GAS HYDRATES

Natural gas hydrates are solids that form from a combination of water and one or more hydrocarbon or non-hydrocarbon gases. In physical appearance, gas hydrates resemble packed snow or ice. In a gas hydrate, the gas molecules are "caged" within a crystal structure composed of water molecules. Sometimes gas hydrates are called "gas clathrates". Clathrates are substances in which molecules of one compound are completely "caged" within the crystal structure of another. Therefore, gas hydrates are one type of clathrate.

Gas Hydrate Importance to the Energy Industry and Society:

1. Are a potential energy resource
2. May play a role in past and future climate changes
3. Potential to cause production (flow assurance) problems

Physics and Chemistry of Hydrates

Gas hydrates are stable only under specific pressure-temperature conditions. Under the appropriate pressure, they can exist at temperatures significantly above the freezing point of water. The maximum temperature at which gas hydrate can exist depends on pressure and gas composition. For example, methane plus water at 600 psia forms hydrate at 41º F, while at the same pressure, methane + 1% propane forms a gas hydrate at 49º F. Hydrate stability can also be influenced by other factors, such as salinity (Edmonds et al., 1996).

Per unit volume, gas hydrates contain a tremendous amount of gas. For example, 1 m³ of hydrate disassociates at atmospheric temperature and pressure to form 164 m³ of natural gas + 0.8 m³ of water (Kvenvolden, 1993).

The natural gas component of gas hydrates is typically dominated by methane, but other natural gas components (e.g., ethane, propane, CO2) can also be incorporated into a hydrate. The origin of the methane in a hydrate can be either thermogenic or biogenic gas. Microbial gas formed during early diagenesis of organic matter can become part of a gas hydrate in continental shelf sediment. Similarly, thermogenic gas leaking to the surface from a deep thermogenic gas accumulation can form a gas hydrate in the same continental shelf sediment.

Geological Settings Where Gas Hydrates Occur

Gas hydrates can be detected seismically (e.g., Hornbach et al., 2003), as well as using well logs (Goldberg and Saito, 1998). Gas hydrates occur in two discrete geological situations:

- Marine shelf sediments (distributed worldwide, see, for example, Kvenvolden 1993; Kvenvolden and Lorenson, 2000).
- Onshore polar regions beneath permafrost
Hydrates occur in these settings because the pressure-temperature conditions are within the hydrate stability field (see, for example, Lerche and Bagirov, 1998).

**Gas Hydrate Importance to the Energy Industry and Society**

Gas hydrates are of interest primarily for 3 reasons:

1. **Gas hydrates are a potential energy resource:** Considering the planet as a whole, the quantity of natural gas in sedimentary gas hydrates greatly exceeds the conventional natural gas resources (e.g., Kvenvolden, 1993). As a result, numerous studies have discussed the energy resource potential of gas hydrates (see, for example, Collett, 1993, 1997, 2002; Iseux, 1992; Kvenvolden, 1993; Milkov and Sassen, 2003).

   However, utilization of gas hydrates as an energy resource has been largely inhibited by the lack of economical methods for production for most hydrate accumulations, especially marine shelf hydrates. A variety of mechanisms have been proposed for economically developing gas hydrates as an unconventional gas source (e.g., see discussions in Goel et al., 2001, Sawyer et al., 2000).

   Thus far, the only method that has been successful used to economically produce gas from gas hydrates is the "depressurization method". This method is applicable only to hydrates that exist in polar regions beneath permafrost. This method is applicable when a free gas phase exists beneath the hydrate accumulation. Under such circumstances, production of the free gas leg using conventional gas development techniques produces a pressure drop. This pressure drop causes the overlying hydrate to become unstable and to progressively disassociate into free gas + water, a process that adds gas to the underlying free gas accumulation.

2. **Potential role of gas hydrates in past and future climate changes:** Gas hydrates are also of interest because of their potential role in climate change. Gas hydrates in continental shelf sediments can become unstable either as a result of warming bottom water, or as a result of a pressure drop due to a reduction in sea level (such as during an ice age). If these marine gas hydrates begin to rapidly disassociate into gas + water, then the methane trapped in the gas hydrates can be released to the atmosphere.

   Methane is a greenhouse gas. In fact, methane is many times more effective as a greenhouse gas than is CO₂. Therefore, if the flux of methane to the atmosphere from dissociating hydrates is sufficient in quantity, this methane can cause global warming. This process is believed to have influenced past climate changes (see, for example, Henriet, 1998; Haq, 1998; Hesselbo et al., 2000; Kvenvolden, 1991), and may enhance the current global warming episode by way of a "positive feedback" loop. Specifically, as the earth warms, increasing bottom water temperatures could cause gas hydrate disassociation in many marine shelf locations. This gas hydrate disassociation would cause further warming due to the greenhouse effects of the gas which is released.

3. **Production (flow assurance) problems:** Gas hydrates can spontaneously form in petroleum production equipment and pipelines associated with deep-water petroleum production and arctic on-shore petroleum production. These unwanted hydrates can clog equipment, preventing optimum production of hydrocarbons.

   Various methods are used to prevent hydrate formation in petroleum production and transportation equipment (see, for example, Paez et al., 2001; Reyma and Stewart, 2001; Yousif and Dunayevsky, 1997; Behar et al., 1994).
Research on Gas Hydrates

A variety of gas hydrate research programs are currently underway in different parts of the world, and a listing of all of them is beyond the scope of this article. However, a few key research programs are particularly worthy of note:

The US Department of Energy Gulf of Mexico Joint Industry Project (JIP) is an aggressive multimillion dollar gas hydrate research program. JIP participants include the US Department of Energy and a group of petroleum industry companies, including ConocoPhillips, Halliburton, Japan National Oil company, MMS, Reliance Industries, Schlumberger and TotalFinaElf. In 2004, the JIP program cored multiple gas hydrate accumulations in the GOM. This multiyear program is summarized by Shirley (2004).

Another program of note was undertaken by a Japanese government-sponsored gas hydrate research organization: the Research Consortium for Methane Hydrate Resources in Japan (also known as the MH21 Research Consortium). That program drilled and cored numerous wells in the Nankai Trough offshore of eastern Japan.

However, MH21 Research Consortium gas hydrate research extends beyond coastal Asia. In 2002, production testing of gas hydrates in the Mackenzie Delta (Canada) was conducted by an international consortium that included the Japan National Oil Company and the Geological Survey of Canada. Detailed results of that project were presented at a conference in Chiba, Japan in December 2003.

Additional Information on Gas Hydrates

At the bottom of this article, we have listed over 50 published articles that provide information on a variety of different aspects of gas hydrates. Three excellent gas hydrate review articles are also available on line at the US Energy Information Administration web site:

- “The Future Supply Potential of Natural Gas Hydrates”
- “Natural Gas Hydrates Update 1998-2000” by David F. Morehouse
- “Natural Gas Hydrates Update 2000-2002” by David F. Morehouse

For more information on the techniques described here, or to discuss a specific project, e-mail us at oiltracers@weatherfordlabs.com, or call us at U.S. (214) 584-9169.

References


Shirley, K., 2003, GOM gas hydrate opportunities explored - Love 'em or hate 'em- They're there: *AAPG Explorer (January 2004)*, v. 25, p. 22-23.
