The Handling of Produced Salt Water for Injection

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INTRODUCTION

The increasing importance of salt water handling, either in disposal or water-flood operations, has demanded development of better methods. A full understanding of basic parameters is a fundamental prerequisite to creating the best plant design and to determining the most effective operating practices. Toward this end various methods have been proposed to define "water quality", diagnose problems, predict potential problems and ultimately, to use these technical methods to maximize operating efficiency.[1,2,3,4,5,6,7,8,9,10,11]

It is a major purpose of this paper to present a heretofore unpublished concept that lends itself to direct application by a non-specialist engineers. While involving a comprehensive in depth, technical investigation, the interpretation process is simplified so that unusual technical skills are not required in most instances. On the few occasions when greater specialized knowledge is needed, the concept provides an essential base from which a more sophisticated approach must begin.

Specifically, a standardized format is proposed whereby engineers can inspect a series of charts or graphs and "read-out" pertinent features of an injection system's performance. While the "read-out" process is, after a little practice, so self-evident as to appear quite simple, the individual is in effect solving partial chemical material balance calculations that logically lead to development of sound engineering practices.

The concept has evolved over a period of almost 11 years from experience on several hundred injection systems. It is hoped that the plan of attack will prove helpful to engineers confronted with problems of water handling.

BASIC CONCEPT

The proposed plan of water quality control can be illustrated by noting the physical similarity of water injection systems and chemical manufacturing plants. Both convert raw material to finished products. Either may be simple or highly complex. Systematic collection of basic in-put out-put data is recognized as a requirement for efficient operation of a manufacturing plant. If operational problems develop, product quality deteriorates and efficiency declines. Control data, both background and current, must be available to recognize and diagnose problems so that corrective adjustments can be made. The same process of data collection, though perhaps less recognized, provides a convenient way to determine performance characteristics of water injection systems. The secret of effective application lies in the selection of data to be collected, the manner in which they are processed and presented and, finally, in the technique of interpretation.

Presented herein is a plan that can be readily adapted to almost every water injection system whether it be large or small, single or complex.

While a comprehensive Water Quality Control study involves physical inspecting and testing, reviewing records and history, laboratory work, etc., it is the technical data package that ultimately forms the base from which conclusions are drawn. It is this phase that normally lies outside of the direct control of field engineers. Other factors, though important to success, are beyond the scope of this paper. Suffice to say, pure technical data must be tempered with a thorough knowledge of physical facts and operating history.

In practice, a water injection system is divided into complexity points and basic data collected at each point so that performance can be determined by chemical material balance calculations. To withstand the technical demands of this plan, precise sampling and testing techniques must be followed and exacting analytical procedures employed. Standardized data presentation forms greatly simplify interpretation so that pertinent features can be readily observed by visual inspection.

Points of investigation begin with raw water sources and follow the path of flow through the plant with data collected wherever water is purposefully changed or has an opportunity to change. For example, purposeful changes include chemical treatment, filtration, etc. Opportunity to change occurs in tanks or other surface vessels and where waters are mixed.

It is important that all testing and sampling be done near as simultaneously as possible. Ideally, a snapshot picture of a representative moment of operation is taken. To the degree that random sampling occurs, the probability of a reliable chemical balance declines. Similarly, if empirically derived "yardsticks" of interpretation are to be used there can be absolutely no tolerance for change in methods of taking samples or processing of laboratory data.

The following basic data are collected:

- (1.) At each individual test point:
  - (a) Membrane filter test with chemical analysis of residue
  - (b) Determination of Sensitivity Factor by analysis of primary suspended solids
  - (c) Analysis of dissolved minerals and gases
  - (d) Determination of Sulfate Reducing Bacteria Activity
- (2.) General. (Type and amount varies with each system)
  - (a) Analysis of scale and/or corrosion products
  - (b) Determination of amount and analysis of tank bottom sediments
  - (c) Analysis of solids back flowed or swabbed from injection wells
  - (d) Destructive inspection of pipe samples removed from service
  - (e) Visual and chemical examination of coupons [12], [13], [14]

It is evident from the type tests conducted that an intense effort is made to learn as much as possible about the chemistry of the system.

The following discussion describes how portions of the above information are collected and illustrates how they can be used by production engineers in deriving a quantitative expression of water quality. Space limitations prevent discussion of every step. However, important, but less familiar items, are treated in detail. Terms unique to this concept are defined. "Rules of thumb" and empirically based "yardsticks" are presented.

In order to facilitate explanation, data from an actual field study are used for illustration.

DESCRIPTION OF SAMPLE INJECTION SYSTEM

The sample injection system disposes of brine from the following batteries:

Battery	Volume Barrels per month	Formation
No. 1	324	Oligocene
No. 2	13,548	Oligocene
No. 3	26,104	Oligocene Miocene and Miocene "B" Upper
No. 4	19,190	Oligocene and Basal Miocene
No. 5	26,104	Oligocene and Basal Miocene
Total	85,270	

Water is collected in a central accumulator tank and pumped through six cartridge type filters to one disposal well.

Operations were commenced into this injection well in 1953. At that time a sand section between 3502 and 3510 ft took 1440 BPD at 85 psi surface pressure.

