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Salt Caverns Used for Disposal of Nonhazardous Oil Field Waste

by John A. Veil, Argonne National Laboratory

Salt caverns show promise for the disposal of nonhazardous oil field waste, and there are no apparent regulatory barriers to this application.[1]

Solution-mined salt caverns have been used for many years for storing hydrocarbon products. Argonne National Laboratory has reviewed the legality, technical suitability, and feasibility of disposing of nonhazardous oil and gas exploration and production waste in salt caverns. Eleven oil-producing states (Kansas, Louisiana, Michigan, Mississippi, New Mexico, New York, North Dakota, Ohio, Oklahoma, Pennsylvania, and Texas) were studied. Figure 1 shows the distribution of major U.S. subsurface salt deposits.

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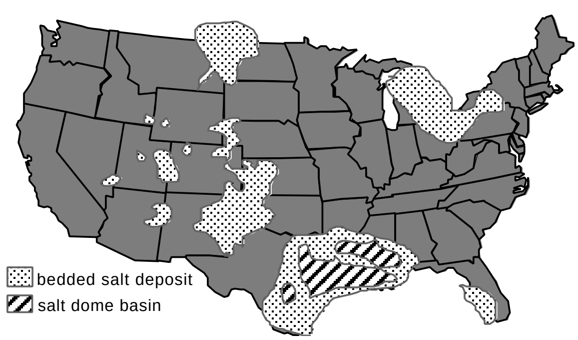

Figure 1 Major U.S. Subsurface Salt Deposits

This newsletter features oil- and gas-related projects implemented through the U.S. Department of Energy's (DOE's) oil and gas environmental research program. BDM-Oklahoma, Inc., as management and operating contractor of the National Oil Program, assists DOE in achieving its objectives.

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Acknowledgments

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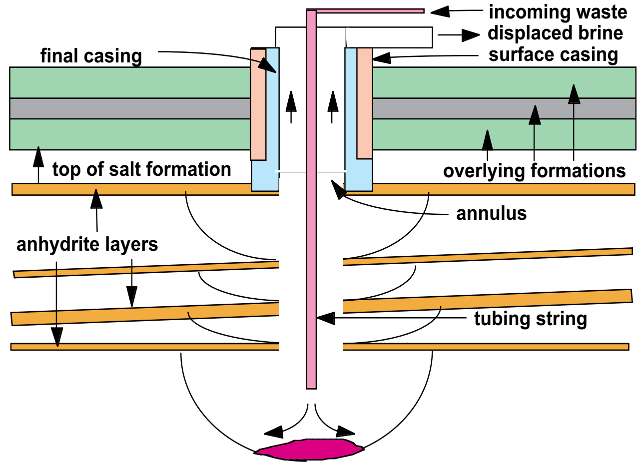
Salt Deposits

The two types of subsurface salt deposits in the U.S. are salt domes and bedded salt (see Fig. 1). Salt domes are large, generally homogeneous formations that are formed when a column of salt migrates upward from a deep salt bed, passing through the overlying sediments. Bedded salt formations occur in layers bounded on the top and bottom by impermeable formations and interspersed with nonsalt sediments (such as anhydrite, shale, and dolomite) with varying levels of impermeability. Bedded salt formations may contain significant quantities of impurities.

Salt caverns are formed by injecting water that is not fully salt saturated into a salt formation and withdrawing the resulting brine solution. Figures 2 and 3 show the main features of salt cavern construction for caverns in domal salt and bedded salt, respectively. The most common use of salt caverns is production of salt, which enlarges the caverns. The post-mining uses of caverns are hydrocarbon storage, compressed air storage, and waste disposal. The U.S. Strategic Petroleum Reserve program, for example, uses 62 leached caverns in domal salt for hydrocarbon storage with a capacity of 680 million bbl.

Figure 3 Idealized Cavern in a Bedded Salt Formation



Regulatory Considerations

In the U.S., waste disposal in salt caverns has been limited. Regulatory considerations were defined by the Environmental Protection Agency in the July 6, 1988, and March 22, 1993, EPA Acts. Oil field wastes fall under the Class II injection well category of wastes brought to the surface in connection with conventional oil or natural gas production.

