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GAS HYDRATES: RECOVERY AND TRANSPORTATION

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ABSTRACT

Gas hydrates is believed to be found beneath the subsurface in different areas around the world with a percentage sum of 98% in marine sediments and 2% onshore. These hydrate reserve holds an extensive spectrum of energy which will unquestionably influence the advancement of the gas energy system to supersede the oil energy system. Gas from methane hydrate contains very much hydrogen atoms compared to its conventional counterpart. This implies a very low production of carbon monoxide during methane combustion which makes it pure, easy and environmental friendly for use as a fuel. Gas hydrate are saturated at very low temperature and relatively high pressure. Gas hydrate has a practical problem of flow assurance which obstruct the transportation of methane gases in pipeline, forming whitish slugs at particular temperature and pressure, The comprehensive research of the challenges on recovering gas hydrate and economically transporting it is paramount for absolute development of a gas hydrates energy system in future exploitation.

1. INTRODUCTION

The most intriguing questions facing mankind today is an energy system that provide the energy needs for future generations. These have led to research and development for novel source of oil and gas. Gas hydrates are ice like compounds containing either methane, ethane, propane, butane, pentane and a considerable amount of water. They are found at a depth greater than 300 meters in marine continental shelf. According to National Energy Technology Laboratory, gas hydrate though still untapped in wide scale holds a significant amount of energy that's two times the combination of coal, conventional gas and petroleum reserves being tapped till date, Figure 1.

Gas hydrate forms when considerable amount of gas and water exists at a temperature below freezing point and a corresponding high pressure. At this condition, methane hydrate is saturated. Factors as temperature and pressure condition of marine sediments offers the necessary condition for methane hydrate saturation but most amount of gas hydrates forms beneath the continental shelf as a result of reoccurring geothermal gradient. The geothermal gradient is the rate of increasingly temperature with respect to increasing altitude in the earth interior. This makes ir possible for the heat at particular depth to be larger than the equilibrium heat which is in-situ with the pressure that enables the stability of methane hydrate. This stability of gas hydrates is ensured in conjunction with van der waal bond that holds the methane (guest molecule) enclosed with the solid water lattice (host molecule) that is held by hydrogen bond, Figure 2.

Gas from methane hydrate is unconventional because of its existence, structure and possible mode of extraction. Gas hydrates are formed from biogenic and thermogenic materials that exist in their disposition. These biogenic matters are microbial organism that produce organic detriments that bacteria converts to methane at the hydrate formation while the thermogenic matters are series of petroleum sediment and vegetative matters near the hydrate zone. This paper review some previous hydrates studies and presents the finding of new research studies that are using advanced technology to assess the uncertainty in their recovery and transportation.

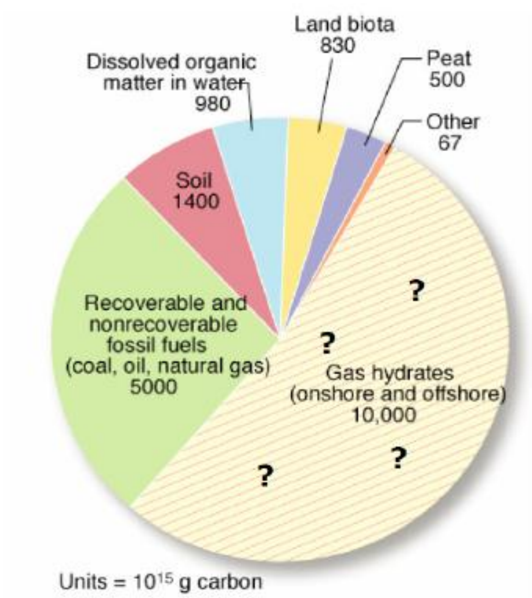

Figure 1 worldwide energy reserves [1]

