Storage of High Pressure Natural Gas in Underground Salt or Rock Caverns

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Storage of natural gas under high pressures in salt caverns, or other rock caverns, becomes an interesting possibility and should be given serious study by many gas distributing companies. Various companies have stored liquid petroleums in brine caverns, but only recently has natural gas been stored successfully under high pressure.

Morton Salt Company, Hutchinson, Kansas, reports that they have at present approximately eleven million cubic feet of gas stored at a depth of five hundred feet and a pressure of four hundred feet and a pressure of four hundred P. S. I. G.

At the mouth of the river Tees, in England, gas is now being stored in a salt cavity that holds ten million cubic feet at thirty atmospheres. This is artificial gas. The cavern is approximately twelve hundred ninety feet deep and is now free of brine so that the gas can be compressed into the cavern and withdrawn at will.

At present, 8 to 10 feet diameter wells can be bored and mining equipment can be lowered to a depth where shale, or suitable formations can be mined. With proper engineering and design, high pressure holders can be made to store natural gas adjacent to or under the cities to be serviced.

The economics and advantages derived from such high pressure, underground gas holders could be great but must necessarily vary with each Utility.

Such a high pressure natural gas holder has been made available by the use of a brine well at Marysville, Michigan. In its search for storage facilities, the Southeastern Michigan Gas Company at Port Huron, Michigan, has spent considerable time and money on making an installation to test the theory and determine the cost and feasibility of using a salt cavern. With the aid of many records obtained from exploratory oil and gas well tests, and the help of some of the salt companies, the area surrounding Port Huron was carefully studied before the test was made.

Subsurface geological data indicated that an abandoned salt well, known as Morton number sixteen, was worthy of the test. This well was located within one hundred feet of the high pressure gas line delivering gas to the north end of Port Huron. Records showed the well to have been drilled in 1949 and the cavity developed between that year and 1958. Fourteen inch drive pipe had been landed at one hundred forty three feet and ten inch casing run at six hundred sixty-five feet. Eight and five-eighths twenty eight pound casing was set at two thousand twenty three feet and three hundred fifty sacks of cement used, but the cement did not return in circulation. A later electric log showed that a porous strata between depths of eight hundred eighty five and twelve hundred ninety had absorbed some of the cement and that no cement was present on the outside of the eight inch pipe above six hundred fifty feet to the surface. The eight and five-eighths hole was completed at a depth of twenty three hundred fifty feet. Six and five-eighths casing was suspended with four inch tubing inside of it. The cavity was washed out by pumping fresh water down through twenty two hundred eighty one feet of six and five-eighths inch and reclaiming the brine from the four inch to a depth of twenty three hundred and five feet.

Our first problem was to determine the condition of the eight and five-eighths casing, cement behind the casing and the depth and size of the cavern. Tools were strung up and the well was cleaned out to a depth of twenty two hundred fifty feet.

A Sonar log was run to determine size and shape of the cavern. Caliper logs were run to measure pits scale or penetration of the eight and five-eighths. Also, Otis calipers to check out of round or possible weakness. A Gamma Density log was run to check cement behind the old eight and five-eighths pipe.

After all the logs were run and analyzed, it was decided that the old eight and five-eighths inch pipe was in good enough shape to equip the well so that it could be used. The Sonar gave us a good picture of the cavern with the expectation of a cavity volume of 4, 122, 695 cubic feet at atmosphere. It was decided to limit the pressure to 1200# per square inch so that all design was based accordingly. The cellar was deepened and constructed around the well head in order to install a proper Christmas tree. 6 5/8 OD casing was welded into the well and a formation packer was set between the 6 5/8 and 8 5/8 at the bottom of the 8 5/8. A perforated 7 inch casing was swedged under the packer and allowed to open end at 2228 feet. Cement was run behind the packer and circulated until there was a good return.

The 14, 10 and 8 inch casings were swedged onto the outside of the 6 5/8 casing in the bottom of the cellar and a 6 5/8 orbit valve was installed. A 6 5/8 single blow-out preventer was bolted above the orbit valve. 2226 feet of 2 7/8 inch upset tubing was hung on a tubing stripper bolted to a 6 5/8 x 2 1/2 inch flanged cross. The 2 7/8 inch tubing equipped with a meter was connected to the Morton Salt Company field brine line. Figure 1 shows the piping diagrams.

