Subsurface Disposal of Industrial Waste Water

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INTRODUCTION

The Petro-Chemical Complex of Odessa, Texas, consists of El Paso Products Co.'s Butadiene, Styrene, Olefin, and Nylon Processing facilities; General Tire & Rubber Co.'s Odessa rubber plant; Rexall's polyethylene plant and Shell Oil Co.'s crude-oil refinery. Figure 1 illustrates the location and relationship of the Complex to the city of Odessa, Texas. These facilities require large volumes of water in their daily operation and this water requirement is primarily supplied through El Paso Products Co.'s agreement with the city of Odessa to process the city's sewage water effluent for reuse by the Complex.

The Odessa City Sewage Treating Plant is located in close proximity to the Petro-Chemical Complex where the sewage effluent is pipelined to a holding pond, referred to as the Odessa lagoon; hence the effluent is transferred to the Complex cold lime treating plant and processed for distribution to the various Complex facilities as diagrammed in Fig. 2.

The Petro-Chemical Complex's daily water requirements have increased with plant development to approximately 107,000 BPD at the completion of the Nylon 66 processing facilities in 1966. With the continuing growth and expansion of facilities comprising the Odessa Complex, there became a need to dispose of the accumulating waste water from the cooling towers, blow downs, drips, and separators from the plants. In 1962, an agreement was negotiated between El Paso Products Co. and the Pan American Petroleum Corp. to construct, at the Complex site, a waste water treating plant to reclaim and treat the industrial waste water for use by Pan American Petroleum Corp. as a supplemental source of water for their South Cowden waterflood project. Figure 2 also diagrams the waste water return system from the various Complex facilities to the waste water plant where the water is then treated prior to being pumped via pipeline to the South Cowden waterflood injection wells. By late 1964, approximately 30,000 BPD of industrial waste water from the Petro-Chemical Complex was treated and reused as make-up water for Pan American's secondary recovery program. However, in January of 1965, Pan American Petroleum Corp. began limiting its requirements for treated industrial waste water which necessitated El Paso Products Co. to dispose of the waste water elsewhere in compliance with the Ector County pollution order.

FEASIBILITY STUDY OF SUBSURFACE DISPOSAL

El Paso Products Co., in February of 1965, submitted to the Texas Water Development Board a recommendation and application to construct, at the Complex site, the facilities necessary to dispose of approximately 40,000 BPD of industrial waste water into the San Andres formation. This recommendation was based on the results of a comprehensive engineering and geological study of the San Andres formation obtained from data of wells drilled in Ector County. The geographic location of the disposal well at the Complex site was ideal as the San Andres formation is a well-developed carbonate reservoir but non-productive of hydrocarbons, proven by numerous drillstem tests and electric logs of wells drilled in the immediate vicinity of the Complex, with the nearest San Andres production 11 miles to the west in the Addis San Andres Field.

Extensive research was conducted on San Andres cores and San Andres-produced waters to determine the flow characteristics and compatability of the formation in the industrial waste water environment. The results of these tests indicated that it was feasible to inject large volumes of the Odessa Complex industrial waste water into the San Andres reservoir particularly

