Scale Prediction From Analysis

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The problem of anticipating scale depositions prior to the time they actually result in difficulty continues to present a substantial challenge to individuals responsible for this aspect of the maintenance of all types of operations which involve the handling of water. The literature on scale is somewhat dominated by the presentation of severe examples of deposits that have already formed and the potential treatments that might be applied to prevent the conditions from recurring. Obviously, this is a necessary aspect of scaling that deserves its position in the problem. However, the most elusive aspect of scaling is in the efforts to predict that scale will form prior to the time it is physically encountered as a solid deposit. The prevalent means of approaching this aspect of scaling is in the use of analyses as a prediction of this potential.

The significance of scaling is continually apparent in oilfield operations where water is being handled. Some of the more prevalent detrimental effects appear in the following categories:

(1) Moving part failures in pumps, meters, valves, etc.
(2) Obstructions or reduction of capacity in piping
(3) Decline in total fluid production in producing wells
(4) Reduction and distortion of heat efficiency in heat-treaters
(5) Filter channeling and reduction in rates and efficiency
(6) Rapid build-up of bottom sediments in lines and vessels
(7) Obstruction of injection well tubing, well bore, and formation
(8) The additional cost involved in downtime for remedial work on the above and other conditions

It is immediately apparent in the above partial list of detrimental conditions that the prediction of scaling can be a vital aid in the maintenance of economical and efficient oilfield operations. When analytical results are utilized to accomplish this goal, then it is apparent that the importance of sampling, analyses, and their interpretation cannot be overemphasized. A summary of the basic requirements to accomplish this is as follows:

(1) The sample to be analyzed must be as representative as possible of the actual water being handled. This is an extremely vital aspect of predicting scale; for if there are any influential conditions involved in the actual sampling, point of sampling, condition of the system when sampling, or handling of the sample, then the remainder of the requirements can be expected to be restricted accordingly.

(2) A minimum amount of time lapse should be allowed between sampling and actual analysis. This varies with circumstance and the sensitivity of the scaling condition. That is, severe scaling conditions will usually be reflected after several days, whereas mild scaling conditions are more sensitive to time lapse. The calcium carbonate scaling tendency is much more sensitive in that only a few hours should be allowed to elapse, whereas calcium sulfate scaling tendency most frequently is still reflected in one to two days. On the other hand, barium sulfate has no time factor if properly handled by the laboratory.

(3) Samples to be utilized for scale evaluation should not be refrigerated or heated excessively.

(4) The accurate analysis of the sample is a vital requirement. The failure to accurately determine the components in the water that are used to evaluate tendencies will invalidate the representative sample and the application of interpretation methods.

(5) The careful interpretation of the analytical results is then vital to fulfill the predictions that evolve from the effec-

tive application of the above precautions and requirements.

All the individuals involved in accomplishing the above requirements should be somewhat familiar with the most influential factors in scaling tendencies in order to understand how changes might influence the combined efforts in accomplishing an effective prediction. These factors are as follows:

(1) Calcium carbonate scaling is very sensitive to carbon dioxide content of the water; therefore, any escape of excess carbon dioxide will convert the bicarbonate in the water to carbonate and, therefore, increase the supersaturation.

(2) The solubility and, consequently, the scaling potential of calcium sulfate is sensitive to concentration of inert ions such as sodium chloride, pressure, temperature, agitation and evaporation. Stiff and Davis have reported a thorough study of the influence of sodium and magnesium and the comparison of the two, along with the significant influence of high temperatures.[1] Tate, Venable, and Nathan differed somewhat in their conclusions but suggested interrelation between solubility and temperature, and reported only a very slight temperature influence between 30° and 85° C. They also indicated that low concentrations of sodium and magnesium gave no variation in the results.[2] Metler and Ostroff have reported a difference in results.[3] The author has reported data revealing the influence of pressure on the solubility of calcium sulfate.[4] Experiments and review of reasons for the influence of pressure have been reported by Fulford.[5] Though some variations in results have been reported, it is still apparent that influence from any of these factors may very well vary the calcium sulfate scaling tendency.

(3) Barium sulfate is a relatively insoluble component but is significantly influenced by agitation and by the concentration of inert ions as reported by Templeton.[6] Scale from this salt is most frequently encountered as a result of combining two waters in which one contains barium and the other contains sulfate. However, it also occurs under other circumstances.

(4) Inspections of equipment are frequently warranted in conjunction with chemical analyses. The inspector should be aware that the most probable point of scaling is in areas of agitation, pressure change, temperature change, or treatment application.

The methods in current use for the evaluation of calcium carbonate scaling tendencies are numerous, but those being used in the oil industry are more limited, to the best of the knowledge of the author. The Ryznar Stability Index and Langelier Saturation Index are the most commonly used that are not covered in detail below.[7] The methods of evaluation of calcium sulfate scaling tendencies are much less common. The predominant method currently being used but not covered below is that presented by Stiff and Davis; they use the same factors suggested in the detailed method given below, but also include magnesium and temperature as influential factors.[1] A similar approach has been taken by Tate, Venable, and Nathan.[2] Metler and Ostroff have recently presented a method for predicting calcium sulfate by the use of calculations.[3] The author is not thoroughly familiar with other methods being used to predict barium sulfate, as it is much less common to the area of the Southwest.

