THE UNIVERSITY of TULSA

Office of Research and Sponsored Programs

Hydrate Flow Performance JIP

14th Semi-Annual Advisory Board Meeting Brochure and Presentation Slide Copy Hydrate Risk Management Program

Principal Investigators

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Hydrate Risk Management Program – Executive Summary

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1. Scope of Work

This phase of hydrate studies at the University of Tulsa continues the investigation of hydrate formation and plugging during production and restart conditions, as well as investigates plug characteristics and dissociation methods. In the first project additional flow loop data will be gathered and modeling performed to focus on key variables affecting plugging in normal production conditions; variables such as liquid loading (or GOR), flow patterns and velocity, as well as salinity will be investigated since they have been demonstrated to play a significant role in plugging. In the second study, transient water displacement in a jumper system configuration based on several operating conditions will be investigated, as well as how this displacement is affected once hydrates start forming. In this study the efficiency of hydrate prevention strategies consisting of displacing the water out of the system, e.g. with dead oil or MeOH will be investigated. Parameters such as liquid/water loading, displacement rates and oil/water properties will be investigated. The third study generates solid hydrate plugs for characterization in a high pressure flow loop. Plug characteristics, such as density, porosity and permeability will be measured for plugs formed under different scenarios. Different dissociation strategies, such as depressurization, wall heating and thermodynamic inhibitors will be evaluated and a comparison of their efficiency provided.

2. Tasks

Twelve major tasks are envisioned for the three projects:

Project 1: Risk assessment of hydrate plugging during steady-state operations

Task 1: Simulation of new and past experiments (12 months)

Task 2: Steady-state hydrate formation experiments (6 months)

- Variables of interest: GOR, rates, oil viscosity, brine salinity and slurry flow

Task 3: Risk assessment matrix development

Task 4: Hydrate Particle Size Characterization Studies

Project 2: Risk assessment of hydrate plugging during restart operations

Task 5: Simulation runs to optimize design of facilities

Task 6: Flow loop design/construction/shakedown

Task 7: Experimental studies with transient flow facilities (18 months)

- Effect of liquid loading, water cut, brine concentration, flow velocity
  Gas vs. liquid dominated restart
- Brine in jumpers and risers if possible
- With Hydrates

Task 8: Risk assessment matrix development

Task 9: Olga simulation correlations/improvements

Project 3: Hydrate Plug Characteristics

Task 10: Facility Modification

Task 11: Formation of plugs & measurements of plug characteristics (6 months)

Task 12: Evaluation of dissociation methods (18 months)

- Depressurization, methanol injection, MEG injection

The schedule for completing the complex and interrelated tasks is shown in Figure 1. The study will last two years, finishing in 2009. Figure 1 also shows when significant deliverables in the form of reports, model validations, and data will be provided to the participants. Those activities colored in green are completed while those colored in blue are scheduled.

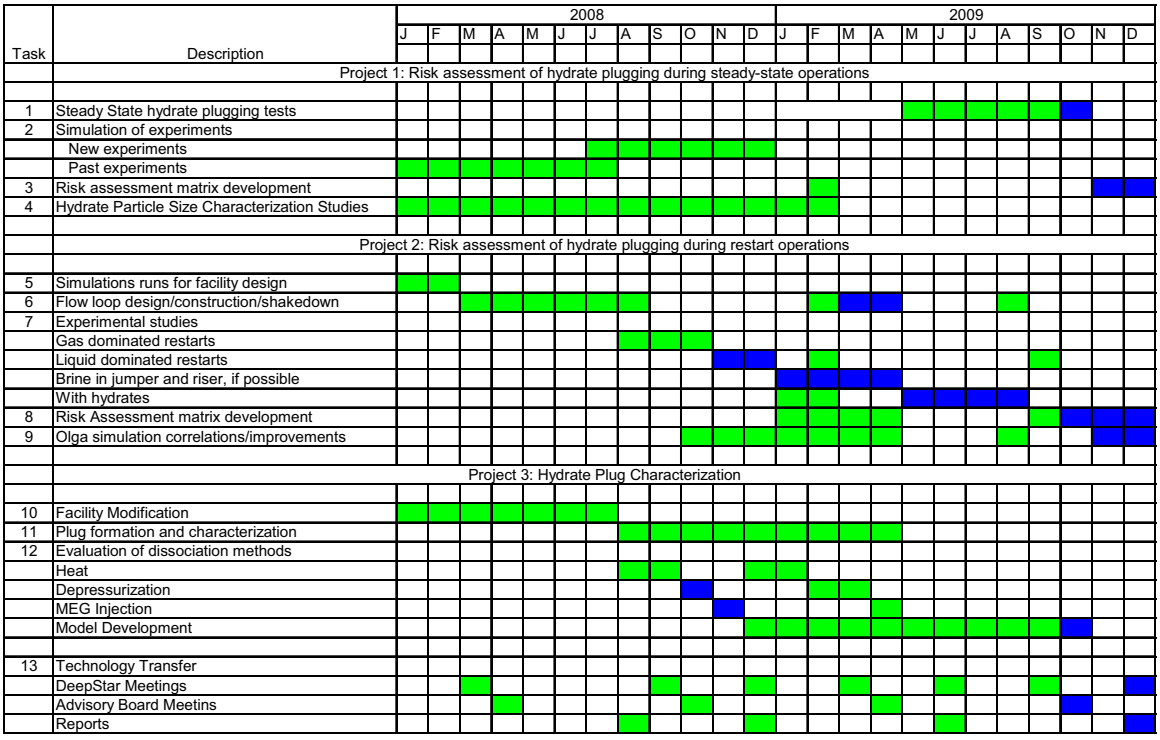

Figure 1 – Task Chart for Hydrate Management Studies

3. Activity Summary

The first six month of the project were focused on constructing or modify facilities and shaking them down to generate high quality data. Since that time, the focus has been on simulating proposed tests and conducting experiments and analyzing data. The progress for the three projects is discussed below.