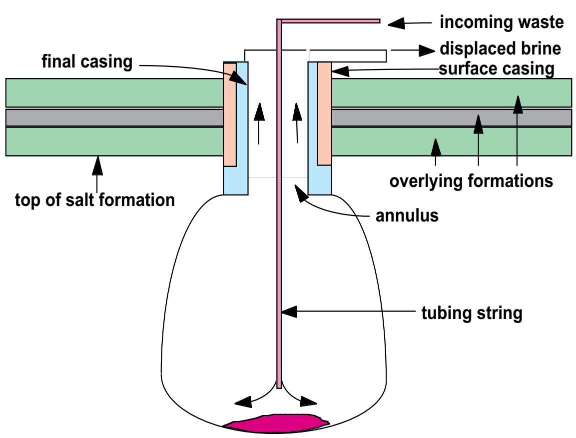
Efforts are currently under way to obtain clarification from EPA on whether all exempt oil field wastes can be injected into Class II wells. At the state level, only the Texas Railroad Commission (Texas RRC) has formally authorized disposal of oil field wastes into salt caverns, beginning in 1991. Ten other states have expressed interest in following the Texas RRC program, but at this time only New Mexico has received an application for disposal of oil field wastes in salt caverns.

Wastes

The types of oil field wastes proposed for disposal in salt caverns are those that are most troublesome to dispose of through regular Class II injection wells because they contain high levels of solids. Wastes containing water that is not fully saturated with salt may increase the size of caverns because the unsaturated water will leach salt from the cavern walls. The presence of freshwater in wastes would not preclude their disposal in salt caverns, but the operator must account for the increased volume of the cavern and what effect it will have on cavern siting parameters, such as distance to adjacent caverns and roof span or thickness.

The solids-containing oil field wastes most likely to be disposed of in salt caverns include used drilling fluids, drill cuttings, completion and stimulation waste, produced sand,

Figure 2 Idealized Cavern in a Salt Dome Formation



tank bottoms, and soil contaminated with crude oil or salt.

Several factors should be considered for siting natural gas/oil storage caverns: (1) distance to populated areas, (2) proximity to other industrial facilities, (3) current and future use of adjacent properties, including agriculture, (4) handling of brine or other displaced fluids, (5) proximity to environmentally sensitive wetlands, (6) proximity to the salt boundary, and (7) proximity to other existing and abandoned subsurface activities.

To minimize the chance of failure due to closure, collapse, or leakage, acceptable designs should be based on a geological review of the location covering all features capable of affecting the cavern. Adequate studies should address regional stresses and strains; mechanical, chemical, and containment properties of the salt and confining rock formations; and structural anomalies, including faulting. During disposal operations, information on operation as well as measurements of subsidence and cavern integrity should be monitored periodically.

Disposal operations

The way salt caverns are formed leaves them filled with clean brine. Wastes are introduced as a slurry of waste and a carrier fluid (brine or freshwater). To avoid excessive leaching of the cavern roof, operators may introduce a hydrocarbon pad that, by virtue of its lower density, will float to the top of the cavern and keep the unsaturated carrier fluid from coming in contact with the cavern roof. As the waste slurry is injected, the cavern acts as an oil/water/solids separator. The heavier solids settle at the bottom of the cavern in a pile. Any free oils or hydrocarbons that are associated with the waste float to the top of the cavern. Clean brine displaced by the incoming slurry is removed from the cavern and either sold as a product or disposed of in an injection well. When the cavern is filled, the operator removes the hydrocarbon pad and plugs the cavern.

There are three ways to fill the cavern:

1. Pump waste down the tubing and withdraw displaced brine from the annulus.
2. Pump waste down the annulus and withdraw the brine displaced from the tubing.
3. Pump waste down one well, and withdraw the displaced brine through a second well.

