Salt Cavern Storage of LPG at Lowell, Michigan, and Hutchinson, Kansas

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ABSTRACT

The development of liquified petroleum gas storage in salt was a major breakthrough for the LPG industry because steel storage is so expensive.

Cities Service drilled its first storage well at Lowell, Michigan in 1951. The cavern is located in the lower zone of the Salina salt section at a depth of 3798-4021 feet.

A 1 inch string of tubing is hung inside the 4 1/2 inch tubing to a depth of 1800 feet. Fresh water is pumped down the 1 inch to dilute the brine and keep the salt from dropping out and choking off the tubing.

Variable stroke, positive displacement pumps were installed for injecting the product at 1250 p.s.i. and varying flow rates.

A pressure switch in conjunction with a motor operated valve was installed to shut in wells automatically when they fill.

Four storage wells were drilled in the Wellington salt to a depth of 600-800 feet at our Hutchinson, Kansas terminal in 1953. Originally brine was disposed of by pumping to a salt company. A 4700 foot Arbuckle Lime disposal well now handles the brine.

An in-line probe detects propane-butane interfaces in the pipeline and automatically switches to the proper wells.

Although operating at much lower pressures, a shut-in device identical to the one at Lowell has proved satisfactory.

INTRODUCTION

Shortly after World War II when liquified petroleum gas began to come into its own as a major fuel, Cities Service found itself in the same position as all of the other major suppliers of LPG. The market was expanding rapidly and production was growing to meet it. However, due to the nature of the producing plants, production continued at a fairly even rate the year round while the really heavy demand was only during the winter months for heating purposes. Therefore, there was always a large surplus in the summertime and a peak winter demand period could bring on serious supply problems. This meant that the summer production had to be sold at distressed prices or flared. By the same token, we could not increase our sales as much as we would like during the winter months due to lack of product.

There was no economic justification for storing summer product in aboveground steel pressure storage which cost from \$20 to \$25 per barrel, and a search for inexpensive storage was constantly underway. The development of storage costing only \$1 to \$2 per barrel in salt formations was therefore a major breakthrough for the LPG industry. This relatively inexpensive storage would allow producers to store the excess summer product and sell it in the winter at quite an advantage over the summer distressed or flare prices. It also made available sufficient product for winter sale which in turn held the winter sale prices at a lower level. Since the winter is the period of highest consumer usage, this meant that a share of the advantage of salt storage was passed on to the consumer.

When this new type of storage became available, we started studies to find areas in which we felt it would be most advantageous. The areas which appeared most attractive at that time were Michigan and Kansas. They were attractive not only because of the salt beds but also because of the local market possibilities and their location for use as intransit storage for rail shipments.

In 1951 a site was chosen in Michigan which was underlain by a salt bed, had railroad and highway facilities, a plentiful fresh water supply and a good formation for disposal of brine, all of which are prerequisites for such a storage facility. The location was at Lowell, Michigan, about 20 miles east of Grand Rapids. The second site was chosen two years later and was located three miles southwest of Hutchinson, Kansas.

LOWELL, MICHIGAN

In April of 1951, drilling of the first storage well started at Lowell. In the attempt to find the best salt in which to wash the cavern, we cored and found the first section of the Salina Salt zone at a depth between 3430 feet and 3630 feet. This section contained so many heavy shale and dolomite layers that we drilled deeper to see if we could find something more desirable. The top of the second section was hit at a depth of 3798 feet. The cores through this section showed ti to be relatively clean with only a few shale and dolomite streaks of any consequence. Seven inch casing was cemented at 3791 feet and 3 1/2 inch O. D. tubing was hung at a depth of 4021 feet.

Washing of the well was started in June of 1951 and proceeded until the capacity was 3,000,000 gallons. The first year of operation showed us that many improvements were needed. For example, we found that when we were injecting propane into the well, the tubing would choke off with salt. The injection operation would have to be stopped and fresh water pumped down the tubing to remove the salt. We believed that the cool propane going down the annulus was cooling the warm, completely saturated brine from the cavern and causing the salt to drop out. To solve this problem, we hung a string of 1 inch tubing inside the 3 1/2 inch tubing to a depth of 1800 feet. When injecting product, we pump fresh water down the 1 inch tubing. This water dilutes the brine below the critical depth and stops the dropout of the salt. This method has been very effective and all of the wells at Lowell are equipped with the 1 inch string of tubing.

During this first year all product was brought in by tank car and shipped out by tank car and truck. It remained this type of operation until 1957 when a large expansion program was approved. The program called for the expansion of the Lowell underground storage facility to work in conjunction with an expanded marketing program in the Chicago and South Bend areas. To bring additional product to Lowell, a pipeline gathering system for light ends was built in Southern Oklahoma. This mixed stream of natural gasolene, propane and butane is moved to Cushing, Oklahoma, and injected into a crude oil line running from Cushing to our East Chicago Refinery. A crude stabilization unit at the refinery removes the propane and butane from the crude.

