TESTIMONY
BEFORE THE KANSAS SENATE UTILITIES COMMITTEE
TOPEKA, KANSAS

By

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Good morning. I wish to thank you for the opportunity to provide this testimony.

My name is Joe Ratigan. I am a consulting Geologic Engineer, Senior Vice President, and Principal Consultant for Sofregaz US, a storage cavern engineering and construction firm in Houston, Texas. I hold bachelor and master degrees in mechanical engineering and a Ph.D. in geologic engineering. I am a Registered Professional Engineer in Texas and South Dakota. I provide consulting services to the underground solution-mining and hydrocarbon storage industry. The services include geomechanical studies and facility permitting.

I am also the Research Coordinator for the Solution Mining Research Institute, a professional organization of solution-mining and underground storage owners, service companies, and researchers. Additionally, I serve on a rules committee for the Louisiana Department of Natural Resources Injection & Mining Division, the organization responsible for developing revised salt cavern storage rules.

I am appearing today on behalf of the city of Hutchinson. I began providing consulting services to the city of Hutchinson on January 19, 2001.

My testimony today addresses the current Kansas Department of Health and Environment (KDHE) rules for underground storage and whether these rules need revision. In my testimony, I wish to describe the technology of storing liquid and gaseous hydrocarbons in solution-mined salt caverns, the state regulation of such technology, and the Kansas regulations and how they compare to those in other states.

This testimony is not intended to be a comprehensive review of the Kansas regulations nor is it a comprehensive review of the regulations of other states. It is, rather, a detailed introduction to the issues that need to be addressed as a result of the incidents in Hutchinson. It is my belief that Kansas needs to revise their rules for underground storage of hydrocarbons. I believe my testimony will convince the committee to adopt that same position.

My testimony today consists of a brief description of (1) North American salt formations, (2) salt as a construction material, (3) solution-mined caverns for hydrocarbon storage, and (4) the history of regulation and regulations in other states. I then conclude the testimony with a discussion of Kansas regulations.

NORTH AMERICAN SALT FORMATIONS

Salt formations are distributed throughout North America, as shown in Figure 1. There are two basic types of salt formations – salt domes and bedded salt.

Salt domes are very large bodies of salt (up to several miles in diameter and many miles “tall”) consisting of nearly pure sodium chloride (usually >95 percent). Hundreds of salt domes in the United States are located along the Gulf Coast in the states of Alabama, Mississippi, Louisiana, and Texas. All of the salt domes in the Gulf Coast developed from a very deep (>30,000 feet) bedded salt called the Louann salt.

Bedded salt formations differ significantly from salt domes. Bedded salt formations consist of “layers” of salt interbedded with nonsalt rocks, such as shale, dolomite, and/or anhydrite. Bedded salt formations can vary considerably from one another. Additionally, a bedded salt formation within a specific basin can vary from one part of the basin to the other. For example, the Hutchinson bedded salt unit is only 40 to 50 percent salt in Oklahoma; whereas, in central Kansas, the Hutchinson salt unit can be as much as 80 percent sodium chloride. The principal “impurity” or nonsalt rock in the Hutchinson salt formation is shale. These impurities exist in small percentages within the salt beds, but primarily exist as distinct geologic units separating beds or layers of salt within the salt formation.

The only salt formations usable for storage caverns in Alabama, Mississippi, and Louisiana are salt domes. Texas is the only state that has both bedded salt and salt domes (at usable depths). The only salt formations in Kansas, Oklahoma, Ohio, Michigan, New York, and Pennsylvania are bedded salt formations.

SALT AS A CAVERN CONSTRUCTION MATERIAL

Salt is an excellent construction material for hydrocarbon storage caverns. It is easily, economically, and predictably mined (through solution mining) and is essentially impermeable at moderate pressures. The nonsalt interbeds that exist in bedded salts are, however, not impermeable and must be given consideration when developing storage caverns in bedded salt formations.

