Research on CO_2 Quality Pipeline Transportation Based on Yanchang Oilfield CCUS

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Abstract. CO_2 capture,utilization and storage (CCUS) is now recognized as an important technology in the global scope of CO_2 emission reduction, pipeline transportation is the main center to connect the capture point and the use storage point, the first issue to CO_2 pipeline transportation is to solve CO_2 source quality research. Yanchang Oilfield has the advantages of CCUS, its coal chemical capture of CO_2 contains different impurities. In the CO_2 pipeline transportation, the impurity content in CO_2 is based on its end use and the actual situation of pipeline. The impurities will affect the efficiency of CO_2-EOR, the choice of CO_2 state equation, the changes of CO_2 phase diagram and the capacity of pipeline transportation.

Keywords. CO_2 quality, pipeline transportation, CO_2-EOR

1 Introduction

CCUS (CO_2 capture, utilization and storage) is a new technology, which has the potential of large-scale CO_2 emission reduction, is expected to achieve low carbon utilization of fossil fuels, which is widely considered to be one of the important technologies to deal with global climate change and control greenhouse gas emissions [1]. CO_2-EOR is the most important part of CCUS, it refers to that CO_2 is separated from the industrial or energy production, then transported to some oilfields to enhanced oil recovery, at the same time, sequestrates some CO_2 [2].According to the geology evaluation, there are 10 billion tons of petroleum geological reserves are suitable for CO_2-EOR in China.If they all used for CO_2-EOR, it is expected to increase the recoverable reserves of 700 million tons to 1400 million tons, which provides a broad prospect for CO_2-EOR;the first problem to used CO_2-EOR to achieve industrial applications is to solve pipeline transportation, CO_2 from capture contains such as CH_4, H_2S, N_2 and other impurities, so CO_2 must need to be need to be purified, then transported by long distance pipeline to the injection point for EOR. According to the data, there are more than 65 million tons CO_2 for CO_2-EOR each year in America, it increases more than 15 million tons oil [3]. CO_2 pipeline construction and operation experience has been more than 40 years in America, which contains impurities CO_2 pipeline's experience is 20 years, however, CO_2 pipeline transportation in China has just started, building a large scale containing impurities CO_2 pipeline and ensuring safety and stable operation, the research of CO_2 quality is the first step.

2 The advantages of Yanchang Oilfield to carry out CCUS

Yanchang oilfield has coal, gas and oil resources in the same area, the natural conditions lays the foundation for the comprehensive development of the CCUS work. Domestic modern energy and chemical base has been formed, especially Coal-to-Oil and Coal-to-Olefins as the representative capture large numbers of high concentrations CO_2. There are more than 9.5 million tons CO_2 had emitted by coal chemical projects every year, of which about 60%, the concentration is above 85%. the use of CO_2 for EOR to reduce CO_2 emissions in Northern Shaanxi means that the coal utilization rate is higher than other areas and it's also the important module of coal chemical industry in Northern Shaanxi [4]. In recent years, there are a total of about 10 million tons of high pure CO_2 capacity in Northern Shaanxi, of which Yanchang oilfield has been formed a huge capture scale that is early 400000t CO_2, mid 700000 CO_2 and forward 4 million tons CO_2, this huge CO_2 capture is the prerequisite for the development of CO_2-EOR.

Yanchang oilfield is extra-low permeability reservoir, which has low oil recovery, CO2-EOR can efficiently enhance oil recovery, this can ensure the long-term stable production of the oilfield; water resources in North Shaanxi is deficient, CO2-EOR saves a large amount of water;according to the abroad experience of CO2 pipeline and the characteristics of CO2, the CO2 pipelines are laid away from the crowd, sparsely populated of northern shaanxi for CO2 pipeline provides a good geographical conditions.

The nature conditions of Yanchang oilfield provided a successful foundation for CCUS: (1) It makes CO2 emission reduction successful and the benefits from enhanced oil and gas recovery can make up for the cost of CCUS. (2) It saves a lot of water resources, these advantages are the key reason that America and China choose Yanchang oilfield as demonstration base of CCUS [5].