DIAGRAM OF THE ODESSA COMPLEX WATER SYSTEM

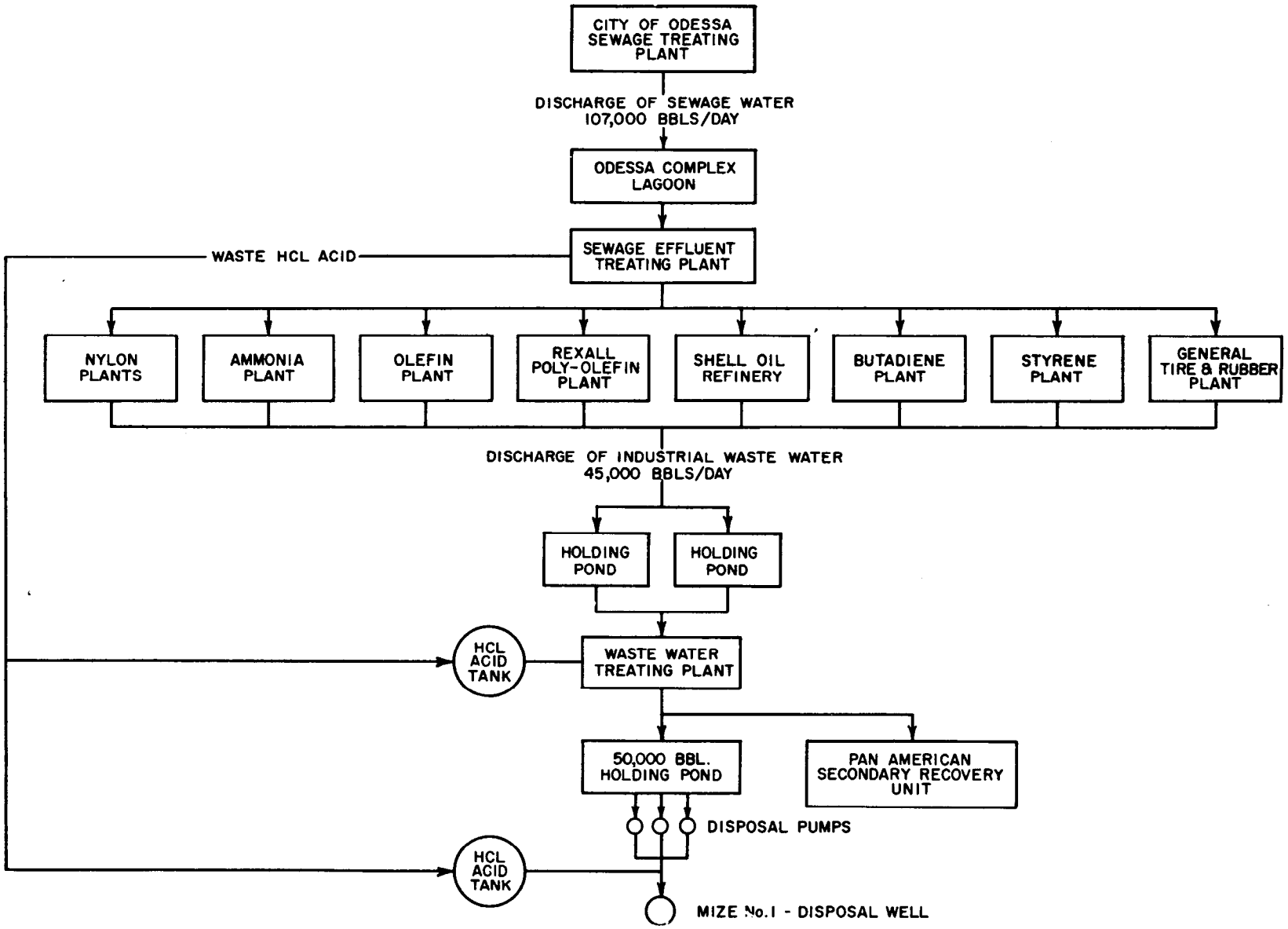

FIGURE 2

when the acidity of the injected water was controlled to produce a weak acid treatment of the formation.

The Texas Water Development Board, on March 30, 1965, approved El Paso Products Co.'s application to drill, complete, and operate an industrial waste water disposal well at the Odessa Complex.

THE MIZE NO. 1 DISPOSAL WELL

Prior to drilling the disposal well, El Paso Products Co. secured permission from the mineral owners and waivers from the companies holding oil and gas leases in the area for disposal of the industrial waste water into the San Andres formation at the Odessa Complex.

