# Use of Hydraulic Fracturing to Make a Horizontal Storage Cavity in Salt

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ABSTRACT

*In order to optimize LPG delivery at the Medford, Oklahoma, plant, consideration was given to various storage methods. This location is on the edge of the Permian salt basin where there is a limited salt thickness. A solution cavity was proposed where the volume was developed essentially in the horizontal direction. Two wells were drilled approximately 400 feet apart and a fracture developed between them. The cavity was dissolved by circulating water between the wells until the volume reached 150,000 bbl. The paper discusses the geological situation and considerations, the fracturing technique, and the solution process.*

## INTRODUCTION

The Medford LPG plant is located approximately one mile south of Medford, Grant County, Oklahoma. Liquefied petroleum gas and natural gasoline are removed from a gas stream, and essentially dry gas is returned to the gas pipeline. Since the gas supply is continuous, there is need for a large storage capacity for the LPG gas as it accumulates during the summer season. Figure 1 shows the location of the plant with reference to Oklahoma and Grant County. Study of the geological section showed that the location is underlain by the Wellington salt and represents the northeastern edge of the Permian salt deposits which are found in considerable thickness in New Mexico and Texas and in mineable thickness in Western and Central Kansas. The salt strata, with reference to the above area, is also shown in Fig. 1. Since it is well established that salt cavity storage made by solution extraction is an inexpensive storage, consideration was given to making a cavity storage in the relatively thin beds.

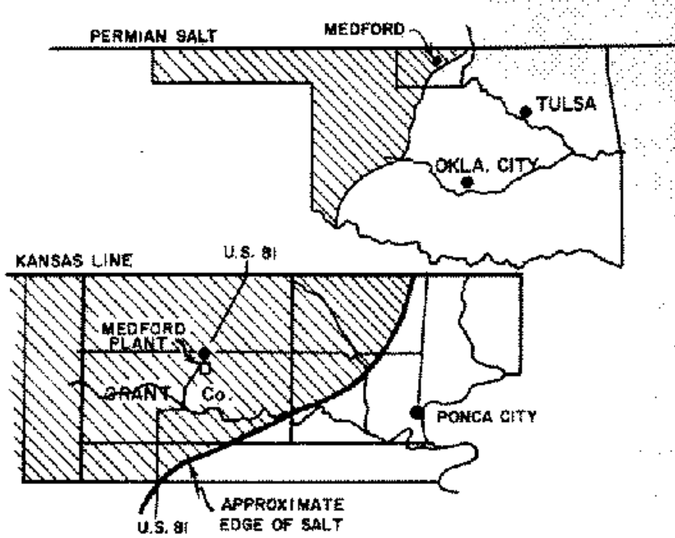


Figure 1. Location of IG & GP plant.

### Geology of Salt

The salt section in Grant County described by Jordan (1) is known to be about 700 to 900 feet in depth in this area. Anhydrite and shale layers are interbedded in some places, quite as thick as the salt beds. Wells were drilled, logged, and cored to ascertain the exact nature of these salt layers. Figure 2 shows a compilation of the core data on the well which was later used for fracturing and solution.