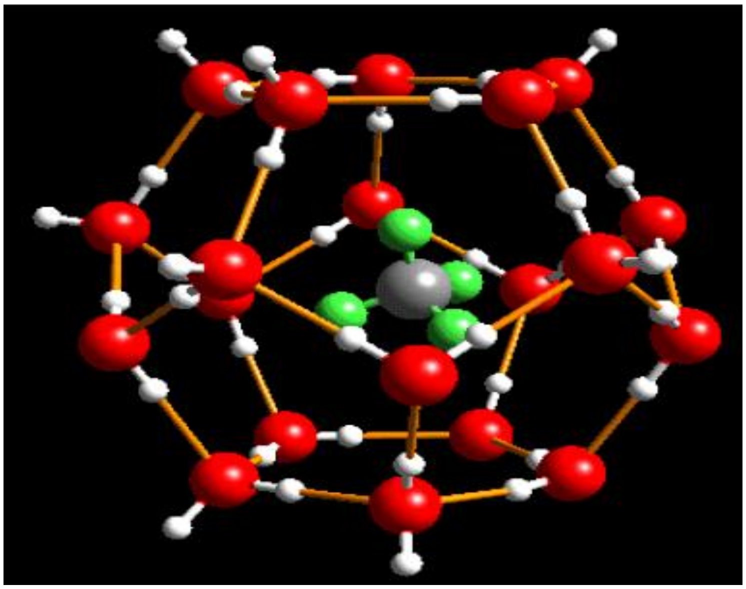

Figure 2 Gas hydrate structure showing methane gas (green and grey) being surrounded by solid ice (red and white). [1]

2. HISTORY OF METHANE HYDRATE

The earliest formation of hydrates in laboratory was in 1778 by Joseph Priestley, who obtained a hydrate of sulphur dioxide. The history of gas hydrates goes back to Humphrey Davy, a chemist from Cornwall, England who identified chlorine as an element in 1810 [2]. Davy and his assistant, Michael Faraday, continued to work with chlorine throughout the early 1800s, mixing green gas with water and cooling the mixture to low temperatures [2].

It's very likely Davy observed the strange solid that forms as chlorine atoms became embedded in ice crystals, but Faraday gets official credit for the discovery. In 1823, Faraday filed a report about the strange substance and named it chlorine clathrate, each involving a guest compound enclosed in the lattice structure of the host were discovered, but that remained a laboratory curiosity [3].

The first identification of methane hydrate was in 1888 by Paul Villard, who synthesized hydrates of methane and other gaseous hydrocarbons. In the course of natural gas prospecting in the 1930s, the drillers complained of an ice like structure hindering easy movements of fluid in the pipelines at very low temperatures. Scientist after series of experiments determined that this ice like structures was not pure ice, but ice surrounding methane gas. Preventive measures were hastened to stop clogging of gas hydrates which causes loss time in the transportation of natural gas through pipelines, they referred to the use of chemicals to inhibit gas hydrate formation. Till date, drilling companies still uses this chemical such as methanol for their natural gas pipelines.

In the 1960s, scientists discovered methane hydrate in a gas field in Siberia. These generated lots of questions and tendencies for research as methane hydrates for the first time was found occurring in a free state. Geologists, alongside researchers was sent to the field immediately to study the condition that supports gas hydrate formations. Results from these experiments showed the permafrost region was wealthy in gas hydrates deposition. Similar expeditions' were done to find gas hydrates layers around the globe. Soon, another team of researchers finds methane hydrate in sediments of the North Slope of Alaska [3].

Pearson et al. [4] researched on the petro physical properties of gas hydrate zones. They developed a model and incorporated various found petro physical characteristic from methane hydrate sediments into the model. Empirical formulas was put in place and compared with Archie's equations. They concluded that the resistivity results from methane hydrate zone differs from the results generated through Archie's equation when various physical properties are accounted for.

