CHEMSYSTEMS
PERP PROGRAM

Unconventional Natural Gas

Technical & Operational challenges, Reservoir Characteristics (tight gas, shale gas, coal seam gas and gas hydrates). Costs & Breakeven Economics, New Developments/ Designs. Global Production & Consumption Forecasts for both conventional and unconventional gas.

PERP08/09S3

Report Abstract

October 2009

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The ChemSystems Process Evaluation/Research Planning (PERP) program is recognized globally as the industry standard source for information relevant to the chemical process and refining industries. PERP reports are available as a subscription program or on a report by report basis.

INTRODUCTION

Natural gas is a naturally occurring gaseous hydrocarbon mixture that is principally comprised of methane and ethane, with lesser quantities of propane, butane, and heavier components. In its natural state, this gaseous mixture is derived from land and marine organic matter that has been buried in the earth's sediments.

Over geologic time and through the effects of pressure, temperature, and gravity, the gas migrates from the source rocks or formations in which it is formed to shallower strata. Until it eventually reaches the surface and escapes into the earth's environment, gas can be trapped by impermeable layers of rock that temporarily interrupt the migration. The accumulations of gas within these traps are known as natural gas deposits or as hydrocarbon reservoir systems.

During the petroleum industry's worldwide search for hydrocarbons over the past decades, large volumes of natural gas have been detected within geologic environments that differ from those where conventional hydrocarbon deposits are found. These non-conventional depositional environments include geological formations of very low formation permeability, formations that have been fractured by geologic tectonics, shale matrices, natural coal seams, and crystallized layers of methane.

One of the most pressing problems for many countries is that conventional natural gas reserves are shrinking fast due to the preferential production of gas from inexpensive and easy to develop deposits, such that they must now rely on more complex and unconventional gas resources to sustain production.

Based on the magnitude of worldwide occurrence, the principal types of unconventional natural gas deposits are:

- Tight Gas
- Shale Gas
- Coal Seam Gas
- Gas Hydrates

Whereas unconventional gas resources are abundant in all regions, the large scale development of these resources is technically challenging and capital intensive. As an example, because of their inherent lack of permeability, the shale gas formations and tight gas sandstones and limestones must be hydraulically fractured to increase permeability and improve flow. The challenge is to improve permeability sufficiently to enable a viable development. However, this process is very costly as illustrated in the figure below (Courtesy Halliburton), fracturing of just one of tens of thousands of wells involves extensive operational logistics.

Fracturing Operations

The drop in natural gas prices since June 2008 threatens the economic viability of emerging and frontier unconventional natural gas developments. For this reason, future development of unconventional gas deposits must seek to achieve reasonable project economics at prevailing natural gas prices while deploying technology to control costs.

The combined unconventional natural gas production in the United States and Canada has increased from 15 percent of total gas production in the year 1990 to 43 percent in the year 2007. While this reflects the high degree of dependency that this region now has on unconventional gas resources, it also heralds the immense potential that exists for the rest of the world where unconventional gas production is still in its infancy.

Conventional gas reserves are expected to play the predominant role in supplying the world's natural gas demand, accounting for over 80 percent of the world's total gas production in the year 2030. However, at this level of depletion, the conventional gas production rate is unsustainable unless substantial volumes of conventional gas reserves are proven. Otherwise, unconventional gas production must play a much larger role around the world and many countries will have to climb the learning curve quickly, requiring more aggressive technology transfers and near term R&D.

Drawing on a comprehensive review of technical and commercial issues, ChemSystems' new Process Evaluation/Research Planning (PERP) report provides an independent and informed basis for organizations and countries to consider as they develop unconventional natural gas to address their individual circumstances and strategies. Technological and operational challenges, reservoir characteristics, production behavior and environmental concerns, commercial drivers (cost and breakeven economics), new developments (technology and designs), worldwide occurrence (in place resources and recoverable reserves), and the long term view (production and consumption scenarios) are discussed.

TECHNICAL AND COMMERCIAL CONCEPTS

The goal of research and development organizations involved with unconventional natural gas resources is to increase the world's supply of natural gas through the development of technologies and commercial approaches that increase the efficiency and reduce the cost of exploration and production programs, while improving safety and environmental performance. During the last 20 years, the application of advanced exploration and production technologies have had a significant impact on unconventional natural gas development, resulting in production increases of up to 100 percent in some fields, reductions in associated costs of up to 25 percent, and decreases in non-productive time losses of more than 30 percent. A general description of some of the most innovative and successful applications is presented.

Notwithstanding the impact of lower gas prices, the most pressing problem for many countries is that conventional natural gas reserves are shrinking fast. Most countries have been extracting natural gas from the inexpensive and easier to develop deposits and are now compelled to rely on the much more complex and unconventional resources to sustain economic development. Whereas, unconventional natural gas resources are abundant in all regions, the large scale development of these resources is technically challenging and capital intensive. Commercial issues related to this are outlined.

