International Journal of Computer Science and Information Technology
ISSN: 3005-9682 (Print), ISSN: 3005-7140 (Online) | Volume 3, Number 3, Year 2024
DOI: https://doi.org/10.62051/ijcsit.v3n3.34
Journal homepage: https://wepub.org/index.php/IJCSIT/index

Development and Safety Analysis for Low Concentration Coal-bed Methane Liquefaction Equipment

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ABSTRACT

In this paper, the principle and characteristics of low concentration coal-bed methane liquefaction process in coal mine area were introduced. The safety performance of the liquefaction process was proved by experimentation. According to the experiments, this paper expounded the security measures those we took. The operation results of pilot plant and industrial demonstration device showed it was security to produce LNG by the cryogenic liquefaction technology of the low concentration coal-bed methane. This technology could be widely used in the coal mine areas those were abundance of coal-bed methane. By using the technology, the product purity could reach 99% and the yield of the methane could reach more than 98%.

KEYWORDS

Low concentration coal-bed methane; Liquefaction process; Security measures; Purity; Yield

1. INTRODUCTION

Coalbed methane (commonly known as gas) has always been a major hidden danger in coal mine safety production, and the fundamental measure to control gas accidents is to extract before mining. The main component of coalbed methane is the combustible gas methane, which can be purified and liquefied to produce liquefied natural gas (LNG). After methane liquefaction, the volume will be reduced by more than 600 times, which is convenient for transportation and fully utilizes resources. According to statistics, in 2015, the extraction volume of coalbed methane (coal mine gas) was 18 billion cubic meters, and the utilization volume was 8.6 billion cubic meters. Among them, the production of surface coalbed methane is 4.4 billion cubic meters, and the utilization is 3.8 billion cubic meters [1-2]. The underground gas extraction volume is 13.6 billion cubic meters, the utilization volume is 4.8 billion cubic meters, and the utilization rate of underground coalbed methane is only 35.3%. Emphasis is placed on introducing the technical principles and characteristics, safety performance and measures, and application effects of the low concentration coalbed methane cryogenic liquefaction to produce LNG equipment.

2. TECHNICAL PRINCIPLES

This technology mainly targets the extraction of oxygen-containing coalbed methane containing more than 30% methane from coal mining areas, for methane purification and liquefaction to produce LNG products. The corresponding technical flowchart is shown in Figure 1, and the main process mainly includes three steps: raw gas compression, purification, liquefaction, and separation. Purification consists of two parts: decarbonization and dehydration, which are carried out in the absorption tower and adsorption purification tower respectively. The liquefaction and separation process is carried out in the liquefaction cold box, which is the core process of this device [3-4]. The required cooling capacity is provided by an external mixed refrigerant refrigeration system.

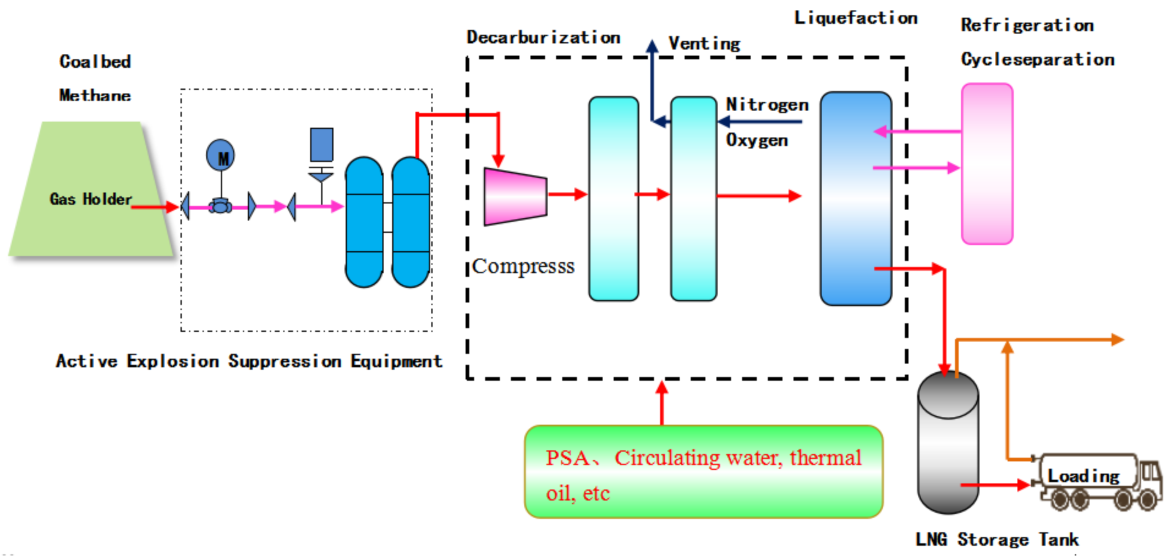

Figure 1. Technical flowchart for producing LNG through low-temperature liquefaction of low concentration coalbed methane

The low concentration coalbed methane extracted from the coal mining area enters the gas tank, is measured and stabilized to 105kPa, and then enters the raw gas compression system. Active explosion suppression devices (including automatic explosion prevention valves, automatic powder spraying explosion suppression devices, and water sealed fire suppression and explosion relief devices) are installed before and after the gas holder, effectively ensuring the safety of the gas extraction system, gas holder, and on-site cryogenic liquefaction equipment. In the compressor, the raw gas is compressed to 500kPa before undergoing purification process.