Additional zones were perforated over a period of years to provide required capacity. In 1960, after two new intervals were perforated, the injection rate was 3500 BPD at 110 psi. All prior injection zones were eliminated in August, 1964, and the well was re-completed in a non-productive Miocene sand at 4750 - 4780 ft. Injected sand face appeared tight and difficulties were experienced in getting the well to take water. Subsequently, tests indicated injectivity rates to be 5.4 bbl per minute or 7776 BPD at 175 psi surface pressure.

The rate decreased rapidly to two bbls per minute. The well was backwashed and the original rate temporarily re-established.

A water quality control study was made to determine the cause of plugging and otherwise define operating conditions.

In the case of the sample injection system, eight test points were investigated. Fig. 1 shows a schematic layout of the system with each test point graphically identified.

MEMBRANE FILTER TESTS

Membrane filtration tests were performed at each selected point to obtain a precise measurement of undissolved solids existing under "in-line" flowing conditions. A side-stream of water was diverted through apparatus installed in a specially equipped test car so that all suspended matter in the flow stream was collected on a cellulose-ester filter element of less than one-half micron pore size. The element containing the solids was then dissolved in acetone, leaving the sediments that were originally present in the water system at the point of test. A chemical analysis was made of the residue. Fig. 2 is a plot of these data in units of Milligrams per Liter. The undissolved constituents existing under "in-line" conditions are referred to as Component "A". Component "B", or the solids precipitating in a sample bottle as a result of time lapse, pressure and temperature changes, and partial oxidation or reduction will be described later.

While the unit Milligrams per Liter, a weight per volume relationship, denotes the concentration of undissolved solids, a more definite expression must take into account the volume of water being handled by each raw water source or combination thereof. In this way, the total contribution of plugging materials from individual sources or mixtures can be determined. The unit, Pounds per Day, is used for this purpose because it is quite descriptive and easily understood. Conversion to Pounds per Barrel is obtained by multiplying Milligrams per Liter by 0.00035. In turn, this value multiplied by Barrels per Day yeilds Pounds of Plugging Solids per Day. Fig. 3 is a graphic presentation of these data.

In combination, Figs. 2 and 3 reveal much in the way of determining what is happening as water passes through the system or is mixed with waters from other sources. A simplified material balance can be quickly made by visual inspection. For example, it may be noted that chemically active constituents, i. e. iron salts, calcium carbonate, borium sulfate, etc., are low or do not exist in water at source No. 1, source No. 2 or source No. 3 and in mixtures of these two waters after passing through small field collection tank. The fact that no further aeration is occurring in the field collection tank taking water from these two sources is evident from both Figs. 2 and 3. The Milligrams per Liter plot remains the same for both individual sources and the mixture of them. Likewise, the Pounds per Day contribution of one source plus that of the other equals that measured downstream of the tank where they are mixed. Therefore, material balance demands that solids are neither decreasing due to settling, nor are they increasing due the further aeration. It can be concluded that iron precipitation in the two affected sources is being caused by aeration either in or upstream of the gunbarrels. Similarly it can be concluded that other sources are not being exposed to air prior to oil-water separation.

By contrast, evidence suggests that the total composite flow is being further aerated in the central station collection tank. The Pounds per Day of iron oxide downstream of this tank exceeds the sum of precipitated iron oxide from individual sources going into the vessel. While it is possible that a portion of the precipitate is settling in the tank, material balance demonstrates that an excess is being formed by air entering the tank. It is evident that a careful physical inspection should be made to assure that an oil seal is intact and that inlet and outlet lines are so arranged as to minimize turbulence.

Following the behavior of chemically inactive products through the system in a like manner also sheds light on overall plant performance. Silica and organic matter are the primary constituents in this category. It may be seen that only one individual source, namely source No. 1, contains a high concentration of silca. Because of extremely low rates from this source, the actual Pounds per Day of Silca is insignificant. However, measurements at the outlet of the central collection tank indicate substantially more silica than the sum of all individual inlet sources. Since silica content is not affected by chemical changes, the excess shown at the central station must orginate from one or more sources by a process of intermittent slugs. A likely suspect in this case would be the No. 1 source.

Organic matter measurements by side stream testing, unlike others previously described, are not absolute values. Clean oil, as a function of test pressure, will pass through the membrane filter and thus not be collected for analysis. Likewise, clean oil can be displaced into the injected formation without difficulty. However, oil will form an envelope around any foreign solid particles. This type material is collected on the membrane filter element to be subsequently identified by chemical analysis In the same manner, these oil coated particles cause significant damage to injected sand faces.

Examination of Figs. 2 and 3 reveals a very high organic content at source No. 4 and source No. 5. The effect of oil coated particles permitted a filtered volume of only a few hundred milliliters at these points. While, admittedly, test pressures were very low, the adverse effect on injectivity remains evident. As oil bearing water mixes with others in the collection tank and comes in intimate contact with an excess supply of iron and silica particles, the overall effect of oil carry over is greatly aggravated.

