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Helium Storage in Cliffside Field

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Abstract

Since Jan., 1963, the U.S. Bureau of Mines has been injecting crude helium into the Bush Dome structure of Cliffside field for storage in connection with the government's helium conservation program. It is predicted that during the life of the injection program about 59 Bcf of crude helium, containing 41.5 Bcf of helium, will be injected. As of July 1, 1966, 15.3 Bcf of crude helium, containing 10.7 Bcf of conservation helium, was in storage.

Introduction

The Cliffside field is located about 15 miles northwest of Amarillo, Tex. Bush Dome, the storage reservoir, is the largest of four or five secondary domes in Cliffside field and was discovered in 1924. The dome was originally developed to supply helium-bearing natural gas for processing at the Amarillo helium plant. Production is from the Brown dolomite formation at about 3,300 ft.

Prior to the injection of crude helium, pure helium had been injected and recovered from underground storage. The success of that project and additional studies confirmed that the reservoir was suitable for storage. Field wells were recompleted in 1961, and the field was converted from production to a simultaneous production-helium injection operation. Wellheads were installed underground to reduce the possibility of damage, and a control system was installed so that each well could be controlled without approaching the wellhead.

History of Conservation

Helium occurs as a constituent of natural gas in most, if not all, natural gas fields in the United States. However, fields containing helium in high enough percentages to make helium extraction economically feasible are limited. As gas produced from these fields was consumed as fuel, the helium contained in the gas was wasted at a rate of 6 Bcf/year. This loss of helium through the flues of gas consumers, coupled with a great increase in helium demand during the 1950's, prompted the Bureau of Mines to consider some method of conserving helium. It was estimated that without conservation the helium available from known sources would be depleted in about 30 years.

Congress recognized that helium was a valuable, irreplaceable resource and that an adequate future supply should be assured, and in 1960 passed legislation enabling the Secretary of the U.S. Dept. of Interior to enter into long-term contracts for the purchase of helium for conservation. Contracts to run 22 years, obligating $47.5 million a year for the purchase of helium, were made with four companies. The private companies constructed five conservation helium plants in Texas and Kansas. Helium produced by the conservation plants is in crude form, which is essentially a helium-nitrogen mixture with small amounts of methane and hydrogen. The helium content of crude helium ranges from 50 to 80 percent and averages about 70 percent.

The crude helium is transported through a government-owned high-pressure pipeline for injection and storage in the Bush Dome structure of Cliffside field.

Geology

Cliffside field is an irregularly shaped high situated on the south side of the buried Amarillo Mountain structure and on the north edge of the Palo Duro basin. Seismic data indicate the presence of four or possibly five secondary domes in the Cliffside field. The largest of these structures is Bush Dome which has a vertical closure of about 550 ft and an areal extent of about 11,000 acres. The dome has a steep dip to the north and northwest and a gentle dip to the south and southeast.

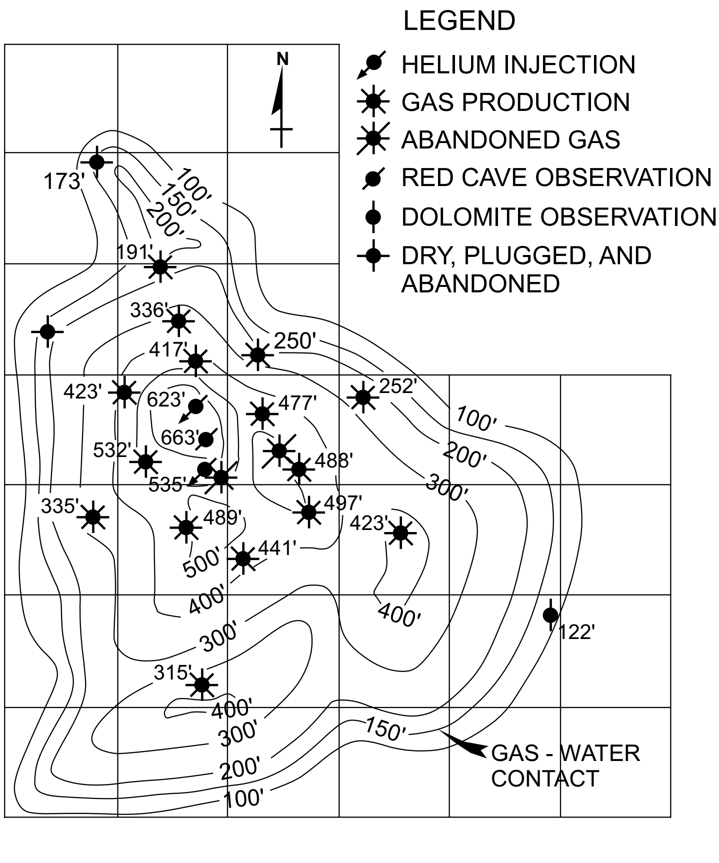
The main gas-producing horizon and also the formation in which crude helium is being stored on Bush Dome is in the Permian-Wichita-Albany-Wolfcamp beds known locally as the Brown dolomite. The Brown dolomite, found at a depth of 3,300 ft, consists largely of dolomite but also contains anhydrite, shale and sandstone stringers. Anhydrite and shale stringers are evident in every well, but individual stringers cannot be correlated between wells. The dolomite is heterogenous and varies in thickness from 250 to 300 ft. Brown dolomite porosity obtained from core analysis ranges from 4 to 20 percent with a weighted average of about 11 percent. Permeability is about 10 md. Immediately above the storage formation is the Panhandle lime formation. This is the caprock of the helium storage reservoir. The caprock consists largely of impermeable anhydrite and averages about 400 ft in thickness throughout Bush Dome. The top of the Panhandle lime is easily recognizable from well logs and is usually used as a marker for contour mapping. The top of the productive Brown dolomite formation is difficult to determine without core analysis, but the structure has been found to resemble closely the Panhandle lime. The Bush Dome structure contoured on top of the Panhandle lime is shown in Fig. 1.