Various researches on gas hydrates has been done by international communities around the universe. Studies conducted by USGS on International Gas Hydrate Research shows some countries around the world did series of research programs to prospect the viability of producing their gas hydrates reserve. Recent expeditions done by some countries includes [5]:

a. Japan
- New Japan Sea Project
- 2014, Deep-water Production Test

- 2013, One Week Deep-water Production Test
- 2012, Research and Development on Artic and Marine Project

b. Canada

- 1998,2002,2007 – 2008, Onshore Mallik Project
- Beaufort Shelf hazard and Climate Research
- Pacific and Atlantic Marine Gas Hydrate Study

c. Korea

- 2015, Marine Production Test
- 2010, UBGH2 Expedition

d. China

- 2013, GMGS2 Expedition
- 2007, Onshore Tests

3. GAS HYDRATE IDENTIFICATION

Gas hydrates forms in varying geological sediments at particular conditions. These conditions include factors as temperature and pressure. The most widely spread proof for gas hydrates accumulation comes from seismic technique and Logging While Drilling (LWD) instrument.

3.1. SEISMIC METHOD

The seismic method is one effective method and involve the use of Bottom Simulating Reflectors (BSRs). This instrument uses seismic signals resulting from high velocity spread across gas hydrate deposit. The BSRs is caused by sound wave across hydrate bearing and non-hydrate bearing sediments. Figure 3 shows BSR mapping along China Sea.

According to Ye Yincan et al. [6] Markl on the single channel seismic profile found the abnormal strong reflection that is parallel to seabed and oblique with some weak reflection layers. After the 11th journey of deep sea drilling, the anomalous reflector was named the bottom simulating reflector (BSR), which was associated with the existence of submarine gas hydrate. The BSR has become the most important geophysical evidence to identify gas hydrate and the gas hydrate researches in China's water started with the use of BSR.

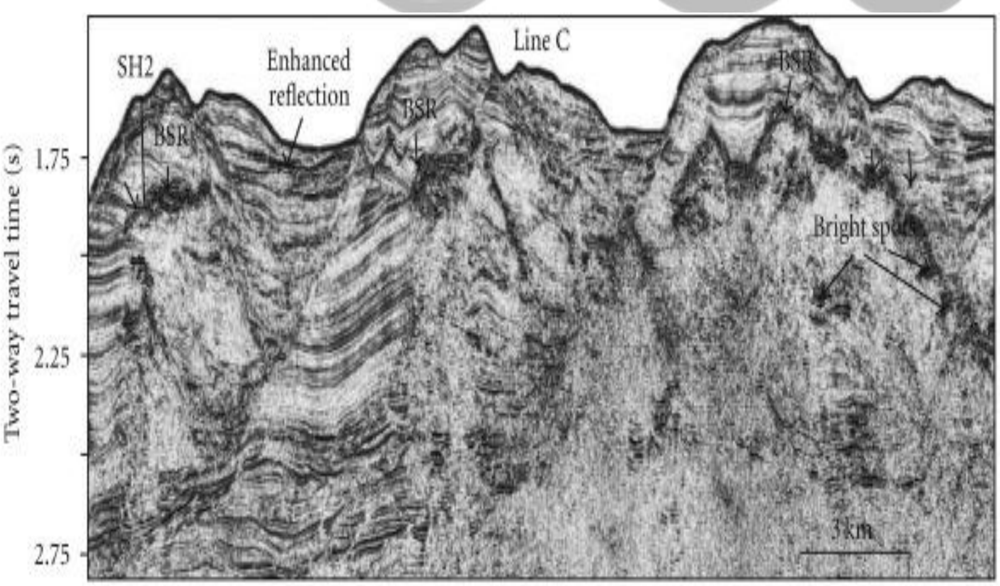

Figure 3 BSR Seismic Exploration along South China Sea.