3 Requirements of CO_2-EOR for CO_2 Quality

The requirements of pipeline transportation for CO2 quality are considered its final use: enhance oil recovery. For EOR applications, CO2 flow must has a high purity, which generally provides the minimum content of CO2 is 95% and the average content of CO2 is about 98.45%~98.72% in foreign countries, which is to ensure that CO2 and oil are mixed in the suitable geothermal basin.different impurities in CO2 flow has different effects on CO2-EOR. H2S can increase the solubility of CO2 in the oil and reduce the mixed phase pressure, increase the water solubility in CO2, so H2S is favorable for CO2-EOR. Therefore, the restriction on H2S is based on security perspective, the recommended of H2S concentration is below 0.02% [6], but in the actual operation, the concentration is determined according to the actual operation situation eventually;CH4 can affect the minimum miscible pressure , and it is an important factor for affecting the mixing capacity, the volume concentration of CH4 is 2% in EOR applications; while N2 and other non-condensable species have a negative effect on the miscible capacity, density and viscosity of CO2 flow [7,8]. In conclusion, the impurities content in the CO2 flow is considered by having a minimal on EOR applications.

4 Requirements of Pipeline Transportation for CO_2 Quality

The pipeline system is very sensitive to the impurities in CO_2 flow, which will affect many parts of CO_2 pipeline transportation. The impurities will affect the phase change of the whole CO_2 flow, pipeline transport process, pipeline transport capacity, pipeline crack propagation and pipeline corrosion and protection, etc.

4.1 Requirements of pipeline transportation for water content

The impact of free water on the transport pipeline is mainly reflected in the following two aspects: (1) CO_2 will lead to the electrochemical reaction between carbon steel and water, then make the pipeline and equipment corrosive and corrosion rate is high; (2) The free water will form hydrates to block the pipes and even damage equipment. So, before entering the pipeline systems, CO_2 must be dehydrated.

Under super-critical conditions, the solubility of water in pure CO2 is 0.0026kg/m3 and it has been determined that the water content is less than 60% saturation (0.0015kg/m3), and carbon steel will not corrode. For super-critical CO2,

along with the increase in pressure and temperature, the solubility of water in CO2 increased. In addition, the existence of free water also can cause hydrogen embrittlement or hydrogen brittleness, because the free water can cause the hydrogen atoms diffusing to the metal substrate to form hydrogen molecules, resulting in local internal pressure decreased the ductility and tensile strength of steel [9,10].

The formation of hydrate is not the main problem but it is a problem to be solved. The concerns about hydrates are mainly from the aspects of the flow protection, hydrate in the pipeline may cause the pipe blockage and flow content reduction and plug the pipeline system and accessories then causing accidents. In addition, if there is some water in CO2 flow, it is easy to generate hydrate in pipeline restart [11,12]. In order to avoid the occurrence of corrosion, the water content in current CO2 pipeline is far less than 60%, and the operation of these pipelines are safe, so in our country designing CO2 pipeline is also to meet this requirement. If in transit appear free water, there is no definite response, the International Petroleum Exchange gives the suggestion is that using ethylene glycol or corrosion inhibitor [13, 14].

4.2 Requirements of pipeline transportation for other impurities

The impurities affect the density, compressibility and viscosity of the whole CO_2 flow. These thermodynamic parameters affect the physical properties of the fluid and the pipeline transport properties, they can determined by the equation of state. The most popular used to predict the CO_2 phase diagram are: Peng-Robinson (PR) equation, Soave-Redlich-Kwong (SRK) equation, Benedict-Webb-Rubin-Starling (BWRS) equation and GERG-2008 equation.The differences of impurities content and kinds make the equation of state's more difficult, so the equation of state for CO_2 pipeline design has not yet reached a consensus, currently used for simulation of the impurities in the CO_2 state equation are based on the published experimental data available in the literature to evaluate, DNV RP J202 *Design and Operation of CO_2 Pipelines* recommended PR equation is used for CO_2 containing impurities. PR equation has higher accuracy, however, in the process of calculation, the equation of state needs use the experimental data to adjust and to assess the calculation of uncertainty.

Impurities affect the phase behavior of the whole CO_2 gas flow and then affect the process of pipeline transportation. Figure 1 show the phase diagram of CO_2, compared the different impurities on the critical point and phase curve of CO_2.