The first porous formation above the storage reservoir is the Red Cave formation which is about 400 ft thick and consists largely of shale with interbedded stringers of fine-grained sand or siltstone. This formation has substantial gas reserves in the Panhandle field and is also productive in Cliffside field, both on Bush Dome and Tuck-Trigg Dome, which is located about 8 miles northeast of Bush Dome.

Field Development History

Gas was originally discovered in Bush Dome by the Producers & Refiners Corp.'s Bivins Well A-1 in June, 1924. Between 1924 and 1929, three additional wells were drilled and completed on the structure. In 1929 the government began negotiations to acquire rights in Cliffside field, and at the same time constructed the Amarillo helium plant which is located about 3 miles west of the city. The government acquired gas rights under approximately 50,000 acres in the Cliffside area. Natural gas produced from Bush Dome has been processed at the Amarillo plant for helium extraction since April, 1929.

To date, 23 wells have been drilled on Bush Dome. Two wells on the crest of the structure are used for helium injection, three are used for observation and the remaining wells, with the exception of four which were plugged and abandoned, are completed as gas producers in the Brown dolomite formation. One observation well is located midway between the two injection wells and is completed in the Red Cave formation. Pressure and helium content data are obtained from this Red Cave observation well periodically to determine if there are any changes that might be caused by vertical migration of crude helium from the storage reservoir. The other two wells being used for observation at the present time were drilled to define the productive limits of the storage reservoir. One of these encountered water in the Brown dolomite formation on the southeastern edge of the dome and was completed as a pressure observation well. The other well encountered subcommercial quantities of gas on the northern edge of the structure and is used to monitor pressure and gas composition.



CONTOURS ON TOP OF PANHANDLE LIME
SEA LEVEL DATUM

Fig. 1 -- Bush Dome structure, Cliffside field, Potter County, Tex.

Pure Helium Storage Operations

The feasibility of helium storage in Bush Dome was demonstrated from 1945 through 1959 with a pure helium injection operation. In Jan., 1945, a 2-in. high-pressure pipeline was constructed connecting the government's Amarillo and Exell helium plants with Cliffside field. Pure helium produced in excess of market requirements was injected in Bush Dome at intervals between 1945 and 1953. During this period, 87 MMcf of pure helium was injected. From Oct., 1953, to Sept., 1959, over 80 percent of the injected helium was withdrawn from storage. Reservoir performance and gas analysis data obtained during the withdrawal period indicated that the ultimate recovery would have been near 100 percent if withdrawal had continued.

Preparations for Storage

In the summer of 1961, a work-over program was initiated to put all producing wells in good mechanical condition. Two wells that had been abandoned because of mechanical problems in 1935 and 1941 were replugged. All wells in the field, with one exception, were initially completed in open hole. The original completion method had been to drill to the top of the producing formation, set casing and then drill to total depth. To eliminate any questions about the condition of the original completions, it was decided to case the wells to bottom and to recomplete through selected perforations.

Each well was killed with mud, and logs were run in the open-hole section. The logs were necessary because none had been obtained during the original completions. After logging, new casing was run to bottom and cemented. Enough cement was used to place about 500 ft in the annulus between the original and new casing strings. After the wells were cemented and cement tops had been located by temperature surveys, an average of 170 ft of selective perforations was made in each well.

