

címa **CAPITAN** incorporated

(N.S.L.)

312 BOOKER BUILDING
POST OFFICE DRAWER 1343

ARTESIA, NEW MEXICO

AREA CODE 505
TELEPHONE 748-1125

October 17, 1967

Oil Conservation Commission
Santa Fe, New Mexico

Re: Application of Hudson and Hudson
for an exception to Order No. R-3221

Gentlemen:

With reference to the subject application, Cima Capitan, Inc., an oil operator in Eddy County, supports the application of Hudson and Hudson.

It has been the experience of the oil operators in Eddy County, who have drilled wells throughout the area from the escarpment at Maljamar to the Pecos River, that no significant potable water exists in this area. Therefore there is no fresh water to contaminate.

Oil operators have drilled throughout the area in search of water of any nature to be used as a source of water for water flooding. Only in the vicinity of Red Lake has any substantial water been found and this water is very saline and mineralized. For this reason, practically all the water for flooding is piped at a considerable cost, from the Ogallala formation found east of Maljamar.

It seems utterly ridiculous that produced oilfield brines could in any way contaminate something that does not exist in any significant quantities, and where it does exist in limited quantities, is already of a quality which is unpotable and unfit for any beneficial use.

The oil industry in New Mexico was among the first to practice the conservation of natural resources. Certainly no one in the industry would hesitate to go to any cost to prevent an actual damage to fresh water resources. However, in the area west of Maljamar to the Pecos River, it is obvious that no contamination is occurring. A great economic hardship will be placed on many operators if the order stands as written; and many wells will be prematurely abandoned--resulting in economic losses to the area and to the state in taxes and royalties.

Very truly yours,

CIMA CAPITAN, INC.



Hal C. Porter,
Vice-President

Oct 19 1967

HCP:ms



UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
P. O. Drawer 1
Artesia, New Mexico 88210

October 13, 1967

CERTIFIED MAILRETURN RECEIPT REQUESTED

Mr. William A. & Edward R. Hudson
Post Office Box 198
Artesia, New Mexico 88210

Re: Leases LC 029415(a) & (b)

Gentlemen:

This office has received a copy of New Mexico Oil Conservation Commission Docket No. 32-67 listing cases to be heard before the Commission on October 18, 1967. Reference is made to your application to continue using surface pits to dispose of waste waters produced in conjunction with the production of oil from the waterflood projects on your Puckett "A" and "B" leases in secs. 24 and 25, T. 17 S., R. 31 E., for a period of one year after January 1, 1968.

The lands in your Puckett "A" and "B" leases in secs. 24 and 25, T. 17 S., R. 31 E., are Federal lands covered by the subject leases. The leases have been inspected, and it has been determined that the leases are subject to surface pollution and damage by improper disposal of salt water.

Federal Oil and Gas Operating Regulations require the disposal of waste water in such a manner that will prevent damage to the surface or pollution of streams or underground waters of the leases or other lands (see 30 CFR 221.32).

We feel that the eight-month deadline prohibiting surface disposal pits in waterflood operations as provided by New Mexico Conservation Commission order No. R-3221 dated May 1, 1967, is reasonable, and should be upheld.

Therefore, you are requested to properly dispose of the produced water on subject leases and cease using all surface pits after January 1, 1968.

Sincerely yours,

10/16 820 JAMES A. KRAUF

James A. Krauf
District Engineer

Copy to: R. L. Gray (delivered by hand)
M.M.O.C.C. ✓
U.S.G.S., Roswell

THIS IS A PREPRINT --- SUBJECT TO CORRECTION

Applying Water Chemistry to Recovery

By

Waylan C. Martin, Member AIME, Martin Water Laboratories, Monahans, Tex.

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American Institute of Mining, Metallurgical and Petroleum Engineers, Inc.

ABSTRACT

This paper presents the established and theoretical influence of the chemical and physical properties of water on ultimate recovery of crude oil. Establishment of useful data and their consequent evaluation in regard to the effect of filterable solids and potential precipitates on recovery are covered. A review of experiences and current research on pressured water effects on the reservoir are presented, with special concentration on calcium sulfate.

INTRODUCTION

The primary objective in the presentation of this paper is to review field experiences and laboratory results of the chemical and physical studies involving secondary oil recovery by water repressuring. There has not been adequate opportunity to effectively correlate these conditions with the existing literature that reports data both directly and indirectly related to the subject matter.

