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The Prospect of Natural Gas Storage

BAI Mingxing[a],*; ZHANG Zhichao[a]; SONG Kaoping[a]; SHANG Wentao[a]

[a]Department of Petroleum Engineering, Northeast Petroleum University, Daqing, China.
*Corresponding author.

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Abstract
The first chapter of the actual paper is assigned to shed light on the current situation in the European gas market—the pivotal introduction into pivotal theme. The up-to-date information on the biggest consumers and the biggest exporters aims at giving the general idea about what countries are the main market players regardless of what role do they play. In addition, the first chapter of the work pursues the gas storage necessity proof—why such an expensive process is currently employed by the industry is explained taking the hydrocarbon production conditions of the XXI century into consideration. The actual natural gas market performance and storage justification is followed by the discovery of demand and supply concepts in chapter two. These phenomena represent the characterization of relationship between the gas supplier and the customer. Issues to be addressed are demand nature, types of supply, balancing the demand and supply and the security of supply. Finally, the chapter three gives an insight into how the industry stores the gas. The discussion there goes around the storage opportunities, their positive and negative features and how do they differ. The storage performance criteria are also subjects of the chapter. After the three main questions of the topic have been addressed, the summary of the work concludes it logically by highlighting the most important arguments and facts.

Key words: Gas storage; Hydrocarbon production; Storage performance

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INTRODUCTION

Operating in this manner, gas suppliers are faced with the challenge of balancing the demand and supply. Delivering the gas to the market on the constant and sufficient base they guarantee the security of supply during summer time. Usually, all the gas required pending the warm period is assigned to support the process load of the industrial customers and represents the biggest share in the annual gas off take chart.

1. FRESH AND INTERESTING FACTS ABOUT THE NATURAL GAS CONSUMPTION IN THE EU IN 2007

On 13th March 2008, the European Union of the Natural Gas Industry Euro gas (Li, Liu, & Song, 2004) promulgated the press release on the natural gas consumption in EU27 in 2007. According to it, the natural gas consumption within the region during the last year experienced a slight decline of 1.5% in comparison to 2006. Probably, the major reason for this lies in the fact that the several countries occupying leading positions in the related Table of Ranks exhibited a small drop in the natural gas consumption with the exception of UK, Spain and Italy, where the tendency was contrary. The dry figures can be presented in Table 1.

Table 1
EU27 General Natural Gas Consumption in 2006 and 2007—the Comparison

Year	Peta joule (PJ)	Billion cubic metres (BCM)[1]	Million tons of oil equivalent(MTOE)[2]
2007	19710	505	424
2006	20010	513	430

Although these figures reflect a negative trend, they can easily be explained: The beginning of 2007 in Europe was highlighted by the mild weather conditions that directly affect the gas off take making it lower (Zhang, Di, & Lei, 2001). Another contributing factor occurred in several countries is increase in energy prices as well as the rise in energy efficiency. Figure 1 demonstrates the relationship between the EU countries in terms of demand for natural gas in the last two years:

