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Economic Analysis and Feasibility study of Gas Production from Alaska North Slope Gas Hydrate Resources

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Gas hydrates are solid, crystalline compounds formed from water and gases under specific temperature and pressure conditions. A notable feature of hydrates is that a volume of hydrate containing a certain amount of gas molecules is considerably smaller than the same molecular quantity of free gas. Methane hydrate deposits occur in the subsurface of many permafrost areas as well as in oceanic sediments. Interest in gas hydrates as an energy resource arises from the large volumes that reputedly exist in these locations. Globally, an estimate of in-place gas hydrate is 100,000 to 3 x 10^9 trillion cubic feet (Collett, 2001). On the Alaska North Slope (ANS), probabilistic estimates indicate approximately 590 trillion cubic feet of gas in place within gas hydrates (Collett, 1997). If these resources can be recovered and transported economically, they may represent a significant energy resource. However, significant practical and economic challenges remain.

Currently, most work is based in the laboratory. However, if the early phases of the research indicate that production of gas from hydrates may be feasible, future ANS project phases could include further data acquisition and production testing. An off-the-shelf simulator was modified to model gas dissociation from gas hydrates due to depressurization. The objective of this work is to model the production profile of a pilot development scheme, analyze the resulting production profiles, and evaluate possible economics of such a project. At present, little quantifiable data is published regarding the ANS gas hydrate accumulation characteristics and no decision has been made regarding the exact location and size of a potential gas hydrate development. Accordingly, this study examines various scenarios of differing geologic characteristics, reservoir size and well configurations.

STARS (Steam, Thermal, and Advanced Processes Reservoir Simulator) is a three-phase multi-component thermal and steam additive simulator, developed by the Computer Modeling Group Limited (CMG) and widely used throughout the petroleum industry. STARS can also be used to model in-situ combustion processes that may be applied for the enhanced recovery of heavy oil-bearing reservoirs. The chemical and thermodynamic processes of different reactions can be entered and simulated. This feature can be adapted to simulate the nature of gas hydrate. Rather than model the exothermic combustion of hydrocarbons, the kinetics for gas hydrate dissociation is specified as an input. Grid systems can be regular cartesian, variable thickness and variable depth, or radial/cylindrical. One, two, and three dimensional configurations are allowed with any of the grid systems. A variety of operating conditions and constraints may be specified for each of the vertical or horizontal wells as envisioned in various potential development scenarios.

Work conducted by Collett (1993) and, as part of this project, by the University of Arizona and the U.S. Geological Survey, interprets ANS gas hydrate accumulations within several sub units of the Sagavanirktok formation. Some gas hydrates may contiguously overlie accumulations of free gas. The investigated production scenario involves producing gas from the free gas zone, using conventional techniques. As the pressure in the free gas zone reduces below the stability pressure of the adjacent gas hydrate zone, the gas hydrate at the gas-gas hydrate interface begins to dissociate into gas and water components. The dissociated gas is then produced with the associated free gas via the existing well.

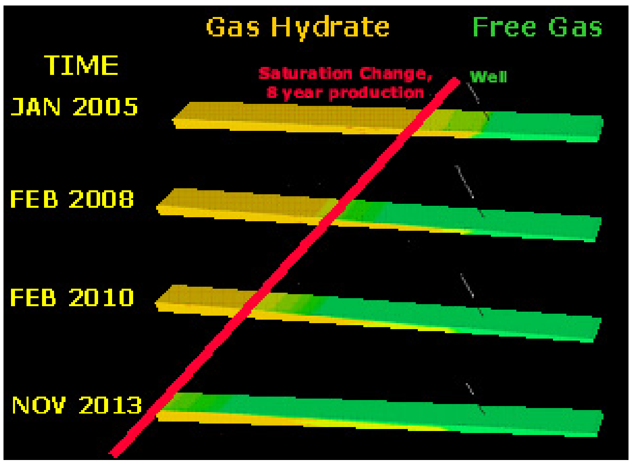

Figure 1. Simulation grid saturation changes

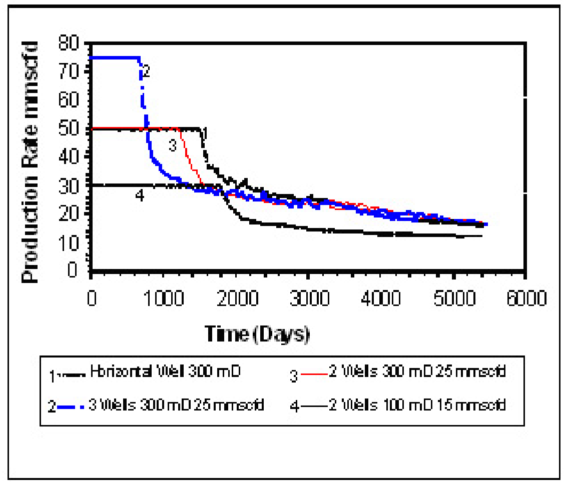

Figure 2. Gas production profile schematic for modeling gas production after 15 years