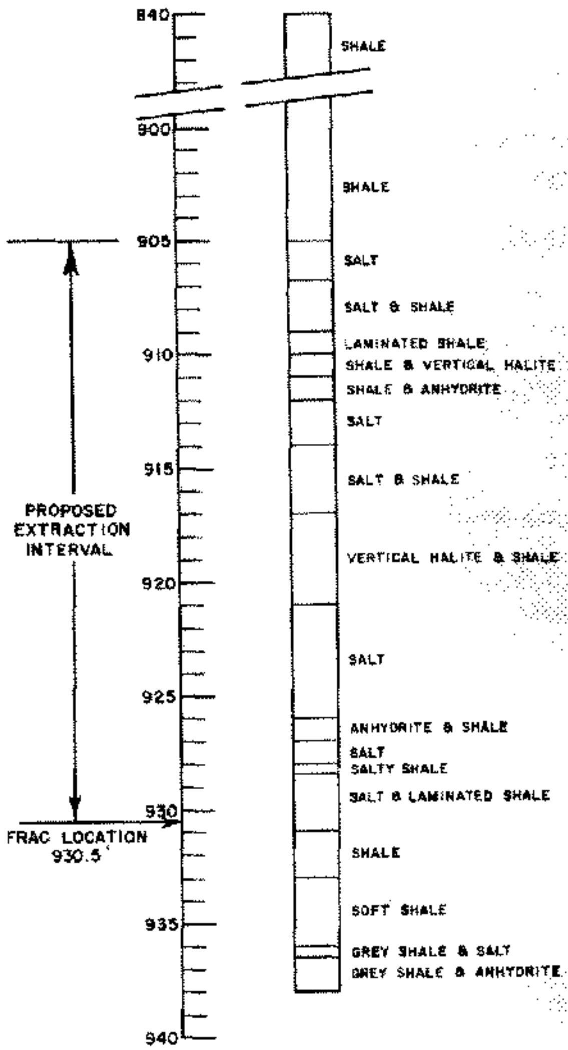


Figure 2. Core description.

Figure 3 shows a typical salt anhydrite, shale interface. Figure 4 shows an occurrence in the shale which was of some concern in that a vertical fissure of salt runs through the core. This vertical salt fissure in the clay was explained by the hypothesis that these fissures were salt-filled mud cracks. The mud flats probably occurred at the edge of the salt basin and filled with salt water in the periodic changes of lake level. A vertical fissure was of concern, as it would have diverted the horizontal propagation of the fracture. Care was taken to avoid these vertical crack areas. Examination of the cores showed that a 30-foot section of salt was available between 900 and 930 feet, which had a maximum of salt present. The 930.5-foot point was taken as the optimum spot to initiate a fracture and perform the solution extraction.

## Well Completion and Layout

The proposed program carried out was to drill three wells, two for the cavern development and one to a deeper horizon for disposal of the saturated water. Circulation piping system and salt injection equipment were installed. The surface installation is shown in Fig. 5. The two cavern wells were 420 feet apart. The frac truck area was designated between the wells where temporary lines could be conveniently placed in the temporary pits. The two temporary reservoirs were provided nearby for fracturing and circulation fluids. One pit of approximately 2,000-bbl. capacity was filled with salt water, the other filled with 6,000 bbl. of fresh water. Fresh-water intake for make-up, the circulation pump for washing, and the injection pump for the disposal well were housed in a permanent structure below the storage pits. The piping was so arranged that circulation control could be maintained immediately after completion of the racture job. Pipes were manifolded so that circulation could be made in either direction. Pernanent storage tanks were filled with reserve water. These tanks were to be used later as saltvater storage prior to salt-water injection.

The salt water resulting from the washing was injected from the storage cavity into a disposal well. The disposal well was drilled into the Layton Sandstone, bottomed at 4,287 feet with 1/2-inch casing set at 4,181 feet. Injection tests showed the well would take fluid at 200 gpm at surface pressure of 380-400 psi, to 400 gpm at 450-500 psi. Operative procedure was to inject at he 200-gpm rate. No difficulties were encountered for the disposal of the brine.

The cavern wells were drilled through the salt section of interest to approximately 940 feet. The well to be fractured into, was open-hole completed on the salt, cased to surface, with 7-inch casing. Tubing was hung into the well, and it was completed with a standard Christmas Tree for low through casing or tubing. The fracture well was drilled, and a packer set from 932 to 928 on he mid-point of the lowermost salt layer as discussed before. The fracture work was done hrough 4 1/2-inch drill pipe with the rig standing over the hole.

## Fracturing Procedure

The fracture was initiated by perforating the 930.5-foot point with an eight-way jet shot. This was run on a wire line through the drill pipe. Three Dowell Allison pumpers injected brine

Figure 3. Core photo.

Figure 4. Shale photo.