Figs. 2 and 3 dramatically demonstrate the ineffectiveness of existing filters in removing precipitated iron products. Filters are expected to remove undissolved solids from the water. It may be seen that none of the precipitated iron constituents are being removed. Hence, so far as this material is concerned, filtration efficiency is zero. The inability of existing cartridge type filters to reduce overall plugging solids to a desirable level is also illustrated. Approximately 7-1/2 lbs per day of solids are entering the filter. Of this only about 2-1/2 lbs per day are being removed. The rest, or almost five lbs per day, is entering the well. In one year, neglecting well cleanout and/or backwash and the quantity displaced into the sand, almost one ton of solids could collect in the well bore.

Although flow rate capacity of the six filter assemblies is allegedly 7,500 bbl per day, it must be kept in mind that this is based on clean water. The capacity in terms of Pounds per Element is more meaningful. There are four elements per filter of a total of 24 elements. If each element has a capacity of three pounds of solids, then the total filter capacity is 72 lbs. At the present rate of filter load, i. e., 7-1/2 lbs per day, the element life, neglecting backwash, is less than 10 days. It is unlikely that backwash efficiency will exceed 75 per cent. If this is achieved, the calculated effective element life would be a little over one month. Looked at in this perspective, the measured low filtration efficiency is not surprising.

In reviewing "in-line" plugging solids data, an empirically derived "rule of thumb" is helpful, i. e., a good quality water should contain less than two milligrams per liter of total undissolved solids. It is evident that different formations have different tolerances. Likewise, various undissolved solids exhibit varying degrees of plugging. However, lacking specific data in this connection, the two milligrams per liter limit provides a good practical starting goal.

SENSITIVITY FACTOR (Primary Suspended Solids)

Primary suspended solids are defined as the undissolved matter existing under "in-line" conditions plus those precipitating after a sample is collected. "After sampling" precipitation is usually the result of:

(1) Lapse in time
(2) Change in temperature
(3) Change in pressure
(4) Partial aeration

and/or

(5) Partial chemical reduction

The quantity of "after sampling" precipitation is referred to as Component "B".

At the instant of sampling, "in-line" undissolved solids (Component "A") are present in the container. Beginning immediately and continuing for an unknown period of time, other precipitates form (Component "B"). Component "A" is measured directly by membrane filter residue analysis (Figs. 2 and 3). Components "A" plus "B" are quantitatively determined by chemical analysis of the residue," obtained by laboratory filtration of the sample.

The combination of undissolved suspended solids (Component "A" and "B") is referred to as Sensitivity Factor. It is an indication of the tendency of a given water to precipitate plugging solids under changing conditions that are common to most injection systems. Precisely controlled sampling procedures control the degree of "changing" conditions and provide reproducibility of data.

If these values are to be quantitatively interpreted, it is essential that the sample be taken in the carefully prescribed manner and that the same laboratory techniques be employed in each determination. It is obvious that this is also true of any subsequent studies which must be compared to previous investigations. Otherwise, a random and uninterpretable mass of data results.

Fig. 4 is a graphic presentation of Primary Suspended Solids in units of Milligrams per Liter. Fig. 5 presents Primary Suspended Solids in terms of Pounds per Day of plugging material. The measured contribution of each individual water source and combination thereof is shown.

Simply stated, Sensitivity Factor (Figs. 4 and 5) depicts what can happen under varying conditions within practical limits and "in-line" solids ((Figs. 2 and 3) demonstrate actual field conditions at the time of test.

It may be noted from Figs. 4 and 5 that the individual waters in this system exhibit varying tendencies to precipitate solids. Without exception, they are all sensitive to aeration. The principal precipitated product in each case is iron oxide.

Source No. 1 contains the greatest concentration of primary suspended solids of any single water source. However, due to its small volume, the contribution in Pounds per Day to the system is small, at least for prevailing conditions on the day of test. Silica, a chemically inactive element, as in the case of "in-line" solids, is present in an amount suggestive of intermittent slugs from Source No. 1.

Potential Suspended Solid values for the composite brine downstream of the collection tank indicate a potential precipitation of almost 20 lbs per day of plugging solids. If air is introduced in the collection tank and time is not sufficient for reactions to be completed, then a large volume of plugging solids will be injected even if filtration efficiency is perfect. The importance of maintaining completely air free conditions is readily apparent.

Other commonly encountered chemically active precipitates, such as calcium carbonate, calcium sulfate, barium sulfate, etc., are not present in this system.

While not measured directly in this case, calculations show that all water sources are also sensitive to hydrogen sulfide. Free, naturally occurring hydrogen sulfide is not present. However, should this gas be generated by bacterial action the end result will be the same. Large amounts of black iron sulfide will precipitate. This factor is discussed because a latent problem exists. While bacteria are present, they are not active enough to cause trouble. Given an enviornment conducive to growth, the bacteria can quickly contaminate the entire system. If this potential condition is recognized, simple mechanical and procedural precautions can be taken to prevent problems. In general, sediments must not be allowed to accumulate in gunbarrels, tanks, or vessels. Unused or infrequently used by-pass lines should be eliminated or flushed on a regular schedule. The volume and frequency of flush can be determined experimentally and will vary from place to place.

Symptoms of increased bacteria activity can be visually detected by observing color changes in flush volumes from "dead" zones. Any evidence of a darkening color should be investigated. Likewise, a build-up of dark colored sediment in vessels should be regarded with suspicion.