3.2. WELL LOGGING

Well log data is another important tool used in geological markings of gas from methane hydrate. It is used to quantify and augment data gotten from the seismic method. According to the petro physical model, making use of the relationship between velocity and hydrate, the distribution of hydrate saturation with depth can be estimated through resistivity logging data and sonic logging data

[6]. This Figure 4 show a downhole well log data from Green Canyon gas hydrate well. The clearest indication of gas hydrates shows high resistivity (Blue), the caliper log shows wash out in the hydrate free zones (black) and a corresponding low density shown in the density log. Hydrate bearing zone have a high saturation which is dependent on the saturation exponent (n) of Archie's equation.

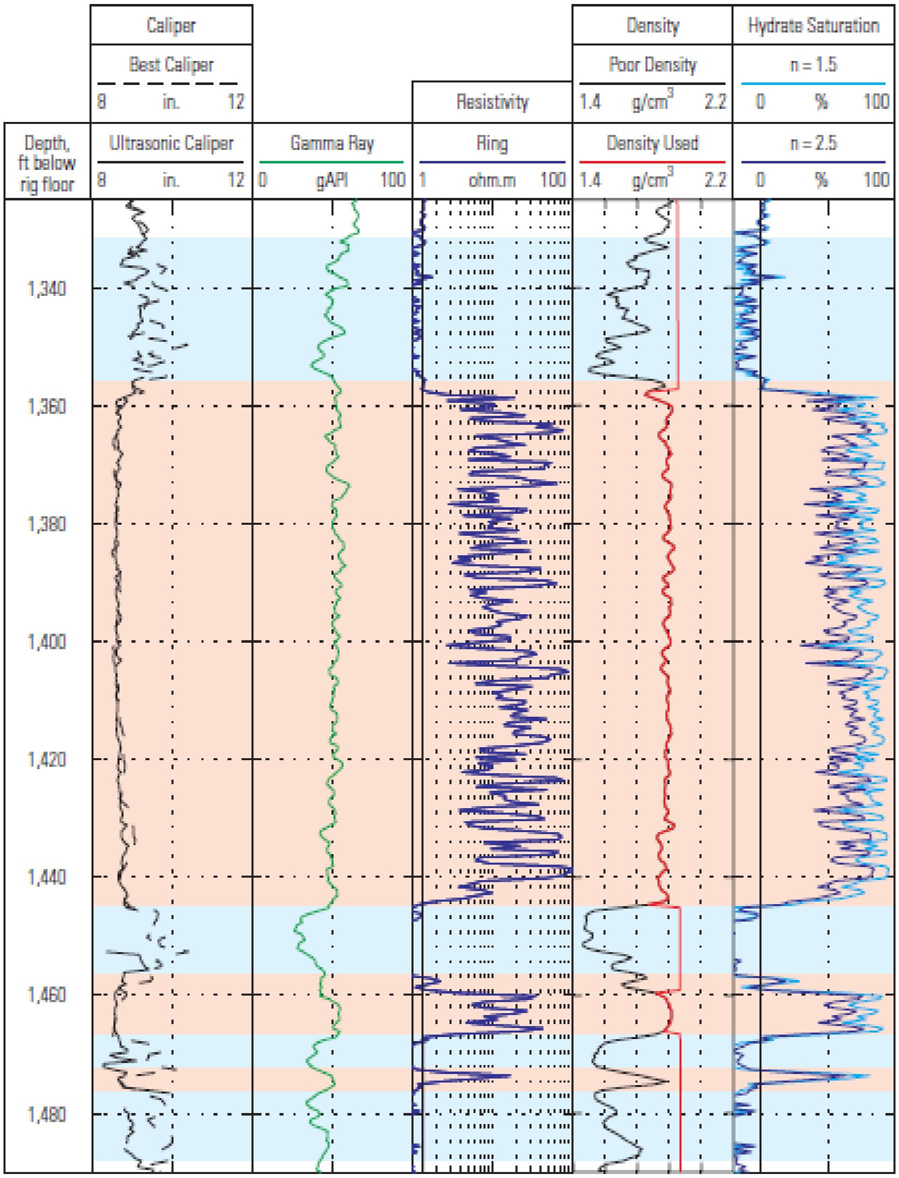

Figure 4 well log data from Green Canyon gas hydrate well [7].

