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PETROLEUM ENGINEERING

ENG 316 (FUNDAMENTALS OF NATURAL GAS ENGINEERING)

1. **Discuss in details the different methods of storing natural gas.**

There are three main types of underground natural gas storage facilities.

1. Depleted reservoirs
2. Aquifers
3. Salt caverns.

 Specific characteristics of depleted reservoirs, aquifers, and salt caverns may be found below.

**Depleted Gas Reservoirs**

The first instance of natural gas successfully being stored underground occurred in Weland County, Ontario, Canada, in 1915. This storage facility used a depleted natural gas well that had been reconditioned into a storage field. In the United States, the first storage facility was developed just south of Buffalo, New York. By 1930, there were nine storage facilities in six different states. Prior to 1950, virtually all natural gas storage facilities were in depleted reservoirs.

The most prominent and common form of underground storage consists of depleted gas reservoirs. Depleted reservoirs are those formations that have already been tapped of all their recoverable natural gas. This leaves an underground formation, geologically capable of holding natural gas. In addition, using an already developed reservoir for storage purposes allows the use of the extraction and distribution equipment left over from when the field was productive. Having this extraction network in place reduces the cost of converting a depleted reservoir into a storage facility. Depleted reservoirs are also attractive because their geological characteristics are already well known. Of the three types of underground storage, depleted reservoirs, on average, are the cheapest and easiest to develop, operate, and maintain.

The factors that determine whether or not a depleted reservoir will make a suitable storage facility are both geographic and geologic. Geographically, depleted reservoirs must be relatively close to consuming regions. They must also be close to transportation infrastructure, including trunk pipelines and distribution systems. While depleted reservoirs are numerous in the U.S., they are more abundantly available in producing regions. In regions without depleted reservoirs, like the upper Midwest, one of the other two storage options is required.

Geologically, depleted reservoir formations must have high permeability and porosity. The porosity of the formation determines the amount of natural gas that it may hold, while its permeability determines the rate at which natural gas flows through the formation, which in turn determines the rate of injection and withdrawal of working gas. In certain instances, the formation may be stimulated to increase permeability.

In order to maintain pressure in depleted reservoirs, about 50 percent of the natural gas in the formation must be kept as cushion gas. However, depleted reservoirs, having already been filled with natural gas and hydrocarbons, do not require the injection of what will become physically unrecoverable gas; that gas already exists in the formation.

**Aquifers**

Aquifers are underground porous, permeable rock formations that act as natural water reservoirs. However, in certain situations, these water containing formations may be reconditioned and used as natural gas storage facilities. As they are more expensive to develop than depleted reservoirs, these types of storage facilities are usually used only in areas where there are no nearby depleted reservoirs. Traditionally, these facilities are operated with a single winter withdrawal period, although they may be used to meet peak load requirements as well.

Aquifers are the least desirable and most expensive type of natural gas storage facility for a number of reasons. First, the geological characteristics of aquifer formations are not as thoroughly known, as with depleted reservoirs. A significant amount of time and money goes into discovering the geological characteristics of an aquifer, and determining its suitability as a natural gas storage facility. Seismic testing must be performed, much like is done for the exploration of potential natural gas formations. The area of the formation, the composition and porosity of the formation itself, and the existing formation pressure must all be discovered prior to development of the formation. In addition, the capacity of the reservoir is unknown, and may only be determined once the formation is further developed.

In order to develop a natural aquifer into an effective natural gas storage facility, all of the associated infrastructure must also be developed. This includes installation of wells, extraction equipment, pipelines, dehydration facilities, and possibly compression equipment. Since aquifers are naturally full of water, in some instances powerful injection equipment must be used, to allow sufficient injection pressure to push down the resident water and replace it with natural gas. While natural gas being stored in aquifers has already undergone all of its processing, upon extraction from a water bearing aquifer formation the gas typically requires further dehydration prior to transportation, which requires specialized equipment near the wellhead. Aquifer formations do not have the same natural gas retention capabilities as depleted reservoirs. This means that some of the natural gas that is injected escapes from the formation, and must be gathered and extracted by ‘collector’ wells, specifically designed to pick up gas that may escape from the primary aquifer formation.

