INJECTION OF WATER INTO UNDERGROUND RESERVOIRS IN THE STATE OF MICHIGAN

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ABSTRACT

Injection of water in Michigan has been solely for the purpose of disposal, but regulations have been such that in excess of 90 per cent of oil-field waters are returned underground. The paper discusses the types of equipment used in injection wells and disposal systems, as well as describing the injection characteristics of each of the seven different formations employed for disposal purposes. Statistics on injection wells by years and by formations are detailed and summarized.

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INTRODUCTION

This study of water injection into underground reservoirs in the state of Michigan is made by the author as a member of the API Eastern District Production Technology Committee. It is stated at the outset that, with one exception, there is no record of water injection in the state of Michigan having been performed for the expressed purpose of secondary recovery of oil but, rather, that the primary purpose of all wells and projects investigated has been for the disposition of water into underground reservoirs in order to prevent pollution of lands, surface waters, and shallow-water wells. The sole exception was the periodic injection of small quantities of water in conjunction with a gas-injection program in the Greendale Field. This was done in one well for a period of approximately 3 weeks in 1932.

The source of information for this study has been semi-annual and special reports of the Oil and Gas Division of the Michigan Department of Conservation, from personal contact with the employees of this department and with the personnel of operating companies, and from general experience in this state.

Purpose

The purpose of this study is to compile all the available statistical information pertinent to water injection in Michigan, to analyze these data in order that significant conclusions might be reached, to describe sufficiently the physical injection and its inherent problems, in order that all such facts will be available for the use of Michigan oil operators and the industry as a whole.

History of Water Injection.

The tourist trade is the second largest industry in the state of Michigan, and for that reason the Department of Conservation in this state has paid particular attention to the matter of prevention of stream pollution resulting from the disposition of oil-field wastes into surface waters. An excerpt from the “general rules and regulations” governing oil and gas operations in the state of Michigan, effective May 1, 1941, best explains the attitude of this department, and is as follows:

“Brine or salt water produced in the drilling for, or the production of, oil shall not be run to earthen reservoirs or ponds, except for such reasonable time and under conditions as may be approved by the supervisor, or his authorized representative, after which it must be returned to some underground formation or otherwise disposed of as approved by the supervisor where it cannot do damage to any fresh water, oil, gas, or other minerals.”

It is for this reason that the oil and gas industry in the state of Michigan in recent years has had such an enviable record in returning underground in excess of 90 per cent of the oil-field water produced, the balance going to ponds constructed for storage. Reference is made to Fig. 1 which illustrates graphically total oil production in the state by years from 1925 through 1944, together with the total yearly water injected during this period. It is noteworthy that during 1937 and 1938 the total water injected was equal to half the total oil produced, whereas currently total water injected is equal to 1½ times the oil produced. Total water injected underground to midyear 1944 is in excess of 150,000,000 bbl.

Fig. 2 is a generalized transverse section of the Michigan synclinal basin from which area the majority of the oil is produced and into which area all of the water is injected. This figure illustrates the approximate thickness and depth of the formations which are used for oil production, viz., the Drift, the Parma, the Marshall, the Coldwater, the Traverse, the Dundee-Monroe, and the Sylvania. Fig. 3, which is included for reference, shows the location of principal Michigan oil fields.

Table 1 lists water-injection wells by fields and indicates: the formation or formations into which each well is opened, the type well, the estimated cumulative injection to June 30, 1944, the 1944 approximate daily rate of injection, and whether or not the well operates on a
pressure or vacuum. A search of the records reveals that there was little information available on water injection previous to 1937, notwithstanding the fact that there were probably a few water-injection wells in existence previous to that time. Therefore, the total cumulative injected barrels contained in this report include no water previous to 1937. It is to be appreciated that the water-injection volumes were prepared from semi-annual estimates of the daily average injection as of July 1 and January 1. Naturally, a change in method of operation would involve errors in the calculation of these total quantities, but it is believed that these errors are sufficiently compensating to make the totals a reliable estimate.

Table 2 is a summary of statistical data revealing by years: the number of wells, the daily average rate of injection, and the yearly total injection in the different types of wells used for water disposal. Table 3 is an analysis of 1944 injection, showing for each injection formation: the number of wells, and the total yearly injection for 1944, with a breakdown as to the wells operating by pressure or by gravity. Further analysis reveals the percentage of the total number of wells and percentage of the total water injected, as well as the average rate of injection for each respective formation.

Description of Operations

Well Completion and Operation

There are 3 general classifications of disposal wells insofar as the mechanics of completion and operation are concerned: 1, wells which inject water into the annular space between casing strings; 2, wells which were originally dug in search for or were used for production of oil and gas and were later converted to water-disposal wells; 3, wells which were dug for the specific purpose of water injection.

