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Review Article

The Design of the Natural Gas Dehydration Tower

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Abstract: Due to water is contained in the natural gas, also some other substance can form into hydrate in some special conditions. Above zero degree natural gas is a solid-state unstable compound. It can not only bring about the blockage of the pipe, but also cause the blockage of the spray nozzle and the separation equipment. So we use method of absorption to dehydrate. In this method we use triethylene glycol (TEG) as a sorbent. Because the TEG has a strong dehydrated capability of natural gas, and also TEG is quiet stable under high temperature, so TEG can not be solidified, at the same time TEG is easy to be regenerated. During the process of carrying, the losing amount of TEG is acceptable, and the dew point is high. All the property decide the TEG is suit for dehydrate. The absorbtion tower have many advantages. First, it is easy made and investment is low and pressure can be maintained long enough so that it can save power. Second, it can be used continuously. Third, the volume of tower is easy to be expanded. forth, the equipment of the tower is easy to be assembled so that it can lower the complexity of construction. Finally, it is convenient to avoid the pollution of solid adsorbent. In this method, the working theory of the dehydration tower is briefly stated. The paper not only make an reasonable choose of the parts of absorbtion tower, but also check the stress on the body of the absorbtion tower. What's more, the way to reinforce the holes of the tower and technical demands of the tower are also explained in the paper.

Keywords: Natural Gas Dehydration, TEG, TEG Dehydration, Dehydration Tower

1. Introduction

The general trend of energy development is the use of efficient and clean fuel, and natural gas is the most clean and efficient energy, also compared with crude oil, natural gas has obvious superiority in clean, economic, convenient, it has become a catalyst for economic development in the world [1].

The most important superiority of Natural gas is convenient to use, do not need concentrate processing like oil refineries, unlike burning coal and cinder left a lot of ash which may bad to environment. Second, the role of environmental protection in China is still serious, it is a direct result of China's large and medium cities take coal as the main fuel which lead to poor air quality. Due to Natural gas has low carbon content, after it burns only produce extremely low SO_2 and small amount of CO, and almost no suspended particulates and greenhouse gas CO_2, the pollutant emission of burning natural gas is only about half of the coal and less than 1/3 of oil, this advantage is in line with the trend of the development of non-carbon energy [2]. Over the past ten years, environmental protection has risen to an important position in the political agenda. As a result, natural gas has become the preferred fuel for environmental protection. At present, the proportion of natural gas in the primary energy consumption structure had increased from 1.8% in 1995 to 3% in 2000, [3] the rising usage of natural gas reduce the proportion of other carbon-produced energy, gradually make the natural gas become the primary consumption energy and optimize the fuel structure, plays a very important role in against the environmental pollution. According to the Professor Michel of economics at University of Houston, who is the authority personage of the US oil and gas industry research field, the American Association of petroleum engineers at SPE forecast: to 2020, natural gas will account for 45 - 50% in the global energy consumption and the share of natural gas will replace oil as the primary energy. Therefore, in the next ten or twenty years the natural gas will become the main energy [4].

As a chemical raw material Natural gas, the process of usage is quite simple. Due to Natural gas have advantages

such as high conversion efficiency, low energy consumption, less investment, easy to achieve, cleaner production, stable performance. Therefore, at present in the world petrochemical industry, the use of natural gas is far more than that of petroleum and its fast development is mainly benefited from abundant storage, low price, environmental protection, comprehensive economic.

But the natural gas, which is exploit from the ground, is usually in a state of saturation of water. in the process of collecting and transporting the natural gas, the separator can separate the liquid state water from the natural gas. But the saturated water vapor contained in the natural gas can not be separated through the separator. under certain conditions, the saturated water vapor contained in the natural gas can transform into liquid water, and the pipeline and equipment can be blocked by it. In addition, for containing carbon dioxide, sulfur dioxide and other acidic gas, when those substances dissolve into liquid water, it will cause corrosion of equipment and pipe, shorten the life span of equipment and pipe. Therefore, it is quiet necessary to remove the water from natural gas, or take other measures to inhibit the formation of hydrate and control corrosion. At the same time, the commodity gas specification require water content in natural gas is much less than the saturated water content in the raw natural gas, so it is necessary to remove most of the water contained in the natural gas. The most widely used process to remove water is referred to as dehydration [5].

2. Natural Gas Dehydration

2.1. The Purpose of Natural Gas Dehydration

Water is one of the most common components of natural gas, when natural gas is exploited from the ground it usually contains saturated steam, due to the presence of water vapor, the pipeline capacity and the calorific value of natural gas is reduced, when the surrounding medium temperature is lower than the temperature of the gas, water vapor will condense into liquid, some time even ice or form hydrate, after long time accumulation the ice and the hydrate may clog the pipeline or some other equipment, thereby affect the stable supply of natural gas. in natural gas process and light hydrocarbon recovery process, Contained acidic gas CO_2 and H_2S in the natural gas will dissolve into water which increased corrosion of pipe, reduce the service life of the pipeline [6].