The first method is the one most likely to be used. Heavier solids in the incoming wastes will be introduced near the bottom of the cavern and will settle (see Figure 4).

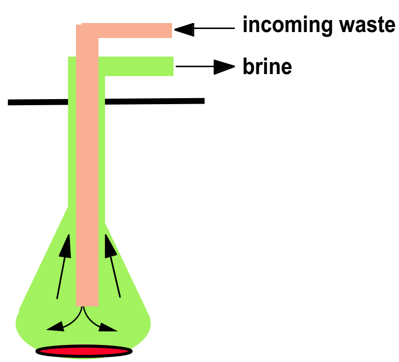


Figure 4 *The Waste Disposal Process:* Wastes are injected as a slurry of ground up waste and brine. Incoming waste displaces the clean brine, which is brought to the surface and either sold or injected into a disposal well.

Closure and remediation

Scientists have modeled cavern behavior, and engineers have conducted limited tests of closed brine-filled caverns. The Argonne report[2] condenses several interviews with various cavern experts on their opinions on long-term cavern stability. In summary, disposal of solids in brine-filled caverns will generally enhance the stability of caverns, solids-filled caverns are unlikely to leak.

Conclusions

The use of salt caverns for nonhazardous oil field waste disposal is in its infancy. There are no apparent regulatory barriers at the state or federal level to the use of salt caverns for disposing of oil field wastes. The types of oil field wastes that are exempted from RCRA hazardous waste requirements are generally suitable for disposal in salt caverns.

Hundreds of storage caverns have successfully been operated worldwide for several decades. Argonne National Laboratory believes that disposal of oil field wastes in salt caverns is feasible and legal. If caverns are well sited and designed, operated carefully, closed properly, and monitored routinely, they represent a suitable means to dispose of oil field wastes.

1. Veil, John A. 1996. "Salt Caverns Show Promise for Nonhazardous Oil Field Waste Disposal," *Oil & Gas Journal*, Nov. 18, 1996, p. 42–44.

2. Veil, J. A., et al. 1996. "Preliminary Technical and Legal Evaluation of Disposing of Nonhazardous Oil Field Waste into Salt Caverns," Argonne National Laboratory, for U.S. DOE, Washington, D.C., June 1996.

Three-Phase Centrifuge Technology for Minimizing Petroleum Waste

by J.W. Parkinson, Los Alamos National Laboratory

Oil companies in the United States generate several million barrels of unusable oil each year. This oil is discarded, wasting a national energy resource and creating an environmental problem. Much of this waste oil comes from refineries. However, a large portion, about 2.5 million bbl each year, is a by-product of oil field production known as tank bottoms.

This oil field waste is a mixture of oil, brine, and solids that collect at the bottom of holding or production tanks in which oil is stored before shipment to an oil refinery. A large portion of this oil waste is disposed of in earthen pits. Many pits and ponds across the U.S. are filled with this discarded oil. Some pits contain as much as a million bbl of oil. In today's environmental climate, the many millions of barrels of oil accumulated in tank bottoms, pits, and ponds pose a severe waste disposal problem.

The waste oil is usually bound in an oil-chemical-water-solids emulsion. Attempts have been made to recover some of this oil using expensive thermal or chemical techniques, either alone or in combination. Unfortunately, adding heat drives off light components, leaving behind an oil-chemical-water-solid mixture that presents an even more difficult separation problem. This mixture, called dead oil, is currently unrecoverable.

Separation Difficulties

Much of the difficulty in separating these mixtures lies in the multiphase character of the mixture. Past attempts to separate such mixtures have been made using two-phase centrifuges, with the idea that multiple two-phase separations would be needed to achieve the desired three-phase separation.

Two-phase decanting centrifuges have been used in oil fields since the early 1950s. These centrifuges were originally used to control the viscosity of drilling muds. In recent years, their role in the oil field has expanded to include environmental cleanup. Little data on these efforts are available, but a two-phase centrifuge cannot separate three phases in a single pass. The product from a two-phase centrifuge is often an oil-coated solid and an oil-water emulsion needing further treatment.