4. POSSIBLE PRODUCTION TECHNIQUES

Series of methane gas production through gas hydrates has been suggested till date. Major propositions involves dissociating the gas hydrate zone to produce methane gas and water into the wellbore. Short term production test at the Mallik field, Mt. Elbert wells and laboratory simulations on sediment cores [8] brought reliable experimental results on producing gas from methane hydrate through thermal stimulation, depressurization and chemical inhibitors, Figure 5.

4.1. THERMAL STIMULATION

Using conventional oil and gas technology, thermal stimulation involve causing a perforation at the depth of the production casing where the gas hydrate pay zone is located using a perforation gun. Steams is pumped from the surface into the wellbore and to the perforated zone in order to alter the equilibrium conditions which in turn seeps gas through the perforated casing and into the tub-ing(s). The only wide-scale recovery technique of this method is Mallik 2L – 38 Gas Hydrate Research well program at Mallik field [9].

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The Japan National Oil Corporation (JNOC) and the Geological Survey of Canada (GSC) [10] working alongside several research institutions injected a mixture of salt and hot water at 70 degree Celsius at the surface and 50 degree Celsius at formation depth. 50,000 cubic centimeters of gas was produced over the whole testing period which was likely not produced at commercial scale. Well, the research was done to query the viability of using steam injection in extracting gas from methane hydrate. The research juxtaposed that injecting steam into a gas hydrate zone wasn't effective in production on a long term.

4.2. DEPRESSURIZATION

Depressurization is considered costly. It involves reducing the pressure of the target methane hydrate depth to produce gas released from dissociated hydrates. The most practical method is to pump the drilling fluid out of the wellbore to the surface when the target depth has been reached, cased and perforated. The pressure present at the bottom of the well and the perforated wellbore reservoir will be reduced which cause a dissociation of methane gas at the depressurized depth releasing simultaneously methane gas and water gushing into the wellbore to the surface.

4.3. CHEMICAL INHIBITION

This involves injecting hydrate inhibitors such as sodium chloride and methanol which affects the water molecules in solids surrounding the gas hydrate and causes a dissociation in the equilibrium condition. These techniques have been used since time immemorial to prevent slugs or solid hydrates in pipelines in order to maintain adequate flow assurance. While chemical inhibitors remain effective for preventing slugs and hydrates formation in pipelines, its wide scale production method for gas hydrate remains limited.

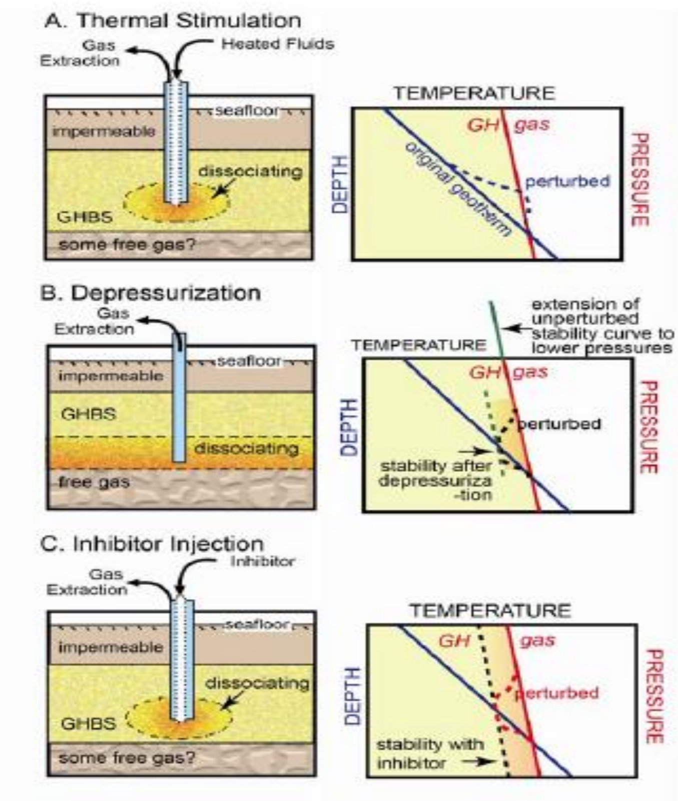

Figure 5 Gas hydrate production methods [11].