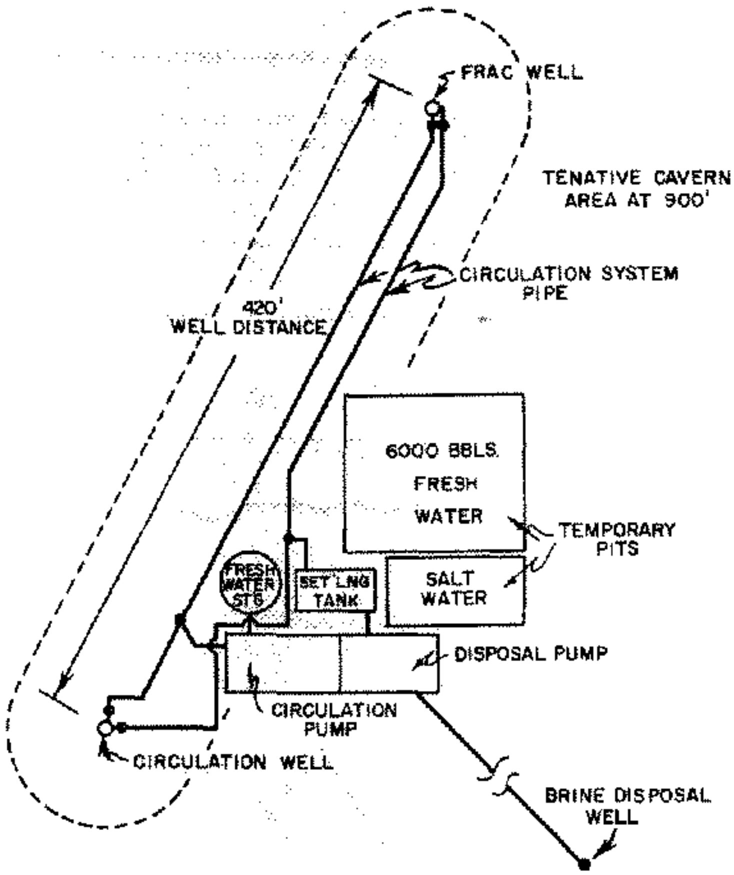


Figure 6. Layout.

into the well at 29 bpm with a surface injection pressure of 2, 620 psi. A definite breakdown pressure was not obtained due to a slight leak in the packer during the first ten minutes. The 2, 000 bbl. of salt water were pumped away and 350 bbl. of fresh water, when breakthrough was achieved in the second well in about 1 1/2 hours. Fresh water was injected at the rate of 4 bpm and after 3 1/2 hours, the injection pressure dropped significantly. The circulation was then reversed, injecting into the second well at a 4-bpm rate for ten minutes, and the injection pressure decreased markedly from 850 psi to 350. This rate was maintained for some 30 minutes, and the auxiliary pump truck was disconnected and released. The washing procedure was then taken over by a centrifugal pump rated at 220 gpm.

## Cavern Washing

The cavern was developed by circulating fresh water through the fracture. This dissolved the lowermost salt layer until the overlying shale layer failed, collapsed, and then exposed the next upper salt layer. This procedure was repeated until the amount of water circulated and the average specific gravity of the brine indicated that the size of the cavern had reached the storage capacity required.

Two things aided in the destruction of the interbedded shale layers. One was a natural tendency of the shale to become brittle and crumbly when exposed to fresh water, and the other was the removal of support beneath the shale section by solution of the salt. This procedure worked out very well with the exception that the tubing which removed the brine became plugged with small chunks of shale at several intervals. In most cases, the plug was removed by reversing the wells and pumping down the plugged tubing. In those cases, it was necessary to move on the well with a sand pump, or pull tubing to remove the obstruction.

Initial washing began at a 50-gpm rate. Fresh water was injected into the No. 1 well and withdrawn from No. 2 and delivered to three skid-mounted metal settling tanks from which the brine was injected into the salt-water disposal wells. The tanks had adequate level controls to maintain constant injection rates and relatively unattended operations. Washing operations began November 25, 1961, and were completed June 14, 1962, at which time 150,000 barrels of cavern storage space had been created. There was little deviation from the schedule except in the last stages of development. This was due to the fresh-water source coming from the City of Medford's fresh-water supply, and they had to reduce deliveries as the city's summer water requirements increased in May and June.

Figure 6 shows the graphic representation of the cavern growth, injection rate, and specific gravity of the effluent brine.