The drilling contractor was instructed in plant safety while operating within the confinement of the Complex and the drilling rig was equipped with safety equipment to prevent any occurrence of blow-outs or fire hazards as the well location was in close proximity to existing LPG subsurface storage wells. The storage wells use the Salado Salt section from 1900 ft to 3000 ft as a storage area which would be penetrated in drilling the disposal well.[1]

Drilling operations commenced May 12, 1965, drilling a 17-1/2 in. hole in the Red Bed formation to 516 ft at which depth 13-3/8 in. surface casing was set with cement circulated to the surface for protection of the surface potable ground waters. A 12-1/4 in. hole was drilled from beneath the surface casing penetrating the salt section at 1888 ft drilling interbedded salts, shale, and anhydrites to 4300 ft at which depth the formation changed to principally dolomite. The top of the San Andres was penetrated at 4870 ft and the well was drilled to the casing point of 4900 ft using brine as the circulating medium to prevent hole enlargement through the salt section. No difficulties were encountered and the well was drilled to the San Andres in 11 days using seven 12-1/4 in. bits. Electric logs were run and 9-5/8 in. casing was set at 4900 ft cementing in two stages with the stage tool set at 3467 ft for continuous cement protection from the base of the 9-5/8 in. casing to ground surface. The brine circulating system was replaced with a low solids fresh water drilling fluid suitable for coring and the entire San Andres formation was cored cutting a 7-13/16 in. hole from 5006 ft to total depth of the well at 5802 ft with full recovery of the San Andres core. The coring operation required 8-1/2 days of rig time and four diamond core heads were used. The drilling mud was displaced from the hole with fresh water and the well head installed for completion of the Mize No. 1 Disposal Well.

Analysis of the San Andres core showed three distinctive zones comprising the reservoir. The first, from 5006 ft to 5504 ft, consisted primarily of fossiliferous fractured limestone with an average permeability of 1.6 md (permeability of fracture intervals in excess of 100 md), porosity of 14 per cent, residual water saturations of 88 per cent of the pore space and 87 per cent soluble in HCℓ acid. The second, from 5505 ft to 5620 ft, consisted primarily of sandy limestone with an average permeability of 2.2 md, porosity of 14 per cent, residual water saturations of 80 per cent of the pore space and 14 per cent soluble in HCℓ acid. The third, from 5621 ft to 5802 ft, total depth, consisted primarily of dense limestone with an average permeability of less than 0.1 md, porosity of 1.5 per cent, residual water saturations of 90 per cent of the pore space, and 98 per cent soluble in HCℓ acid.

Data obtained from the core analysis pertaining to permeability damage with injected waste water in the San Andres showed that a weak concentration of acid, 0.3 per cent by volume, would eliminate any damage caused by precipitates and would in fact improve the natural permeability of the reservoir due to the high solubility of the limestone in an acid environment.

Each of the zones was acidized and swabbed to recover formation water which was analyzed and mixed with the Complex waste water and it was determined that the waters were compatible, that no precipitation would occur in this environment. The following is a chemical analysis of the San Andres and Complex waters.

Chemical Analysis	**San Andres**	**Complex**
Specific Gravity	1.015 @ 74°F.	1.001 @ 74°F.
Chloride	11,000 PPM	2,060 PPM
Bicarbonate	454 PPM	634 PPM
Sodium	6,026 PPM	1,995 PPM
Sulfide	Present	None
pH	7.1	7.1
Calcium	1,280 PPM	84 PPM
Magnesium	648 PPM	46 PPM
Sulfate	3,000 PPM	- - -
Total Hardness	5,900 PPM	400 PPM
Total Dissolved Solids	22,408 PPM	5,979 PPM