DISSOLVED SOLIDS AND GASES IN WATER

Dissolved minerals and gases in water samples were determined by chemical analysis. Again the sampling procedures, as well as laboratory analytical techniques, are important if the data are to be quantitatively interpreted according to established empirically derived "yardsticks"

From these data, scaling and corrosion tendencies are determined. Stability index at two temperatures is routinely calculated. (Fig. 7).[15] Likewise, calcium sulfate solubility is calculated along with the theoretical maximum of calcium sulfate possible in a given water. This information is reported in the lower left hand corner of standard water report form shown in Fig. 11. [17] As a rule of thumb, if the maximum calcium sulfate possible value is less than 70 per cent of the solubility at both temperatures, then no field problem is anticipated. This is the case in all water sources shown here, (Fig. 6). On the other hand, when the possible calcium sulfate value exceeds 80 per cent of solubility at either temperature, precautionary steps must be considered.

Compatibility of waters is also estimated from dissolved mineral data. For example, while barium and sulfate ions can co-exist in solution up to certain rather vaguely defined limits, the presence of both ions in a single water signals concern. The text book type theoretical solubility of barium sulfate is very low.[18] However, experience has shown that, in some complex oil field brines, small concentrations can remain in solution with no harmful effects. Technical uncertainties are such that the degree of precipitation cannot be accurately predicted from analytical data alone. As a "rule of thumb", based on empirical evidence, the presence of both barium and sulfate in a range of one part per million to 30 parts per million is considered a caution zone. Barium sulfate may or may not precipate. When the lesser ion exceeds 30 parts per million, a dangerous condition exists and the odds greatly favor precipitation in the field.

This compound, forming on the face of an injected formation, is particularly harmful because it cannot be reliably removed by any known chemical procedure. Mechanical underreaming, heavy fracing or some other equally drastic step must be employed to correct the damage.

It may be noted that all these waters contain substantial concentrations of barium and small, but measureable, amounts of sulfate. Fig. 8 graphically presents these data. In view of the indicated caution zone condition, special fusion techniques were employed to establish the presence or absence of barium sulfate in primary suspended solids, sediment removed from a field filter element, and in membrane filter residues. With the exception of only 0.5 per cent found in the filter element deposit, all other results were negative.

It is not believed that barium sulfate deposition is a problem at this time. However, if and when sulfate ions enter the system from casing leaks, cement channels or in any other manner, serious difficulties will be encountered.

Recognizing the latent possibility, the operator should remain alert for the presence of sulfate ions. Any rapid change in water-cut from individual wells should be viewed with suspicion. In the absence of observed changes in produced water volumes, periodic analyses of wellhead samples will provide positive preventive control.

A theoretical value of sensitivity of a water to aeration and/or reduction by hydrogen sulfide can be deduced from dissolved solids analysis. For example, if dissolved iron is present, the amount of iron that will precipitate, given sufficient exposure to oxygen, can be calculated by multiplying 1.43 times the iron concentration shown in the dissolved solids column of the water analysis report form. (Fig. 11) This calculation value can then be compared to the iron oxide value reported in the suspended solids column to determine the per cent reaction resulting from partial aeration inherent to the prescribed sampling procedure. If the measured iron oxide from suspended solids is small compared with the theoretical calculation from dissolved solids data, it is quite likely that the iron can be held in solution with nominal effort to avoid aeration. On the other hand, if the measured and calculated values are nearly equal, more demanding requirements will be placed on design and operating practices.

While not pertinent to this study, it is often necessary to compute the per cent distribution of various waters in an unknown mixture. This can be accomplished graphically by plotting dissolved solids data on the graphical calculator form for determining water mixtures. Fig. 10 illustrates the application of this technique.[19]

SULFATE REDUCING BACTERIA ACTIVITY

Adverse effects of bacteria on water quality have been described in the literature. Of the many organisms that can potentially cause problems, the type often referred to simply as "sulfate reducing bacteria" is most common. While sulfate reducing bacteria can and do produce harmful effects in water systems, their presence does not necessarily mean that field problems will result. This type of bacteria can be cultured in a high percentage of waters. However, they are harmful in only a few. Problems caused by this organism are usually related to its capacity to generate hydrogen sulfide. While not denying the importance of other bacteria, specific tests for sulfate reducers only are included in the standardized data package.

In most cases, the simple and inexpensive Bacteria Activity Index technique will detect significant contamination.[20] Interpretation of measurements by this procedure is based on statistical evidence compiled over a 10 year period involving thousands of indivedual tests on several hundred injection systems.

Infrequently, when conditions do not permit the simplified approach, other evidence is used to measure the effect of bacteria. On occasion, the more comprehensive, and more expensive, standardized procedure suggested by the API- Recommended Practice RP38 is desired.

The Bacteria Activity Index procedure was used in the sample study. Data are presented in Fig. 9. It may be noted from the printed form that Index Values below 10 denote a safe operating range. Above 20 is a danger zone and the odds are that practical field problems exist. Between 10 and 20 lies a twilight zone of unpredictable meaning and caution is indicated. Not the least of these factors is the sensitivity of the water to reactions with hydrogen sulfide as discussed elsewhere in this report.