2.2. The Method of Natural Gas Dehydration

In history, there are many methods for the dehydration of natural gas, according to the different absorbent used, those methods can be divided into solvent absorption, solid adsorption, cooling method and chemical method, the most common chemical reaction method in natural gas industry is solvent absorption method. With the development of scientific research and technology, natural gas dehydration methods have break new ground, also scientist continue to explore new dehydration process, such as the membrane separation dehydration of natural gas [7].

In short, many industrialized method for natural gas dehydration have be developed, when choose the dehydration method, should take requirements and processing scale into account, also must combined with the characteristics of various dehydration methods, to make sure that the process method of dehydration is the most suitable way and the most low-cost way.

2.3. Dehydration Process and Main Equipment

Figure 1 shows the typical glycol dehydration unit process. The device is composed of two parts, the high pressure absorption system and the low pressure regeneration system. Due to the gas into the tower is not allowed to contain liquid water and liquid hydrocarbons, chemical substances, compressor oil and sediment. So, before the wet gas into the device, the gas must first go through inlet scrubber (scrubber or separator) to remove liquid and solid impurities. If the impurities in natural gas is too much, also need to use the filter separator. The top of the inlet air filter is a mist sprayer, which is used to remove the liquid drops carried in the outlet gas [8].

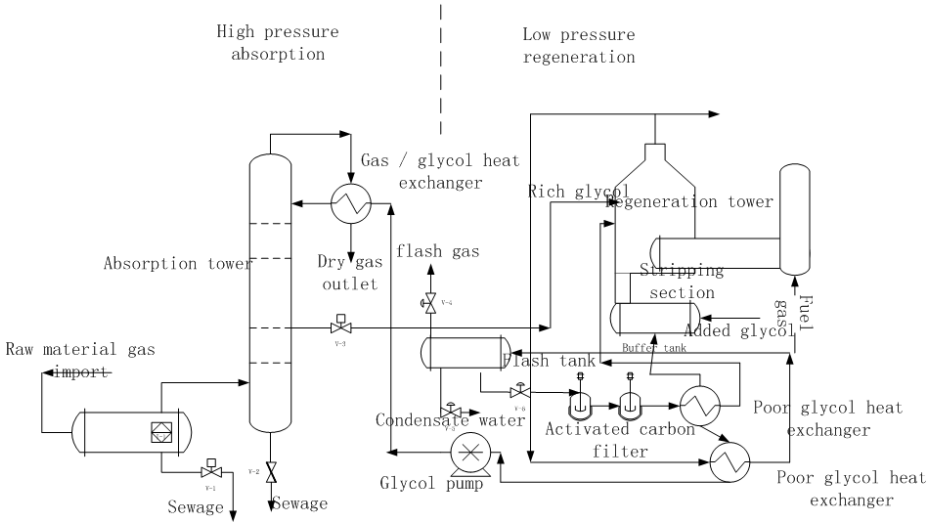

Figure 1. *Dehydration principle of glycol.*

The absorption tower (contactor) in the picture is a plate type tower, which is usually select the bubble cap column or the float valve tray as the stuffing. The wet gas enter from the top of the bottom of the tower via the import scrubber to absorb, when the gas up through the layers of trays, the gas contact with diethylene glycol solution passes down through the layers of the tray, the water vapor in the gas is absorbed by diethylene glycol solution. at the top part of the tower should place the absorption to remove dry gas in the outlet to carry the glycol solution droplets, reducing the loss of glycol (in addition to foam filter). After the dry gas leaving the absorption tower, it passes through the gas / the poor glycol heat exchanger (the poor glycol cooler), which is used to cool the liquid in the intake tower. For small-scale dewatering device, the gas / the poor glycol heat exchanger can also be installed in the absorption tower plate or the trap. After cooling through the gas / poor glycol heat exchanger, the poor glycol enters the absorption tower top part, and passes through each layer to the bottom tray. A liquid sealing groove is arranged on the overflow pipe of the bottom tower plate to avoid the liquid leak down directly. Rich TEG liquid absorption of natural gas and water vapor (rich glycol) from the absorption tower bottom, first through high pressure filter to remove solid impurities from the feed gas with people, with good thermal regeneration of lean glycol liquid (hot lean glycol) heat into the flash separator (flash tank). After low pressure flash separation, separated by Gansu gas hydrocarbon alcohol solution absorption. This part of the general gas as the regeneration system of reboiler fuel containing hydrogen, but sparse flash steam should go to the torch burning empty.

Discharged from the flash separator at the bottom of the rich glycol followed by fiber filter (solid filter) and activated carbon filter to remove diethylene glycol solution in the absorption tower in absorption and a small amount of solid, carrying over liquid hydrocarbon, chemical agent and other impurities. The impurities can cause the distillation column (usually packed column) of the methanol solution to bubble and block the regeneration system, and also can make the fire tube fouling of the heavy boiler. If the absorption tower in absorption of liquid hydrocarbon in more glycol solvent, also can use three-phase flash separator will separate from the bottom of the liquid hydrocarbon. Otherwise, the liquid hydrocarbon in addition to the glycol solution in the regeneration of foaming outside, into the regeneration system of these liquid hydrocarbons will eventually be discharged to the atmosphere of the top of the distillation column, not only is not very safe, but also increase the loss of the distillation column glycol [9].

