The Operation of Salt Water Disposal Systems

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Rice Engineering & Operating, Inc. designs salt water disposal systems and after the design is completed we supervise the construction and operate the systems for the various participating parties (oil operators). Although our operations extend into Canada, Michigan and Kansas, this paper is limited to experience gained in the West Texas and New Mexico area.

In this above mentioned area, we have designed and now operate nine cooperative salt water disposal systems which handle produced brine from 2900 wells through about 260 mi. of gathering line into 20 disposal wells. The volume of water disposed daily into these wells is over 100,000 bbl, and it is necessary to inject this water by pressure pumps in only three of these 20 wells. The remaining 17 wells take water by gravity flow with a vacuum showing on the tubing gauge under usual operating conditions.

The cost per well for disposal averages approximately $1700 for these nine systems. This includes all costs such as construction of gathering lines, the drilling or workover of disposal wells, the purchase of necessary right-of-way, and all engineering fees.

The focal point in the basic design of a gravity salt water disposal gathering system is the location of the disposal well or in large systems, the wells. Of course, we try to select, if at all possible, a dry hole or an abandoned well located favorably, both geologically and geographically to convert to disposal. Of the 20 disposal wells in these subject systems, 12 were either dry or abandoned wells. Eight of the disposal wells were drilled and equipped specifically for disposal at the outset. The advantage of drilling a new well is that it can be drilled in the best location to serve the gathering line design; and also the casing, completion and wellhead programs can be planned solely for disposal purposes.

The disposal wells discussed in this paper range in total depth from 4753 to 13,837 ft and are all completed in a limestone or dolomite formation. Thirteen are completed in the lower part of the San Andres formation, six are Devonian and one is completed in the Ellenburger. It has been our experience that a limestone or dolomite rock, providing it has the necessary porosity and permeability, makes the best disposal completion because it can be stimulated and rejuvenated with a relatively simple acid job. A disposal well completed in a limestone reservoir of large volumetric space and low bottom-hole pressure, providing the permeability is suitable, can be expected to perform in a very satisfactory manner.

After completion of a disposal well, we have found that it is very important to test the capacity or rate that the well will accept the water. In a well that will not take the water by gravity, it is necessary to perform a pumping test in order that the injection equipment may be sized properly. In a well that takes water by gravity, a successful capacity test can be secured if the tubing is completely loaded; that is, the size of the surface lines or hoses from the tankage must be large enough so that the wellhead is not starved for water, Also, the tankage must be of sufficient volume that a fairly stable rate can be established so that the true well capacity can be determined. Since the gravity or weight of the water will affect the capacity, it is better to take the maximum injection test with the particular water that is to be disposed.

All of our disposal wells are equipped with injection tubing that has been internally plastic coated. Various types of corrosion resistant linings have been used including air dried coal-tar epoxy, straight epoxy, and modified baked-on epoxy.

To protect the exterior of the tubing and the interior of the casing from corrosion we use an "oil-balance" method, i.e., the tubing-casing annulus is filled with an oil or naphtha of the proper gravity to balance the weight of the static water column in the tubing. The gravity of the oil used in the annulus is dependent on (1) the setting depth of the tubing, (2) the static fluid level (or bottom pressure) and (3) the specific gravity of the injected water. By using this method, rather than a packer installation, we are able to secure very valuable information by observing and recording the casinghead pressure. Any change in the well conditions, such as a tubing or casing leak, is immediately reflected at the surface casing pressure gauge. Also, by keeping records of these pressures and the injected volumes, preferably by graphs, we are able to predict accurately certain well stimulation or workover jobs.

In the 260 mi of gathering line that are maintained in these subject systems, we have found it necessary to install only five small centrifugal pumps to move the water to the terminal facilities located at the disposal wells. For the most part, the water flows by gravity and these pumps are used only in spots where we find it necessary to lift the water over a hill, or to lift the water from a low portion of the field to a place where the gravity portion of the system can handle it. Our gathering lines are normally designed for gravity flow and the sizes calculated by using a Hazen-Williams friction factor of $C = 100$. Experience has shown us that the use of a higher C factor will often lead to later operational difficulties. All the materials used in the lines will have a smooth surface when new, but after a period of use the internal surface collects material that alters its original smoothness.

In the large pipe sizes, from 3 to 12-in, asbestos-cement pipe has been used exclusively in the line design. In the two-in. and smaller pipe, plastic pipe was used. We have found that the pressure and temperature specifications of the plastic pipe are critical and its use should be limited if temperatures on the treating facilities approach 180°.

Malfunctions in the lease treating facilities frequently allow gas and oil to get into the gathering lines. Because of this, it is very important to use gas boots at every pressure vessel to vent the gas before it reaches the line. It is the function of the gas boot, by acting as an atmospheric separator, to vent the gas from the water before the water enters the gathering line. The water enters at the bottom of the boot, flows up through a riser and then drops down and back into the line. The gas is vented off at the top as it breaks out of solution with the produced water.

The gathering system is designed so that no high spots occur in the pipe that might trap gas. During the construction, close supervision is important so that the pipe is laid either uphill or down, with any high spots in the pipe deliberately located at a gas boot, vent or siphon so that the gas may vent and not cause gas locking.