Table 2 illustrates that, although there have been 316 wells which injected water between the casings and 120 which have been completely converted to water disposal, the former type wells have contributed a total of approximately 50,000,000 bbl of water injected as compared to a total of 97,000,000 bbl for converted wells. There have been only 18 wells dug specifically for the purpose of water disposal, and the total water injection into this type of well has been less than 3,000,000 bbl to date. In view of the fact that there are so many disposal wells in the state injecting water between strings of casing, it would be helpful perhaps to mention briefly the method of well drilling and the casing program in order that this type of injection may be more understandable.
The thickness of the glacial drift in Michigan varies from 100 ft to 1,100 ft. A great percentage of the wells are drilled with cable tools, and in such cases surface casing is generally driven completely through the Drift. Many, although not all, of the cable-tool wells, set a permanent intermediate casing string. Most production strings are set on a shoulder with a packer, and without the use of cement. Surface casing in rotary-drilled holes is set from 100 ft in the Drift to the base of the Drift. Both intermediate strings, when used, and production casing strings are cemented in the rotary holes. The resulting casing programs in both cable-tool and rotary wells make available the annular spaces between the surface casing, the intermediate casing, and the production casing, for water disposal to any of the several formations which are usable for this purpose.

Wells converted for salt-water disposal may use the formation in which they were originally completed, may have been deepened to other horizons, or may have been perforated in shallower permeable zones. Wells dug specifically for the purpose of salt-water injection have been dug to the Drift, to the Parma, but no deeper than to the Marshall formation.
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**Well:** [Well Name]

**Formation:** [Formation Name]

**Depth:** [Depth in feet]

**Date of Injection:** [Date in Y/M/D format]

**Rate:** [Injection rate in gpm]

**Duration:** [Duration in hours]

**Comments:** [Additional information]

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**Number of Tables:** 3

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**Table 1**

**Table 2**

**Table 3**
Injection Equipment

There is no record of either chemical or physical water treatment in disposal plants other than the use of sufficient skimming tanks to separate oil from water, and the use of oil seals to prevent the contact with air from the time of production to the time of injection. Steel pipe, either new or used, is employed in gathering lines for the transportation of salt water in the vast majority of cases. This does not mean to imply that the Michigan salt water, or brines as they are commonly termed, are non-corrosive; for there is evidence of corrosion in all types of equipment associated with saltwater disposal. However, the life of the properties has been relatively short, and apparently operators have not taken pains to install non-ferruginous materials. In later years there have been several installations of Transite lines to eliminate the corrosion problem.

Referring to Table 3, of the total of 279 wells in operation during 1944, 194 took water by gravity and 85 required pressure for the disposal of water. In the majority of the cases pressure is furnished by pumps connected to the walking beam of the producing wells. This is particularly true in the case of scattered operations or small volumes of water. A larger concentration of operations, or larger quantities of water, are generally served by separately-powered and centrally-located pumps installed for use in conjunction with a disposal pipe-line system.

Well Treatment

The contaminating materials resulting from inadequate physical or chemical treatment of the water which cause the plugging of injection wells are principally carbonates, iron oxide, salts, and paraffin. There has been an appreciable amount of trouble from these several contaminating agents which periodically reduce the ability of injection wells to take water. However, it is generally believed in Michigan disposal operations that, considering the overall picture, it is cheaper to treat wells after they have become partly contaminated than it is to prevent contamination by the installation of complex and comparatively expensive water-treating equipment.

There are four different methods of well treatment or repair which are generally applied to water-injection wells in this state. They are, in order of their general importance: acid treatment, application of pressure, fresh-water injection, and lye-solution injection.

Acid treatments, varying in concentration of hydrogen chloride from 15 to 30 per cent, have been extremely successful in increasing the effective permeability of limestone-injection wells by either dissolving the reservoir rock, dissolving the contaminating material, or both. No accurate records of the frequency of this type treatment are available, but the acid service company most generally employed for this work in the state reports in excess of 30 acid treatments per year from 1940 through 1944. In addition to these treatments, a considerable quantity of bulk acid has been sold to operators injecting their own acid with lease equipment. In many cases it is the practice to repeat acid treatments on certain wells at not infrequent intervals, thereby periodically increasing the capacity of the well to meet requirements.

Pressures, generally not in excess of 1,000 psi at the surface, are applied to wells which have experienced a decline in injection rate, and results have been sometimes quite successful. Pressures so applied to limestones and the unconsolidated sands of the Drift break down any film of contaminating materials that may be against the permeable portion of the formation.
The injection of fresh water to dissolve water-soluble salts has been used with some success, and is often done just previous to an acid treatment.

It is reported that well treatments have been effected by the injection of a solution of ordinary lye, but little is known of the results.

**Description of Disposal Formations**

**Glacial Drift**

The Glacial Drift covers practically all of the state in which there exists the problem of salt-water disposal. The Drift is an unconsolidated formation varying in thickness from 100 ft to 1,100 ft containing sands, gravel beds, boulders, and clay. This formation generally contains water which may be potable at any depth, although normally it has sufficiently high salinity at its base to be unsuitable for domestic or commercial uses, and it is, therefore, sometimes employed for water disposal. The unconsolidated nature of this formation makes well completion for disposal a relatively difficult procedure, but the method of setting casing through the Drift and gun-perforating has proved relatively successful. Perforating with $\frac{1}{3}$-in.-diameter bullets has recently been tried to prevent sanding-up of these wells. When disposal is effected into this formation between strings of casing, it is always unknown as to just how much of the formation might be exposed or, rather, how much of the formation has caved or bridged.