The remoteness of the producing interval and the use of comparatively small core samples for studies have left us with the inability to accurately duplicate formations and their natural conditions. There particularly seems to be a limitation on the data of producing intervals in regard to the natural connate water [hereafter used as a reference to the total original interstitial water in the reservoir], the chemical characteristics of the matrix, and the sensitivity of the matrix to the foreign water introduced in an injection program and the changes that result therefrom. This paper makes a meager effort to reveal some of the conditions encountered and the interpretation of their implications.

FILTERABLE SOLIDS IN INJECTION WATER

A factor that is frequently puzzling in a waterflood project is the significance of the
References and illustrations at end of paper.

filterable solids. The author suggests the use of this term "filterable solids" as describing that material suspended in the water that has particle sizes in excess of 0.5μ [one micron equals 0.001 mm] in diameter. This generally differentiates the significant suspended solids from smaller suspended particles such as colloids, which are not filtered out by normal millipore filter tests and are not considered of significance in a flood water. This also separates these filterable solids from suspended liquids such as oil.

The interpretation of the significance of filterable solids in injection waters is relatively complex and involves a multitude of factors. The nature of the solid is considered the primary factor in such an evaluation. It becomes necessary to include consideration of the particle sizes, the relative number of the different sizes, and the physical characteristics of the particles. Another factor of considerable concern in regard to these particles is the permeability of the combination at higher pressures. Also to be considered in this regard are the interstices in the formation through which these particles must pass. This in itself involves considerable complexity in view of the different sizes of interstices in a single zone and the relative distribution of these sizes. This is further complicated by the variation in interstices from one zone to another in the same producing interval. It is immediately apparent that this subject is entirely too broad to allow detailed coverage in the paper; therefore, it will be covered more generally by relating actual conditions and the implications.

In making massive numbers of filtration tests at the injection wellhead pressure, it is immediately apparent that, if the producing interval were as tight as a millipore filter [0.45μ], then the injection well would plug almost immediately in many instances. In view of the fact that the formation does not plug with anywhere near the rate that is indicated on

the millipore filter, it is then apparent that at least partial penetration into the formation by these filterable solids does occur. It is further apparent that this penetration is not minor [that is, a few feet], as there would be relatively rapid plugging if they were held up in the immediate vicinity of the injection wellbore. Though the efforts to identify these filterable solids at the producing well are plagued with many complications, there have been several instances in which it is considered conclusive that these particles do not reach the producing well in anywhere near the amount that is injected, if at all. This evidence includes even bacterial cells in that the bacterial flora of the injection and return waters do not correlate in all instances. It should also be brought out that some constituents that are dissolved in the injection water, such as phosphate, do not appear at the producing well in the return water. It would then be concluded that the limited studies that have been directed toward this subject give at least preliminary indications that these filterable solids are typically stopped in situ at some point in which they attempt passage of an interstice that is of insufficient size to allow penetration.

The foregoing indications are sufficiently stable to allow careful consideration of the following two questions: [1] Does this in-situ restriction of interstices by the filterable solids significantly influence the ability of the injection water to sweep a maximum amount of oil from the producing interval? [2] If there is a detrimental influence on the sweep efficiency, then are we crediting this condition in its proper proportion when a reservoir does not appear to be responding as anticipated just because the evidence of direct plugging of the formation face in the injection well does not appear?

In answering the above questions, it is necessary to evaluate all the potentially influential conditions involved in any single project. Even though the evidence is slight and scattered, it is our opinion that the presence of excessive filterable solids does significantly influence the sweep efficiency, whether or not there is definite injection wellbore plugging. It is further considered likely that this is more frequently involved in lower permeable zones and therefore is inclined to have an undesirable influence on water channeling tendencies. It appears advisable to consider this factor in reservoir evaluations, and especially while a flood project is in progress.

The reader should be cautioned not to interpret this as indicating that an injection water needs to be perfectly free of filterable solids. It is becoming generally accepted in

the oil industry that, in the absence of oil, an average filterable solids of less than 1.5 mg/liter is satisfactory. In the presence of oil, this material is usually coated; therefore, the tolerance is increased to approximately 2.5 mg/liter. This should not be confused with suspended oil, for we believe that in the absence of filterable solids the liquid suspensions do not result in an obstruction. As the average filterable solids begin to exceed these figures, the concern becomes directly proportional to the amount. There are exceptions to this as, for example, 1.5 mg/liter of bacterial cells is considered a prominently detrimental condition, whereas this quantity of large sand particles is of concern only in the abrasive effect.