By the fiber filter and activated carbon filter to the rich Gan alcohol by the poor / rich glycol heat exchanger, into the top of the distillation column. Column filled packing, such as the British ceramic Intalox packing (Intalox). Rich glycol in the distillation column to the inflow of the reboiler, and the reboiler of gas rising hot glycol vapor and water vapor contact of heat and mass transfer. The top of the distillation column is provided with a reflux condenser, which generates partial reflux at the top of the column. The reflux condenser can be cooled by air, and can also be cooled by cold. From the rich glycol gasified water vapor, finally from the top of column is discharged to the atmosphere. Usually, the distillation column, reboiler of regeneration system and buffer tank is equipped with a heat exchanger coil, referred to as the regeneration tower or regenerator.

3. Container Design

3.1. Strength Calculation of Cylinder

In order to ensure the strength of the cylinder, the hoop stress should not be higher than the allowable stress of the material in the cylinder.

$$\frac{pD}{2\delta} \le [\sigma]^t \tag{1}$$

The following factors must be taken into account:

(1) Welded joint coefficient is generally welded by steel plate. Because the heating in welding process, have an adverse effect on the weld metal at the same time, often occur slag formation, porosity, incomplete welding defects, all those defects resulting in weld metal strength lower than the strength of steel plate body. Therefore, type (3-1) allowable stress should be replaced by allowable stress which is the allowable stress of the weld multiplied by the coefficient φ, φ <1, and type (3-1).

$$\frac{pD}{2\delta} \le [\sigma]^t \varphi \tag{2}$$

(2) The inner diameter of the container is determined in the process design, and the inner diameter of the cylinder is measured during the manufacturing process [10].

$$\frac{p(D_i + \delta)}{2\delta} \le [\sigma]^t \varphi \tag{3}$$

The inner pressure cylinder is calculated by the calculation of the wall thickness.

$$\delta = \frac{pD_i}{2[\sigma]^t \varphi - p} \tag{4}$$

3.2. Design Parameter Determination

3.2.1. Design Pressure

Design pressure is designed in the corresponding temperature to determine the pressure vessel cylinder wall thickness. It should be marked on the nameplate, the design pressure is generally slightly higher than the maximum working pressure. The opening pressure of the safety valve should not less than the pressure of safety valve, or 1.05~1.10 times of the maximum working pressure; the pressure of blasting membrane safety device, determined base on the

blasting diaphragm type, generally take 1.15~1.4 times of the maximum working pressure as the design pressure [11].

3.2.2. Design Temperature

The design temperature is not directly reflected in the design formula, but it is directly related to the selection of the container material and the allowable stress of the metal.

The design of a container temperature must through the heat transfer calculation in normal operation state, through calculation can determine the corresponding design pressure, metal wall temperature, in order to facilitate the calculation process, often take the highest or lowest temperature of the medium as the design temperature; for steam, hot water or other heat carrier or cold carrier often take the highest temperature of medium as the design temperature. In the course of work, the different parts of the container may appear at different temperatures, so we should base on the expected temperature to determine the design temperature of corresponding part.

3.3. Pressure Test

According to the strength and rigidity calculation, vessel wall thickness can be determined, if the material, plate bending, welding and installation of manufacturing process is not perfect, it may put the vessel in a dangerous situation, and it will be cause deformation or weld leakage phenomenon in the work under pressure, so we must be take pressure test before it is put into use.

The most commonly used pressure test method is hydraulic experiment. Water pressure test is usually used at normal temperature. Other liquids that are not dangerous can be used as hydraulic tests when required. The liquid temperature should be lower than the flash point or boiling point. the container for hydraulic test not allow use residual liquid or available clean air, nitrogen or other inert gas instead of liquid. The pressure of the experiment is as follows:

Hydraulic experiment

$$P_T = \begin{cases} 1.25\dfrac{[\sigma]}{[\sigma]^t}P \\ P+0.1 \end{cases} \quad \text{take the max} \qquad (5)$$

Air experiment

$$P_T = \begin{cases} 1.15\dfrac{[\sigma]}{[\sigma]^t}P \\ P+0.1 \end{cases} \quad \text{take the max} \qquad (6)$$

p—design pressure，Mpa;

$[\sigma]$ —Allowable stress of materials at the experimental temperature，Mpa;

$[\sigma]^t$ —Allowable stress of materials at design temperature，Mpa;

4. Conclusion

Due to Natural gas has low carbon content, after it burns only produce extremely low SO_2 and small amount of CO, and almost no suspended particulates and greenhouse gas CO_2, the pollutant emission of burning natural gas is only about half of the coal and less than 1/3 of oil, this advantage is in line with the trend of the development of non-carbon energy.

This paper introduces the methods and technical points of dehydration of natural gas, and expounds the production, testing and use of the container from the practical point of view, which provides reference for future project practice.

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