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**OYENIYI VICTOR OREOLUWA**

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**Question**

1. Discuss in detail the different methods of storing natural gas

2. Why is compressor stations necessary in oil and gas industry?

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

**ANSWERS**

1. METHODS OF STORING NATURAL GAS

**There are five different methods for storing natural gas underground:**

* Salt caverns.
* Aquifers.
* Depleted reservoirs.
* Hard-rock caverns
* Abandoned mines.

**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.

 Cavern construction is costlier than depleted field conversions when measured on the basis of dollars per thousand cubic feet of working gas capacity, but the ability to perform several withdrawal and injection cycles each year reduces the per unit cost of each thousand cubic feet of gas injected and withdrawn.

 **AQUIFERS**

An aquifer is suitable for gas storage if the water bearing sedimentary rock formation is overlain with an impermeable cap rock. Storage is created by injecting gas and displacing the water. Therefore, the water movement and cap rock quality should be taken into account when selecting and designing the storage (Katz and Tek, 1981). This type of storage usually requires more base (or cushion) gas (for definition see Section 8.3 “Storage Measures”) and greater monitoring of withdrawal and injection performance. With the presence of an active water drive, the deliverability rates may be enhanced.

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. To learn more about the Underground Injection Control program at the EPA.

 **Depleted reservoirs.**

 The advantage of converting a field from production to storage duty is that one can use the existing wells, gathering systems, and pipeline connections. It is usually close to consumption centers.

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. For information on well treatment.

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.

**HARD-ROCK CAVERNS**

Rock caverns are mined underground using conventional mining techniques and consist of a system of shafts or ramps and drifts, forming cavities in solid rock deep underground, for example, in granite. Although just as stable, unlike rock salt, solid rock is not impervious to liquids, and especially gases, because of fractures within the rock. Sealing therefore has to be achieved by engineering measures.

The most widespread technology to create impervious rock caverns is hydrodynamic sealing, which is primarily used for liquid storage.

**mines.**

 Abandoned mines, which were previously used for the extraction of commodities such as salt, ores, coal, or limestone can sometimes be used for storage of gases and liquids, depending on the local geological situation. Numerous abandoned mines with appropriate volumes and suitable depths exist worldwide. However, whether a mine is actually suitable for the construction of a storage facility largely depends on the imperviousness of the surrounding rock mass and the expense of creating a technical seal. The position and quality of the mined minerals are the priorities in conventional mining so that the resulting underground workings often only have limited suitability later on as compressed air storage facilities.

 An abandoned mine was converted for the first time in Sweden at the end of the 1940s for storing liquid hydrocarbons. The storage of gaseous hydrocarbons followed in the 1960s. Compared with other storage options in deep underground geological formations, mines have only been used very rarely for the storage of gas. For instance, only one former mine in Europe is currently used for the storage of natural gas (The former Burggraf-Bernsdorf salt mine in Germany)

 No experience has been gained to date in the use of abandoned mines for compressed air storage, but this technology has been looked at in some scientific investigations.

**2. Why is compressor stations necessary in oil and gas industry?**

A **compressor station** is a facility which helps the transportation process of natural gas from one location to another. Natural gas, while being transported through a gas pipeline, needs to be constantly pressurized at intervals of 40 to 100 miles. it is one of the most important steps in natural gas industry. It compresses natural gas and raise its pressure to make it continue flowing and reach further distances, they are located at natural gas pipeline, and they are essential to guarantee a continuous flow of gas, this is done by gas compressor mainly driven by a gas turbine, and sometimes by an electrical motor.

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

the gas compressor station consists of the following units:

* a suction scrubber.
* a gas manifold or a distribution header.
* gas compressor “single or multiples stages” according to the required discharge pressure.
* gas cooler fan.
* discharge scrubber.
* condensate gathering system.
* corrosion inhibitor skid.
* a dehydration unit.
* metering station.
* blow down flares.
* Utilities:

**1.  suction scrubber**:

it is the first component of the gas compressor station, its 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.  its 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](https://www.arab-oil-naturalgas.com/surge-control-centrifugal-compressors/).

compressors are equipped with seal [oil](https://www.arab-oil-naturalgas.com/what-is-crude-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, vapors 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 vapor will be converted to liquid water, it may react with hydrogen sulfide to form sulfuric 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](https://www.arab-oil-naturalgas.com/natural-gas-dehydration-p1/),  it is used to remove the water vapor 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](https://www.arab-oil-naturalgas.com/flare-types-and-components/) used to dispose the gas from the compressor station when shut down happens, Emergency Shut-Down [Valves](https://www.arab-oil-naturalgas.com/what-are-the-types-of-valves/) “ESDVs” that are equipped in each scrubber will do this.

**11. Utilities**:

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