In the purification section, coalbed methane first enters the absorption tower and flows upward from the bottom of the tower. The regenerated monoethanolamine (MEA) solution enters the absorption tower from the top and flows downward after being evenly distributed by the liquid distributor. It fully contacts with the reverse flowing coalbed methane, and acidic gases such as CO_2 are fully dissolved in the liquid, thus achieving the purpose of deacidification. The low concentration coalbed methane flowing out from the top of the absorption tower enters the adsorption purification tower, and the molecular sieve temperature and pressure swing adsorption (PTSA) process is used to deeply remove water and residual CO_2. The gas coming out of the top of the adsorption tower has a pressure of about 430kPa and can be regarded as a mixture of methane, nitrogen, and oxygen.

The purified coalbed methane enters the liquefaction cold box for cooling. There are two channels in the cold box for raw gas and refrigerant. The mixed refrigerant is used to provide cooling for coalbed methane through the main heat exchanger and the refrigerant channel in the condenser at the top of the distillation tower. The oxygen-containing coalbed methane in the feed gas channel is cooled to -165 ℃ in the main heat exchanger and then enters the throttling valve. After throttling, the pressure is about 320kPa and it enters the distillation tower. In the distillation tower, liquid components flow from top to bottom, and gas components flow from bottom to top, with mutual transfer of matter and energy between the two phases. The liquid flowing downwards is heated by the gas flowing upwards, and the low boiling point components (oxygen, nitrogen) are evaporated first; The upward flowing gas is cooled by the downward flowing liquid,The high boiling point component (methane) is first condensed. So, nitrogen and oxygen components with very low methane content can be obtained at the top of the tower, while liquid fuel LNG with methane purity of over 99% can be obtained in the tower kettle [5-6].

3. TECHNICAL CHARACTERISTICS OF THE DEVICE

The liquefaction and separation of this device are carried out synchronously at low temperature and low pressure, completed in one go, eliminating the deoxygenation process. It has a small footprint, low investment and operating costs, simple process, high product purity, high methane yield (≥ 98%), good product efficiency, mature and reliable equipment in each unit of the process, can be designed as a modular or fixed factory, has a high degree of automation, and corresponding measures are taken to prevent possible dangerous links in the process flow. The process safety is guaranteed, and the product structure can be flexibly adjusted according to local market demand. It is suitable for coal mines with extraction concentration of more than 30% and extraction coal seam gas purity of more than 30000 m3/d.

In terms of technology, there are mainly the following characteristics:

(1) The purification process fully considers the possible changes in acidic gases and high boiling point hydrocarbons in the raw gas, and uses activated MEA solution to absorb acidic gases (carbon dioxide, hydrogen sulfide), with high removal accuracy and low consumption; The raw gas after removing acidic gases enters a unique molecular sieve dehydration unit, where three adsorption purification towers operate alternately to achieve continuous treatment of process gas; Regenerate gas into process gas, closed-loop circulation, high operational flexibility, easy to strengthen operation. The entire process is safe and stable, easily removing moisture to below 1ppm. At this point, the entire combined purification process is completed. The characteristics of this process are high operational flexibility, stable purification effect, and the ability to ensure that the cold box does not experience ice blockage when there are significant changes in the composition of the raw gas; Secondly, the regeneration gas volume is low, greatly reducing operational energy consumption.

(2) After the final compression of the mixed refrigerant in the liquefaction process, gas-liquid separation occurs. The liquid phase is directly sent to the cold box under pressure for supercooling and then throttled for refrigeration, simplifying the process; The gas phase is cooled to around -120 ℃, then exits the main heat exchanger and enters the bottom reboiler of the distillation tower to provide heat. It then enters the third stage main heat exchanger to absorb the cooling capacity, and finally undergoes throttling and reheating before exiting the cold box; The nitrogen cycle involves compressing the nitrogen gas and entering the cold box, which is then cooled to about -178 ℃ through the main heat exchanger and subcooler before entering the condenser at the top of the distillation tower to provide cooling capacity. Finally, it is reheated and discharged from the cold box. The above treatment method for gas and liquid phase fluids successfully avoids the problem of uniform distribution required for the exchange of positive flow gas and liquid phases, as well as the disadvantage of too much heavy hydrocarbons being supercooled and slow to gasify during the reflux process after depressurization; At the same time, when the heavy hydrocarbons are depressurized and enter the cold box, the amount of low-pressure reflux gas is large, which is conducive to gas-liquid entrainment and gas-liquid uniform distribution.

4. CONCLUSION

(1) The low concentration coalbed methane cryogenic liquefaction equipment adopts a low-temperature and low-pressure process, which is safe, reliable, and has a wide range of applications. It is particularly suitable for extracting more than 30% of gas from coal mines underground, with a product purity of up to 99% and a methane recovery rate of over 98%.

(2) According to the high temperature and high pressure three parameter coupled explosion test and the low temperature three parameter coupled explosion test, as long as the methane concentration of the feed gas is greater than 30% and appropriate measures should be taken to control the ignition energy of the device, safe operation can be ensured.

(3) This technology has been applied in multiple mining areas with good technical parameters. After methane liquefaction, it is convenient for transportation, energy is effectively utilized, and pollution to the environment is reduced, achieving the national policy of "energy conservation and emission reduction". This is the development direction of low concentration coalbed methane cryogenic liquefaction technology.

ACKNOWLEDGEMENTS

We are grateful for the financial support from the scientific research project of Chongqing Engineering Vocational College (grant number KJB202323), the Project of Science and Technology Research of Chongqing Education Commission (grant number KJQN202103408); the Chongqing Natural Science Foundation General Project (grant number cstc2021jcyj-msxmX1083).

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