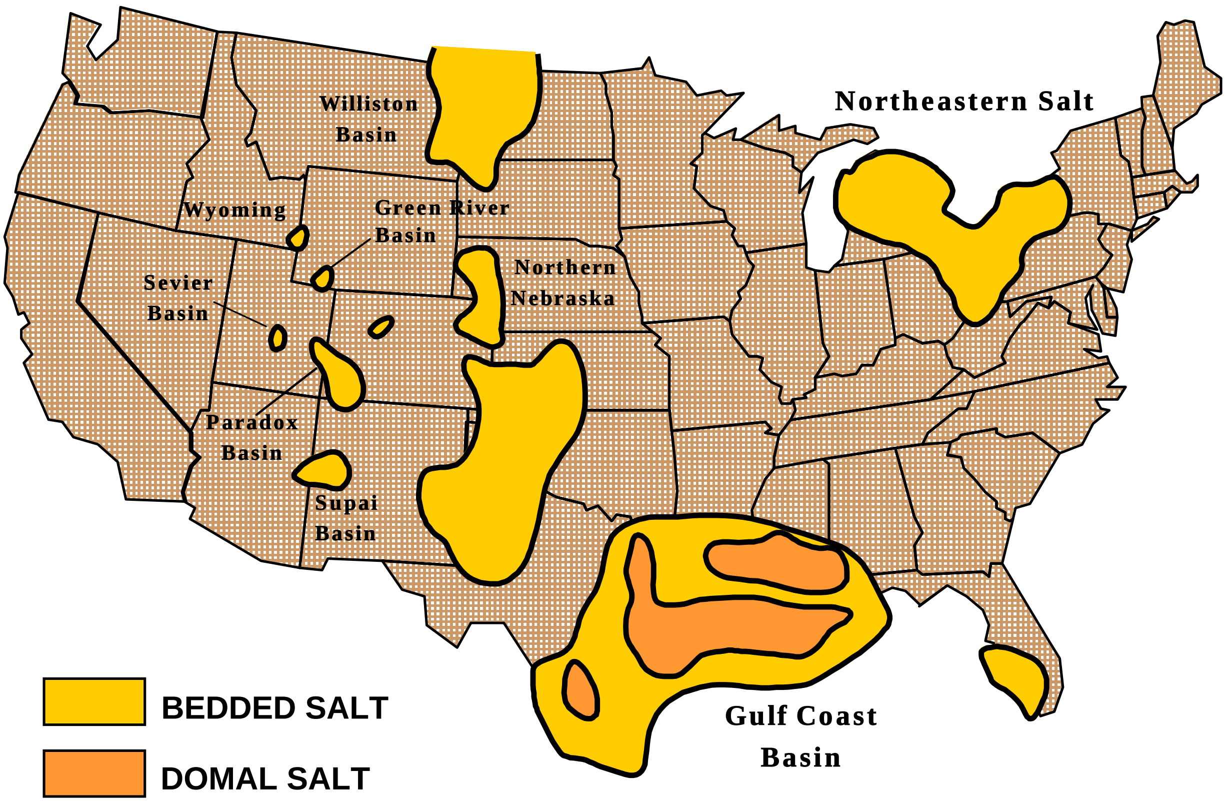

Figure 1. Salt Formations in North America.

Like any other construction material, properties and in situ conditions[1] must be determined for the salt and nonsalt rocks in which a storage cavern is to be developed. These properties and conditions must be used in concert with the operating conditions of the intended storage cavern to ensure a successful storage project. For example, the fracture gradient[2] in the nonsalt units of the Hutchinson salt unit must be determined to establish a safe maximum gas storage pressure for a gas storage cavern developed in the Hutchinson unit.

SOLUTION-MINED CAVERNS FOR HYDROCARBON STORAGE

Salt has been mined by "solution-mining" since the late 1800s. The Hutchinson area was one of the first areas in the United States where solution mining of salt was practiced. In the late 1940s and early 1950s, the oil and gas industry realized that the cavities created during salt solution mining could be used to store natural gas liquids (NGLs) or liquefied petroleum gases (LPGs)[3]. The NGLs/LPGs could be injected into the solution-mined caverns and brine would be displaced as the NGLs/LPGs were injected. Similarly, when the cavern owner wanted to recover the NGLs/LPGs from the cavern, he could merely inject brine back into the cavern and NGLs/LPGs would be produced at the surface. Figure 2 provides a schematic illustration of a NGL/LPG storage cavern in a bedded salt formation.

Again, Hutchinson was on the leading edge of the hydrocarbon storage technology as Cities Service Oil Company developed propane storage caverns southwest of Hutchinson in the very early 1950s. Kansas currently has more NGL/LPG salt storage caverns (more than 600) than any other state in the Union. Texas ranks second in the number of NGL/LPG salt storage caverns.

