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Market and technology assessment of natural gas processing: A review

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ABSTRACT

Natural Gas has become one of the most desired energy sources after oil discovery for its efficient combustion and low carbon dioxide (CO_2) emissions. In some regions, natural gas plants have even replaced nuclear energy plants as they are safer in terms of waste and storage. This paper provides a review of processes involved in natural gas (including extraction, transportation, storage, and treatment) as well as the natural gas cost and its market in different regions in the world. This review also includes liquefaction and re-gasification processes available in the market in addition to emerging technologies proposed in these areas.

1. Introduction

Natural gas goes through several processes before it is received by the consumer. At first, natural gas is extracted from reservoirs by means of drilling, pumping and extracting. There are three methods that have been used in the industry for extracting the natural gas. These methods (including water, chemical and steam injections) allow for natural gas extraction up to 60% of the reservoir's capacity. After extraction, the natural gas is transported to the treatment plant in which solid particles (fine sands), liquid (mercury, oil, and natural gas heavy liquids), and harmful gases (CO_2 and H_2S). After treatment, the natural gas is compressed or liquefied through several technologies (such as refrigeration cycles using single or mixed refrigerants). Following liquefaction/compression stage, the natural gas is transported to the receiving terminals through pipes or ships after which the liquefied/compressed gas is re-gasified again and sent to the consumers end. This paper presents a thorough review of the above processes and the current technologies adopted by the industry as well as emerging technologies proposed for enhancing the performance of the natural gas processes. In addition to the review on the technical background of the natural gas processes, this paper summarizes the regional and global natural gas market as well as the current and future demands based on the current and proposed natural gas plans.

2. Natural gas (NG) processes and current technologies

Natural gas has to go through several processes from the moment it is extracted until it is reached to the consumer. Fig. 1 shows a schematic of the overall natural gas processes including drilling/extraction, treatment, preparation to transport, transportation to the desired destination. These processes are explained in the following sections in detail:

2.1. NG extraction

Extracting oil and gas is relatively harder than simply drilling a hole. In essence, the hole must be supported by a cemented pipe (Gaszprom, 2014). In current wells, a stepwise-drilling method (see Fig. 2) is used to maintain the pressure uniformity around the walls of the drilled hole. There are a number of factors which affect the efficiency of the oil and gas extraction from the well. These factors include the porosity of the rock and the viscosity of the oil and gas deposits (Adventures in Energy (2014)). Table 1 summarizes a list of

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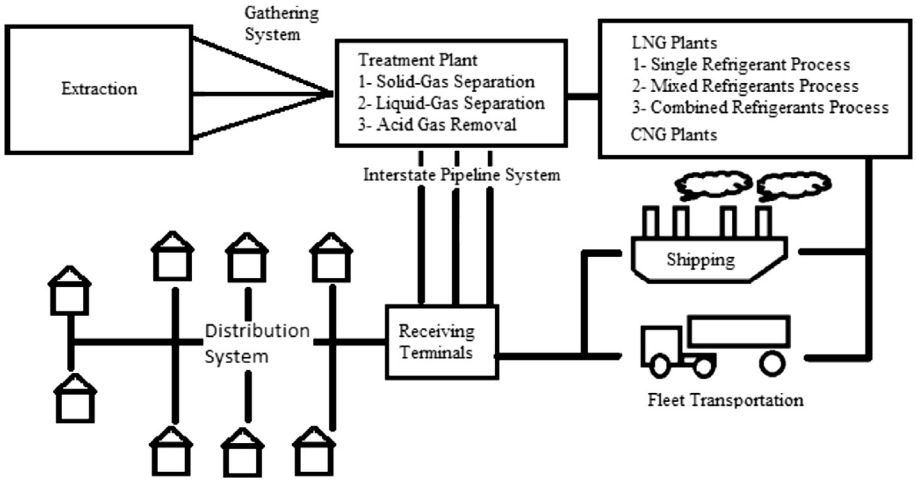

Fig. 1. A schematic of the natural gas processes.