In operating this well, a gas pressure of 1065# gauge was used before the water commenced to flow.

The design of the compressor station was made with the idea of economy until the tightness of the cavern was proven, but provisions for future improvements were included in this design.

The 2 7/8 tubing had to be installed so that it could be raised or lowered or totally withdrawn under pressure, without loss of any gas. The blow out preventer was equipped with stainless steel 2 7/8 rams so that when closed, the gas would be shut within the annulus between I. D. of 6 5/8 and O. D. of 2 7/8. This blow out preventer was connected with hydraulic lines to a separate instrument shed 56 feet east of the well head. It was connected to a Payne accumulator and so equipped that the blow out preventer would automatically close at a pre-set pressure drop. The blow out preventer valve stem was also extended with universal joints and 2 7/8 inch welded pipe to a hand wheel which was located 100 feet east of the well head.

In designing and equipping the well head, we had to consider and provide for unusual stress and strain due to the contraction and expansion with temperature variation from below zero to 250 degrees above.

As compared to a conventional gas well measured in terms of open flow, the loss in the event of pipe failure down stream from the control valve would be no greater than the open flow capacity of the well. In this sort of well, the flow of gas would only be restricted by the friction through the space between the OD of the 2 7/8 and the ID of the 6 5/8. If the entire cavern was holding, say, 300 million cubic feet at 1100# gauge and some surface line between the well-head and the main line should fail, unless automatic fool-proof equipment took over, it would not take long to waste the contents of the holder. Another safety factor to continually watch is the design of high pressure well heads, and all high pressure equipment near the well site is anchorage and location of the piping. The original installation of Morton #16 well allowed the flow lines to extend 8 feet above the derrick floor. Later, the entire Christmas tree was located and installed below the derrick floor. Piping from the well was brought above the ground so that 25 feet from the well head, the pipe was laid on concrete pedestals 3 feet above the surface. Between that point and the main pipe line separator, compressor, regulator, drip heaters and meters were all above ground and anchored. Experience has shown that failure in equipment or piping can cause great destruction because of forces in the expansion of high pressure gas. If fire is eliminated and the gas can be valved quickly, damage can be limited to the initial blowout. Should fire occur or valves and pipe be hurtled through the air to collide and destroy other installations, the initial