The appearance of barium sulfate scale is most commonly related to a mixing of two waters, in which case the barium and sulfate contents of the individual waters are predominantly utilized. This is also supplemented by combining the two waters, allowing 24 hours with agitation, filtering the mixture, and then determining barium content of the filterable solids. This method can also be applied to field conditions by acquiring samples and determining the barium precipitated in the same manner.

The method used by the author to predict calcium carbonate scaling tendencies is commonly referred to as a stability test.[8] In this method the alkalinity is determined; and then another sample that has been treated with calcium carbonate, stirred, and filtered is also analyzed for alkalinity. The difference between these two alkalinity determinations is the supersaturation or undersaturation. The percentage of the supersaturation to the alkalinity determines the scaling tendency as presented in Fig. 1.

The method of predicting calcium sulfate scale that has been originated by the author is the result of extensive accumulation of field data in conjunction with treating natural oilfield brines with calcium sulfate dihydrate and determining the calcium and sulfate contents. This has led to the use of the determinations of calcium, sulfate, and chloride to draw up solubility charts that would represent the point of solubility at a specific chloride content and varying quantities of calcium and sulfate. Each chloride content then carries a solubility line on a chart. An example of this is the level of solubility with varying calcium to sulfate ratios at a specific chloride level (50,000 mg/1 as NaCl) presented in Fig. 2. This method excludes the use of the influence of temperature which has been reported to be comparatively minor as reviewed earlier in this paper. In using the above described method of accumulating data to compile these charts, the author was unable to identify a major difference in the influence of sodium and magnesium but simultaneously does not suggest to the reader that this has been confirmed by sufficient experimental data.

In cases where the above method of predicting calcium sulfate scale appears to be in question, then supplementary procedures can be used to obtain additional verification. This is predominantly approached by acquiring the raw water that has not been exposed to air and treating with calcium sulfate dihydrate for a period of four to six hours with periodic agitation. Determ-