5. TRANSPORTATION OF GAS HYDRATES

In understanding the gas from methane hydrate transportation, various condition needs to be considered. The ambient pressure and temperature, modes of transportation, and the chilled vessel or pipeline needed to aid the transportation to prevent unsaturation. Transportation of produced gas requires higher cost for it logistics. The transportation of produced methane gas requires three major steps.

5.1. COALESCENCE

The coalescence of methane gas needs to be chilled at the stabilizing hydrate pressure. This implies that the conditions ensuring it stability before recovery at its subsurface bearing should be similarly maintained at the surface.

5.2. TRANSPORTATION PHASE

It involves transporting the coalescence gas to storage or processing plant. The transportation method which could involve the use of vessel or pipeline must account for properties that will enable the stability of the hydrates. Transportation of gas hydrates in slurry form allows for faster loading, ease of handling and delivery.

5.3. REGASIFICATION

Regasification is done upon the removal of methane gas from the vessel. This is done to reduce to its minimal producible water before sending the gas to the consumers for domestic and industrial use.

6. CHALLENGES AFFECTING THE RECOVERY OF GAS HYDRATES

There exist varieties of challenges which occurs during the recovery of gas hydrate while drilling through it strata. It varies from gas released into the wellbore by over pressured gas which lies at the bottom of methane hydrate bearings to gas leaking to the surface from the outside casing caused by disturbance from the drilling equipment which shift the equilibrium position, and possible crumbling of the already cemented and cased well caused due to the presence of existed conventional hydrocarbon near the gas hydrate zone, Figure 6. These challenges are technical, environmental and economically caused, thereby causing hindrance in achieving a wide scale production of a gas based energy.

Gas hydrate has a practical problem of flow assurance which obstruct the transportation of methane gases in pipeline, forming whitish solids at a particular temperature and pressure. This problem is particularly serious because without proper management, transportation of this energy source will be made futile. The transportation methods have caused major concern for the usage of gas hydrates as a result of its diminishing densities which arises from an increasing volume of methane in a little amount of gas hydrates.
The dissociation of gas hydrate at the sea floor releases some escape gases which affects sediment bodies and death to aquatic and marine lives. The impacts on gas hydrate commercial productions on our ecological system needs to be closely studied in order to come up with efficient and sustainable production processes before proceeding to exploit this energy source. Figure 6 shows various problem relating to gas hydrate recovery.