**Parma**

Notwithstanding the current use of the Parma formation in 108 disposal wells, a limited number of cores from this formation do not indicate that it would lend itself readily to water injection. This formation is generally a relatively impermeable sandstone with some carbonate cementing material which responds to acid treatment in some areas. The number of disposal wells in this formation is 38.7 per cent of the current total in operation, but these wells contribute only 17.2 per cent to the total injection of water—which fact would tend to confirm the mediocrity of this formation for injection.

**Marshall**

The Marshall formation consists of relatively thick sands interbedded with shale. This formation has not been used a great deal because of its relative depth and its proximity to the Michigan Stray gas sand which it immediately underlies; i.e., sufficient protective measures for the Michigan Stray must of necessity be taken where it is gas-bearing, and the use of the Marshall for water disposal has been generally precluded in such areas.

**Coldwater**

There are a total of 61 disposal wells which inject water into the Coldwater lime, the porous lime member in the basal part of the Coldwater shale formation. All of these wells are located in southwestern Michigan, and all water disposal into this formation is in the annular space between casings. These wells represent 21.9 per cent of the current total number of wells, but contribute only 6.3 per cent to the total water injected. Disposal into the Coldwater formation has been by gravity when quantities less than 100 bbl per day are injected; whereas pressure is generally required for quantities in excess of 100 bbl per day. Acid has been used in most of these wells with good results. Some of these wells have required pressure during the initial period of injection, later breaking down and taking water by gravity. Water in the Coldwater formation has been found to be fresh in some areas in southwestern Michigan.

Because of the setting of surface casing above the base of the Drift in some wells, and the destruction of drive-pipe casing seats at the base of the Drift as a result of injection breakdown pressures as high as 600 psi, there is the probability that at least a portion of the water allocated to the Parma, Marshall, and Coldwater formations is actually going into the base of the Drift formation. Just what percentage of this water finds its way to the Drift is naturally unknown, but mention is made of the fact in order that the quantities allocated to these other three formations might be qualified to forestall any misrepresentation of the ability of these formations to take water.

**Traverse**

The available permeable lime members of the Traverse formation readily lend themselves to water disposal. Generally, there exists a lime bed in the upper portion of the formation which may or may not be sufficiently permeable for water injection. At greater depths in this section the limes may or may not be present. It should be noted that the ability to find a permeable lime in the Traverse formation will not only vary from field to field, but from location to location—which fact distinctly lowers the number of disposal wells in this formation.
the desirability of this formation as a potential water-disposal horizon. Notwithstanding, in fields where the permeable zones have been found, they have a great potential capacity for disposal. There are, as of mid-1944, 42 Traverse disposal wells in the state which are returning during the year 4,800,000 bbl, or 14.3 per cent, of the total water. It is to be noted that of the total of 42 wells presently in operation, 32 take water by gravity. The significance of this is that Traverse wells are used for disposal principally in fields which have Traverse production, and most generally there will be some degree of pressure decline within these reservoirs. This results in a progressively lowering static fluid level in injection wells, affording a greater height to the injected column of water, with the resulting advantage that there is available for injection increased pressure at the formation.

Dundee-Monroe

The Dundee and Monroe formations have been grouped together, and include the porous members of the limestones and dolomites below the base of the Bell Shale. The Monroe formation is designated on the generalized transverse section, as the upper part of the Detroit River formation. These zones are presently being used in 38 water-injection wells (13.6 per cent of the total), and have contributed 18,000,000 bbl injected, which represents 53.6 per cent of the total for 1944. As in the case of the Traverse formation, the wells which are used for disposal in the Dundee-Monroe exist in fields which are producing from these formations and enjoy the same benefits of declining reservoir pressures. All of these 38 wells are operated by gravity.

Sylvania

Only two wells are known to have been open to the Sylvania formation for water injection and, therefore, adequate information on this horizon is lacking.

SUMMARY

The unavailable portion of the early history of water injection in the state of Michigan does not represent a sufficiently high percentage of the data to make an appreciable difference in the total picture presented herewith. Water has been injected in sufficient volumes, and with sufficient variance of attendant conditions, to conclude that the information available can be a guide to future operations in Michigan, as well as an addition to the general information available on the subject of water injection.

Formations available for water injection in the state are numerous, and have proved adequate (with a minimum of expense) to dispose of the vast majority of the water incidental to the production of oil. It is noteworthy that, currently, half of the total number of wells in operation inject into a limestone, and that these wells contribute three-quarters of the present water injected. Attention is again called to the fact that the best available wells for injection are those completed in the same horizons as the oil-producing wells because of the advantage resulting from declining reservoir pressures. Capital cost of accessory equipment for injection has been comparatively low in the state, as has been the cost of equipment, maintenance, and well repair.

ACKNOWLEDGMENT