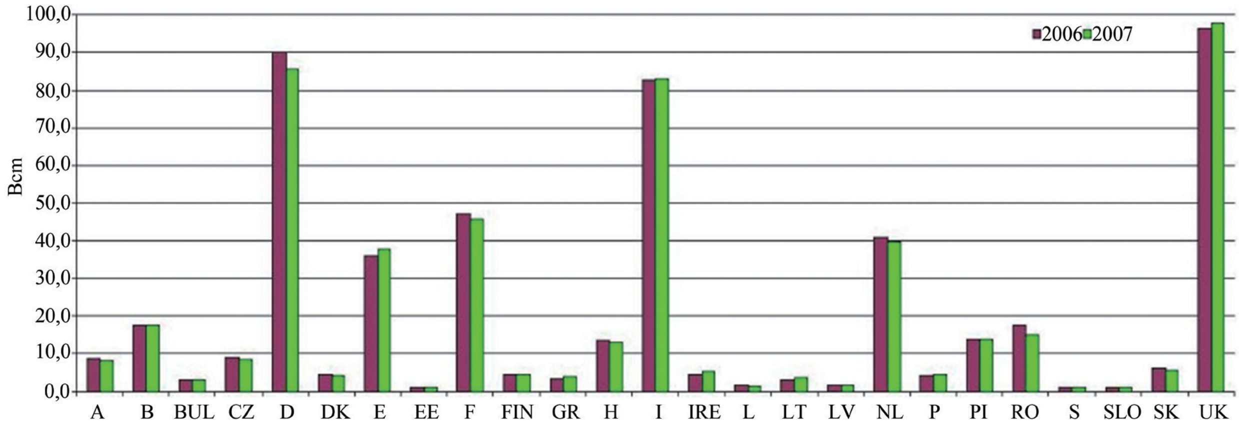

Figure 1
The Natural Gas Consumption of the EU Member States in 2006 and 2007

The advantage of the year 2007 over 2006 is the total number of gas customers connected to the EU27 natural gas grid, which rose by 1% and reached the point of 110,171,000 customers. A known fact is that the new transmission pipelines are either projected, or under construction or about to be commissioned - this proves that the last mentioned figure has a high potential to grow during the following several years (Ikeda, Ueda, & Mukai, 1983).

The major European gas producing countries including Germany, Denmark, Italy and the UK have reduced their production rates and this resulted in the total production rate reduction of 7% to 7,739 PJ (198 Bcm) across Europe. However, the highest percentage of gas supply is still covered by the domestic production of 38% and the other 62% are divided by the external sources such as Russia (23%), Norway (18%), Algeria (10%) and other. It is obviously difficult to predict how events would develop during 2008. All the foregoing factors are subjects to change and the current year performance would play a key role in the situation on the European gas supply market.

2. NATURAL GAS AS THE RELIABLE SOURCE OF ENERGY

Fortunately or unfortunately, the world we live in is full of contradictions, nonuniformities and inequalities, which together could be called a dis-balance. From ancient times, this forced our ancestors to find solutions to the variety of problems or to bring the circumstances under. Today, the situation has hardly changed and the natural gas industry represents a perfect example of the dis-balance mentioned before.

The main idea of this much-talked about dis-balance is consisted in uneven distribution of natural gas resources throughout our planet. Based on this irrefutable fact, one may make a reasonable assumption that the whole history of gas transportation is the aspiration for an artificial equilibrium in the availability of gas between the oppositely situated (in terms of energy resources) parties or states.

All the states playing on the market may be divided into two major groups: Exporters and importers (even though the situation is a little bit more complicated). If we only skim over the map of European natural gas transmission system, we will easily observe that it is roughly meshed. Of course, the network didn't appear at once but has been developing during decades. And the most interesting thing is that it will grow further. Reasons for such a growth are different but the most important are depleting of the fields in Europe, a desire of the EU to reduce carbon dioxide emissions (and here the natural gas represents a good candidate to play the role of number one energy source) and promising exploration expectations in a row of Europe-surrounding countries.

The following figure is assigned to give the reader an overall impression to where and from where the natural gas is being supplied:

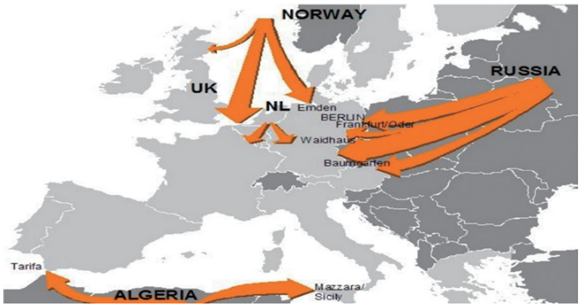

Figure 2
The Status of Natural Gas Supplies in Europe

Figure 2 is a clear indicator that Europe is the region currently in the need for natural gas. However, society is curious about the future developments—what to expect in the next 20-30 years? With the certain degree of care it is possible to reveal the situation.

3. NATURAL GAS DEMAND AND SUPPLY: OUTLOOK TO 2030

First of all, let's collect the major factors shaping the curve of energy demand in Europe.

According to the related analysis held by Eurogas (Cron & Marsh, 2002) these factors are as follows:

Continued economic growth of more than 2% p.a.

Hardly any rise in population

Oil prices remaining at a high level

Gas prices determined by market forces

Increased environmental awareness in politics and among customers

Growing trend to save energy and to improve energy efficiency

Thoughts at national level on use of nuclear energy and expansion for renewable

ITE Seminar series 2008 / Natural gas storage / Page 9 The analysis (Cron & Marsh, 2002) predict, that the share of natural gas in primary energy consumption will reach a point of 30% by 2030. Figure 3 shows the steady growth of this parameter:

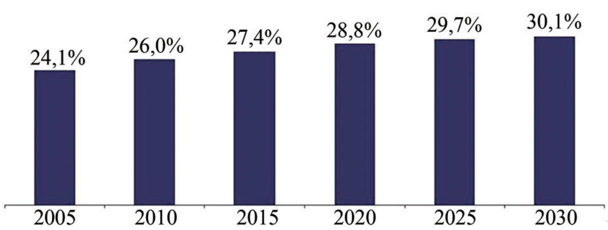

Figure 3
The Growth of Share of Natural Gas in European Primary Energy Consumption

4. THE GAS STORAGE JUSTIFICATION

At the moment, the majority of books dedicated to the natural gas storage justify the need for it mostly from the temperature and the pipeline limitation points of view. However, the problem is rather deeper.