TIGHT GAS

A formal universal definition does not exist for tight gas. Generally speaking, natural gas that is trapped in sandstone or limestone formations that have an unusually low permeability to gas flow is known as tight gas. Whereas some petroleum experts have defined tight gas deposits as those having a permeability of less than 0.1 millidarcy, the German Society for Petroleum and Coal Science and Technology (DGMK) defines tight gas reservoirs as those with permeability below 0.6 millidarcy. However, based on actual measurements, tight carbonate and sandstone can exhibit in-situ matrix permeability to gas lower than 0.1 millidarcy, and the ultra tight reservoirs can have permeability to gas as low as 0.001 millidarcy. The very low and ultra low permeability reservoirs are generally considered stranded gas.

In this section tight gas is discussed in terms of

- Technological concepts (reservoir characteristics; basin centered-, shallow-, and deep gas systems)

- Technical and operational challenges (e.g., recovery factors, gas immobility, formation damage, declining fracture performance, water off-loading))

- New technology developments (drilling bits & fluids, formation image well logs, 3-D seismic based horizons, integrated models)

- Worldwide resource potential (in place gas reserves, recoverable gas)

SHALE GAS

Shale rocks make-up more than half the earth's sediments; however, despite its geographic abundance, it was not until the year 1995 that the appropriate hydraulic fracturing technology was developed and applied in the United States to produce shale gas wells at commercial rates. "

Shale gas is also discussed in terms of Technological Concepts, Technical and Operational Challenges, New Technological Developments (simo-fracs, staged fracturing, numerical simulators, real time micro-seismic monitoring) and Worldwide Resource Potential.

COAL SEAM GAS

Natural gas has been known to exist in coal seams since the beginning of the coal industry. When coal is mined, the methane gas that is trapped in the seams is released, which poses a potential threat to the miners. However, if removed through a controlled process before the coal is mined, then this gaseous by-product can become an important source of natural gas.

While seeking to discover and produce oil and natural gas from deeper strata, the petroleum industry has drilled wells through and observed coal seam gas for decades, yet it is only within the last twenty years that significant gas production been realized from coal deposits.

Coal seam gas, also known as coal bed methane (CBM), is now being developed in several countries. Using these countries as an analog, it is reasonable to expect that many of the world's coal deposits have the potential for commercial coal seam gas production. This source of unconventional natural gas is discussed further in the report.

GAS HYDRATES

Gas hydrates are the most recent form of unconventional natural gas to be identified and researched. However, research is in its infancy and it is still not well understood what effects the recovery of gas hydrates will have on the world's long term energy balance and, perhaps more importantly, on the earth's natural carbon cycle.
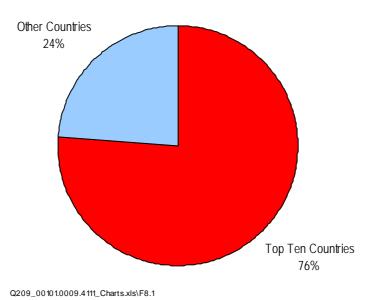
Gas hydrates are naturally occurring accumulations of natural gas that are trapped in ice-like solid structures called clathrates that can potentially contain large volumes of gas. Clathrates have been detected in the polar regions and in the deep water areas of continental margins. Although many gases form hydrates in nature, methane hydrates are the most common.

Based on current knowledge and technology, gas hydrates are a sub-economic resource. However, because of their vast potential, if only a small percentage of the accumulations can be recovered, gas hydrates would provide a very significant source of natural gas. This topic is further expanded in this section of the report.

COMMERCIAL DRIVERS

If natural gas supply is to meet increasing consumption levels, all of the world's conventional gas reserves must be exploited in a timely manner. Unfortunately, natural gas resources are unevenly distributed across the globe. As illustrated in the figure below, just ten countries possess 76 percent of the world's total proven conventional natural gas reserves.

Distribution of Global Conventional Gas Reserves

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This highly uneven distribution of reserves places enormous pressure on just a few countries, to make available for near and medium term development most, if not all, of their conventional gas reserves. Even among these top ten countries there is an uneven distribution of reserves.

To a large degree, the inability of conventional natural gas supplies to meet global demand will be one of the principal drivers for the development of unconventional supplies. This topic is discussed further in terms of the following:

▪ Global gas supply and demand (distribution of reserves and supply deficit)

▪ Development of unconventional supply sources (field development costs & optimization, development credit, technology, exploration and appraisal risk)

▪ Project economics (performance metrics, gas prices, economy of scale, breakeven gas prices)

▪ Long-term view

– Global gas consumption and production

– Unconventional gas production forecast

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