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Meeting Paper



**Geometric Control of Disposal
in Bedded Salt**

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GEOMETRIC CONTROL OF DISPOSAL IN BEDDED SALTS

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The disposal of oil and gas waste containing naturally occurring radioactive material (NORM)³ has previously incorporated the use of hydraulic placement in subterranean formations, landfill disposal, and hydraulic placement in sub-pressured caprock formations. Below is a short overview of these three most common NORM disposal options:

(a) **Hydraulic Placement in Subterranean Formations:**

Commonly referred to as “deep well injection” (See: Plat 1). This disposal method has proven itself to be a safe and viable disposal option for NORM, as it has with both hazardous and non-hazardous liquid wastes and those waste streams carrying a “land ban” restriction from landfill disposal. This is the disposal method currently employed by LOTUS, L.L.C.⁴ for NORM disposal at its facility in Andrews County, Texas. The single largest challenge presented to disposal well operators is controlling disposal costs charged to the waste generators. This is especially true of an operation such as the Lotus Disposal Facility which processes solid NORM wastes (contaminated soils, pipe scale, sludges, etc.) And renders these solids into a slurry which can be injected into a deep subterranean strata that is non-productive of oil and gas.

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² Dan Snow is the General Manager of LOTUS, L.L.C., and designed this particular method of waste disposal in bedded salts.

³ NORM is commonly composed of three primary radionuclides, Radium-226, Radium-228, and Lead-210, which are decay daughters of Uranium-238 and Thorium-232.

⁴ LOTUS, L.L.C. is one of only two facilities in the United States permitted for the processing and deep well injection NORM generated from oil and gas exploration and production operations.

(b) Landfill Disposal:

Historically, landfill disposal has been the most common disposal technique utilized for the internment of everything from municipal garbage to the most deadly of toxins. We are all aware that properly designed, constructed, and maintained landfills offer secure internment for a multitude of waste streams. However, we are also all too aware of the potential for environmental disaster that can, and has, occurred from the leaching of hazardous and toxic substances from landfills into aquifers utilized for drinking water, and a myriad of other problems too lengthy to be dealt with in this paper. Another draw-back to landfill operation is the enormity of the operation itself. Commercial landfills require a lot of real estate to operate, and this commodity is becoming less and less available as our population continues to increase.

(c) Placement in Sub-Pressured Caprock Formations:

This is another injection well technique (See: Plat 2)⁵. Sub-pressured caprock formations are commonly associated with domal salt formations in coastal regions. These formations create the "cap" enclosing the salt domes. Oil and gas operators have utilized these formations for the disposal of produced waters resultant of oil and gas production activities. These formations literally provide no resistance to the injection of fluid and actually create a vacuum above the fluid falling through the pipe into the formation. For some, the largest concern associated with this type of disposal is that of well control. The question of where the liquid waste actually settles and the ability of the formation to contain the waste stream within itself, is posed frequently. Additionally, it is possible that these caprock formations may lie above aquifers of usable quantity and quality which may have to be exploited for human consumption at some point in time.

Recently, it has been proposed to dispose of NORM wastes in abandoned or existing solution mined salt caverns. While the safe operation of such a facility while employing the most economic means is always desired, it must be noted that salt cavern subsidence and collapse has been demonstrated, and is always a potential threat. The collapse of any cavern, especially those engaged in the disposal of NORM or other hazardous constituents, is to be avoided at all cost.

Historically, single source/receiver well completions (See: Plat 3) have been utilized in the solution mining of salts from bedded formations, such as the immense Salado formation of Western Texas and Eastern New Mexico. Unfortunately, this well completion method tends to promote the potential of cavern collapse in that during the solution mining process, cavern height and lateral

⁵ Currently, five injection wells have been permitted by the Railroad Commission of Texas for the injection of NORM into a sub-pressured caprock formation in the Big Hill Field in Eastern Texas. All five wells are owned and operated by one entity, and three of the wells have been dually permitted to a Class I Non-Hazardous status by the Texas Natural Resource Conservation Commission.

expansion is largely uncontrolled⁶. The operation of such a cavern makes size monitoring difficult, and lends itself to large cavern roof structures. When lateral geological and over-burden pressures exceed the strength of the cavern roof, collapse of the roof structure is imminent. Additionally, liquid filled caverns are at the same risk.