As the producing fields situated in favorable areas are becoming more and more depleted, the question of new production zones emerges. The increase in the world gas consumption anticipated by 2030, as highlighted previously, exaggerates the problem. The features of the gas production in the XXI century are (Cron & Marsh, 2002; Schwalm, 1971):

Remote location of production—the reserves are becoming more and more distant. In addition, they may be situated in a hostile environment (low temperature, offshore). Only the ultimate production of this kind of field may lead to the economic benefit.

Reservoir tightness—a challenge Europe faces already now. To achieve a success with tight formations a sound technical approach as well as adequate investments are required.

Infrastructure—the commodity extracted from beneath is likely to cause chemical damage to the equipment involved. That is why this equipment must be resistant enough to fence the hazards of environment off.

Inappropriate composition of the gas— the produced gas is never fit to be sold right after the production. As a result, a range of processing plants have to be constructed to exempt the gas from impurities.

Competition for gas—the growing economies of North America and Asia or other regions need substantial energy supply including gas. This would lead to a better price a gas supplier will have to offer to bring the gas to a certain country.

Transmission-increased expenses are a direct consequence of lengthened routes of commodity from a well site to the end user.

Exploration—the issue of growing investments. Another property of remote reserves.

5. THE NATURAL GAS STORAGE: A CLOSE LOOK

As underlined, the natural gas is the unique source of heat to be treated and consumed

with the special care. The deeper it immersed in the worldwide energy market, the broader the technology serving it became, especially concerning storage. The present chapter represents an attempt of getting closer to the gas storage peculiarities.

5.1 Types of Gas Storage

First of all it should be mentioned that the kinds of the gas storage may be divided into two major groups -surface storage facilities and underground storage facilities (UGS). To make the image of storage opportunities sharper, let's try to sum up all of them on the single figure (with exception of the surface storage facilities to be described below):

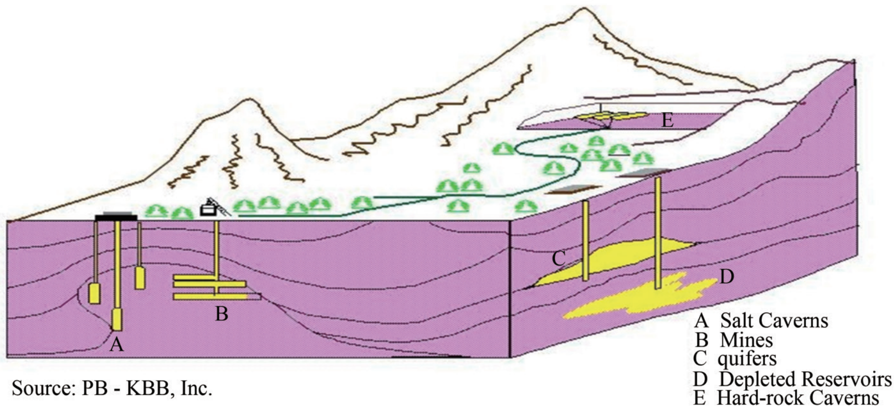

Figure 4
A Joint Image of the Natural Gas Storage Possibilities

5.2 Surface Storage Facilities

5.2.1 Line Pack

A technology for the natural gas storage not indicated on the Figure 4. The main point of the Line pack is to hold the gas inside of the pipeline network. The method is applicable for both transmission and distribution pipelines - the operating pressure for the former lies in the range of 5 to 10 bar, while for the latter this parameter is roughly 1 bar. Status of a gas accommodation ability – 1,000 km of 20'' pipeline stores 200,000 m³/bar (Schwalm, 1971).