It may be noted from Fig. 9 that all values of bacteria activity on the day of test were below 10 and therefore in the safe operating zone. As discussed previously, these bacteria, given a favorable environment, will increase in activity. Changes can occur quickly. Since water sensitivity is high with respect to hydrogen sulfide reaction, the operator should take reasonable preventive measures and in addition, should remain alert to visual symptoms of changes. Some of these steps have been outlined previously. It would not be unwise to run a set of bacteria activity measurements at monthly or bi-monthly intervals. The cost is nominal and adequate control will be assured.

MISCELLANEOUS LABORATORY DATA

In the course of processing samples in the laboratory, it was observed that the effective density of oil-coated iron oxide and silica particles was such that they would only partially settle. A major portion floated on the water surface. Lesser amounts seemed to be suspended and, with minimum disturbance, would neither float nor settle. Samples of deposits retained on a cartridge filter element in field service were tested and produced similar properties.

Since this characteristic could produce difficult handling problems, methods of destroying the oil film were explored.

It was determined that a very small amount of non-ionic surfactant was capable of removing the oil film so that inorganic particles settled quite readily. From a theoretical point of view, this response suggests the possibility that treatment of this system wiith a small concentration of surfactant can likely reduce the plugging solids reaching the disposal well.

Caution in this approach must be exercised. Surface tension reducing materials, in addition to performing the desired action, will also dislodge much of the sediment the has accumulated in the system over a period of time. If not removed by flushing or filtering, often impractical steps, the particles will be delivered in massive quantity to the injected sand face. Serious immediate plugging can result. If this occurs, a well clean out will be required.

Alternate or perhaps supplementary steps to surfactant chemical treatment involve elimination of iron oxide and silica and oil carry-over. It is highly desirable to take steps in this direction in any event. If effective, chemical treatment can be wholly avoided or, at worst, used only intermittently.

As indicated previously, the elimination of air in the central collection tank will prevent most of the iron oxide formation. Also, points of air entry unpstream source No. 4 and source No. 5 should be located and eliminated. Open siphons and/or open casing annuli are suspect points.

The major source of intermittent slugs of silica (sand) should be located. Steps to minimize this factor range from re-completion of wells, installation of desanders, to providing additional retention time for settling. Local circumstances will determine the most pratical approach.

Emulsion treating practices are usually expected to produce pipeline oil. Minor oil carry-over to the water phase is considered to be of no consequence. However, if this oil, in combination with inorganic sediments, creates substantial quantities of plugging solids, it may be desirable to review emulsion treating procedures. Under the new perspective, a "pipeline water" may be practical at little or no additional expense thus removing another important cause of reduced injectivity.

CONCLUSIONS

It has been an expressed purpose of this discussion to demonstrate by illustration the application of a standardized data package in defining water injection system performance.

Armed with adequate technical data, an engineer familiar with field conditions can arrive at a quantitative expression of "water quality". By applying uniform data presentation techniques the field engineer can quickly learn to inspect a series of charts or graphs and "read-out" pertinent features without spending the time to become a specialist in the field of water handling.

Corrective or preventive action based on a true diagnosis of problem causes, instead of treatment of superficial symptoms, results in optimum performance in the shortest time and at minimum expense. Ineffective and sometimes expensive trial and error procedures can be avoided.

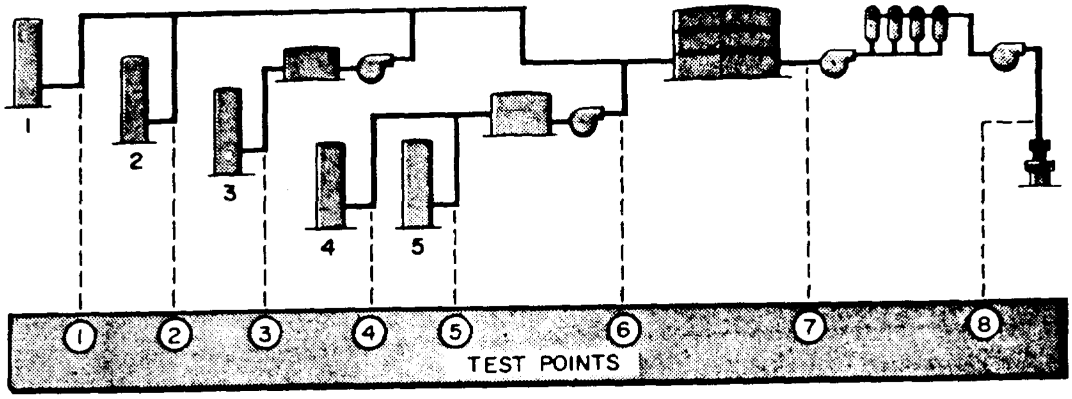


FIG. I
SCHEMATIC DIAGRAM OF SYSTEM

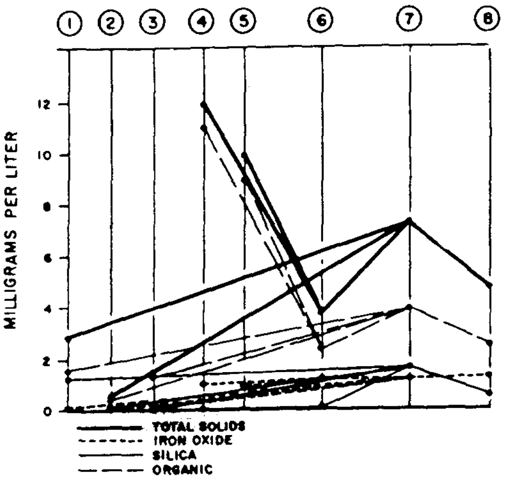


FIG. 2
SUSPENDED SOLIDS
IN-LINE CONDITIONS
(MILLIGRAMS PER LITER)