FILTERABLE SOLIDS DEVELOPMENT IN SITU

The in-situ development of filterable solids becomes even more complex in its implications than filterable solids in the injection waters. Most common reference in this regard is to the compatibilities between the injection water and the reservoir and its natural connate water. In a great majority of instances, the chemical and physical characteristics of the natural connate water give at least a preliminary indication of the water sensitive characteristics [excluding swelling clay] of the reservoir. Studies have shown that in most cases satisfactory compatibilities between injection waters and natural connate waters will simultaneously suggest compatibility with the chemical properties of the reservoir. The exception to this is when the produced water is indicative of the possibility of the existence in the reservoir of an undissolved salt that is soluble to any extent in water. Studies have revealed that the matrix can be as much as 8 percent water soluble in formations in the Permian Basin.

Studies of incompatible conditions have revealed an extremely wide variation in the quantity of filterable solids that would be anticipated to precipitate in situ. These have shown quantities varying from 0.1 lb to 3,000 lb of solids precipitating per 1,000 bbl of water injected. It is immediately apparent that the former would be completely insignificant, whereas the latter would likely result in no response at the producing wells. Quantities between these two figures occasionally require decisions with consideration being given to reservoir characteristics, source and cost of different waters, etc. Of course, this is also clouded with the inevitable doubt of just how much of the predicted precipitation will actually occur in the footage between injection well and producing well.

In regard to this decision, there is the ever-present question of how much in-situ mixing

there is between the injection water and the natural connate water; if, in fact, there is any at all. It seems clearly evident that there is at least some mixing of natural connate water and injection water in situ. This is apparent in that, as the injection water reaches the producing well, there is not a completely abrupt change; but rather the returning injection water continues to carry produced water characteristics for a considerable length of time in practically all instances.

Efforts to identify the relationship between sandstone interstices and passage of filterable solids have not been conclusive. An example is a single sandstone that was examined in regard to sand particle sizes, with permeabilities in the range of 5 to 50 md, and that did not show any uniform variation in the proportion of sand particles of different sizes. The average sand particle size ranged near 100 μ in each core sample in this permeability range. However, if interstice sizes could be effectively evaluated, there would still not be a definite indication of the potential particle size passage. This involves the fact that openings of certain sizes will filter out much smaller particle sizes.

CALCIUM SULFATE SOLUBILITY AND PRESSURE

The fact that the most common of all precipitates in the Permian Basin is calcium sulfate has prompted a concentrated study of this compound. Studies that have been in progress since 1956 have been reasonably reliable in estimating the solubility of calcium sulfate in the average oilfield waters in the Permian Basin. This study has applied only to natural waters, as there was a failure to obtain satisfactory correlation with artificially constructed waters. The dominating influences to consider in determining whether a water is supersaturated with calcium sulfate are the calcium-to-sulfate ratio and the chloride concentration [calculated as sodium chloride] as exemplified in Fig. 1. These studies have indicated that the factors which either have too limited effect to be considered or are very inconsistent in their involvement are the levels of temperature, magnesium, bicarbonate, or hydrogen sulfide. If any of these varies widely from the average, it is then taken into consideration. The magnesium and temperature have been previously reported as other influencing factors.^{1,2}

A very common production problem in the Permian Basin area has always been the restriction of flow of fluid into the producing wellbore by depositions of calcium sulfate. Our experiences have been that pressures were involved in these depositions on the face of the formation.³ One of the most prominent field indications of this involvement of pressure is

that many fields that do not show this problem during primary have encountered it as a major problem when the producing interval is re-pressured. This has prompted the following concentrated study on the involvement of pressures and calcium sulfate solubility.

Method

The waters used for these experiments were all taken from various oil-producing or related intervals. The specific study reported herein was made on an equal combination of El Capitan Reef water and Yates water. This water had a chloride content of 38,000 mg/liter as sodium chloride. Theoretical combinations were utilized in reporting the results. This water was placed in a chamber with 2 percent anhydrous calcium sulfate powder and the pressure brought to 4,500 psi at 80F and held for 48 hours. A sample was then removed, filtered, and calcium and sulfate determined immediately. This sample was then divided, with one half being untreated and the other half being treated with 1 percent anhydrous calcium sulfate powder. Each of these was allowed to stand in the dark sealed at 80F at atmospheric pressure for a period of 24 hours. They were filtered, and calcium and sulfate determined on each. The pressure on this chamber was then dropped at 48-hour intervals to 3,500, 2,500, 1,500 and 500 psi. Identical procedures were then carried out on each of these samples with the exception that mild agitation was periodically given to the untreated aliquot that was taken at pressures of 3,500 and 500 psi.