The propane is pumped into a six inch pipeline which was built between East Chicago, South Bend and on to our underground storage at Lowell. Sales terminals were built on this line at Gary and South Bend, Indiana. This pipeline was designed to flow in either direction. During summer months the production from the refinery goes into the pipeline with Gary and South Bend removing their requirements and the excess going on to Lowell storage. In the winter when East Chicago production is not sufficient to serve Gary and South Bend, the flow in the line is reversed and product is moved back from Lowell to supplement these terminals with additional volume.

Bringing product into Lowell at a higher flow rate made it necessary to replace the 3 1/2 inch tubing in the wells with 4 1/2 inch tubing so that the injection pressure would remain at a reasonable level. The pressure required to inject the product into the storage wells after this change is 1250 psi. The product received from the pipeline obviously has to be boosted to meet the injection pressure. The variation in flow rate on the pipeline required flexibility in pumping capacity. Positive displacement pumps with a variable stroke were installed to satisfy both the high pressure and variable flow rate conditions. The pumps receive the product directly from the pipeline with no surge tankage. The length of stroke on the pumps is controlled by a suction pressure controller. As the flow rate into Lowell increases, the suction pressure rises and the length of stroke is automatically increased, thereby pumping the additional volume into the storage wells.

When going back to the pipeline, the 1250 psi of wellhead pressure should be sufficient to move the product through the dehydrators and into the pipeline at the desired flow rate of 320 GPM. However, until this winter we were having to displace the product with fresh water. The column of fresh water in the tubing reduced the static annular pressure to 850 pounds. To be able to hold 900 to 1000 psi on the pipeline in addition to overcoming the friction loss through the well, it was necessary to pump the displacement water into the tubing. When a well was nearly empty, we discontinued the pumping and let the water enter the well by gravity.

Fresh water for use at this plant is taken from the Grand River. Brine displaced by product is pumped into two disposal wells completed in the Marshall sand. After several years of displacing product with fresh water, the storage caverns were getting large enough that we felt we should stop the enlargement caused by using fresh water. Last summer we drilled a fifth well which is to be used only for the production of brine to displace the product. When brine is required, we simply wash this well and use the resulting brine for displacing product. We estimate that this brine has reduced the cavern enlargement rate from 25% per year to 4% per year since we go in and out of the wells more than one time a year. In addition to reducing the enlargement rate of the caverns, this brine gives us a second advantage. Although we still pump the brine into the tubing for displacement, the column of brine instead of fresh water in the tubing makes it easier to maintain a high wellhead pressure when going back to the pipeline.

We now have four storage wells at this plant with a total capacity of 25, 000, 000 gallons. This is quite an increase from the one well and 3, 000, 000 gallons of capacity which we originally had in 1951.

Handling this larger volume required some changes in the method of operation. With only one storage well and receiving only by tank car, operators could watch the well very closely. When it filled they could detect the product as it started out of the well into the brine tank and close the valve on the well. With the increased workload due to the expansion, this system was no longer safe. To keep product from blowing into the brine tank and spreading over the area, an automatic device was needed to close in the well when it filled. To achieve this, we placed a pressure detection switch on the brine line. The pressure on this line is normally about 10 psi. When the propane starts up the tubing, the velocity in the brine line increases and the pressure will start to rise. The pressure switch detects this rise and signals a motor operated valve in the brine line to close. It also stops the injection pumps, the pump being used to put fresh water into the well for diluting the brine, and sounds an alarm. The operator then closes in the well at the wellhead, bleeds the pressure off of the brine line, resets the pressure switch and starts injecting into another well. The system was relatively inexpensive and has proven quite reliable.

Another device was added to the plant to take care of an "abnormal" trait the Lowell storage wells have. When a "normal" well empties, the brine in the cavern starts up the annular space behind the product. The higher it rises in the annulus, the more it balances the column of water in the tubing, resulting in a lower wellhead pressure. When the wellhead pressure reaches the pressure of the vessel into which the product is flowing, the flow stops automatically and no brine flows into the product line. However, when the wells at Lowell empty, water will come out with the product and into the dehydrators when wellhead pressure is still as high as 1000 psi. We could find no logical explanation for this and we tried amny different approaches to stop the water from coming out with the product at high pressure. When none of these were successful, we placed a probe on the product line. This probe is set to detect any "free" water in the product. When "free" water is detected, a motor operated valve on the product line closes to keep the water from entering the dehydrators. This device did not solve the problem of brine coming out with the product, but it does keep the brine out of the dehydrators and above-ground storage tanks.