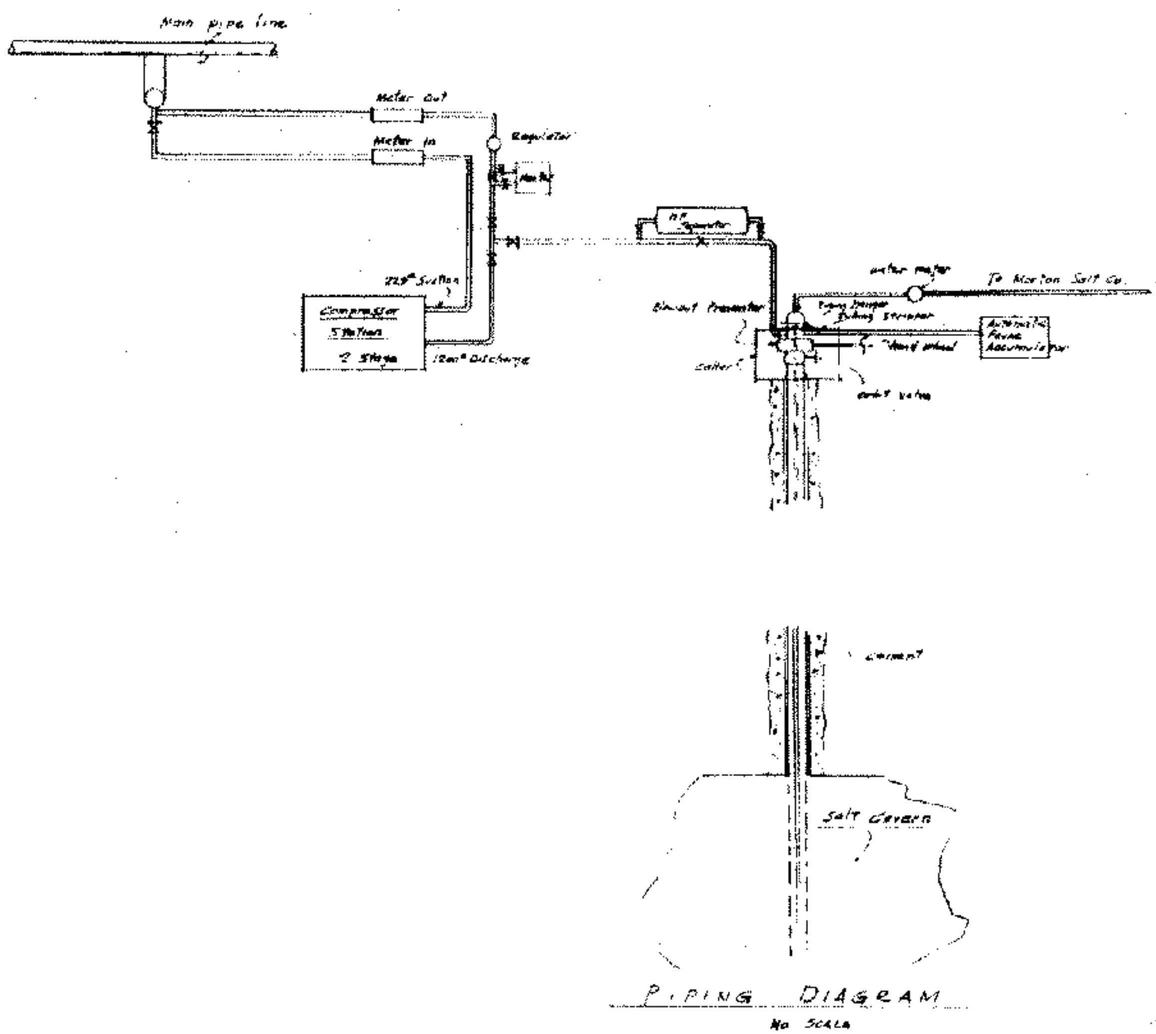

Figure 1. Salt cavern and pipe line connections.

damage can be quickly spread. Thence, the necessity of keeping the Christmas tree and well-head below grade and anchored, as well as automatically valved.

Figure 2 showing the cavern has been reproduced to scale from one of the sections taken from the Sonic log. Several sections were taken from n-s, e-w and other compass bearings and their reciprocals. When these cross sections are plotted on one drawing, very little difference in the shape is noticed, consequently we are assuming the shape is fairly symmetrical so that the largest diameter is approximately 250 feet.

The theoretical calculations on the project were all made in advance and tabulations were presented to the Company. Estimates of costs, based on oil field experience of similar work, but with no guarantee as to limit, the project for construction was approved. Because nothing of this size had been attempted before, and the uncertainties of possible leakage, only the bare necessities of a plant were constructed. After-coolers were not installed and for test purpose, 150 HP compressor was used which had a delivery of 1,400,000 cubic feet when the suction pressure was 240# and the discharge was 1200#. The design, however, provided for future expansion of compressor facilities for a more flexible and versatile usage.

It is interesting to note that after the totally inexperienced personnel were trained in operation, maintenance and safety precautions, the installation functioned smoothly and the initial calculations were confirmed by actual operation. 135 million cubic feet of gas was compressed into the cavern and a shut-in pressure test of 30 days made. During the test, a Neutron log was run, the cement again was shown to be secure, the level of the brine in the cavern checked with the calculated level based on water metered out as gas compressed in.

The management of Southeastern Gas Company is to be congratulated on the investigation and completion of the first test of this cavern.

The work of gathering all data necessary to get such a project approved by the regulatory body calls for the cooperation and understanding of directors and officials as well as salesmanship beyond the ordinary. It is most difficult to convince distributing companies, not familiar with drilling and high pressure well operation, that they can afford to spend money on experiments. This is particularly true when contracts must be let out to drillers and other contractors where a firm price cannot be given and when the results of the work are so speculative.

During the past winter this holder has been used successfully. Management of the Company feel the investment to be worth while and have expansion and improvement in compressor capacity under consideration. Calculations indicate that this cavern will hold approximately 300 million cubic feet of gas at 1200# gauge pressure. Time did not permit storing over 135 million before cold weather prohibited further storage. When the plant is improved, gas can be withdrawn during peak hours and after such demands have been met surplus gas can be immediately put back into holder.

Aside from money saved on peak shaving the holder was used to carry the entire system when the main pipe line was taken from service to be cleaned internally.