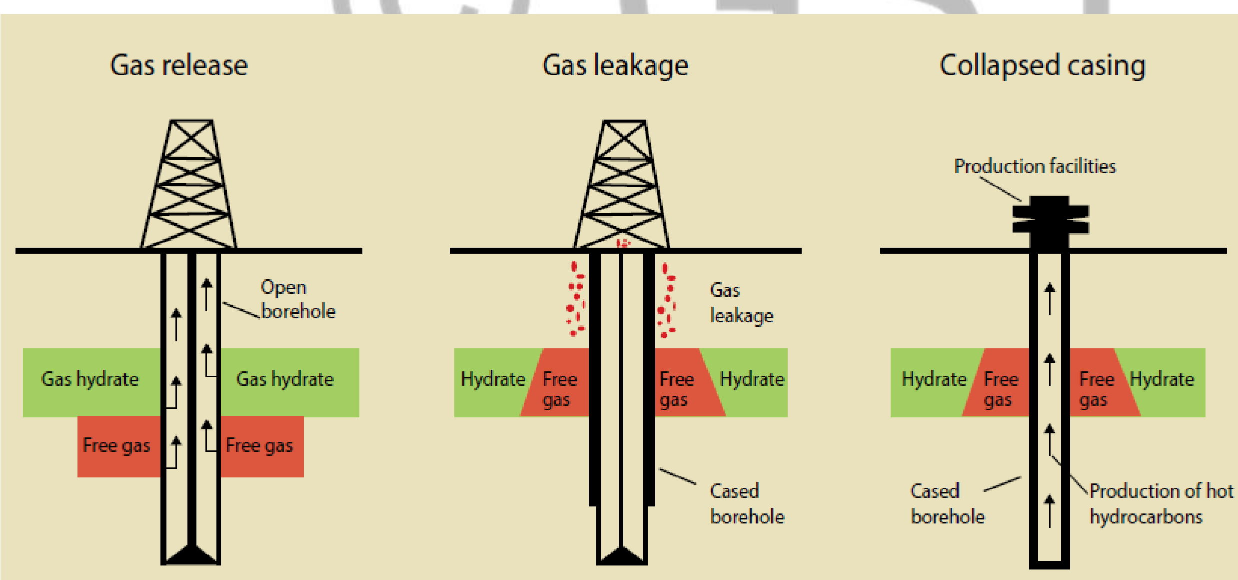

Figure 6 Gas Hydrate Drilling and Production Problems [12].

7. POSSIBLE SOLUTIONS

It's no doubt the occurrence of gas hydrate is complex. Series of optimization needs to be done in order to quantify these hurdles so that gas hydrate development can become a near distant possibility.

- Instead of complete dissociation of gas from methane hydrate at the gas hydrate zone, we can introduce a method of production by partial dissociation which compress the solid gas hydrate to slurry form. It is then sent to the surface where an entrapment facilities is waiting for it to be collected and processed.

- The seismic process of identifying gas hydrate needs to be quantified in order to be able to locate methane hydrates which are not in layers of conventional oil and gas.
- During drilling for gas hydrates, the weight of the drilling mud should be closely monitored in order not to destabilize the saturation condition of the gas hydrate.
- The drilling rate of penetration should be maintained to minimal to present cases of gas release or gas leakage.
- The choice of cement should be considered in order to create a lasting bond with the underlying formation so that cases of collapsed casing can be prevented and the gas hydrate zone unaffected before perforation.
- More reservoir simulation and petro physical data testing is required for gas hydrate zones.
- Well completion for gas hydrate needs to be critically addressed to prevent scenarios of sand or water production at the surface.
- Safe standardized practice should be ensured in managing the heat needed for gas hydrate dissociation.
- Transportation of methane gas in slurry form is very effective because it ensures the quickest and safest transportation of this energy source with reduced cost. However, the pressure condition needs to be paid attention to because high pressure facilitates the process.

8. CONCLUSION

Large volume of methane hydrates in the deposit range of 500 – 1,200,000 scf for permafrost region and from 110,000 – 270,000,000 scf for oceanic sediments exist in the subsurface region of hydrates zones. These sustainable energy source will meet future energy needs. Comprehensive study on recovering gas hydrate and economically transporting them was made in order to facilitate development of methane gas on a near term possibility. Partial dissociation of methane hydrates to slurry forms should be practiced to allow for effective and quantum exploration of its reserve. Gas exploration through slurry make ease of operation, faster loadings and unloading's. Research work on gas hydrate shows that a refrigeration temperature of 20 degree Fahrenheit is required to prevent hydrates from being dissociated at its saturation point. The cost of deep water exploration has been reduced compared to early times. These should pave way for hydrate exploration and development. Research and development should be encouraged with the use of proven technologies as previous exploration has changed the ideology with proven realization that gas hydrate can be produced with existing oil and gas facilities.

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