A single-pass operation would obviously be more economical than a multipass process. Therefore, this article focuses on the three-phase centrifuge process.

The Three-Phase Centrifuge

Oil field cleanup is really a three-phase problem. The problem mixture usually contains oil, solids, and water in a range of ratios. Some mixtures may contain solids and oil in such a nonfluid mix that water must be added before the mixture can be introduced into a centrifuge. In a good separation, the solid product will have a low basic sediment and water (BS&W) concentration. The required BS&W concentration for salable oil varies with location. For example, oil reclaimed in New Mexico is required to have a BS&W concentration of 1% or less, while oil reclaimed in Wyoming is required to have a concentration of 0.3% or less.

A three-phase centrifuge is capable of three distinct phase separations in a single pass. Three-phase centrifuges are uncommon in the petroleum industry, but have been used in other industries. The olive oil industry has used three-phase machines to separate mixtures of fruit flesh, water, and olive oil. The oil field separation is a far more difficult problem, because the oil field mixture is a solid-stabilized emulsion produced from a liquid-solid mixture that often contains very small particles with relatively large surface areas.

Figure 5 provides a flow diagram of the centrifuge process. The process requires pumps, a heater, and holding tanks, in addition to the centrifuge. The heater is used to

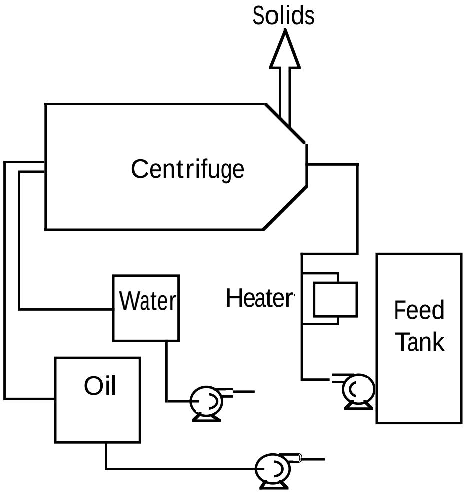


Figure 5 Flow Diagram for Three-Phase Centrifuge Process

reduce the viscosity of the feed mixture and to improve the flow characteristics. A feed-holding tank (desired but not required) provides a place to uniformly mix the feed for easier process control and to add water or chemicals when they must be added to the feed mixture to achieve the desired separation.

Some Results

Los Alamos National Laboratory recently completed a Cooperative Research and Development Agreement (CRADA) with Centech Inc., a small Wyoming-based centrifuge developer and operator. The CRADA goal was to develop an intelligent control system to be used with the Centech three-phase centrifuge.

The Centech three-phase centrifuge design is based on a two-phase decanter centrifuge with several creative modifications. The ability to separate a three-phase mixture into three individual phases in one pass requires, in addition to the three-phase centrifuge, an expert knowledge of the many waste mixtures to be separated and how they will behave in the machine. The intelligent control system provides this expertise to operators who often have less experience with three-phase problems than the inventor and current operator of the three-phase centrifuge.

Even though successfully cleaning the oil field waste was of less concern to Los Alamos than developing a control system, we observed successful cleanup at two waste disposal sites, two refineries, and an oil field over the three-year period.

The results were good in all cases, even though the waste to be cleaned was potentially troublesome in nearly all cases. Usually, the feed BS&W content was very high, which indicates that the problem mixture had been previously treated with heat and/or chemicals to remove the salable oil, leaving behind the very difficult to recover oil. In each case the product specifications varied, yet the specifications were met.

The challenge was to reduce the BS&W concentration to an acceptable level so that the oil product would be salable. Table 1 lists the results from tests at the New Mexico waste disposal site. The three-phase centrifuge produced salable oil from these runs. In fact, the average product oil BS&W content was below 1%, making the entire batch salable. (For reasons related to performance and maintenance, it does not make good business sense to produce better quality products than required.) Also, the water was clean enough to be reusable on site.

