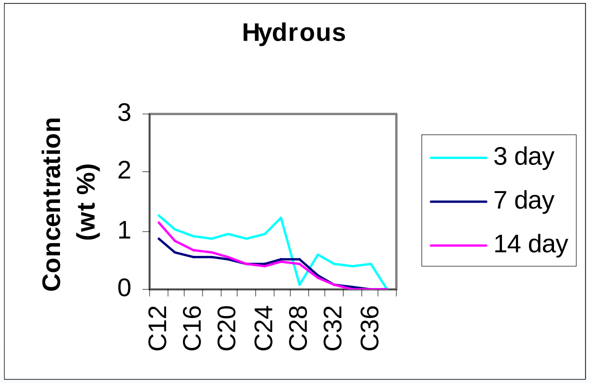
Longer Term Testing Results

- **Liquid Oil Quality …. in general….yes**









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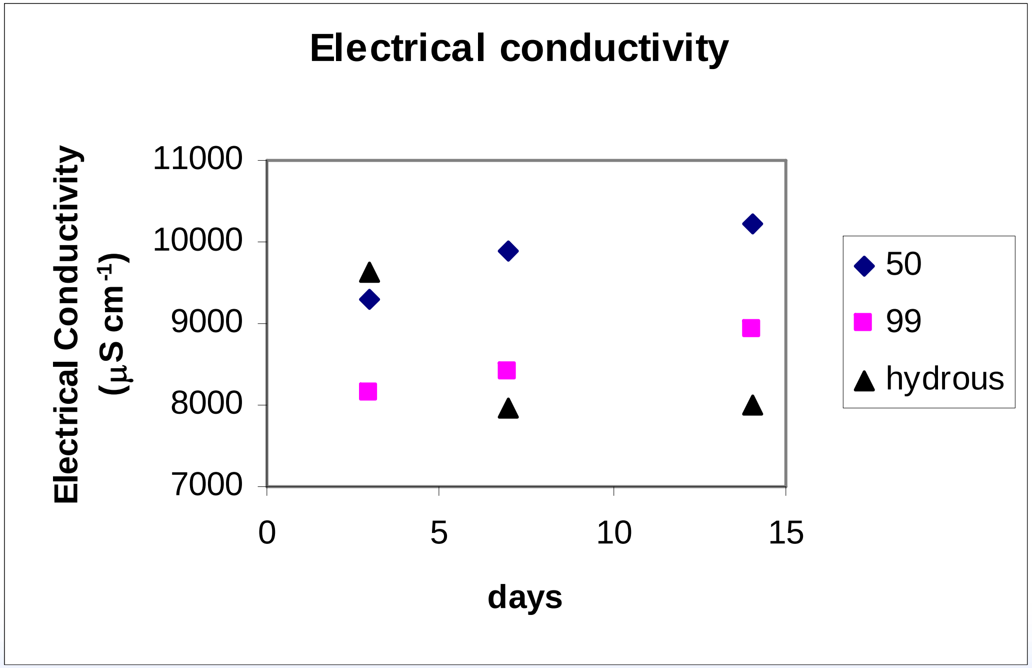
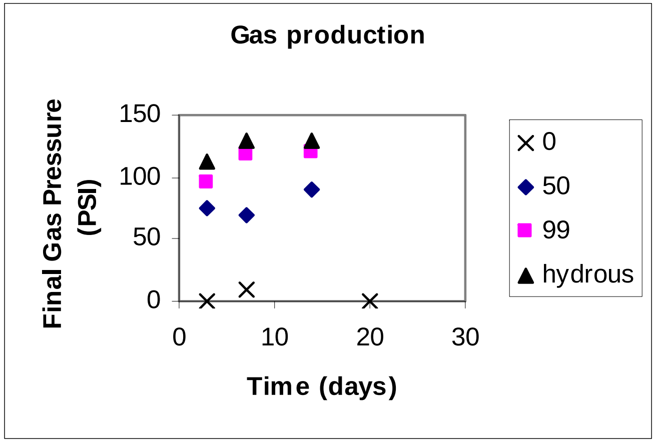
Longer Term Testing Results

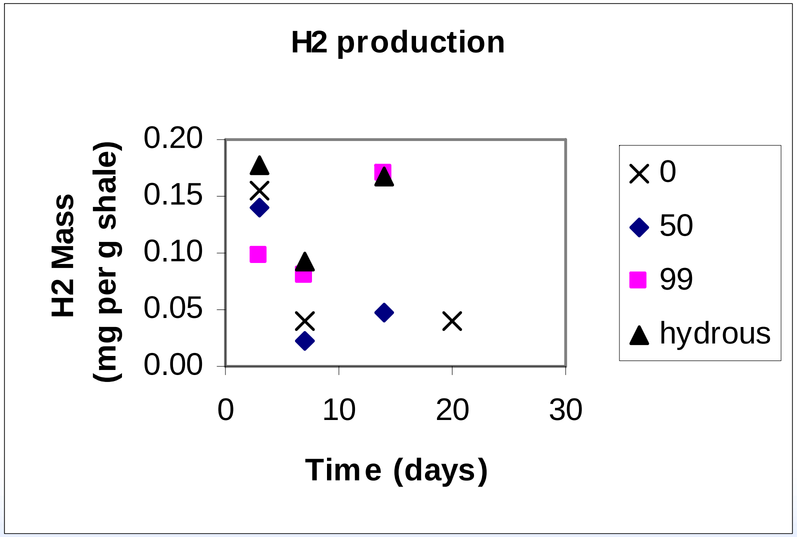
- **Water quality**
  - **In general….is becoming more conductive**