In addition to these considerations, aquifer formations typically require a great deal more ‘cushion gas’ than do depleted reservoirs. Since there is no naturally occurring gas in the formation to begin with, a certain amount of natural gas that is injected will ultimately prove physically unrecoverable. In aquifer formations, cushion gas requirements can be as high as 80 percent of the total gas volume. While it is possible to extract cushion gas from depleted reservoirs, doing so from aquifer formations could have negative effects, including formation damage. As such, most of the cushion gas that is injected into any one aquifer formation may remain unrecoverable, even after the storage facility is shut down. Most aquifer storage facilities were developed when the price of natural gas was low, meaning this cushion gas was not very expensive to give up. However, with higher prices, aquifer formations are increasingly expensive to develop.

All of these factors mean that developing an aquifer formation as a storage facility can be time consuming and expensive. In some instances, aquifer development can take 4 years, which is more than twice the time it takes to develop depleted reservoirs as storage facilities. In addition to the increased time and cost of aquifer storage, there are also environmental restrictions to using aquifers as natural gas storage. In the early 1980’s the Environmental Protection Agency (EPA) set certain rules and restrictions on the use of aquifers as natural gas storage facilities. These restrictions are intended to reduce the possibility of fresh water contamination.

**Salt Caverns**

Underground salt formations offer another option for natural gas storage. These formations are well suited to natural gas storage in that salt caverns, once formed, allow little injected natural gas to escape from the formation unless specifically extracted. The walls of a salt cavern also have the structural strength of steel, which makes it very resilient against reservoir degradation over the life of the storage facility.

Essentially, salt caverns are formed out of existing salt deposits. These underground salt deposits may exist in two possible forms: salt domes, and salt beds. Salt domes are thick formations created from natural salt deposits that, over time, leach up through overlying sedimentary layers to form large dome-type structures. They can be as large as a mile in diameter, and 30,000 feet in height. Typically, salt domes used for natural gas storage are between 6,000 and 1,500 feet beneath the surface, although in certain circumstances they can come much closer to the surface. Salt beds are shallower, thinner formations. These formations are usually no more than 1,000 feet in height. Because salt beds are wide, thin formations, once a salt cavern is introduced, they are more prone to deterioration, and may also be more expensive to develop than salt domes.

Once a suitable salt dome or salt bed deposit is discovered, and deemed suitable for natural gas storage, it is necessary to develop a ‘salt cavern’ within the formation. Essentially, this consists of using water to dissolve and extract a certain amount of salt from the deposit, leaving a large empty space in the formation. This is done by drilling a well down into the formation, and cycling large amounts of water through the completed well. This water will dissolve some of the salt in the deposit, and be cycled back up the well, leaving a large empty space that the salt used to occupy. This process is known as ‘salt cavern leaching’.

Salt cavern leaching is used to create caverns in both types of salt deposits, and can be quite expensive. However, once created, a salt cavern offers an underground natural gas storage vessel with very high deliverability. In addition, cushion gas requirements are the lowest of all three storage types, with salt caverns only requiring about 33 percent of total gas capacity to be used as cushion gas.

Salt cavern storage facilities are primarily located along the Gulf Coast, as well as in the northern states, and are best suited for peak load storage. Salt caverns are typically much smaller than depleted gas reservoirs and aquifers, in fact underground salt caverns usually take up only one one-hundredth of the acreage taken up by a depleted gas reservoir. As such, salt caverns cannot hold the volume of gas necessary to meet base load storage requirements. However, deliverability from salt caverns is typically much higher than for either aquifers or depleted reservoirs. Therefore, natural gas stored in a salt cavern may be more readily (and quickly) withdrawn, and caverns may be replenished with natural gas more quickly than in either of the other types of storage facilities. Moreover, salt caverns can readily begin flowing gas on as little as one hour’s notice, which is useful in emergency situations or during unexpected short term demand surges. Salt caverns may also be replenished more quickly than other types of underground storage facilities.