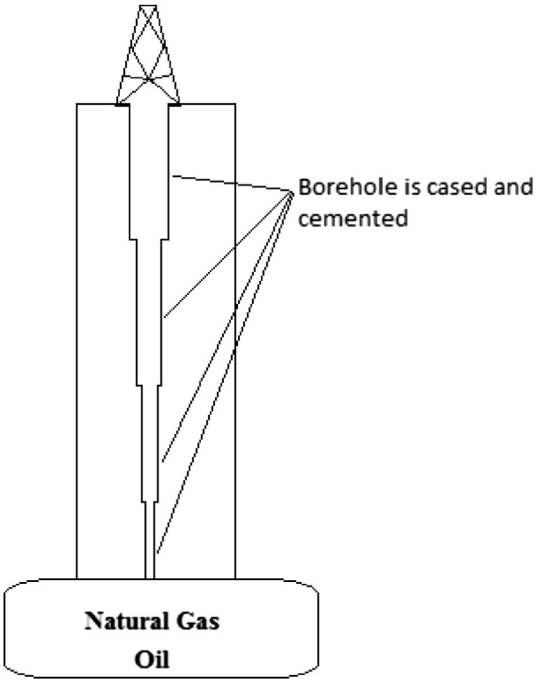

Fig. 2. A schematic of a step-wise drilling hole technique.

the world wide companies involved in oil and natural gas drilling operations based on different regions (TNT Energy Services, 2014; Yahoo, 2014).

In the early time of oil and gas extraction, the efficiency of the extraction methods was around 10% (only 10% of the reservoir's content was extracted due to its natural pressure). The recent technologies have enhanced the efficiency to 60% by implementing additional recovery steps including secondary and enhanced recovery (see Fig. 3). As mentioned above, the first recovery step, referred to as primary, relies on the natural internal pressure of the well. After the underground pressure deteriorates, pumps are used for further extraction. The efficiency of the first recovery step is limited to 10%. The secondary recovery method involves injection of water from the other side of the well to push oil and gas towards the drilled section (Adventures in Energy, 2014) (see Fig. 3(b)). Water used for the drilling process is taken from two sources: i) underground water (wastewater) which is found in the geological formations (United States Environmental Protection Agency, 2013), and ii) external sources such as nearby water sources. In essence, the water is injected back to the well to maintain the underground pressure. The secondary recovery step enhances the efficiency to 20% (20% of the reservoir's content is extracted at this step). To enhance the recovery process to 60%, the final step is applied using thermal recovery methods, gas injection techniques, and chemical flooding techniques (shown in Fig. 3(c)). The thermal recovery process is conducted through injection of the steam into the well. The heated steam reduces the viscosity of the reservoir's content, enhancing the recovery process. The gas injection technique uses miscible or immiscible gases. The miscible gases dissolve the light gasses to lower the viscosity of the reservoir's content and increase the flow; whereas the immiscible gases increase the pressure in the "gas cap" (i.e. the segregated gas zone overlying the oil column) to drive additional reservoir's content to the well. Third enhance recovery technique is conducted by injecting a mixture of dense water-soluble polymers with water into the well to push the reservoir's content to the well.

2.2. NG treatment

Depending on the reservoir's source, the raw natural gas has certain compositions (Table 2 shows the composition of natural gas from a typical reservoir in USA). It is generally composed of methane (CH_4), other light hydrocarbons (C_2H_6–C_5H_{12}), heavy hydrocarbons, water, carbon dioxide (CO_2), hydrogen sulfide (H_2S), helium and nitrogen (Scholes et al., 2012). To meet the pipeline specifications and regulatory standards required during transportation, natural gas has to be sweetened (treated). Fig. 4 shows a typical natural gas treatment process plant where the feed gas extracted from the reservoir is sent to an inlet processing unit through which gas, liquid gas, water and mixed solid particles are separated from each other (Rufford et al., 2012). The liquid portion of the raw natural gas which contains heavier hydrocarbons (such as ethane and propane) will be used as refrigerants in the cooling process (natural gas liquefaction process explained in Section 2.3.2). The gas portion of the raw natural gas is first transferred to the acid gas removal unit (referred to the gas sweetening unit) to remove CO_2 and H_2S due to their corrosive properties. After this step, the sweetened gas is transferred to the dehydration and mercury removal unit to prevent solidification of water during cooling process and reaction of mercury with aluminum heat