

Introduction to Underground Natural Gas Storage

An Online Continuing Education Course for Engineers

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The Basics of Underground Natural Gas Storage

Natural gas—a colorless, odorless, gaseous hydrocarbon—may be stored in a number of different ways. It is most commonly held in inventory underground under pressure in three types of facilities. These are: (1) depleted reservoirs in oil and/or gas fields, (2) aquifers, and (3) salt cavern formations. Each storage type has its own physical characteristics (porosity, permeability, retention capability) and economics (site preparation and maintenance costs, deliverability rates, and cycling capability), which govern its suitability to particular applications. Two of the most important characteristics of an underground storage reservoir are its capacity to hold natural gas for future use and the rate at which gas inventory can be withdrawn—its deliverability rate (see *Storage Measures*, below, for key definitions).

Most existing gas storage in the United States is in **depleted natural gas or oil fields** that are close to consumption centers. Conversion of a field from production to storage duty takes advantage of existing wells, gathering systems, and pipeline connections. Depleted oil and gas reservoirs are the most commonly used underground storage sites because of their wide availability.

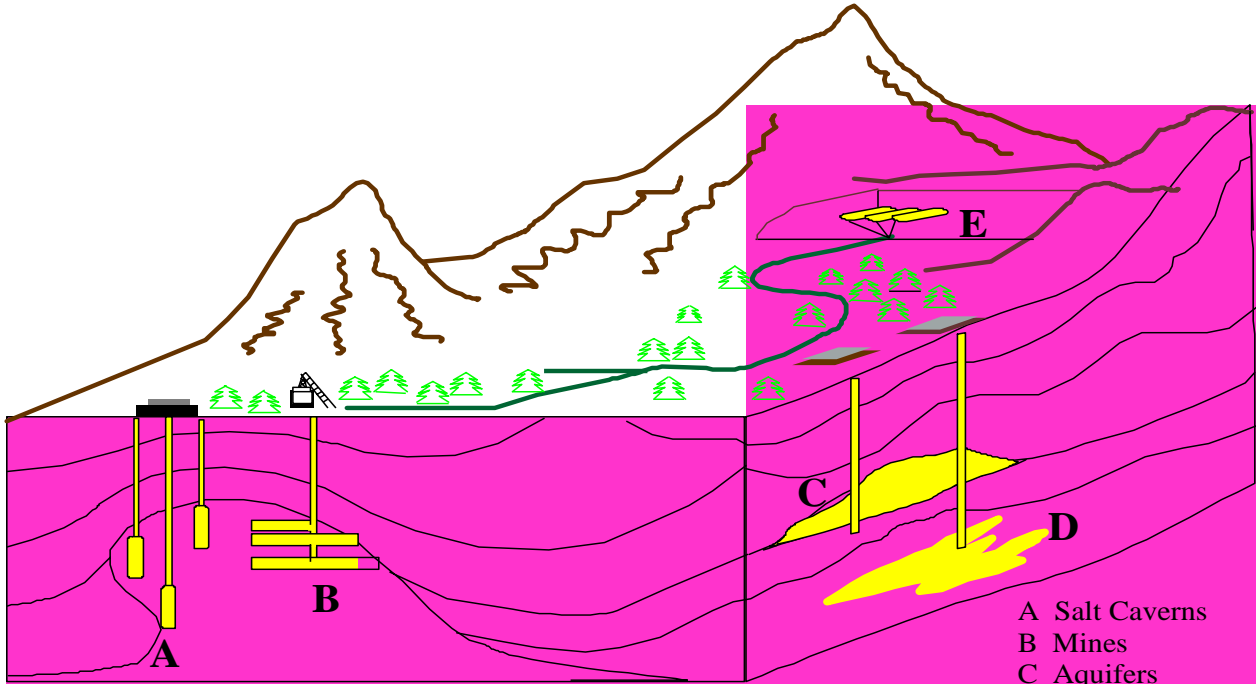
In some areas, most notably the Midwestern United States, natural **aquifers** have been converted to gas storage reservoirs. An aquifer is suitable for gas storage if the water-bearing sedimentary rock formation is overlaid with an impermeable cap rock. While the geology of aquifers is similar to depleted production fields, their use in gas storage usually requires more base (cushion) gas and greater monitoring of withdrawal and injection performance. Deliverability rates may be enhanced by the presence of an active water drive.