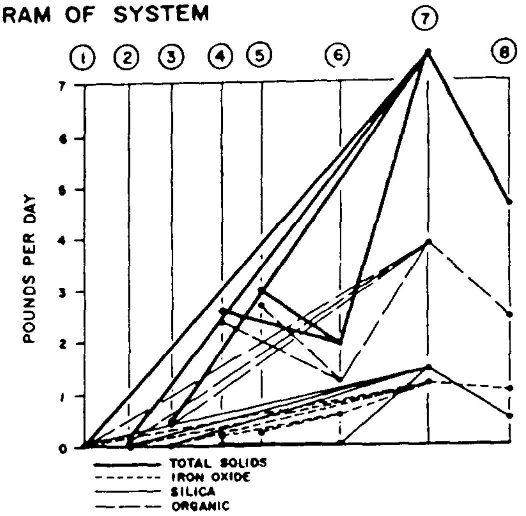


FIG. 3
SUSPENDED SOLIDS
IN-LINE CONDITIONS
(POUNDS PER DAY)

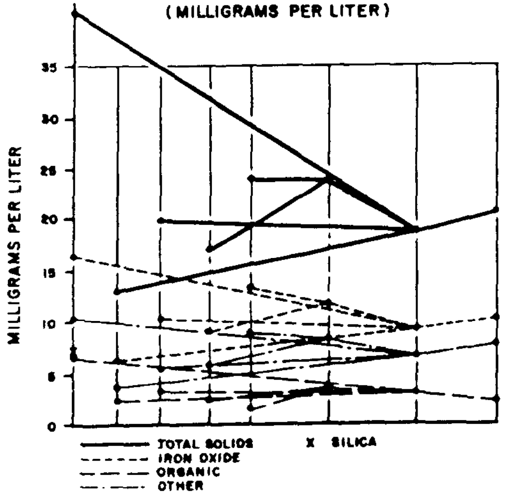


FIG. 4
SENSITIVITY FACTOR
PRIMARY SUSPENDED SOLIDS
(MILLIGRAMS PER LITER)

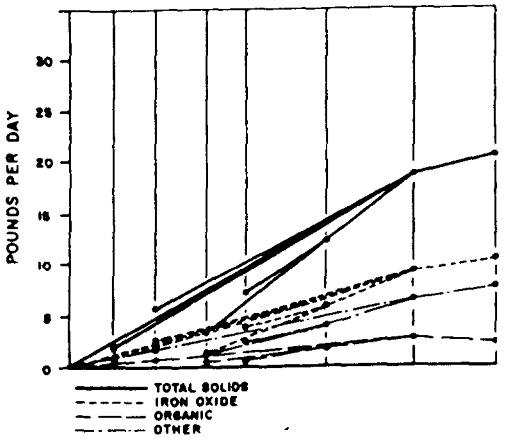


FIG. 5
SENSITIVITY FACTOR
PRIMARY SUSPENDED SOLIDS
(POUNDS PER DAY)