5.2.2 Surface Storage in Distribution

May be considered pioneers in the storage history. These (Wang, Luo, & Lü, 2012) have been in use in large ITE Seminar series 2008 / Natural gas storage / Page 19 cities since the beginning of the XX century. The holders were equipped with the telescoping sections that rose upwards as the gas was introduced inside. With the capacity of about 28,316 m³, 30 m in diameter and 30 m high when full, they discontinued to be economical as the larger volumes of the natural gas were adopted in cities.

Status of a gas accommodation ability - according to (3.1) 10,000 m³/10 bar (Schwalm, 1971).

5.2.3 LNG

A relatively young way to store the gas. The main advantage of LNG over the conventional gas state is providing with the same heating capacity requiring 600 times less space. Also, using LNG, one would easily avoid the need for long length pipelines as it can be delivered to the very point of consumption. The only minus of the LNG is the terminal construction cost. Status of a gas accommodation ability—the ratio of LGV/GGV=1/600. Underground storage facilities "Underground storage—the uniquely efficient process that matches the constant supply (of natural gas) from long-distance pipelines to the variable demand of markets, which are subject to weather, for engineering and economic advantage"/I (Wallmann, 2002). In general, storage reservoirs may be described as "unique warehouses developed to provide a ready supply of gas in times of peak demand permitting pipelines to operate at or near their design capacity despite seasonal or daily fluctuations which occur in energy consumption"/II. UGS's are being replenished pending the summer because during the season the demand for natural gas can be totally covered by the pipeline supply. As the winter comes and the situation changes by 180 degrees, the pipeline operates together with the UGS in tandem in order to meet an ever increased energy requirement (Hinterhuber, 1972).

According to the Energy Information Administration (EIA)—Official Energy Statistics from the US Government , neither abandoned mines, nor the hard-rock caverns are currently in operation. That is why the actual paper is concentrated on the three main types of UGS: Depleted reservoirs, salt caverns and aquifers.

5.2.3.1 Depleted Reservoir

Before starting the formation description, it is worth mentioning that the very first case of strata utilization for the purpose of storage has been registered in 1915 in Ontario, Canada. This had been a producing field later transformed into the UGS.

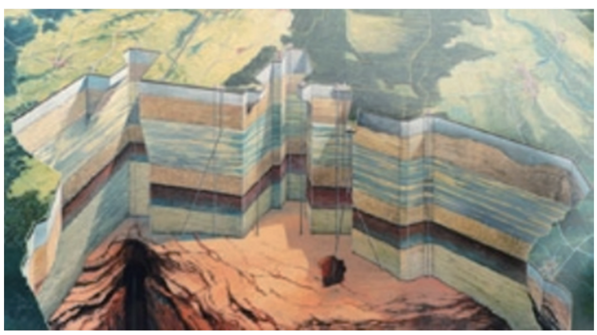

Figure 5
Cross-Section Illustration of the Porous Rock Storage

From the past and till the present the depleted fields have been the most attractive means to store the gas in from the different points of view. Natural Gas Supply Association (NGSA) discusses several of them (Heath, Hodrien, Kostakis, & Harrison,1998).

First of all, a reservoir, previously bearing the gas, can obviously do this job again and what's more, not once. In addition, the formation owner gets rid of the problem to remove all the extraction and distribution equipment from location as it can be in place when rendering the reservoir. And finally, compared to other two types of UGS to be described below, "depleted fields, on average, are the easiest and cheapest to develop, maintain and operate"/III (Coats, 1967).

In order to accept the reservoir as a 'storage-fit', the Association recommends to inspect it ITE Seminar series 2008/Natural gas storage/Page 20 both geographically and geologically.

Geographically, the most important factor is the proximity to the consuming areas. Also, a distance to the transportation and distribution pipelines may play a crucial role (Katz & Tek, 1981).

Geologically, the porosity and the permeability of a reservoir must be high enough to provide with the sufficient storage volume and the adequate injection and withdrawal rates. That is why the tight gas fields well spread in Europe are unlikely to become a storage units after the total depletion.

Status of a gas accommodation ability — several 10^3 Mio m^3 storage potential (Schwalm, 1971).