About the same time that the oil and gas industry began exploiting solution-mined caverns for storing liquid hydrocarbons in bedded salt formations, the same development was going on in the salt domes along the Gulf Coast. Today, over 500 caverns in salt domes are used for storing NGLs/LPGs.

The solution-mined caverns in Kansas are very different from the solution-mined caverns used for LPG storage in the Gulf Coast. Specifically, the Kansas caverns are much smaller and are much shallower. A typical Kansas cavern has a volume of about 100,000 barrels (4.2 million gallons) and is located at a depth of about 600 to 800 feet. A typical Gulf Coast cavern is at least 10 to 20 times larger than a Kansas cavern and is usually located at a depth of more than 1,500 or 2,000 feet. Gulf Coast salt dome caverns used to store crude oil for the United States' Strategic Petroleum Reserve (SPR) are each 100 times the volume of a single typical Kansas cavern. One single SPR cavern has more volume than all of the Yaggy caverns combined.

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[1] In situ conditions are conditions "in the ground," such as temperature and stress state.

[2] The fracture gradient for a formation is a common term in the oil and gas industry. It is the pressure (in pounds per square inch) required to "fracture" a formation at a certain depth divided by the depth (in feet).

[3] NGLs or LPGs are hydrocarbon compounds that can be stored as liquids if pressurized slightly.