HUTCHINSON, KANSAS

Our second underground storage facility was started in 1953 at Hutchinson, Kansas. Four storage wells were drilled and washed to 2,000,000 gallons each as a part of the original plant development. The top of the Wellington salt section is found at a depth of 600 feet. The 9 5/8 inch casing was therefore cemented at this point, the 7 inch casing used to keep a "cap" on the roof during the washing was hung 10 feet below this, and the 3 1/2 inch O. D. tubing was hung at 800 feet.

Fresh water supply for the terminal is taken from a fresh water formation at a depth of 70 feet. While the solution to the fresh water problem was simple, the brine disposal problem was a little tougher. We knew that we could drill a disposal well into the Arbuckle limestone formation at a depth of 4700 feet. This was quite expensive for such a small operation and our closeness to a major salt producer seemed to provide an alternative. We therefore worked out an arrangement with the salt company to lay a pipeline to their plant and pump our brine to them. During the winter we would reverse the line and obtain brine from the salt company for use in displacing product. This arrangement was satisfactory until our plant expanded to the point where we had so much brine to dispose of and required so much brine for displacement that this service was becoming a major operation for the salt company.

In 1958 we drilled a disposal well into the Arbuckle Lime. The well is rated at 350 GPM and takes brine under a vacuum. To keep air from entering the well, and air locking it, we equipped the brine tank with level controllers which operate a valve in the line going to the disposal well. The low level controller which closes the valve is located two-thirds of the way up on the tank. The line going to the disposal well is always under several feet of brine and no air can enter the well.

This facility, like the one at Lowell, Michigan, operated the first several years as strictly a tank car and truck terminal. By 1956, we had a total of ten storage wells with a capacity of 25,000,000 gallons. The brine from the washing of the additional wells had been used to displace product.

In 1956 we laid a 4 inch pipeline from our Blackwell, Oklahoma, and Wichita, Kansas, gasolene plants to our Hutchinson storage. The line was originally designed to pump propane at a 5000 BPD rate to Hutchinson. It was then decided to store butane at Hutchinson and additions were made to the pumping equipment to handle butane through the line. As production at both Blackwell and Wichita increased, it was necessary to increase the capacity of the pipeline. Two booster stations were added to increase the capacity to 7500 BPD. During the season when crude oil refineries have a high demand for butane, it is desirable to have the butane back at Wichita to inject into a crude oil pipeline. The 4 inch line was therefore made reversible from Hutchinson back to Wichita. At times of peak winter demand, propane has also been shipped back to Wichita for sale there. The above was outlined simply to show how the value of underground storage can be enhanced by the addition of a pipeline connecting it with other plant facilities.

When both butane and propane started moving through the pipeline, it was necessary to find some method of detecting the interface between the two products so that they could be switched to the proper storage wells. This detection was first done by manually sampling the product moving through the line. A gravitometer with a recorder to show what product was in the line was then added. Even with this instrument, it was still necessary for the operator to watch the chart to know when to make the switch. The final solution lay in the installation of an in-line probe. The probe was placed approximately 200 feet upstream of the point where the switching valves are located and motor operators were placed on these valves. When the probe detects an interface, it automatically opens one valve and closes the other, lights flash and a horn blows to notify the operator that an interface has arrived.

The filling of wells with the consequent flow of product into the brine tank was a problem at Hutchinson the same as it had been at Lowell. On one occasion a butane well filled, butane came out of the brine tank and was ignited. We investigated several different methods of shutting in the wells when they filled. We finally decided on a pressure switch and motor operated valve arrangement identical to the setup at Lowell. The relatively low well head injection pressure of

275 psi was the only reason we hesitated to use this system. To date, it has worked quite satisfactorily on both propane and butane wells.

We now have 14 storage wells at this terminal with a total capacity of 43,000,000 gallons. Its location and pipeline connections give this plant a great potential for growth. If this growth takes place as we hope it will, several changes in plant equipment must be made in addition to drilling and washing more storage wells. Some of the changes we are studying are: (1) Installing a large lined brine pond. (2) Installing equipment to pump displacement brine to the storage wells. (3) Connecting the storage wells in groups to provide more flexibility. (4) Drilling wells for the production of brine. (5) Installing a motor operator on the wellhead brine valve of each storage well so that the wells can be controlled remotely.

Several features and problems of our storage which I thought might be different from other installations have been outlined. While all of the ones mentioned involved surface facilities, this doesn't mean that we have not had problems such as roof caving, sheared tubing, and product losses, all of which occur in the caverns. The reason that these have not been discussed is because each cavern is an individual case with its own peculiarities and no general solution is available. When trouble occurs in a cavern, we analyze that particular cavern as thoroughly as we can and perform what work we feel is necessary to put it back in shape for storage. Sometimes the analysis points out an obvious solution while on some occasions we must "feel" our way to a solution.

The problems we have encountered in salt cavern storage of LPG are many and varied. However, the great advantages of such storage so far overshadow any and all of the difficulties involved in its use, our only regret is that a greater portion of the United States is not underlain with salt deposits.