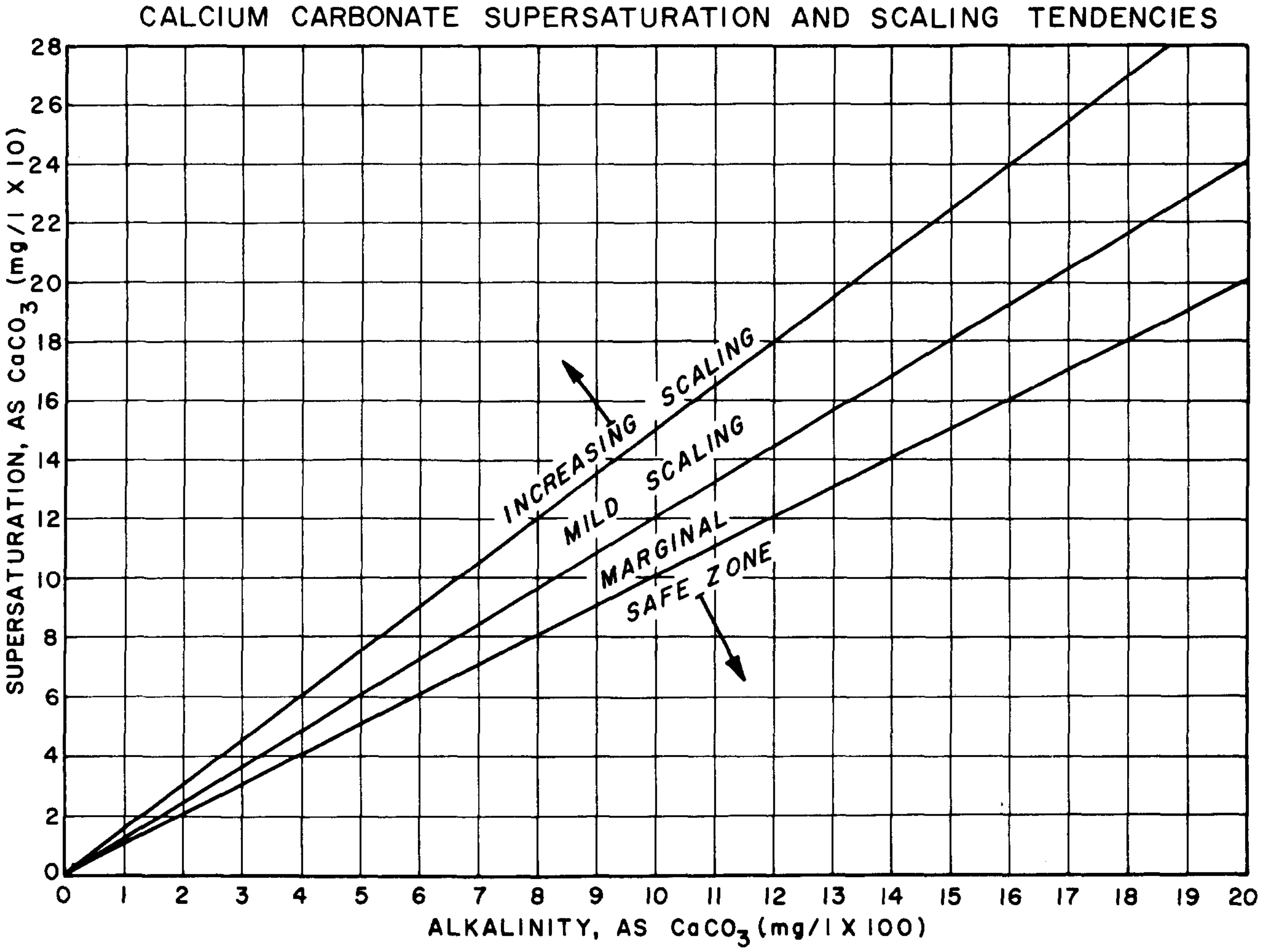

FIGURE 1

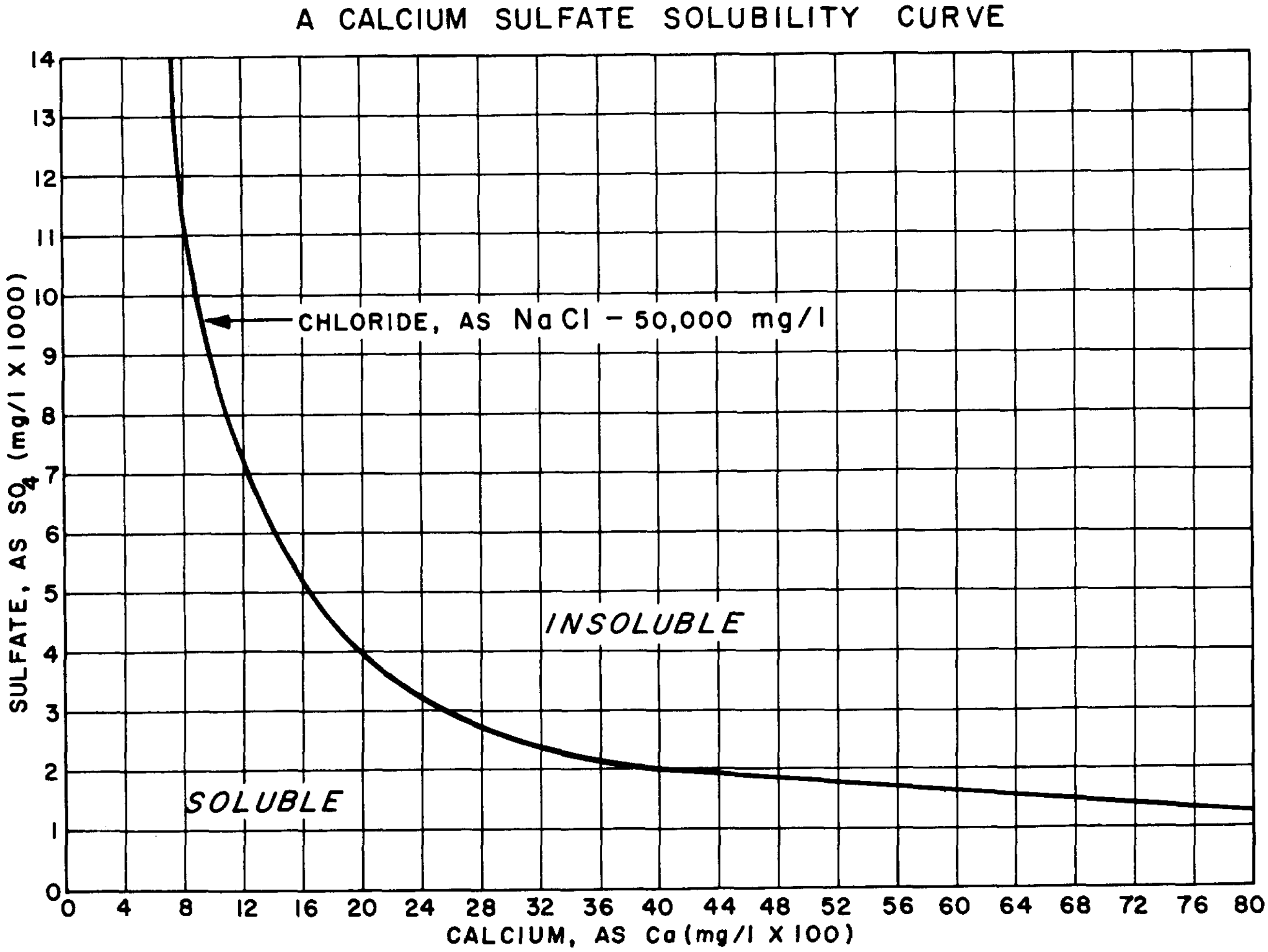

FIGURE 2

inations of calcium and sulfate are made before and after the treatment to determine whether the water dissolved or precipitated calcium sulfate. This can also be supplemented by filtration tests of the water being examined and using microscopic examination for the detection of typical calcium sulfate crystals.

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