Care was taken to insure that leakage from the storage reservoir would not occur through the wellbores. Each joint of new casing was given a combination magnetic particle and internal optical inspection. Casing collars were modified and equipped with Teflon seal rings to prevent helium leakage through the casing joints; 2-in. tubing was run into each well and a new wellhead was installed. The wellheads are located underground in concrete cellars to reduce the possibility of wellhead damage. The wellheads have a working pressure of 2,000 psi and are assembled so that production or injection can be accomplished through either tubing or casing. The wellheads are equipped with rams that can be closed against the 2-in. tubing. A safety valve is installed in each flow line and injection line near each wellhead. These safety valves are set to close at predetermined maximum and minimum pressures and offer automatic protection against helium loss in the event of a pipeline break or failure. Remote wellhead operating controls and 2-in. kill lines extend from the wellhead to a concrete “kill-box” located about 60 ft from the well. The tubing master valve and casing rams can be operated from the kill-box, and in the event that it should be necessary the well can be controlled without approaching the wellhead.

In conjunction with the workover program, two former producing wells on the crest of Bush Dome were deepened and converted to injection wells. An injection system enabling the crude helium to be filtered and measured prior to storage was designed and installed. The crude helium enters the Cliffside storage facility through an 8-in. high-pressure pipeline. The gas is filtered through one of two dry-type filters designed to remove 99 percent of the foreign material in the gas stream 3 microns or larger in size. The filters reduce the possibility of plugging the sand face in the injection wells by removing dust and other foreign particles before the gas passes through the metering facilities and into underground storage. The filters are installed in parallel with only one being used at any one time. As foreign material builds up on the filter cartridges of the operating filter, the pressure differential across the filter increases. When this differential pressure exceeds a preset amount, the crude helium flow is automatically switched to both filters. The operating filter is then isolated manually and filter cartridges are changed.

After the crude helium has been filtered to remove foreign particles, it passes through the Cliffside measurement facilities. These facilities consist of two 8-in. main-line meter runs and two 4-in. and one 6-in. meter runs for individual measurement to injection wells. The runs are bidirectional for measuring either injection or withdrawal volumes and are equipped with standard orifice fittings. The meter runs were designed and installed in accordance with AGA Gas Measurement Committee Report 3. Flow computation procedure also follows AGA general procedures.

Production-Injection History

All natural gas produced from Bush Dome is processed at the Amarillo helium plant for the extraction of helium and then sold for fuel. Because gas production from Bush Dome has been for helium extraction, the production rate from the field has been governed almost entirely by helium demand. Fig. 2 shows the production and injection history for the field. During the period between 1929 and 1939, demand for helium was small and, consequently, only small volumes of gas were produced. The same is true for the period between 1945 and 1950. However, during the World War II, and again during the Korean conflict, helium demand increased, requiring more natural gas for processing. From the time of field discovery in 1924 until crude helium injection was begun in Jan., 1963, a total of 53 Bcf of gas had been produced from Bush Dome. The reservoir pressure declined during the period from 817 to 684 psia (Fig.3).

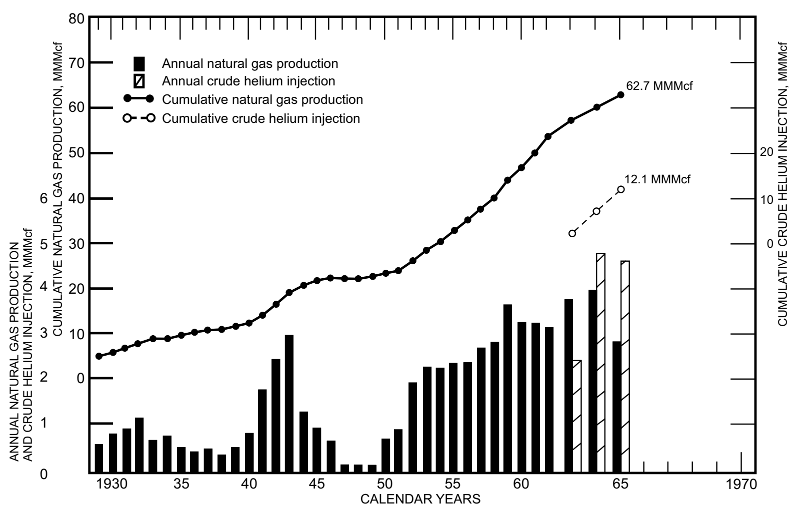


Fig. 2 -- Natural gas production and crude helium injection, Cliffside field

During 1963, 2.2 Bcf of crude helium was injected for storage and about 3.7 Bcf of natural gas was produced. By 1964, all five private industry plants were in operation and since then the rate of crude helium injection has exceeded the rate of natural gas production. The net result has been an increase in reservoir pressure from a low of 672 psia in Feb., 1964, to 700 psia as of July 1, 1966. Cumulative natural gas production as of July 1, 1966, was 64.2 Bcf. At that time, 15.3 Bcf of crude helium containing 10.7 Bcf of conservation helium was in storage.