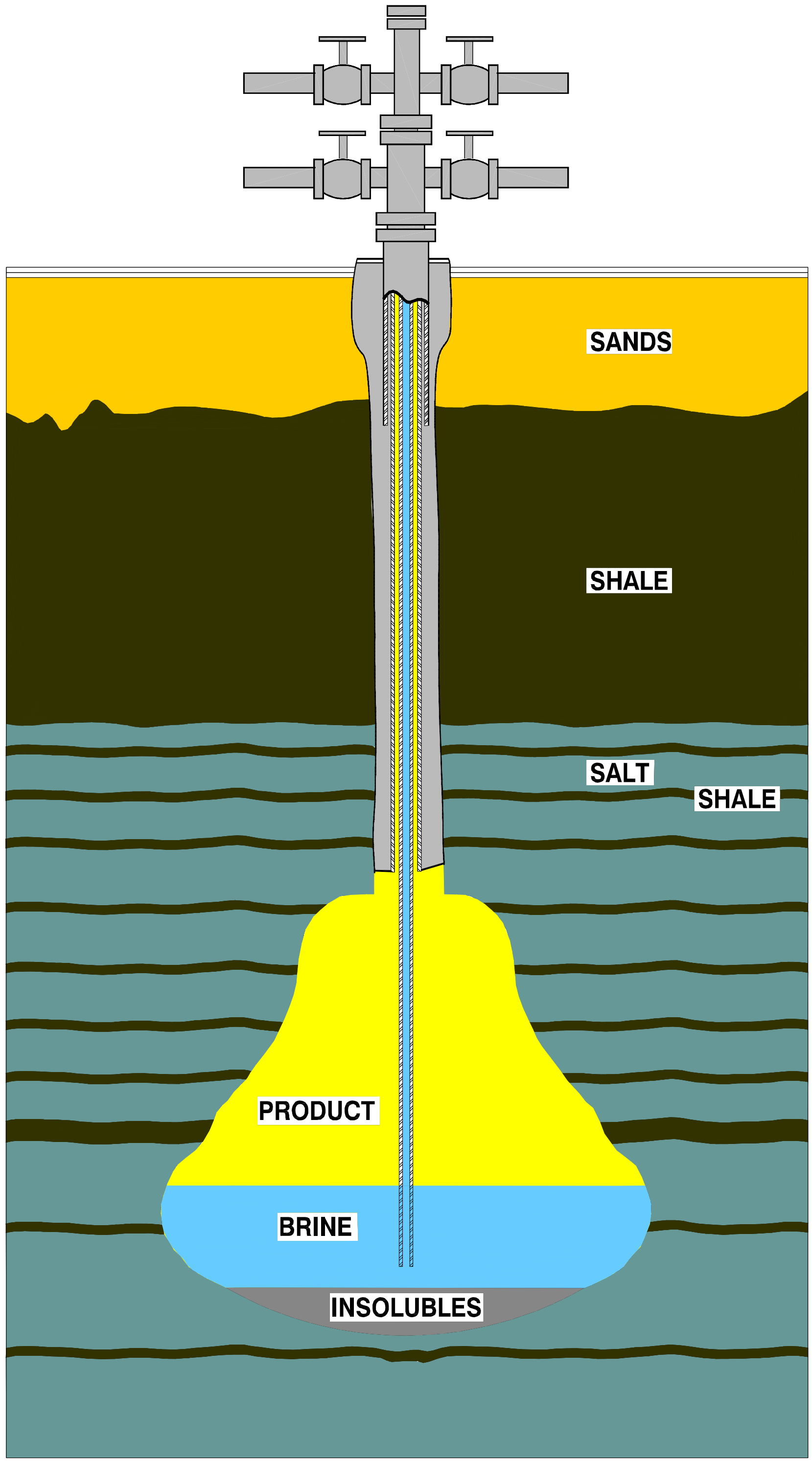

Figure 2. Schematic Illustration of a NGL/LPG Storage Cavern in a Bedded Salt Formation.

In the 1960s, the gas industry began to use solution-mined caverns in salt formations for storing compressed natural gas. Significant development of this technology for storing natural gas did not really take off until the deregulation of the natural gas industry in the early 1990s. Today, there are several hundred natural gas storage caverns in salt in the United States. Again, Kansas has more natural gas storage caverns than any other state in the Union. Gas stored in salt caverns can be delivered to the market place much faster than gas stored in depleted oil and gas reservoirs. Thus salt cavern storage is designed to respond to the peak demand market more so than to the seasonal demand market.

Natural gas is stored in solution-mined caverns in a much different way than LPG is stored (see Figure 3). In an LPG cavern, the cavern is always "full of liquids." The liquids are LPG and brine with the lighter LPG always on top of the heavier brine.

There is essentially no liquid in a natural gas storage cavern. Initially, the brine in a solution-mined cavern is removed by first installing tubing inside the casing. Gas is then injected down the annulus, forcing the brine up the tubing and out of the cavern. Thereafter, the cavern is operated "dry." The pressurized gas in the cavern is injected and removed by "free flowing" the gas through the well or by using compressors on the surface, as needed.

While the pressure in a LPG cavern is nearly always constant, the pressure in a compressed natural gas storage cavern can vary significantly. The pressure in the cavern is proportional to the amount of gas in the cavern. Some gas must always be left in the cavern "to hold up the cavern roof and walls." This amount of gas is called the "cushion gas" or the "base gas." The amount of gas that can be removed from the cavern and sold to the marketplace is called the "working gas." The sum of the *cushion gas* and the *working gas* is the total volume of gas that is injected into the cavern. The higher the maximum allowable pressure, the more gas that can be injected into a cavern. The lower the allowable minimum pressure, the less *cushion gas* in the cavern and thus, the greater the volume of *working gas*.

HISTORY OF REGULATION AND REGULATIONS IN OTHER STATES

Even though solution-mined caverns have been used for hydrocarbon storage for about 50 years, contemporary regulations are not nearly as mature. The first state regulation specifically dealing with solution-mined caverns for hydrocarbon storage was promulgated less than 25 years ago. Current rules in states with solution-mined storage caverns used for hydrocarbons are generally less than about 10 years old. Table 1 provides a list of many of the current state regulations and the dates the rule became effective.

The development of many state regulations for storing hydrocarbons in solution-mined storage caverns has generally occurred following an industrial accident at a storage facility. The current regulations in Louisiana (Statewide Order 29-M) followed a fire that occurred during the initial oil filling in a Strategic Petroleum Reserve cavern in the West Hackberry salt