One problem with these test mixtures was that most of them had been treated very heavily, so a solid hydrocarbon phase was present. At operating temperatures, which necessarily must be below the boiling point of water, the hydrocarbon solids were recovered with the other solids, making the solid phase high in hydrocarbon content. This particular solid phase required further treatment to separate out the solid hydrocarbons.

In this trial, the three-phase centrifuge usually provided excellent separation on all three phases, even for hard-to-treat mixtures. Testing continues with data from the Wyoming sites (with lower BS&W requirement) expected soon.

Table 1 Three-Phase Centrifuge Separation Data

Run Number	Feed BS&W, %	Product Oil BS&W, %	Product Water Oil Content, ppm
I	75	0.96	5.3
II	4	0.94	11.6
III	72	0.6	2.6
IV	40	1.48	2.3
V	78	1.44	1.6
VI	80	1.44	2.3
VII	63	0.92	2.4

NORM—Treatment and Underground Disposal

by Viola Rawn-Schatzinger, BDM-Oklahoma

Naturally Occurring Radioactive Material (NORM) has become a significant issue for both regulatory agencies and petroleum producing companies in recent years. NORM will become an increasingly visible environmental issue, as it can threaten the health of both workers and potentially the surrounding communities if not properly managed.

Environmental Impact

NORM exists in soil, water, plants, petroleum, coal, lignite, phosphate, geothermal waste, waste water, animals, and humans. Because people cannot smell, see, or feel NORM, a potential health threat could go undetected. Accumulation of NORM creates a growing economic and environmental liability for oil and gas producers. Additional impacts on the public include higher prices at the pump, shutdown of wells and leases resulting in loss of jobs, and increased dependence on imported oil.

In 1994, DOE identified the need to assist industry with developing and testing a method for treatment and underground disposal of NORM from oil and natural gas production. This need was demonstrated by the increasing amount of NORM being discovered throughout the industry and the difficulty of obtaining affordable, accessible NORM disposal options.

Pilot Demonstration

DOE is sponsoring a project focused on treatment of NORM generated by the oil and gas industry. The project, directed by DOE's National Petroleum Technology Office, is being conducted by BPF, Inc. of Duncanville, Texas. BPF, Inc. is developing and field testing an integrated semiautomated mobile system to economically dissolve solid NORM waste into a solution suitable for injection into either a produced water disposal well or an operating injection well. The NORM solids will be processed so that residual solids have radioactivity below the minimum regulatory level for NORM.

BPF has completed a bench-scale test of the NORM disposal technology at three NORM storage sites. These three field sites are located in Lea and Eddy Counties in southeast New Mexico and in Reeves County, West Texas. The sites are on operating oil field leases, and all contain stored NORM wastes and have saltwater disposal wells which are currently operating under the regulatory guidelines. BPF is currently developing full-scale processing equipment for the pilot-scale demonstration planned for late fiscal year 1997.

The bench-demonstration at Ford Geraldine Site, Reeves County, Texas, will process 200 drums of NORM solids. At Dagger Draw/King SWD Site, Eddy County, New Mexico, 200 drums from the open-top tank will be processed. At Britt Battery B Site, Lea County, New Mexico, 10 drums of NORM will be processed. Also, the pilot-scale test will inject 16,800 gallons of NORM in solution at Ford Geraldine and Dagger Draw and 840 gallons at the Britt Battery B site.

NORM is treated on site by separating the NORM solids from other exempt oil field waste containing less than 30 pCi/g total radium and dissolving it into aqueous solutions. Transportation of NORM-containing solutions is confined to the lease property. The lease operator will reinject the solutions containing the dissolved NORM solids into saltwater disposal wells. The injection wells currently support several thousand gallons of saltwater injection each day. It is expected that the injected NORM would precipitate out into the geologic matrix and be permanently returned to the formation of its origin.

Suggested Treatments

Treatments of NORM currently approved and in use by industry include (all costs listed here exclude shipping and documentation expense):

- Burial at a licensed facility at an estimated cost of $300 to $750 per drum.