SCHEMATIC OF MIZE No. 1
INDUSTRIAL WASTE WATER DISPOSAL WELL

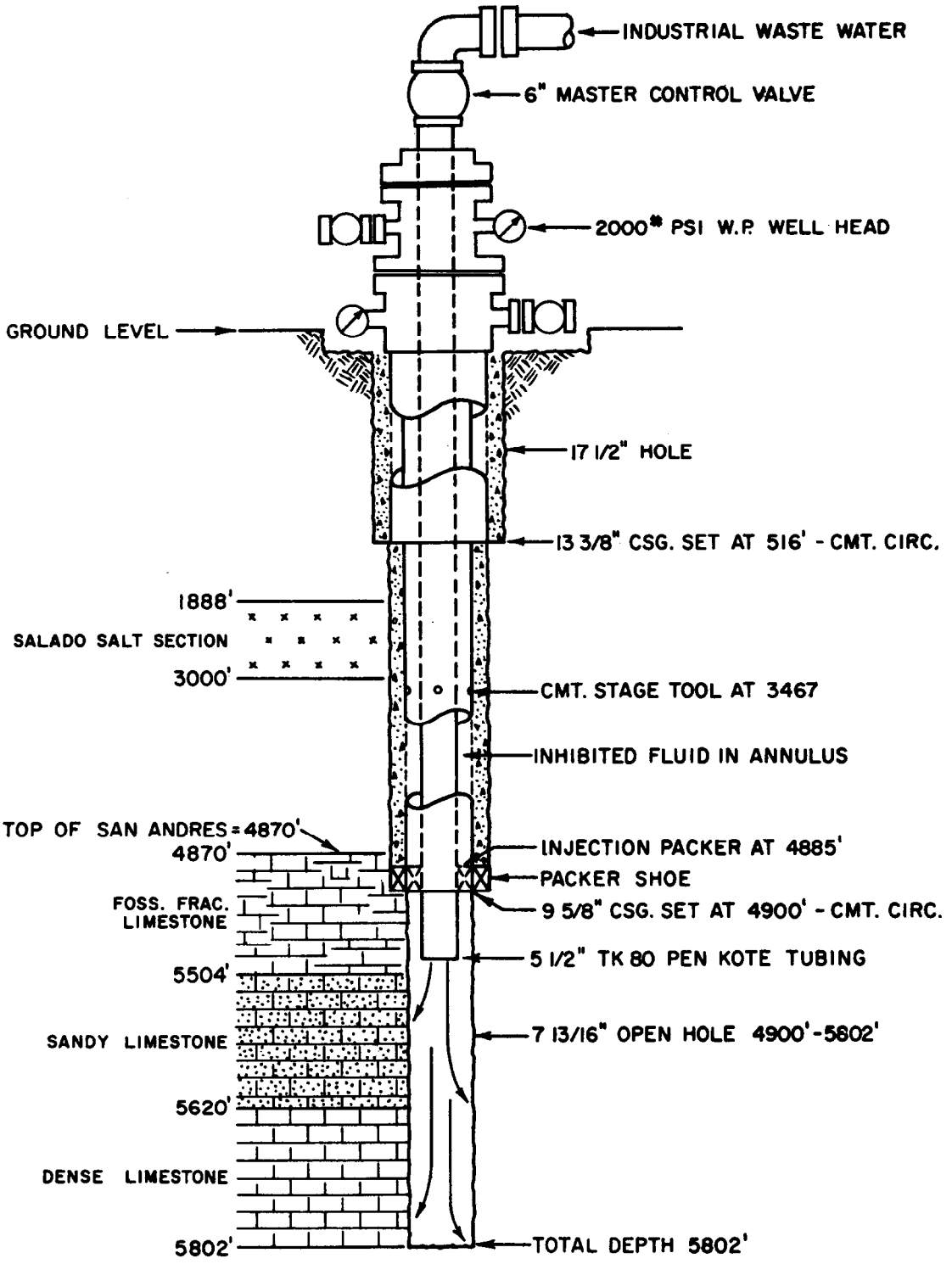

FIGURE 3

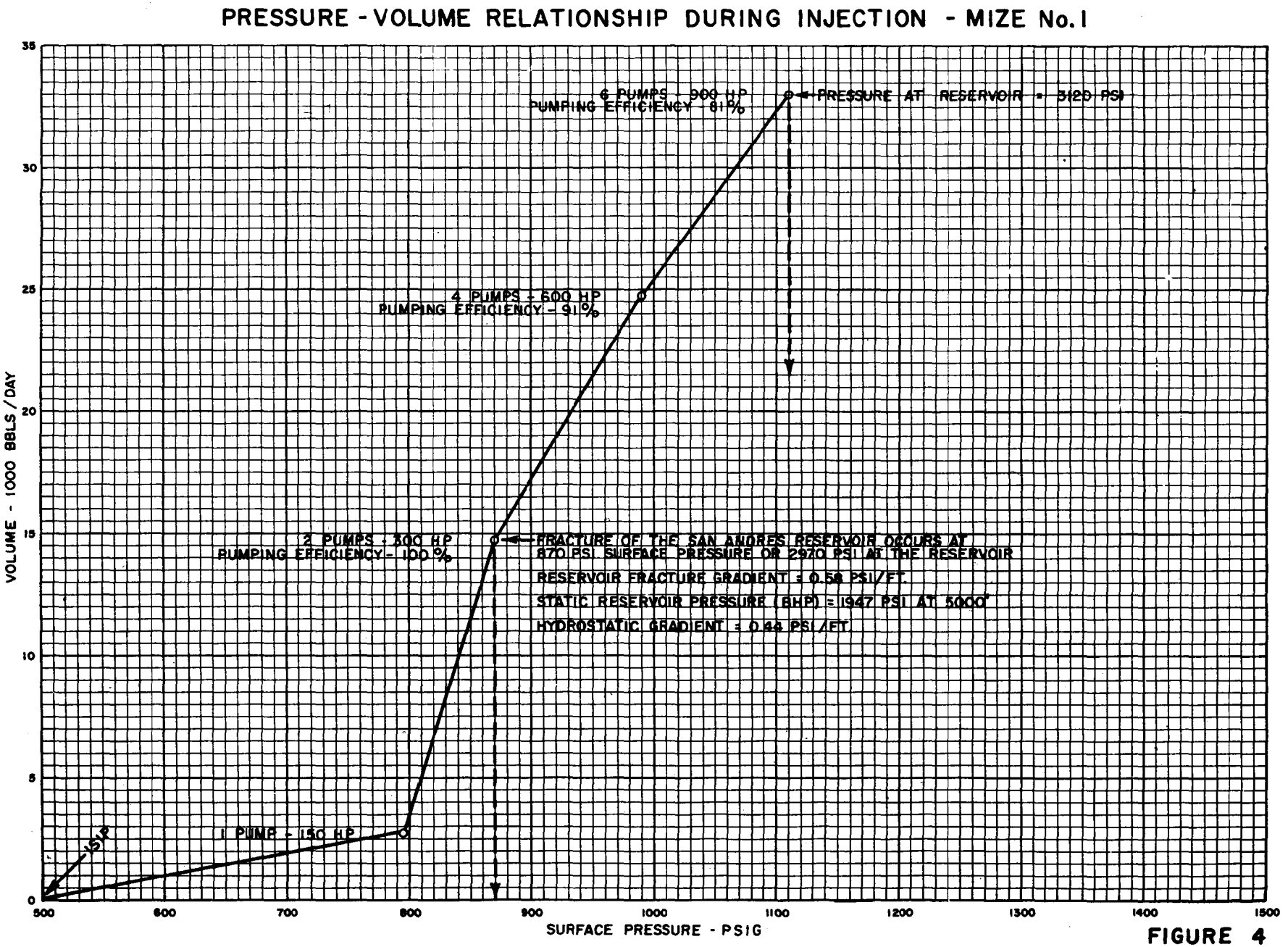
PRESSURE - VOLUME RELATIONSHIP DURING INJECTION - MIZE No. 1
6 PUMPS - 900 HP
PUMPING EFFICIENCY - 81%
PRESSURE AT RESERVOIR = 3120 PSI
4 PUMPS - 600 HP
PUMPING EFFICIENCY - 91%
2 PUMPS - 300 HP
PUMPING EFFICIENCY - 100%
FRACTURE OF THE SAN ANDRES RESERVOIR OCCURS AT
870 PSI SURFACE PRESSURE OR 2970 PSI AT THE RESERVOIR
RESERVOIR FRACTURE GRADIENT = 0.58 PSI/FT.
STATIC RESERVOIR PRESSURE (BHP) = 1947 PSI AT 5000'
HYDROSTATIC GRADIENT = 0.44 PSI/FT.
1 PUMP - 150 HP
45°
VOLUME - 1000 BBLS/DAY
SURFACE PRESSURE - PSIG
0
5
10
15
20
25
30
35
500
600
700
800
900
1000
1100
1200
1300
1400
1500