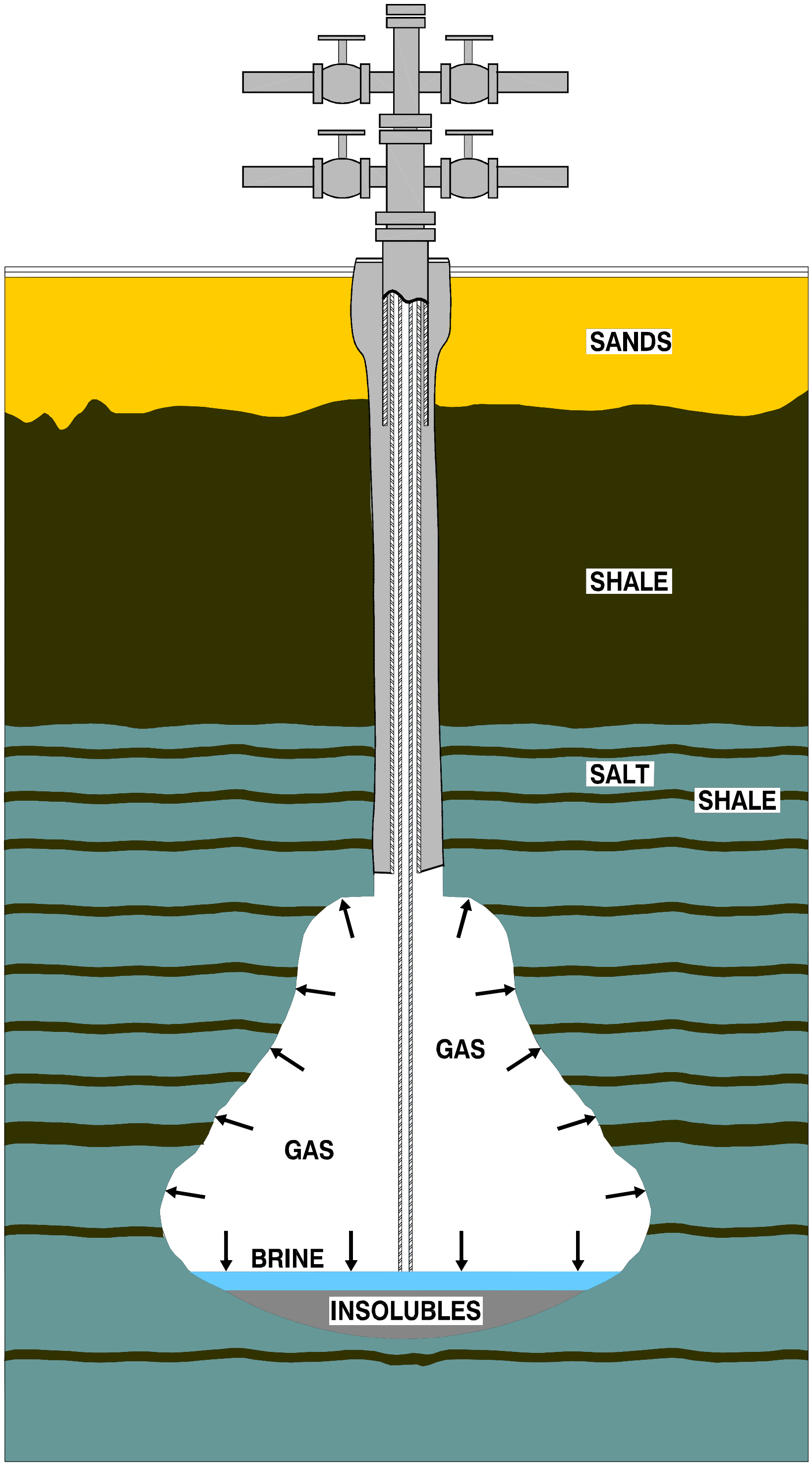

Figure 3. Schematic Illustration of a Compressed Natural Gas Storage Cavern in a Bedded Salt Formation.

dome. The current Texas Regulations (Railroad Commission Rules 95 and 97) were developed following the loss-of-product accident at the LPG storage facility in the Brenham salt dome. Development of the Kansas regulations followed the loss-of-product near Conway.

Table 1. Effective Dates for State Regulations for Hydrocarbons Storage Caverns

State	Rule	Effective Date
Alabama	Alabama State Oil and Gas Board 400-6 (Gas)	May 16, 2000
Kansas	Kansas Administrative Regulation 28-45 (Liquids and Gas (?))	1984
Louisiana	State Wide Order 29-M (Liquids and Gas)	July 20, 1977
Mississippi	Mississippi State Oil & Gas Board Rule 64 (Liquids and Gas)	February 19, 1992
New York	6 NYCRR, Part 559 (Liquids and Gas)	In Draft
Oklahoma	None	NA
Texas	Railroad Commission Rules No. 95 (Liquids) and No. 97 (Gas)	January 1, 1994

There are states that have promulgated rules that are not correlated to accidents within their state boundaries. For example, Mississippi, Alabama, and New York rule development did not follow a specific accident. The Louisiana rule is currently being revised by the Louisiana Department of Natural Resources. Oklahoma, despite having hydrocarbon storage caverns, has no rule specifically regulating this type of storage.