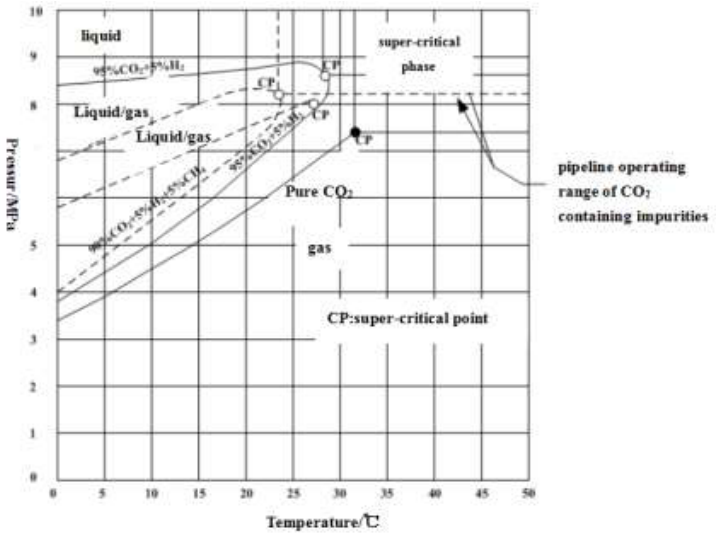

Fig. 1. CO_2 phase diagram

The critical point of pure CO2 is T=31.4, P=7.38MPa, which has a lower critical point. Because super-critical CO2 has good flow characteristics and transmission characteristics, it has high transmission efficiency in the process of conveying. So all foreign operation of CO2 pipelines are using super-critical CO2. Figure 1 shows that different kinds of impurities make CO2 phase diagram in a two phase region and changed CO2 critical point, this influences the operation scope and transportation way of pipelines. With the increasing of impurities, critical pressure increases and critical temperature decreases [15], this means compared with transporting pure CO2, CO2 containing impurities need higher pressure, so in the pipeline transportation, determining the types and contents of impurities in the CO2 flow is the first step for determining the operating conditions.

Impurities will also affect the transport capacity of the pipeline, it can consume additional compression, and with the increase of impurities, the pipeline transportation capacity will be reduced. It has been shown that [16, 17], for example, in the same transport conditions, compared with pure CO2, if the content of CH4 is 5% or 10%, the pipeline transport capacity decreased by 9.4% and 16%, if the content of N2 is 5% , the pipeline transport capacity decreased by 12.6%, which is due to the impurities reduce the volume of the pipeline transport capacity.

Impurities can also affect the design of pump and compressor, which is based on CO2 components such as NOX, H2S, CO, SOX, etc. The existence of such impurities increase the pipeline leakage risks; Impurities can affect the use of the pipeline infrastructure. Above all, the impurities in CO2 flow influence multiple aspects of the pipeline, so it must control the content of impurities reasonably and effectively during the process.

5 Conclusions and Recommendations

Compared with natural gas pipelines and other hazardous liquids pipelines, few accidents happened at the current CO_2 pipelines in America.Throughout the CO_2 pipeline technology, it can be seen that CO_2 pipeline transportation is not really difficult to overcome, so large-scale and long-distance CO_2 transmission pipeline will be fully realized in China.

(1) Yanchang oilfields as CCUS demonstration project implementation in China, CO_2 capture needs combine with CO_2-EOR, and explore the best way to capture for CO_2-EOR.

(2) It must be to do a good job of dehydration and removing impurities before CO_2 flow into the whole pipeline system and monitor the water content in the entrance to ensure the saturation limit of moisture content below 60%; Impurities also can affect the critical point of CO_2, pipeline transport process and transport properties, so it should be strictly controlled the content of impurities and monitored carefully.

(3) The research on CO_2 pipeline transportation needs to combine American's 40 years of experience in CO_2 pipeline transportation and China's experience in rich natural, gas oil pipelines, then develop a suitable standard for China's large-scale CO_2 transmission pipeline.

(4) Capture, transportation, storage, injection, separation, detection, monitoring of high pressure and large impurity CO_2, CO_2 anti-corrosion technology and equipment need to be tested research and optimized.

(5) With the development of experimental and industrial applications, the government and related enterprises should take into account the planning and construction of the CO_2 containing impurities transport pipeline in due time.

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