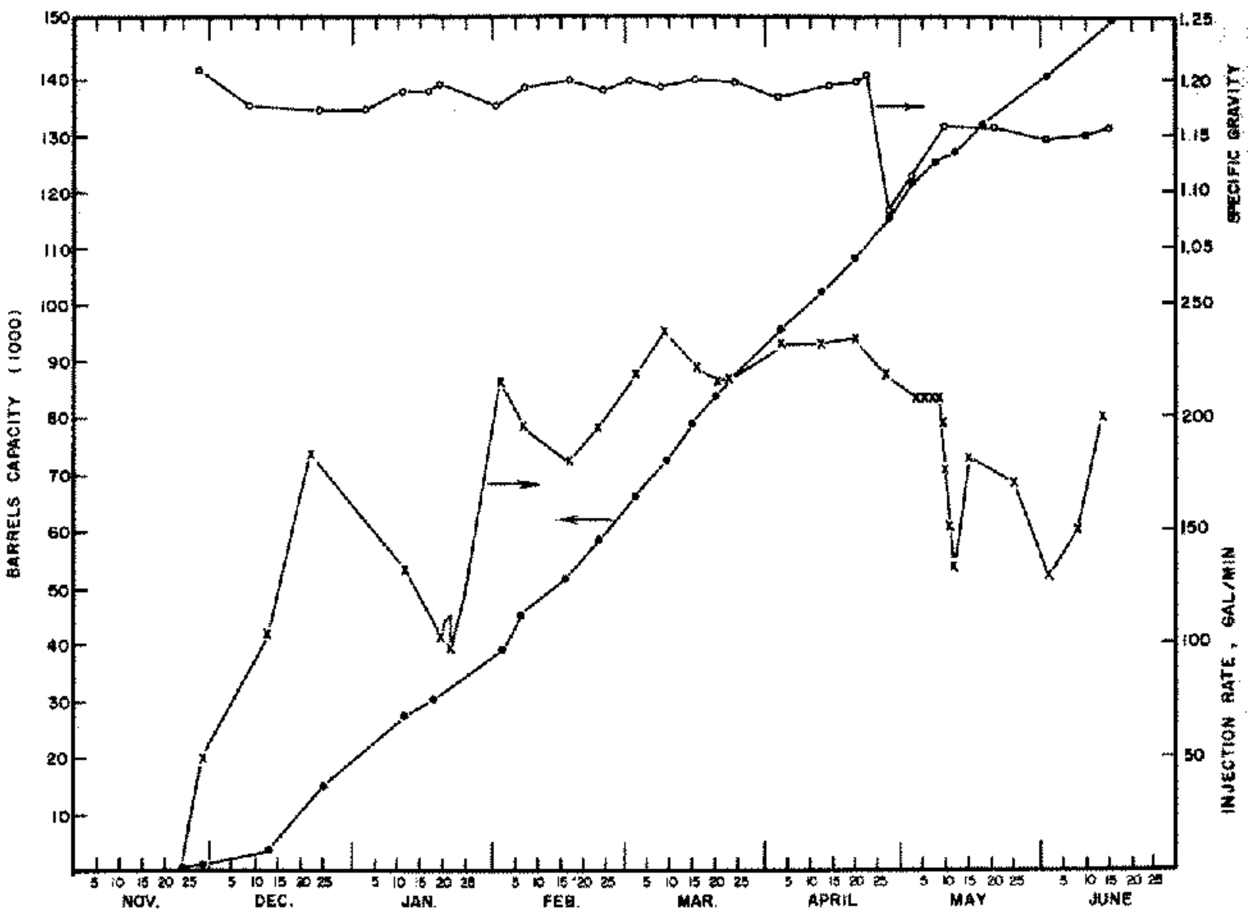


Figure 6. Solution data.

## CONCLUSION

The general operation was carried out without any unusual difficulties and within the schedule set for the completions. It was felt that the project demonstrated that the hydraulic fracturing technique adds another possibility to the location of storage cavities in a bedded salt strata.

## CREDIT

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# BIBLIOGRAPHY

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