KANSAS REGULATIONS

The KDHE rules for underground storage wells and caverns are contained in Kansas Administrative Regulation 28-45. These rules have been around for some time, and KDHE recognized the need to revisit these rules some time ago. KDHE has been working with industry to revise the rules for several years.

It is important to recognize that these rules were promulgated at a time when there were no natural gas storage caverns in Kansas and thus, the rules can reasonably be expected to be deficient for gas storage caverns.

The significant weaknesses in the KDHE rules have been well documented in the press in recent weeks. For example, the rule does not require a Mechanical Integrity Test nor does it require any sort of casing inspection log. The rule does not address (nor perhaps contemplate) the reentry or drilling out of plugged and abandoned wells.

The Kansas rule does not address how close caverns can be to one another. This is perhaps not a major issue with liquid wells, but is important for gas storage caverns.

The Kansas rule does not require Emergency Shutdown Valves at the wellhead, which is a common requirement in other states. The Kansas rule requires minimal information to be reported to KDHE by operators compared to other states.

When discussing the Kansas rules, it is important to recognize that whereas Kansas has more liquid hydrocarbon wells and caverns and natural gas storage wells and caverns than any other state in the Union, they do not have the largest regulatory and enforcement staff or the largest budget. Clearly, that may be the biggest change required at KDHE.

It is difficult to make direct comparisons of manpower in one state versus manpower in another state merely because the areas of responsibility can be different from a state agency in one state to a seemingly similar state agency in another state. However, it is interesting to note that the Louisiana agency responsible for regulating underground storage wells employs nine professionals in Baton Rouge and regulates about 4,500 wells or about 500 wells per professional. The Texas agency responsible for regulating underground storage caverns employs two professionals in Austin who regulate about 950 wells or slightly less than 500 wells per professional. It is my understanding that KDHE employs two professionals in Topeka who are responsible for regulating more than 6,000 wells. *The number of "wells per professional" regulated in Kansas appears to be six times the number in the comparable Louisiana and Texas regulatory agencies.*

QUESTIONS

Are the Kansas regulations sufficient for regulating underground natural gas storage caverns and wells? When the current regulations were promulgated, natural gas was not stored in salt caverns in Kansas. Clearly, the Kansas regulations need revision. In that regard, the natural questions that arise are twofold:

1. What should be regulated?
2. How should the items in (1) above be regulated?

In response to the first question, at a minimum, the following should be regulated:

- Wells and wellheads
- Caverns

- Operations
- Testing and monitoring.

Wells and Wellheads

Kansas requires two casings in storage wells – one for groundwater protection and one casing at least 105 feet into the salt formation (50 feet in “existing” wells). Many states require one casing for groundwater protection and two casings in the salt, but these are states with caverns developed in salt domes. Salt domes are typically overlain with a “caprock” which is very porous and saturated with sodium chloride brine, which can be very corrosive. The same corrosive environment may or may not exist above or at the top of bedded salt formations. Texas, which has both bedded and domal formations, does not require two casings set into the salt for caverns developed in bedded salt formations.

Some states require pressure testing of the casing during the construction of the well (after cementing). Kansas does not. Some states require cathodic protection for some wells. Kansas does not require cathodic protection.

Questions that KDHE will need to address include:

1. Will Kansas require two cemented casings (or one casing and a protected annulus) into the salt in the future for wells?
2. Will storage wells in Kansas require cathodic protection?
3. Is corrosion a significant problem in well casings in storage wells in Kansas?
4. Will Kansas require pressure testing of cemented casings during construction of new wells in the future?
5. Will KDHE require Emergency Shutdown Valves?

Caverns

In many states, the location of the cavern (within the salt formation) is restricted and the size of the cavern must be periodically checked. In Kansas, performing a “gamma log” in the well periodically checks the “size” of the cavern. The gamma log is able to establish the location of the cavern roof and thus, the location of the cavern within the salt formation. Texas has rules similar to those in Kansas for monitoring the location of the cavern roof in bedded salt caverns. In Kansas, periodic sonar surveys are generally only required in caverns that have reached a volume of 120,000 petroleum barrels. There are, however, other situations for which KDHE may require a sonar survey.