Salt caverns provide very high withdrawal and injection rates relative to their working gas capacity. Base gas requirements are relatively low. The large majority of salt cavern storage facilities have been developed in salt dome formations located in the Gulf Coast states. Salt caverns have also been leached from bedded salt formations in Northeastern, Midwestern, and Southwestern states. Cavern construction is more costly 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.

There have been efforts to use abandoned **mines** to store natural gas, with at least one such facility having been in use in the United States in the past. Further, the potential for commercial use of **hard-rock cavern** storage is currently undergoing testing. None are commercially operational as natural gas storage sites at the present time.

Figure 1 is a stylized representation of the various types of underground storage facilities, while Figure 2 shows the location of the nearly 400 active storage facilities in the Lower 48 States.

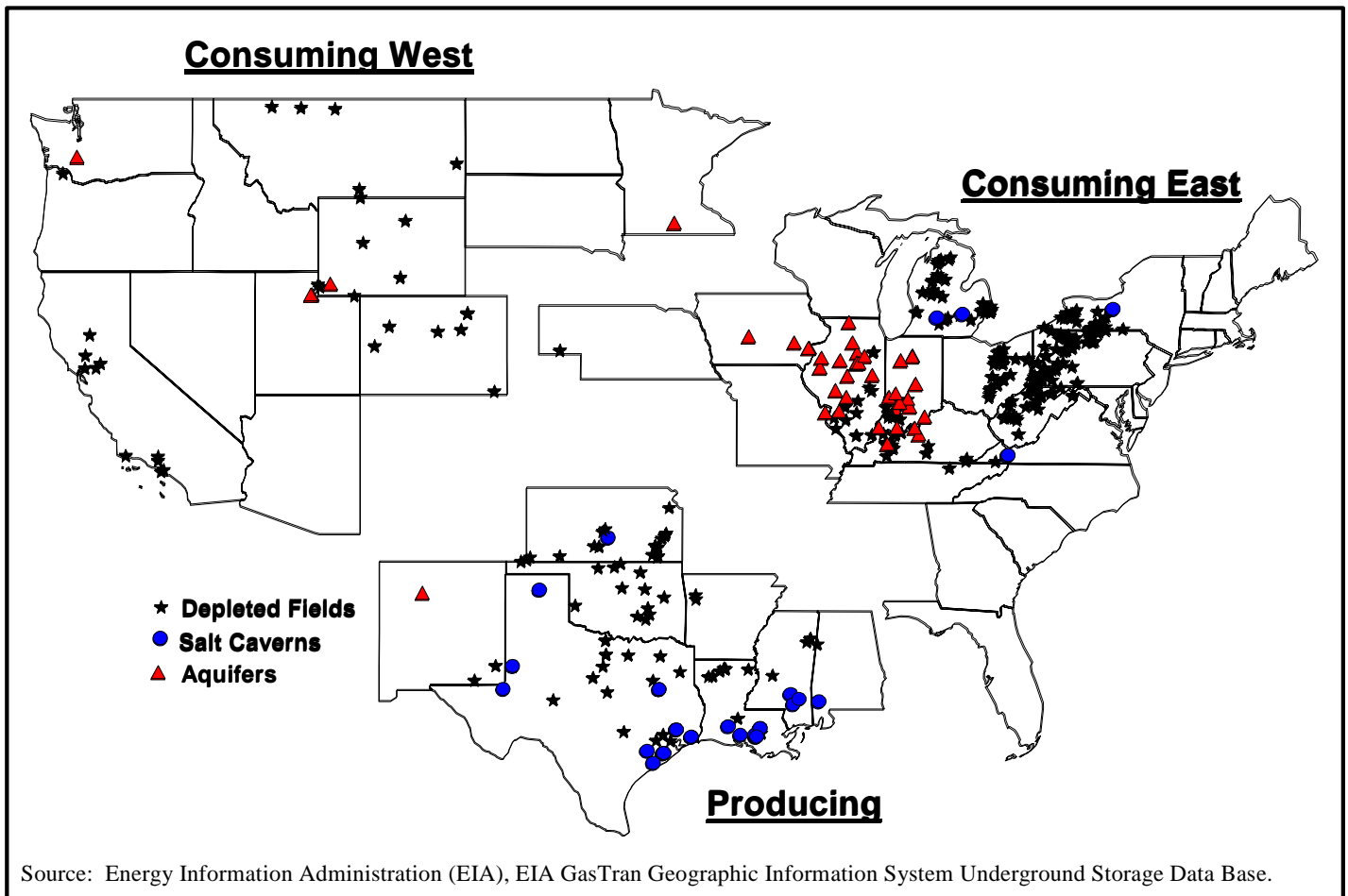
Figure 1. Types of Underground Natural Gas Storage Facilities



Source: PB-KBB, Inc.