1. **Why are compressor stations necessary in oil and gas industry?**

Compressor stations enable the natural gas itself to travel through the pipelines which is crucial to the natural gas transport system. They also allow the gas to be rerouted into storage areas during periods of low demand. In addition, compressor stations are often accompanied by PIG launchers and PIG receivers which are vital for the maintenance and efficiency of the pipeline. They even include many safety features allowing the pipeline and station to function safely. These stations perform the essential task of compressing natural gas as it travels through pipelines. It is this compression which allows the gas to continue flowing through the pipe and eventually to its final destination for distribution to refineries and other end users.

1. **Outline the key component parts of compressor station and what are their functions?**

The gas compressor station consists of the following units:

1. a suction scrubber.

2. a gas manifold or a distribution header.

3. gas compressor “single or multiples stages” according to the required discharge pressure.

4. gas cooler fan.

5. discharge scrubber.

6. condensate gathering system.

7. corrosion inhibitor skid.

8. a dehydration unit.

9. metering station.

10. blow down flares.

11. Utilities.

**1. SUCTION SCRUBBER:**

It is the first component of the gas compressor station, it’s is a 3-phase separator used to separate liquids and condensate from natural gas, the existence of any liquid in the natural gas stream will cause a compressor vibration.

The liquids will be disposed to the burn bit to be burned, while the condensate will go to the condensate gathering header.

**2. GAS MANIFOLD OR A DISTRIBUTION HEADER.**

After leaving the scrubber, natural gas will enter a manifold or a distribution header, it is used to distribute the gas to the compressor station trains” in large compressor station and if there is a big amount of gas is compressed”, before entering the compressing train it goes through a strainer to eliminate any liquid droplets.

**3. GAS COMPRESSOR**

Single or multiples stages according to the required pressure. It’s is either driven by a gas turbine or an electric motor, single stage or multiple stages “2 or 3” according to the required discharge pressure.

Centrifugal compressors are the most preferred in gas compressor station, and it is equipped with an anti-surge system.

Compressors are equipped with seal oil system that seals the sour gas from the lubricating oil, which in turn lubricates the bearings, it is also equipped with vibration, speed and temperature sensors.

**4. COOLER FAN:**

After being compressed, the temperature of natural gas is greatly increased, sometimes reach to 170 – 180 ºC, this requires cooling the gas, it is done by air cooler fans, which draw air beneath, and cools the gas.



**5. DISCHARGE SCRUBBER:**

After being compressed and cooled, vapours in natural gas will condense to liquids, these liquids can be separated and disposed in the discharge scrubber, as mentioned in suction scrubber; liquids will be disposed to the burn bit to be burned, while the condensate will go to the condensate gathering header, each compressing train is supplied with a suction and discharge scrubber.

**6. CONDENSATE GATHERING SYSTEM:**

The condensates are gathered from all the scrubbers in the compressor station, there are many options to make use of this amount, but the most common one is to inject this condensate in the gas discharge pipeline, there is a special technology to do this, it is injected by a sparger to guarantee the homogeneous propagation in the pipeline.

**7. CORROSION INHIBITOR SKID:**

Because of compression and cooling for the natural gas, water vapour will be converted to liquid water, it may react with hydrogen sulphide to form sulphuric acid, this will lead to serious corrosion problems to the pipelines and equipment, so corrosion inhibitor is injected before the air cooler to prevent corrosion. this is done by special type injectors which receive the chemical from a chemical injection skid consists of a dosing pump and a tank, injection pressure must be higher than the gas pipeline pressure, otherwise there will be no chemical injection.

**8. DEHYDRATION UNIT:**

Each gas compressor station is equipped with a gas dehydration unit; it is used to remove the water vapour from natural gas.

**9. METERING STATION:**

It is used to measure the quantity of natural gas, gas volumes are expressed in Standard Cubic Foot and the Standard Cubic Meter.



**10. BLOW DOWN FLARES:**

It is a kind of flare used to dispose the gas from the compressor station when shut down happens, Emergency Shut-Down Valves “ESDVs” that are equipped in each scrubber will do this.

**11. UTILITIES:**

Such as: instrument air system and fire-fighting system.