Where this type of underground holder is economically possible, distributing companies should investigate. It should not be compared to the large volume storage put into abandoned gas formations. These salt or rock caverns, when feasible, can vary in capacity up to 600 million cubic feet. The high pressure feature gives immediate availability of the gas and when these holders are located in the distribution system, they also reinforce the pressures and increase the capacity of the mains in the area.

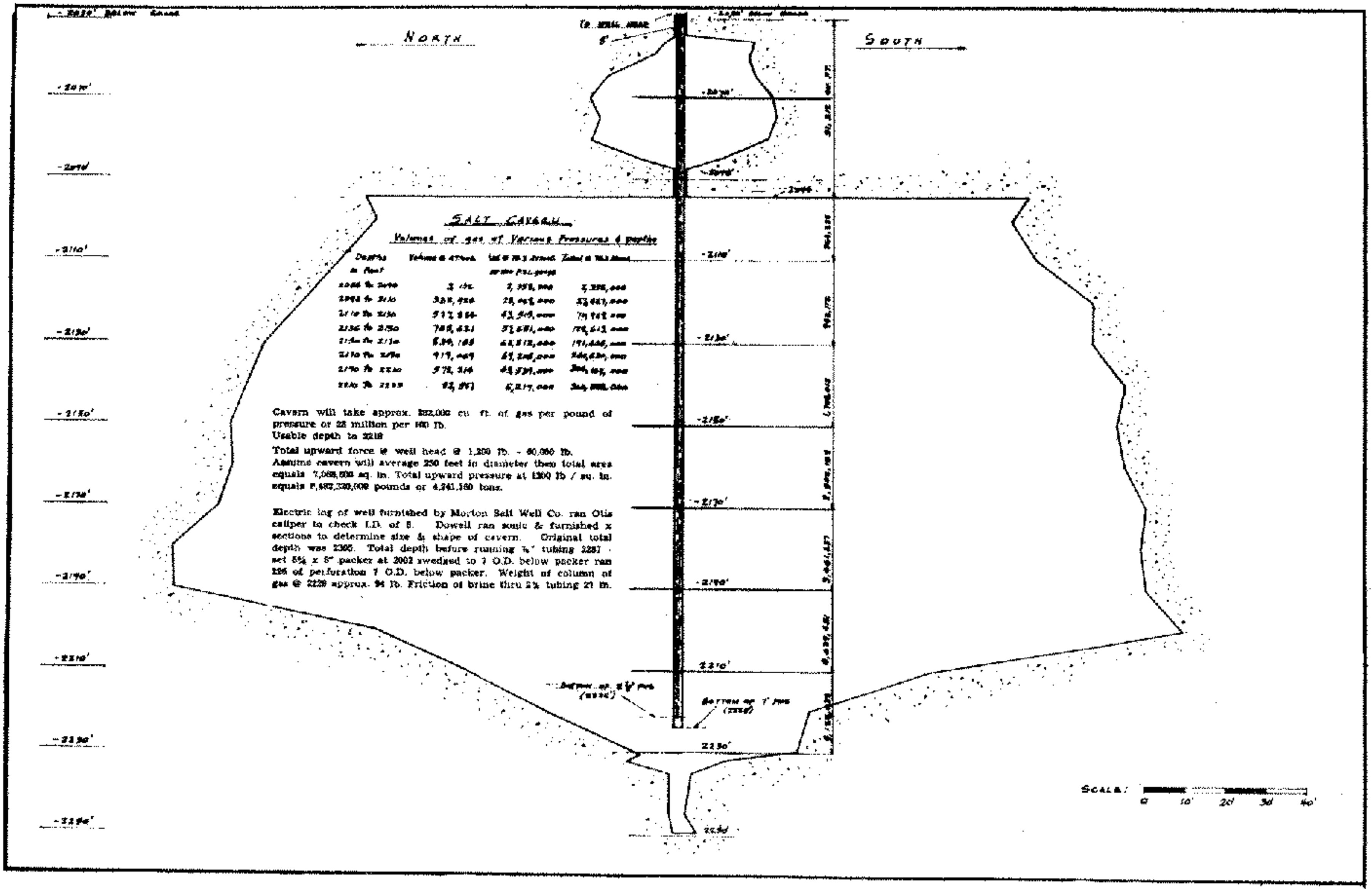

Figure 2. Cross section of salt cavern brine well #16, Southeastern Michigan Gas Company, Port Huron, Michigan.