5.2.3.2 Salt Cavern

Lying deep underground salt formations emerged as a case for the gas storage in 1961 in the USA. Shortly after, winning a worldwide recognition the technology was introduced in Europe and in the former USSR (Li, Xu, & Li, 2009)

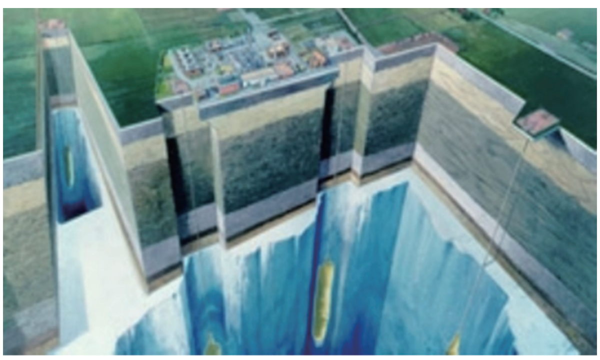

Figure 6
Cross-Section Illustration of the Salt Cavern Storage

The main reason why the salt is considered to be a favorable substance to hold the gas is tightness. However, this property must be used with the certain degree of precaution. During the injection period the cavern internal pressure builds up in the proportion to the injected gas volume reaching its limit at a particular moment. This moment must be precisely specified for each salt cavern during the designing. If not, the pressurized gas may over go the salt yields stress and escapes.

On the whole, the salt deposits are encountered in nature being embodied in either a salt dome or in a salt bed.

> Salt domes are typically large pillar-like subsurface salt bodies having a diameter of up to 1.5 km and a height up to 5,000 m. As the salt mass is driven up by the buoyancy forces, it pierces in the overlaying sedimentary rock and creeps up following the paths with the lowest overburden pressure. Due to the difference in densities, the salt mass and the rock formation behave like two liquids: If a heavy liquid is superimposed on the light one, the buoyancy forces drive the light liquid to the top of the reservoir. Domal structures appear at the transient stage of their segregation as a consequence of so-called Rayleigh-Taylor instability/IV.

Salt bed is thin and broad salt formation. Usually, they are not higher than 300 m but are capable of accommodating two or more cavities within one bed. This makes salt beds economically attractive, even though their developing price is higher than the price for domes. In contrast to aquifers or depleted reservoirs, salt cavities are man-made void spaces. That is why the process of salt dissolution and brine exhaustion must be thoroughly thought with respect to an individual salt rock. This process is called "leaching process".

The leaching process is performed in the following sequence: The fresh water is injected into the cavity and is followed by the dissolution of salt. Obviously, the concentration of salt in fresh water builds up and, finally, the resulted from the process brine is withdrawn to the surface.

Basically,

> depending on the fresh water circulation direction, two types of leaching process may be distinguished: Direct - the fresh water is introduced through the central flow string near the cavern bottom and the brine is pumped out from the tubing annul-us near the cavern top. Indirect—the fresh water is introduced through the annul-us at the top and the brine is removed through the central tubing at the bottom/V.

As a consequence, a cavern takes the pear-shape during direct leaching, while inverted pear represents the result of indirect process.

SUMMARY

The XXI century will become a century of the natural gas energy. The gas industry is like never before experiences a boom in all its branches. This happens because the environmental properties of the commodity are recognized suitable for the majority of the states in the world. The result of the worldwide gas requirement increase is the same trend in its production. However, production is no more implemented in convenient locations but more and more in arduous environments. Because of that, the costs for production are also rising almost proportionally to the gas demand. Consequently, meeting the gas demand with the adequate production rate is inappropriate. Based on this, the gas storage, even though also of considerable costs, are becoming the best option of customer demand satisfaction simultaneously with saving on production: The gas is being produced on the constant base load slightly higher than non-heating energy demand throughout a year and the surplus goes into storage replenishing. Hence, the production is implemented on the steady and economic basis allowing the high demand peaks to be shaved by in advance filled in gas storage.

Operating in this manner, gas suppliers are faced with the challenge of balancing the demand and supply. Delivering the gas to the market on the constant and sufficient base they guarantee the security of supply during summer time. Usually, all the gas required pending the warm period is assigned to support the process load of the industrial customers and represents the biggest share in the annual gas off take chart.

As the winter comes, the business becomes more complicated. Almost inactive during the summer season, the residential consumers raise their gas demand as the ambient temperature gets below 16°C - time for gas storage to meet the peak load. Such temperature is normally maintained during the whole cold period and is covered by seasonal balancing. However, there is no winter without perceptibly low ambient temperatures. In this case, a gas supplier has to implement short term balancing, which could be also induced by transitory activities of a customer like cooking or clothes washing. The difference between two short term balancing reasons is that the former may last a day or more, while the latter takes about an hour only.

The variety of loads to be satisfied has led to the development of the storage technology. At the moment, a volatile customer demand is not met by a single storage facility. Instead, every gas storage has its own “target group”.

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