Many other states regulate the distance between caverns (the “web thickness”). Kansas does not (except for brine production wells). It is not necessarily as important to regulate the distance between liquid storage caverns. However, since the pressure difference between adjacent natural gas storage caverns can be significant, the distance between caverns can be important.

Questions that KDHE will need to address include:

1. Has consideration been given to requiring a “minimum” web thickness between caverns?
2. Has consideration been given to requiring a “minimum” gas storage pressure? What does KDHE believe is important in establishing a minimum gas storage pressure?

Operations

All states have some level of regulation of cavern operations. Perhaps the most significant operational characteristic that is regulated is the maximum pressure allowed in a storage cavern. The maximum pressure in a storage cavern is stated as a pressure (in pounds per square inch) divided by a depth (in feet) at the depth of the casing shoe. The casing shoe is the deepest point of the “last” (most “inner”) cemented casing. Maximum permissible pressures in many states range from 0.8 psi/foot to a high of 0.9 psi/foot. The higher maximum pressures are generally associated with caverns in salt domes rather than caverns in bedded formations.

Kansas does not specify a maximum pressure in terms of psi/foot. Rather, they ask for “a description of methods to be used to prevent overpressuring of wells to the point of lifting or fracturing overburden.”

All states require reporting of maximum pressures and volumes of hydrocarbon injected and withdrawn over a period of time. Most states require reporting on a monthly or quarterly basis. Kansas requires reporting on an annual basis. The operator of a facility in Kansas need only report a maximum pressure for the entire year; whereas, operators in other states must report maximum pressures for every month or quarter of operation.

Most states besides Kansas require continuous monitoring of the pressure on every wellhead. Kansas only requires that the operator maintain records of product injections and withdrawals and maximum pressures during injections or withdrawals. These records need not be provided to the state, but must be available for inspection. Kansas also allows for recording of “each well or well system” pressures. Seemingly, if two or more wells are connected at a common manifold at the surface (as is the case at Yaggy), individual wellhead pressures need not be monitored or recorded. Rather, only the common manifold pressure need be recorded.

Questions that KDHE will need to address include:

1. What maximum pressure criterion will KDHE adopt?
2. Will KDHE have a different criterion for liquid storage than for gas storage?
3. What will KDHE require from an operator as proof that the maximum pressure is safe?

4. Does KDHE intend on increasing the requirements for reporting of wellhead pressures and product movements?

5. Will KDHE require continuous monitoring of wellhead pressures?

Testing and Monitoring

Most states require various types of testing and monitoring. Perhaps the most significant test required by most states (Kansas being an exception) is the Mechanical Integrity Test (MIT). Most states require this test of storage wells on a 5-year frequency. Kansas does not require an MIT for liquid or compressed natural gas wells, but does have an MIT requirement for brine mining wells.

Many states require MITs when the wellhead or cemented casings are modified. Kansas does not.

A few locations in some states require casing inspection logs on storage wells on a regular basis. For example, storage wells in salt domes with single cemented casings into the salt formation in Texas are required to have a casing inspection log on a regular basis. Texas wells in bedded salt formations are not required to have a casing inspection log. Kansas does not require casing inspection logs for any storage wells.

Many states are requiring (through permit conditions rather than rule) subsidence surveys on an annual basis. Kansas requires subsidence surveys every 2 years. Surveys in Kansas are required to be only third-order surveys. This may be inadequate for capturing any subsurface movement.

Questions that KDHE will need to address include:

1. Will KDHE require regular MITs?

2. Will KDHE allow alternative testing to substitute for MITs?

3. Will KDHE revisit their subsidence survey specifications?

4. Has KDHE considered requirements for casing inspection logs, particularly for "reentered" wells?

Again, I appreciate the opportunity to present these views on behalf of the city of Hutchinson. The city justifiably has very serious concerns regarding the aptness of the current Kansas regulations for underground hydrocarbon storage caverns. As a consultant that has committed his career to salt storage cavern technology, I have stated to the city that when properly designed, tested, monitored, operated, and regulated, salt caverns can be extraordinarily safe and effective facilities for storing hydrocarbons.