Results

The results of the above tests are reported in Fig. 2. They reveal a definite increase in solubility to calcium sulfate with an increase in pressure. The average test indicated that this water would hold approximately 1,400 mg/liter [490 lb/1,000 bbl] more calcium sulfate at 4,500 psi than it would at atmosphere. They further show a gradual precipitation of calcium sulfate on reduction of pressure with a definite acceleration resulting from the presence of calcium sulfate powder or agitation. The presence of sand in other tests did not show an acceleration of precipitation as did the calcium sulfate powder.

Conclusions

It is concluded from this study that when any water enters a formation and is exposed to anhydrite, it then becomes saturated with calcium sulfate at that pressure at a rather rapid rate. As the pressure then declines, this calcium sulfate will in turn commence precipitation and if additional anhydrite is encountered, the rate of precipitation will be accelerated. Movement through the formation may produce

sufficient agitation to cause at least some acceleration of precipitation. If a continuous drive is sustained within the reservoir, then the more prominent drop in pressure and agitation will occur as the fluid enters the wellbore of the producing well. As the calcium sulfate deposit starts to build on the face of the formation, it then tends to accelerate the rate of additional depositions. If the fluid is gaseous, some additional agitation could be expected that would cause additional acceleration of precipitation. The author suggests that substantially more influence of fluid flow restriction by calcium sulfate results from this principle than results from the influence of temperature and evaporation.⁴

Some extreme field situations we have experienced tend to throw significant light on the foregoing. In one instance, a well receiving water at approximately 5,000-psi bottom-hole pressure was backwashed, and three minutes out of the formation it was found to be severely supersaturated with calcium sulfate. This tends to reveal how rapidly the water becomes saturated with calcium sulfate at a given pressure after it has been injected. Another example was two immediately adjacent leases. One project had a single injection pump, was occasionally down for several days, eventually lost communication between injection wells and producing wells, and had no trouble with calcium sulfate at the producing well. The adjacent lease had continuous uninterrupted injection and did not lose communication between injection wells and producing wells, but had a prominent gyping problem at the formation face in the producing wells. This latter example tends to indicate that the first lease allowed pressure drop in situ and experienced essentially all of the precipitation there, whereas the second lease maintained more consistent pressure in situ and experienced more precipitation at the producing well.

SUMMARY

Current data on the significance of filterable solids in injection water are classified as incomplete, but the evidence available is indicative that these solids most frequently are involved in in-situ obstruction of interstices as opposed to the less common wellbore plugging at the injection well. The development of filterable solids in situ on the introduction of a foreign water, which is commonly referred to as incompatibility, is a potential detriment to sweep efficiency when it exists between two waters or between the injection water and water soluble salts in the matrix. The concentrated studies on the influence of pressure on calcium sulfate solubility give conclusive evidence of its involvement in restriction of production by scale in the producing wellbore. The studies further reveal a distinct probability of some calcium sulfate precipitation in situ by virtue of its becoming saturated at the pressure in and around the injection well and then precipitating as the flood water proceeds toward the producing well with a declining pressure.

ACKNOWLEDGMENT

The author wishes to acknowledge the assistance of W. Reagan White in the experimental procedures.