Bush Dome, although discovered in 1924, was only about 18 percent depleted when crude helium injection was begun on Jan. 5, 1963. To make sufficient space in the reservoir to store the volume of crude helium anticipated, additional natural gas must be produced. This means that while crude helium is being injected for storage, simultaneous production of natural gas must occur.

It was recognized that during the program of simultaneous injection and production, some, if not all of the presently producing wells, would be invaded by injected helium. Prior to crude helium injection, a gas sampling program was conducted to determine an average gas analysis for each producing well in the field. This average gas composition is used as a basis to determine when the producing well has been invaded by injected crude helium, and after invasion has occurred, to determine the volume of conservation helium produced. Continuous gas samplers are installed on producing wells where invasion has occurred or is predicted. Composite gas samples are collected daily and analyzed for helium content in the field using a special helium analysis apparatus. Spot samples from the remaining producing wells are collected and analyzed twice a week.

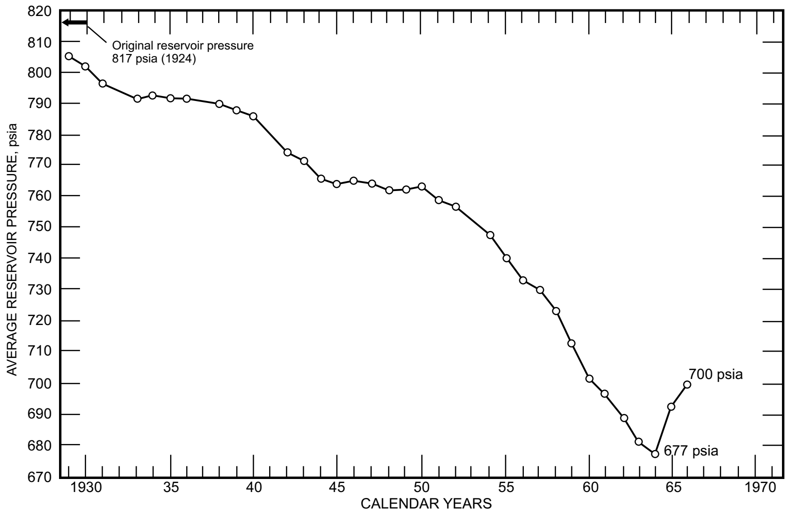


Fig. 3 -- Reservoir pressure performance, Cliffside field.

Five producing wells have thus far been invaded by stored helium. The first well is located about 2,000 ft from the nearest injection well. Invasion was first indicated in Nov., 1963, when the helium content began to increase from the established average of 1.87 percent. This was 11 months after injection had begun and 2.5 Bcf of crude helium had been injected. A second well located about 4,000 ft from the nearest injection well was invaded in June, 1964, when 5.3 Bcf of crude helium was in storage. The third well to be invaded is located 2,800 ft from the nearest injection well. Breakthrough occurred in Oct., 1965, after 11.1 Bcf of crude helium had been injected. The last two wells were invaded early in 1966.

The helium content of the invaded wells has continued to increase, but at a relatively low rate. After producing for about 20 months until Aug., 1965, the helium content of the gas in the first well to be invaded was up to only 4.5 percent. The well was shut in for a 9-month period for pressure interference tests and was not produced again until June, 1966. When the well was placed on production, the helium content had risen to almost 9.5 percent. During this same time interval, the helium content of the second well to be invaded continued to increase, and now exceeds 14 percent. The helium content of the other invaded wells now varies from 2.2 to 3.4 percent.

Future Operations

Other production wells will be invaded by conservation helium as the injection program continues. As this occurs, replacement wells for the production of native gas will be drilled nearer the reservoir productive limits. The invaded wells will be used for pressure and helium content observation to monitor helium movement. Eventually, the wells may be used for helium injection and later, at the end of the injection period, for the withdrawal of conservation helium.

As a safety precaution against potential helium leakage through the caprock, the original reservoir pressure of 817 psia will not be exceeded. Native gas production will be controlled during the crude helium injection period to allow storage reservoir pressure to build up to a value approaching, but not exceeding, original discovery pressure.

It is estimated that during the life of the present helium conservation contracts, 62.5 Bcf of helium will be purchased. Approximately 21 Bcf is expected to be sold to meet a part of the market demand for refined helium during the period. This will leave an estimated 41.5 Bcf of pure helium, contained in about 59 Bcf of crude helium mixture, to be stored underground in Cliffside field for future use. At the end of the injection period, or before that time if helium is needed, crude helium will be withdrawn, purified and sold to meet market demands.

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