At present, detailed reservoir and fluid characterization of the ANS gas hydrate accumulations is in-progress; initially, a schematic representation was created. Major faults compartmentalize the reservoir into blocks approximately 1 mile wide (1600 m) and 4 miles long (6437 m). The SW portion of the simulation block starts at a thickness of 20 meters and uniformly thins to reach a thickness of 10 meters at the NE extremity and the block dips 1.9° to the NE. Based on the pressure and temperature gradients of the locality, the lateral extent of the gas hydrate to free gas interface was calculated to be 760 meters. A water saturation of 20% was chosen throughout the reservoir, including some movable water in the gas hydrate zone. Gas hydrate saturation in the initial gas hydrate zone is 70% and is zero elsewhere. The gas hydrate zone also has 10% excess methane gas saturation, while in the free gas zone there is a gas saturation of 80%. Two production wells were positioned below the gas hydrate to free gas interface, with an operating constraint of 25 mmscfd maximum flow and a minimum BHP of 300 psi.

To make efficient use of computing power, only half the reservoir was simulated and the results doubled to represent the whole reservoir block (Figure 1). Various cases were run with variations in absolute permeability, well spacing, production rate and gas hydrate saturations. The simulation period was for 15 years. While recognizing this study has limitations due to the small amount of definitive input data and the approximations used, coupled with the imprecision of the gas hydrate dissociation simulator, useful conclusions can still be drawn. Production profiles generated from the simulations indicate that an accumulation of methane hydrate in a reservoir will begin to dissociate into free gas when the reservoir pressure is lowered. Gas and water production profiles, reservoir pressure, temperature and saturation profiles are displayed (Howe, 2004) after 15 years of the process. An illustration of the production profiles for horizontal and multiple wells is given in Figure 2. Comparing the rates with other well configurations for the same reservoir, the horizontal well proves to have some incremental benefits, with an extended plateau compared to a two-well case, and a slower decline rate as opposed to a three-well scenario. Cumulative production with a horizontal well is 173 bcf in comparison to 161.5 bcf for the two-well case and 169.8 bcf for the three-well case. Recognizing that at the end of a 15-year production period, only approximately 50% of the gas initially in place has been recovered, an extended 30-year production simulation of the base case was performed. At the end of the simulation, the total cumulative production was 230 bcf. This is a recovery rate of 73.7% of the initial free gas in place of 312 bcf. Due to the long computation times required to evaluate field-wide development scenarios, a system is being developed to capture the salient behaviors of these simulations in a pseudo-material balance treatment. These methods are commonplace in forecasting coalbed gas reserves (Jensen, 1997).

Certain characteristics were noted during the simulation: as it moves up the reservoir, the dissociation interface is not uniform across the reservoir, but exhibits fingering and variation. The cooling effects of the gas hydrate dissociation into free gas were also observed. In the region of the dissociation, reservoir temperatures approached 0° C. A limitation of the STARS is that it cannot account for temperatures below 0° C and so the total effects of the cooling may not be fully modeled. Further work to investigate the magnitude of cooling and thermal recuperation is recommended. The large amounts of water that are produced during gas hydrate dissociation are not produced to the surface: water from dissociation tends to drop to the bottom of the reservoir and is only produced in small volumes.

One potential development scenario uses directional or extended reach drilling (ERD) techniques from centrally located well pads. At each well pad, the gas would be piped to a manifold building, with a slug catcher, primary and test separation, and mass flow meters. From the gathering point a large ID pipeline could transport the gas to a central processing plant. At this location, the gas could be used for field operations or delivered to a gas sales pipeline.

Hydrate derived gas will be nearly pure methane so will require little processing before it joins any associated gas to be compressed. This gas would then be piped through a large-diameter, long-distance pipeline to connect with the existing North American distribution system. Using this scenario, which assumes a completed gas pipeline, an independent economic analysis was performed by UAF using the simulated production profiles. The UAF analysis suggests that such a project could be economic if certain assumptions are realized. Some of the cases with a lower permeability and well flow rate were uneconomic as stand-alone projects, but could potentially be viable if several reservoir blocks could be developed at the same time.

In summary, a commercial simulator was adapted to model gas hydrate dissociation due to depressurization of an adjacent free gas. This was applied to a scenario of ANS gas hydrate accumulations, with production and sale of the produced gas. The depressurization method of dissociation was found to be feasible and the results give encouragement that further research into gas hydrate resource potential may be beneficial.

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References

Collett, T.S., 1983. "Detection and Evaluation of Natural Gas Hydrates from Well Logs, Prudhoe Bay, Alaska". M.S. Thesis, University of Alaska – Fairbanks, pp.-77.

Collett, T.S.,1997. "Gas Hydrate Resources of Northern Alaska". Bulletin of Canadian Petroleum Geology, v. **45** pp. 317-338.

Collett, T.S.,2001. "Natural Gas Hydrates-Vast Resource, Uncertain Future". USGS Fact Sheet FS-021-01.

Howe, S.J., 2004. " Production Modeling and Economic Evaluation of a Potential Gas Hydrate Pilot Production Program on the North slope of Alaska". M.S Thesis, University of Alaska Fairbanks, AK.

Jensen, D and Smith, L.K. "A Practical Approach to Coalbed Methane Reserve Prediction Using a Modified Material Balance Technique", Proceedings, International Coalbed Methane Symposium, Tusaloosa, Alabama, USA, May, 1997.