Project 1

To fully understand the plugging risk, and to develop a plugging risk map, four system types need to be investigated.

A. Oil systems. All water converted into hydrates and the “dry” hydrate particles are suspended in the oil.
B. Oil dominated systems. A small amount of free water is present in a continuous oil phase.
C. Gas condensate systems. A small amount of condensate is present in a continuous water phase.
D. Dry gas systems. Hydrates suspended in water.

To date, the project has primarily focused on oil-water mixtures below the inversion point (system types A and B). Current knowledge suggests that type A and B systems have a lower plugging risk than type

C systems; however, little is known about system types C and D. Therefore, the purpose of the test program this reporting period was to determine the volume percent hydrate in the total liquid for type C and D systems that could be transported without flow disturbances and without forming a plug. Further, under-inhibition may change the agglomeration properties for the systems tested. More specifically some observations suggest that MeOH makes hydrate particles more “sticky”.

Twenty gas-water tests were conducted of which several had a small amount of MEG or condensate added. For the tests conducted to date, little to no pressure drop increase was seen for slurry concentrations less than 6 % but all cases plugged at concentrations greater than 20%. The staged (slow) cooling experiment exhibited a lower pressure drop than the fast (crash) cooling experiments. No plugging was seen when 10% MEG was added.

Project 2

Twenty one liquid restarts were conduced using kerosene and the 19 and 220 cp model oils. Higher velocities (>1 ft/s) displaced the water phase out of the jumper as a slug while lower velocities (<0.5 ft/s) promoted more mixing and removed less water. Restarting with a viscous fluid helped displace the water phase but flowing more than one jumper volume did not remove more water.

Modifications to the previous jumper facility were made in order to begin the THI – water mixing experiments as well as the hydrate experiments using cyclopentane, The limited chemical resistance of the acrylic pipe along with the fact that the previous facility design did not allow for sufficient expansion and contraction of the plastic components led to the decision of replacing the material of the pipes in the jumper. Polycarbonate pipes were used to substitute the acrylic tubes and the assembly of the new jumper facility was completed. Six shakedown tests are planned the last quarter of the year; three with MEG and three with methanol. A proposal was prepared for continuation of this effort in the next phase. The design of the new polycarbonate pipe in pipe facility for the formation of hydrates was also completed.

OLGA simulations were found to over predict water carry over. Up to 90% difference was found for the water with gas restarts, up to 45% difference for the oil with gas restarts and up to 25% difference with liquid restarts. As a result, CFD modeling efforts were initiated for both gas and liquid restarts. Preliminary results for the gas restarts are promising with as much as 50% improvement seen.

Project 3

The final experiments for plug characterization and dissociation studies with a low spot/leaky valves configuration have been completed – totaling 19 experiments. In the last experiments, a measurement technique to accurately measure dissociation times using plug density profiles was developed and dissociation data was compared with TU’s dissociation model and CSMPlug. Experiments for plug formation with different subcoolings have been conducted; subcooling was varied by changing salinity, temperature or both. A last series of four tests was aimed at comparing dissociation techniques: heating, depressurization, nitrogen and MEG injection.

Gas-water hydrate plugs formed using the leaky valve or low spot configuration were rather uniform with porosities that varied between 0.8 to 0.9. Porosities were not quantifiable for the plugs that were liquid filled.

4. % Completed: 87%

5. Conclusions/Observations

For the hydrate transportability tests faster cooling rates were detrimental to transportability while higher velocities were found to increase formation rates but they also increased transportability. Liquid loading did not seem to have a large impact on transportability.

For the transient studies, higher velocities (>1 ft/s) displaced the water phase out of the jumper as a slug while lower velocities (<0.5 ft/s) promoted more mixing and removed less water. Restarting with a viscous fluid helped displace the water phase but flowing more than one jumper volume did not remove a lot more water.

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Heating and depressurization, to some extent, show radial dissociation of the plugs as expected, while dissociation with MEG does not occur radially but seems to depend on plug porosity, permeability and contact with the inhibitor. Feasibility of dissociation with nitrogen was confirmed for the selected operating conditions; the dissociation with nitrogen was found to be very slow (very low injection rate).

Two types of hydrate blockages were observed, full and partial. Full plugs formed when the hydrate slurry stalled due to friction and plug permeabilities ranged from 1 to 100 Darcies. If these plugs were liquid filled the permeability was dramatically reduced. Inflow or pressure pulses could collapse the plug or make them impermeable. Plugs also form when the slurry stops flowing partially filling the pipe. Permeability for these plugs were high (>5000 Darcies) because of the open void space on top of the slurry.

6. Future Work

Transient and steady state tests will be completed; only six liquid jumper restart tests with MEG and methanol and one hydrate transportability test for condensate systems remain. A risk matrix for both transient and steady state hydrate blockages will be developed. The new “pipe in pipe” jumper facility for studying hydrate formation and dissociation will be constructed. Shakedown tests will be conducted before several tests with cyclopentane are made. Calsep will continue modeling the flow loop experiments using the recently developed flow loop simulator. The hydrate characterization studies will be documented in a report. Evaluation of dissociation methods compared to plug dissociation simulation tools will conclude and the findings will be documented in a report.