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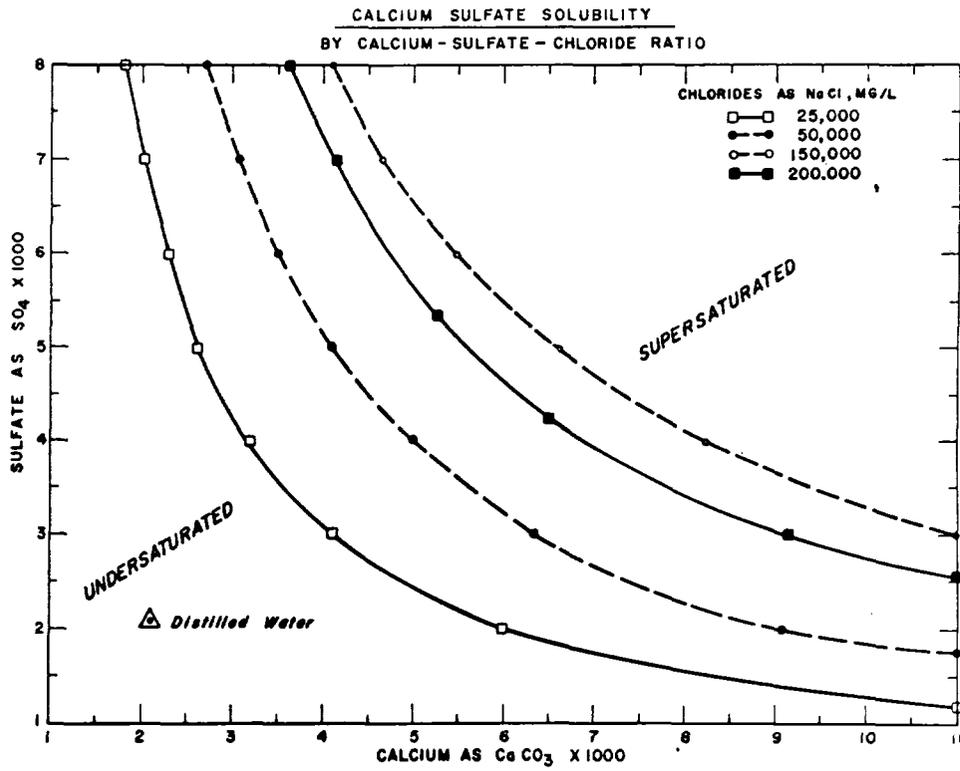


Fig. 1

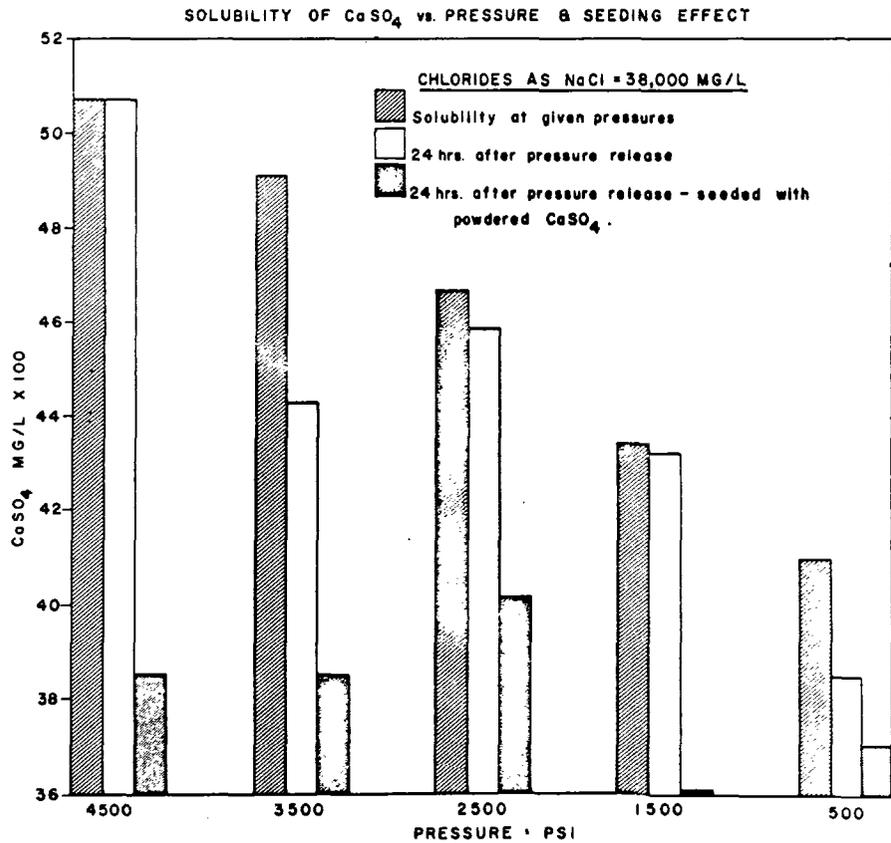


Fig. 2



Wm A. & Edward R. Hudson -
Puckett "B" Lease water
disposal pit - looking
west from battery walk
way.

Cases 3664 + 3665 //

Pictures taken Oct. 16, 1967.



Wm A. & Ed. R. Hudson -
Puckett "A" Lease - Edge
of salt water pit looking
east. Waterflood plant
is in background.

Cases 3664 +
3665

Picture taken Oct. 16, 1967



Wm A. & Ed. R. Hudson -
Puckett "B" Lease water
disposal pit - looking
north east ward.

Case 3664 + 3665

Picture taken Oct. 16, 1967.