FIGURE 4

An experimental injection string of 6-in. ID Fiberglas tubing designed to handle capacities of 50,000 BPD at 1000 psi was developed for operation in the corrosive environment of acids mixed with the waste water. The Fiberglas tubing was latched into a production packer set at 4885 ft in the 9-5/8 in. casing with inhibited water circulated in the annulus. The Fiberglas tubing failed during the injection test period due to structural loading alternating from compression to tension resulting in fatigue (splitting) of the glass fibers to the bonding epoxy. The experimental Fiberglas tubing was replaced with TK-80 PenKote coated 5-1/2 in. OD J-55 steel casing using special Teflon seal couplings and tested holiday free as each joint was run in the well.[2] The Penton coated string was latched into the production packer at 4885 ft with the annulus filled with inhibited water and connected to the disposal pumps for injection. An injection test was conducted injecting 23 bbl per min (33,120 BPD) at 1100 psig without failure or communication and the Mize No. 1 Disposal Well was certified by the Texas Water Development Board as operational. Figure 3 illustrates the completed Mize No. 1 industrial waste water disposal well.

Excess industrial waste water, that is, the volume of treated plant water not required by Pan American for its secondary waterflood operations, is transferred from the water treating plant to the disposal well's 50,000 bbl Butyl rubber-lined holding pond. Three series of 2 Layne & Bowler Vertiline pumps, each powered by 150 Hp explosion-proof electric prime movers developing 13,700 BPD per series at 1000 psig, inject the water into the disposal well. Manifold into the discharge header of the injection pumps is an auxiliary triplex acid pump to inject plant waste HCℓ acid (3.8 per cent strength) for control of the desired acid level of 0.3 per cent by volume of the injected effluent. Volume pressure meters and pH recorders are downstream of the injection pumps to record the rates of disposal into the waste water disposal well. Figure 4 illustrates graphically the volume/pressure relationship of injection.

OPERATIONAL EXPERIENCE

Disposal of industrial waste water alternates from small daily injections to maximum rates of 33,000 BPD at 1100 psig depending on the daily demand of Pan American Petroleum Corp. for supplementary water for its secondary waterflood operations in Ector County. El Paso Products Co. disposed of 408,571 bbl in 1965, 1,407,409 bbl in 1966, and 566,000 bbl in January of 1967 into the San Andres formation.

CONCLUSION

Subsurface disposal of excess industrial waste water at the Odessa Complex is necessary for prevention of possible contamination of ground waters; however the cost of prevention is not inexpensive as the investment cost for the disposal system is approximately $200,000 with an average cost of two cents per bbl for treating and disposing of the waste water. El Paso Products Co., in expanding and developing new facilities at the Odessa Petro-Chemical Complex, recognizes the need for improving the reclamation of all waters as a valuable resource. Therefore, El Paso Products Co. is, at the present time, researching means and methods to reclaim and reuse the industrial waste water for plant use and subsurfacely disposing of only excess nonusable waste water.[3]

REFERENCES

1. Lockett, D., **Underground LPG Storage, Development and Operation,** Tenth Annual Southwestern Petroleum Short Course, April 1963.
2. AMF-Tuboscope, Product TK-80 PenKote, Houston, Texas
3. Kirkpatrick & Smythe, **History and Possible Future of Multiple Reuse of Sewage Effluent at the Odessa, Texas Industrial Complex,** American Institute of Chemical Engineers, February 1967.

ACKNOWLEDGMENTS

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