Fluid Mechanics of Environmentally Significant Hydrate Slurries

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What is a Hydrate?

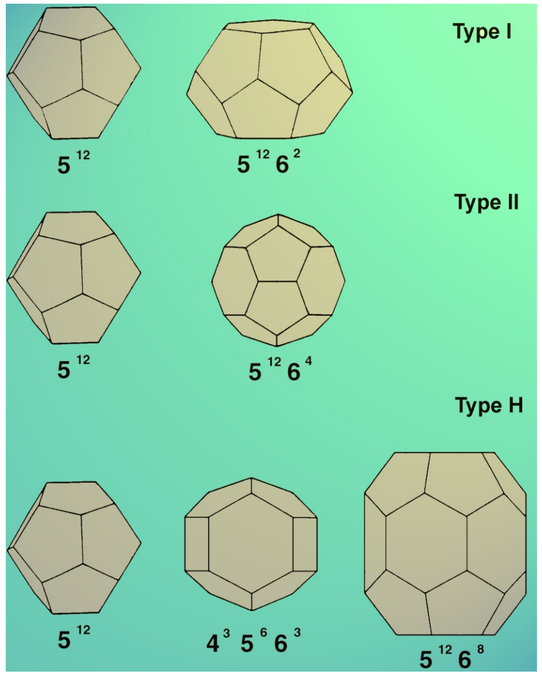
A Clathrates is a cage like lattice of a single type of molecule, such as water, which forms around a guest molecule of a different type, such as methane. A clathrate formed of water and gas, has an appearance similar to ice and is termed a gas hydrate.

Hydrate formation can occur at much higher temperatures than water will freeze. Formation is dependent on a combination of critical temperatures and pressures.

Propane Hydrate Combustion

Some Common Hydrate Clathration Conditions

Hydrate Guest Molecule	Temperature (C°)	Pressure (atm)
Propane	5.2	5
Methane	15	100
Tetrahydrofuran	4	1
Xenon	24	9.9

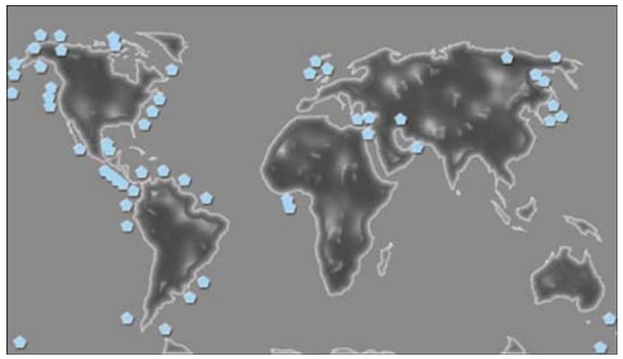


Clathrate Hydrate Structures

Structure 1 consists of 46 water molecules forming two types of cages. All clathrates share dodecahedral cages in common. Methane guest molecules form Structure I cages.

Structure 2 consists of 136 water molecules forming two types of cages. Propane guest molecules form Structure 2 cages.

Structure H consists of 34 water molecules forming three types of cages. Structure H does not occur naturally.



USGS Map of Seafloor Hydrate Deposits

Current Work: Clathrate Production

We are currently exploring the production issues related to:

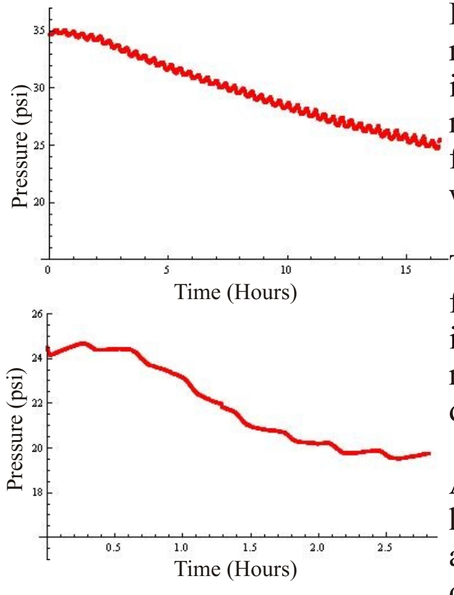
1)Minimization of Nucleation Time: Without assistance, hydrates formation can take days to months to begin.

2) Guest Molecule Cage Fill Rates: Principal difficulty in hydrate utilization research is effectively controlling and quantifying the ratio of empty hydrate cages.

We are exploring the best mix of the following solutions to best match our experimental needs:

1) over pressurization
2) super cooling
3) agitation
4) seeder hydrates
5) surface area variation
6) gas composition

Propane Hydrate Gas Consumption Vs Over pressurization



Hydrate formation removes gas from its environment. If no clathrate were forming, pressure would be constant.

The rate of formation can be inferred from the rate of pressure drop.

At 13° C, this hydrate would form at any pressure over ~13 psi.

Why study Hydrates?

Hydrates form naturally in the world around us. Methane hydrates can be found in the sediments of the sea floor, in the ice of the arctic tundra, and in natural gas pipelines.

Future Energy:

- A substantial fraction of the Earth's energy reserves can be found in hydrate sediments
- Higher mass density than liquid methane makes hydrates an attractive fuel

Global Warming:

- Methane is a 25x more powerful green house gas than Carbon Dioxide.
- Above a critical temperature hydratres become unstable. The arctic tundra methane hydrates are approaching this temperature
- Conjectured to be previous source of global extinction events.
- Potential solution to carbon sequestration as a green-house gas sink.

Inhibition of formation:

- Damaging to oil and natural gas industries, hydrates form in pipelines and wells.

Future Work: Combustion Measurements

Very little is currently know about hydrate combustion.

We plan to study:

- Burn rates
- Extinction characteristics
- Dissociation and gas release rates

Studies will be conducted at various concentrations of hydrates of propane, methane, and propane/methane solutions.

Recently, a related proposal from investigators entitled "Combustion of Fuel Hydrates" to NSF has been recommended for funding