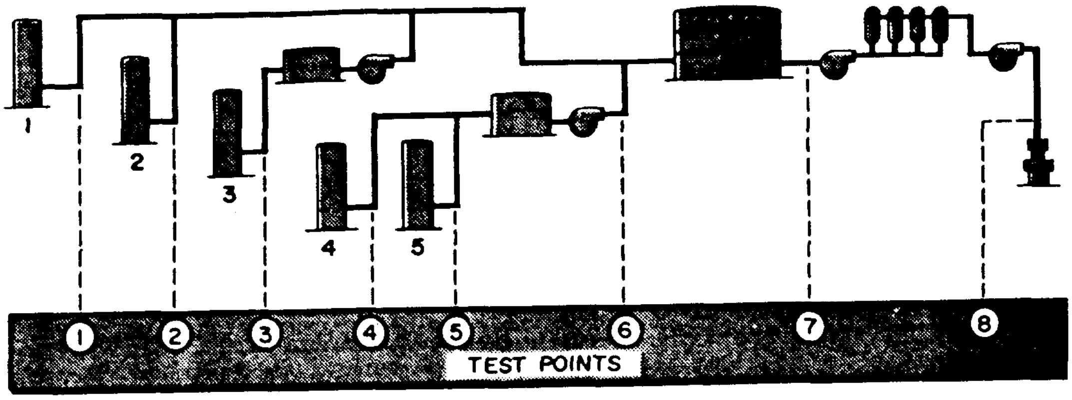


FIG. I
SCHEMATIC DIAGRAM OF SYSTEM

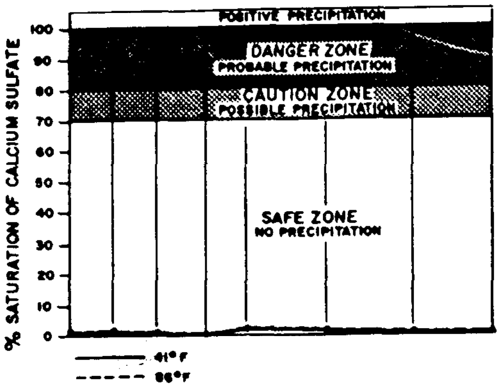


FIG. 6
CALCIUM SULFATE SATURATION

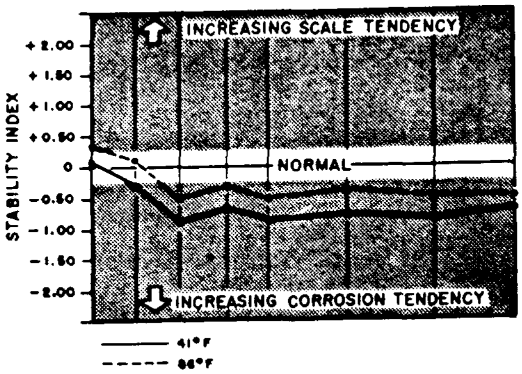


FIG. 7
STABILITY INDEX

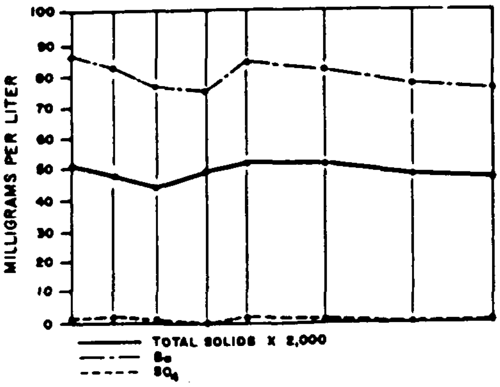


FIG. 8
DISSOLVED SOLIDS

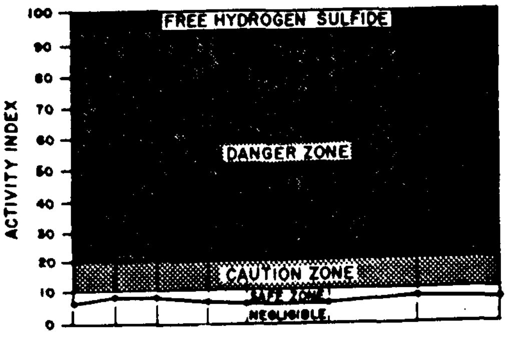


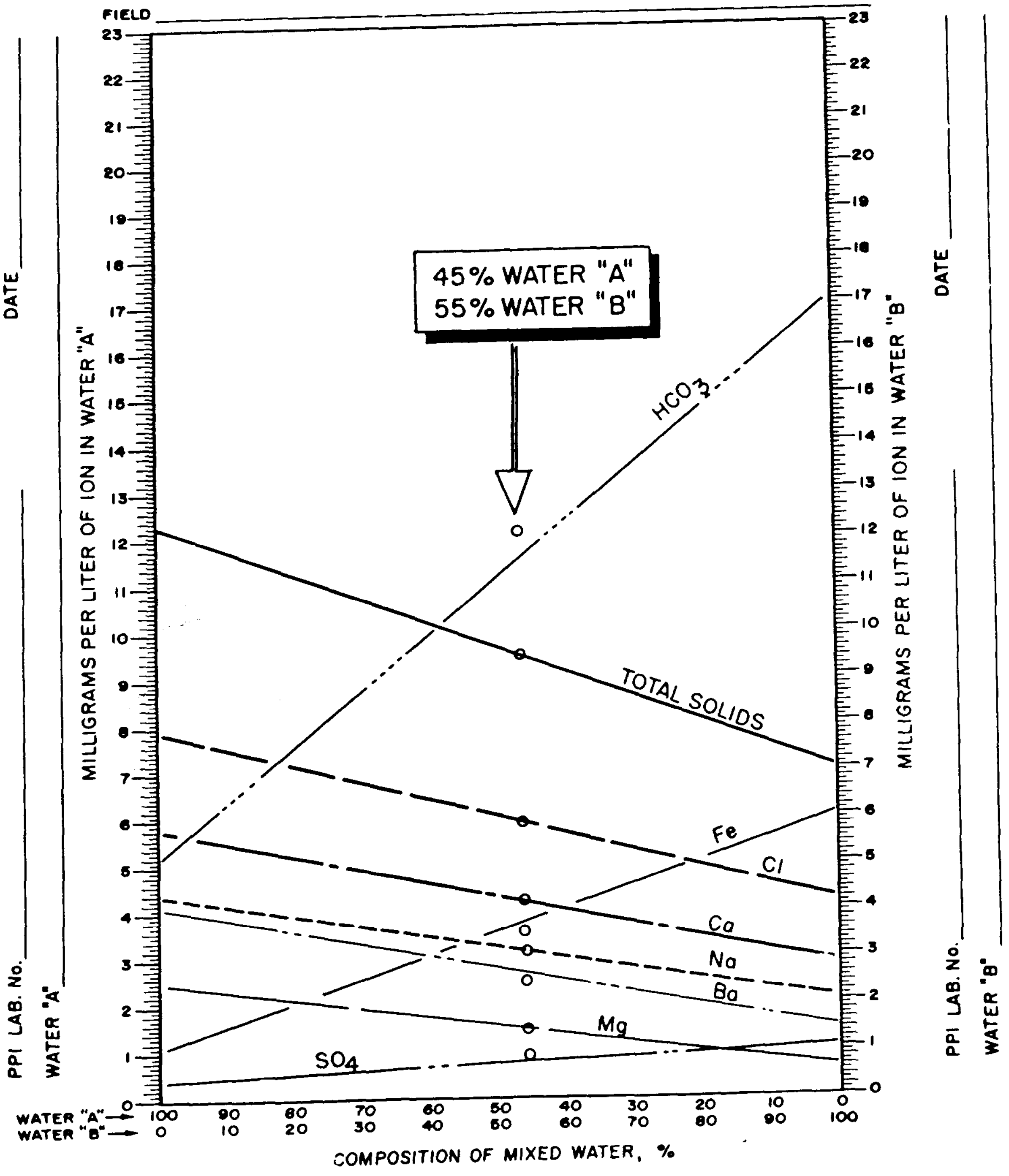
FIG. 9
SULFATE REDUCING BACTERIA

FIG. 10

GRAPHICAL CALCULATOR
FOR DETERMINING WATER MIXTURES

COMPANY ____________ STATE ________ COUNTY ________

FIELD ____________



LEGEND

— T.S.	— Ca	— CO₃
— Na	— Mg	— SO₄
— Fe	— Cl	
— Ba	— HCO₃	

PRODUCTION PROFITS, INC.
9130 VISCOUNT ROW, DALLAS, TEXAS .... ME 1-5400

FIG. 11

PRODUCTION PROFITS, INC.
Consultants in Petroleum Production
9130 VISCOUNT ROW
DALLAS, TEXAS

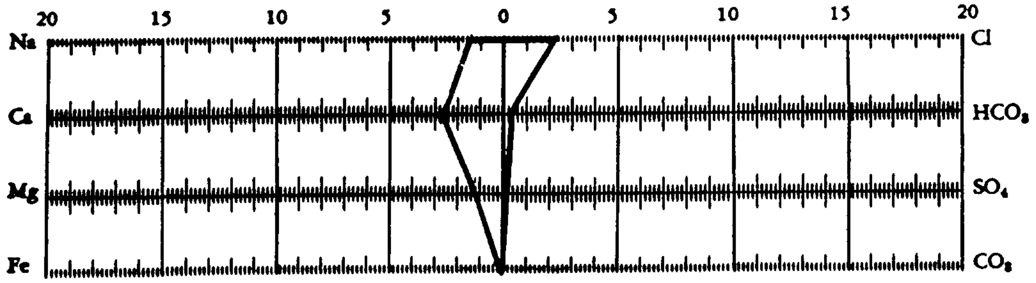
REPORT OF WATER ANALYSIS

SAMPLE NO.________
TOTAL SOLIDS________

CLIENT________ OPERATOR________
FIELD________ COUNTY________ STATE________
LEASE AND WELL NO.________ PROD. FORM.________