LOTUS, L.L.C. (Lotus) believes that the implementation of a horizontal well system will provide a viable alternative to traditional cavern disposal, and has applied for patents on such a process. A two well horizontal system will allow the operator to control the geometry of the injection interval and therefore allow an accurate calculation of the life expectancy of the injection interval. Additionally, by controlling the geometry of the injection interval between the wells, the operator can accurately calculate the thickness of the roof and guarantee the roof integrity. Horizontal well operations can be employed in any salt strata of sufficient depositional thickness to lend itself to modern horizontal drilling techniques.

WELL AND CAVERN CONSTRUCTION (patent pending)

- (a) Well #1 is drilled vertically to a depth of approximately 2700'⁷, then the well bore will be kicked off horizontally to a depth of approximately 2850' and a horizontal bore made for approximately 500' (See: Plat 4).
- (b) Well # 1 is completed utilizing three casing strings, cemented to surface for protection of all known aquifers, and tubing is run in the hole to the approximate end of the horizontal bore. (See: Plat 5).
- (c) Fresh water injection is commenced through the tubing at a rate of 2 bpm. Return is accomplished through the casing. The returning water is weighed until a saturated 10 lb per gallon brine solution is returned. Fresh water is pumped down the tubing until 8,640 bbl of of 10# brine has been returned. This will have removed approximately 725,760 lbs of salt at the end of the horizontal bore (See: Plat 6).
- (d) A cut off tool is run down hole to cut off the tubing in the horizontal bore. This section of tubing is abandoned in place.
- (e) 3 ½" tubing is run in Well #1 to a depth of approximately 2400 ft and a packer is set at approximately 2350 ft.

⁶ Salt erosion above the casing shoe of conventional solution mining caverns has accounted for numerous well failures and contributed to instances of subsidence.

⁷ Depths noted for drilling correspond with known formation tops and thicknesses of the Salado formation in Western Andrews County, TX.

- (f) Well #2 is drilled approximately 500' from Well #1, vertically to a depth of approximately 2850' to intersect the horizontal bore from Well #1.
- (g) Well #2 is completed with casing and tubing set on a packer in the same manner as Well #1 (See: Plat 7).
- (h) Fresh water injection is commenced through the tubing of Well #1 at a rate of 2 bpm. Return is accomplished through the tubing of Well #2 (See: Plat 8). Fresh water is pumped down the tubing until 8,640 bbl of 10# brine has been returned. This will have removed approximately an additional 725,760 lbs of salt from the horizontal bore.

EMPLACEMENT OF NORM WASTES

- (a) Solid NORM wastes, (contaminated soils, produced sands, pipe scale, tank bottoms, etc.) are processed into an injectable freshwater slurry and pumped down the tubing of Well #1. The freshwater slurry continues to leach salt as the NORM solids precipitate out of solution and are deposited in areas of low fluid velocity within the horizontal bore. The displaced 10# brine is returned through the tubing of Well #2 and is pumped to an existing disposal well which is permitted for the disposal of oil and gas NORM wastes (See: Plat 9).
- (b) The freshwater slurry injection is reversed occasionally to facilitate as even a distribution of solids within the horizontal bore as possible.
- (c) Once mass volume calculations indicate that the horizontal bore has reached a maximum diameter of 80 to 100 ft., the injection slurry is changed from freshwater to a 10# brine slurry. This will allow for the continued emplacement of NORM solids within the horizontal bore, but will eliminate further salt leaching. Again, as with the freshwater injection, the receptor well is reversed occasionally. 10# brine injection continues until the horizontal bore has accepted all of the NORM solids which could possibly be placed within it (See: Plat 10).
- (d) To facilitate closure, Well #2 is plugged and abandoned and Well #3 is drilled at a right angle to Well #1, and is kicked off horizontally to intercept Well #1. The process is thus repeated within the new horizontal bore (See: Plat 11).

DESIGN BENEFITS

- Injection and recovery is accomplished through tubing set on a packer.
- Superior protection of groundwater.

- Geometry of the injection interval is controlled.
- No large and uncontrolled cavern is formed.
- Tubing can be moved up or down within each well to control cavern dimensions.
- Massive amounts of salt remain undisturbed above the roof section, minimizing any likelihood of roof collapse or subsidence.
- Solids are deposited in the horizontal injection interval as it is formed, adding additional stability to the injection interval.