- A Salt Caverns
- B Mines
- C Aquifers
- D Depleted Reservoirs
- E Hard-rock Caverns

Figure 2. Underground Natural Gas Storage Facilities in the Lower 48 States



Owners and Operators of Storage

The principal owners/operators of underground storage facilities are (1) interstate pipeline companies, (2) intrastate pipeline companies, (3) local distribution companies (LDCs), and (4) independent storage service providers. There are about 120 entities that currently operate the nearly 400 active underground storage facilities in the lower 48 states. In turn, these operating entities are owned by, or are subsidiaries of, fewer than 80 corporate entities. If a storage facility serves interstate commerce, it is subject to the jurisdiction of the Federal Energy Regulatory Commission (FERC); otherwise, it is state-regulated.

Owners/operators of storage facilities are not necessarily the owners of the gas held in storage. Indeed, most working gas held in storage facilities is held under lease with shippers, LDCs, or end users who own the gas. On the other hand, the type of entity that owns/operates the facility will determine to some extent how that facility's storage capacity is utilized.

For example, **interstate pipeline companies** rely heavily on underground storage to facilitate load balancing and system supply management on their long-haul transmission lines. FERC regulations allow interstate pipeline companies to reserve some portion of their storage capacity for this purpose. Nonetheless, the bulk of their storage capacity is leased to other industry participants. **Intrastate pipeline companies** also use storage capacity and inventories for similar purposes, in addition to serving end-user customers.

In the past, **LDCs** have generally used underground storage exclusively to serve customer needs directly. However, some LDCs have both recognized and been able to pursue the opportunities for additional revenues available with the deregulation of underground storage (see **“Open Access” to Storage Capacity**, below). These LDCs, which tend to be the ones with large distribution systems and a number of storage facilities, have been able to manage their facilities such that they can lease a portion of their storage capacity to third parties (often marketers) while still fully meeting their obligations to serve core customers. (Of course, these arrangements are subject to approval by the LDCs’ respective state-level regulators.)

The deregulation of underground storage has combined with other factors such as the growth in the number of gas-fired electricity generating plants to place a premium on high-deliverability storage facilities. Many salt formation and other high-deliverability sites, both existing and under development, have been initiated by **independent storage service providers**, often smaller, more nimble and focused companies started by entrepreneurs who recognized the potential profitability for these specialized facilities. They are utilized almost exclusively to serve third-party customers who can most benefit from the characteristics of these facilities, such as marketers and electricity generators.

Storage Measures

There are several volumetric measures used to quantify the fundamental characteristics of an underground storage facility and the gas contained within it. For some of these measures, it is important to distinguish between the characteristic of a facility such as its *capacity*, and the characteristic of the gas within the facility such as the actual *inventory level*. These measures are as follows:

Total gas storage capacity is the maximum volume of gas that can be stored in an underground storage facility in accordance with its design, which comprises the physical characteristics of the reservoir, installed equipment, and operating procedures particular to the site.

Total gas in storage is the volume of storage in the underground facility at a particular time.

Base gas (or **cushion gas**) is the volume of gas intended as permanent inventory in a storage reservoir to maintain adequate pressure and deliverability rates throughout the withdrawal season.

Working gas capacity refers to total gas storage capacity minus base gas.

Working gas is the volume of gas in the reservoir above the level of base gas. Working gas is available to the marketplace.

Deliverability is most often expressed as a measure of the amount of gas that can be delivered (withdrawn) from a storage facility on a daily basis. Also referred to as the deliverability rate, withdrawal rate, or withdrawal capacity, deliverability is usually expressed in terms of millions of cubic feet per day (MMcf/day). Occasionally, deliverability is expressed in terms of equivalent heat content of the gas withdrawn from the facility, most often in dekatherms per day (a therm is 100,000 Btu, which is roughly equivalent to 100 cubic feet of natural gas; a dekatherm is the equivalent of about one thousand cubic feet (Mcf)). The deliverability of a given storage facility is variable, and depends on factors such as the amount of gas in the reservoir at any particular time, the pressure within the reservoir, compression capability available to the reservoir, the configuration and capabilities of