Scraper traps are necessary in order that the gathering lines may be properly maintained and also are a place where an inspection of the pipe interior may be performed. These traps are installed at junctions and access to them is provided by the proper bolted couplings and valves. Conventional line scrapers pumped through the lines are used to keep them free from scale, basic sediment, and paraffin deposit.

At the terminal facilities located adjacent to the salt water disposal well, we have found that a redwood tank or sometimes two tanks partially buried (for gravity flow) provide excellent storage for the water before it is injected into the well. The tank allows settling time for the suspended solids to drop out, accumulates any oil, allows for fluctuations in production and permits storage necessary to test the disposal well.

Our tank design is made so that the incoming water enters the tank through a perforated spreader located about 12 in. above the bottom of the tank, and the outgoing water leaves the tank through a boot arrangement which permits an accumulation of about 250 bbl of oil on the tank but will not allow the oil to go into the disposal well. Oil accumulation and removal often creates a considerable problem in salt water disposal. Water in the tank carries an oil seal and the gas escaping from the oil and water provides a gas blanket over the fluid surface. The water level in the tank is regulated by a float operated valve at the disposal wells where it is necessary to inject the water under pressure, the pumps are activated by a contact switch and anodes extending into the tank.

Table I lists a tabulation of various water analyses that are typical of the waters disposed in the systems. You will note that the constituents of these waters vary greatly—even within the same general formation.

Scale which forms in the gathering lines and occasionally in the injection tubing sometimes creates a problem. These scales are calcium carbonate, calcium sulfate, barium sulfate or iron sulfide. The most troublesome scales are the calcium sulfate and the barium sulfate which are not acid soluble. In multipay fields where waters from different formations are disposed of in the same gathering lines, there are precipitates which usually form at the point of mixing. Fifteen chemical pumps are used in the nine systems that we operate to inject polyphosphate inhibitors into the gathering lines upstream from the mixing point of the dissimilar waters. Twelve of the chemical pumps are located in the two largest systems that we operate which have a combined total of over 1900 wells.

In one of the largest systems we have had barium sulfate scale form in the injection tubing. This occurs after the water passes through a butterfly control valve between the tank and the gravity disposal well. Evidently the precipitate forms there because of the change in the water from a positive pressure to a vacuum on the tubing. Further examination showed that this tubing scale extended down in the well only to the working fluid level. Installation of a chemical pump a mile or so upstream from this particular disposal well eliminated this scale formation.

The operation of these nine salt water disposal systems requires continuous supervision by experienced personnel in order that the most efficient and economical service can be attained for the producing life of the various oil fields.

TABLE I

FORMATION WATER ANALYSES
(Milligrams per Liter)

FIELD Zone	Wasson San Andres	Monument San Andres	Hobbs San Andres	Robertson Upper Clearfork	Robertson Lower Clearfork
Sodium, Na	24,000	4,058	4,345	7,997	51,760
Potassium, K	550	-	-	-	-
Calcium, Ca	2,800	349	1,259	2,058	9,840
Magnesium, Mg	2,400	278	300	1,064	2,940
Sulfate, SO_4	3,300	3,296	2,750	1,200	1,100
Chloride, Cl	46,400	4,893	6,660	17,465	104,800
Bicarbonate, HCO_3	1,000	610	1,928	1,244	299
Carbonate, CO_3	Nil	-	-	Nil	Nil
Hydrogen Sulfide, H_2S	2	323	190	Much	Nil
Barium, Ba	-	-	-	-	-
Total Solids	90,000	13,807	17,242	31,028	170,739
Specific Gravity @ 60°F	1.055	1.009	1.011	1.025	1.121
Iron	10	-	-	Trace	Much
pH	7.10	7.5	7.6	-	-

TABLE I (Contd.)

FORMATION WATER ANALYSES
(Milligrams per Liter)

FIELD Zone	Wasson Wichita-Albany	Deep Rock Wolfcamp	Lane Penn.	Gladiola Devonian	Hutex Devonian	Wilshire Ellenburger
Sodium, Na	18,480	65,288	29,913	19,750	15,835	45,715
Potassium, K	-	-	-	-	-	-
Calcium, Ca	2,500	5,298	4,738	1,920	1,572	7,405
Magnesium, Mg	640	1,715	873	745	372	1,160
Sulfate, SO_4	2,500	1,850	570	1,040	1,650	795
Chloride, Cl	32,500	113,520	56,450	34,000	26,690	86,320
Bicarbonate, HCO_3	205	195	305	465	640	104
Carbonate, CO_3	Trace	Nil	Nil	-	Nil	Nil
Hydrogen Sulfide, H_2S	-	None	Nil	Some	Some	Nil
Barium, Ba	-	-	Nil	-	Nil	Nil
Total Solids	-	187,866	92,849	58,920	46,759	141,499
Specific Gravity @ 60°F	1.042	1.127	1.008	1.042	1.034	1.102
Iron	-	Much	Trace	Much	-	Trace
pH	8.7	-	-	6.8	-	-