- Dilution treatment costing $210 to $325 per drum with additional cost for radiochemical analysis.
- Landspreading, which involves long-term storage by placing exempt waste containing less than 5 pCi/g above background total radium on each lease site.
- Downhole encapsulation in tubing strings, with costs averaging $1081 per drum.
- Slurry injection with NORM-containing solids suspended into a gel which is injected into Class II disposal wells. Costs average $916 per drum.

BPF Solution Injection Advantages

BPF's process developed for solution injection has three primary advantages over other processes:

1. NORM solids are dissolved and then reinjected into the original geologic formations from which they originated.
2. Disposal is accomplished without the need to transport the NORM solids over significant distances or off the lease property.
3. This is a true disposal process in that the NORM solids, once dissolved, no longer exist as NORM. As a result, custody of the NORM wastes is no longer an issue for the generator.

The cost of process wastes using BPF pilot-scale technology is currently estimated to be $500 per drum. This cost compares favorably with the total cost of disposal for competing technologies. There are no additional transportation or documentation charges.

Treatment Process

The NORM treatment process involved a number of components and chemicals. Figure 6 outlines the steps in the NORM treatment and underground disposal.

Step 1: Solids go directly to Step 2. Liquids can be removed by treatment with a hydrocarbon solvent. Liquids are also extracted by a thermal pretreatment of vaporizing hydrocarbons and other organics at above 600° C.

Step 2: Volume reduction is accomplished by the sorting/assay module. This truck-mounted system uses a specially designed, high-speed sorting machine which can separate NORM into two categories based on the radioactivity of the material.

Step 3: Extraction of radionuclide is done by dissolving the radioactive material (NORM) in one or more aqueous solvents. Hydrocyclones are used in the solvent extraction module to separate solids from liquids.

Step 4: The radioactivity of the insoluble residue remaining after solvent dissolution is measured by in-situ radioassay capability. Materials rated at below regulatory concern are returned to the customer for disposal as a nonhazardous waste. The NORM-containing solution was injected into injection wells on each lease site.

Future Application

The reduced total cost, $500 per drum, of NORM disposal developed by BPF makes this method attractive to the petroleum industry. There is also an environmental advantage to not transporting NORM off the lease. The result of the process—that NORM wastes once treated and disposed of no longer exist as NORM—is an advantage to all involved.

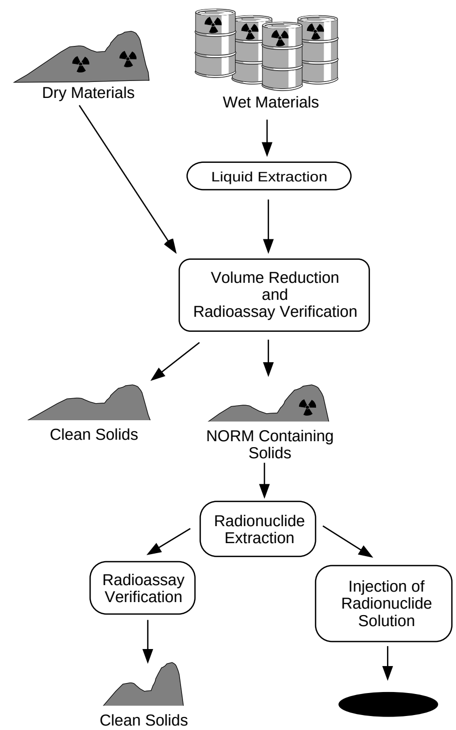


Figure 6 Process Flow Diagram for the BPF NORM Treatment and Underground Disposal System

This article was excerpted with permission of the National Petroleum Technology Office, Tulsa, Oklahoma (formerly the Bartlesville Project Office, Bartlesville, Oklahoma) from "Development and Testing of a Method for the Treatment and Underground Disposal of NORM Associated with Oil and Natural Gas Production," BPF, Inc., Don Capone, 205 E. Center St., Duncanville, TX, for the U.S. DOE, January 1997.

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