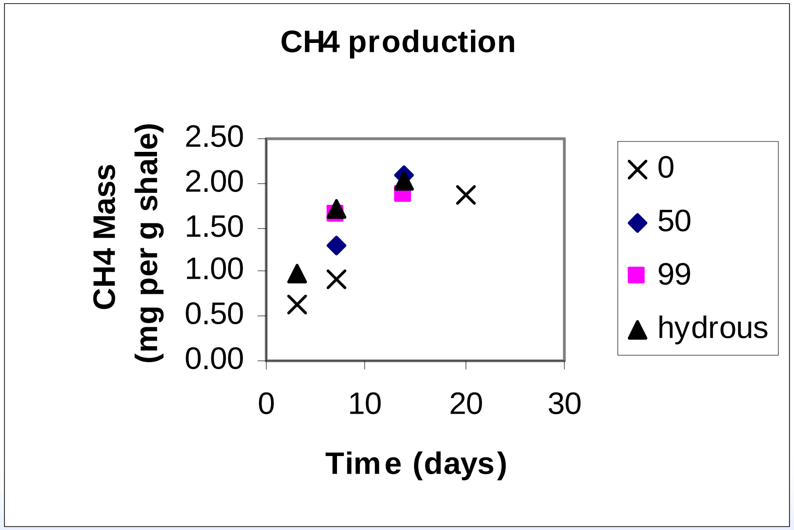


Longer Term Testing Results

- Gases quality
  - Greater pressure
  - Varying composition

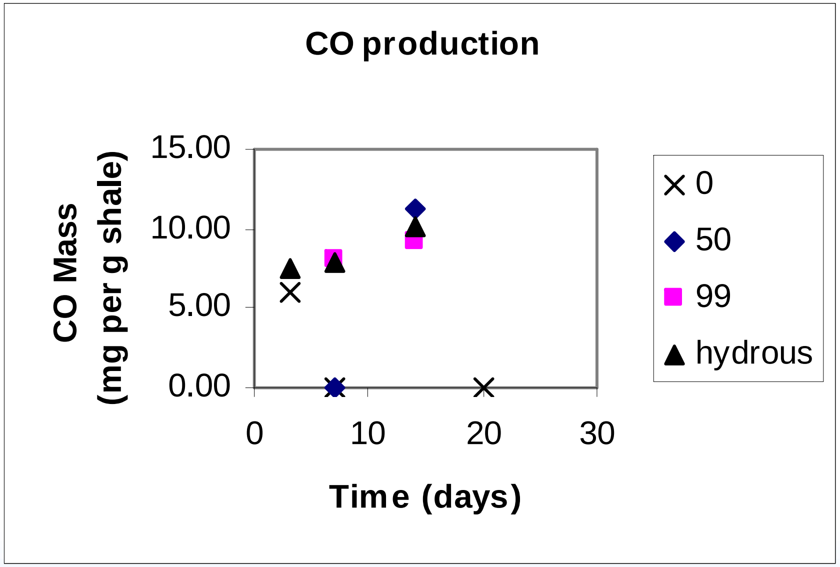


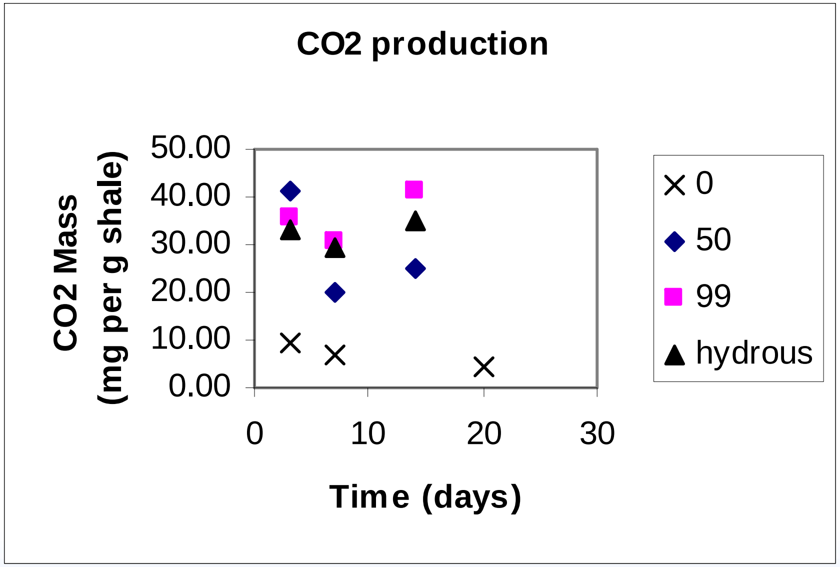




Longer Term Testing Results

- **Gases quality**
  - **More CO**
  - **Less CO_2 (??)**





Summary

- 3-day tests
  - Oil Quantity
    - Increases with water partial pressure
    - Hydrous retorts produce the most oil
    - Potential experimental bias in saturated tests
  - Oil Quality – needs more analysis
  - Gas quantity increases with water (7 day)
  - Water EC generally decreases with more water

Summary

- **Long-term (3-14 day) tests**
  - **Oil Quantity – no significant change with time**
  - **Oil Quality – improvement with time**
  - **Gas – overall quantity increases with time**
    - **more methane, decreasing hydrogen**
    - **increase CO, decrease CO_2 (??)**
  - **Water – increased EC with time**

Caveats

- Caution to applying these results to the field tests
  - Preliminary result
  - Need longer testing time
  - Need additional experiments
  - Need to examine constant pressure implications