SOURCE OF SAMPLE________ DEPTH: TOTAL________ PERF.________
SAMPLE OF: PRODUCED WATER ☐ INJECTION SYSTEM WATER ☐ OTHER ☐________
DATE COLLECTED________ ANALYST________

MINERAL ANALYSIS PATTERN

(NUMBER BELOW ION NAME INDICATES MEQ./SCALE UNIT)



PRECIPITATED AND SUSPENDED SOLIDS

CONSTITUENT	MG/L (PPM)
TOTAL UNDISSOLVED SOLIDS	49.0
IRON OXIDE	24.3
CALCIUM CARBONATE	2.5
CALCIUM SULFATE	
MAGNESIUM CARBONATE	
BARIUM SULFATE	6.0
SILICA	1.4
ORGANIC	9.1
Unidentified	5.7

PHYSICAL PROPERTIES

SP. GRAVITY 1.080
PH 6.0
RESISTIVITY________ OHMMETERS @ 68°
STABILITY INDEX @ 41°F -1.32
@ 86°F -0.92
$CaSO_4$ SOLUBILITY @ 41°F 95.14 MEQ/L
@ 86°F 107.51 MEQ/L
MAX. $CaSO_4$ POSSIBLE 0.22 MEQ/L

DISSOLVED SOLIDS

CONSTITUENT		MG/L (PPM)
TOTAL SOLIDS	(CALC.)	116,488
SODIUM	(CALC.)	37,030
IRON	(TOTAL)	27
MANGANESE		-
BARIUM		53
CALCIUM		5,571
MAGNESIUM		1,725
CHLORIDE		71,984
BICARBONATE		83
CARBONATE		0
SULFATE		15

DISSOLVED GASES

CONSTITUENT	MG/L (PPM)
HYDROGEN SULFIDE	0.0
CARBON DIOXIDE	-
OXYGEN	0.0

REMARKS:

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