An Approach to Estimating Skin Damage and Appropriate Treatment Volumes

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Nowhere in the oil field are experience and "rule of thumb" employed more frequently than in recommending the volume of treating chemical to be used in wells to stimulate production. These techniques work well if the "rule of thumb" has a logical basis such as observation and comparison of various treatments previously attempted in the area. Too often, however, recommendations are made blindly because "this is what has been done in the past" or is "standard operating procedure."

This paper proposes an approach to logically recommending treatment volumes. This is not the *only* approach, and the charts and equations used here are not new. Unfortunately, in this complex problem of designing chemical treatments, available knowledge is frequently ignored. Therefore, the main objective of this paper is to encourage the use of all the information available to solve damage problems. One serious stumbling block to making full use of this knowledge is the failure to do follow-up evaluation of treatments. Regardless of the success or failure of a treatment, it should be analyzed for information that may be helpful in future operations.

The majority of chemical treatments performed are attempts to improve fluid flow by removing restrictions around the wellbore. These restrictions, usually referred to as "skin damage", may result in a reduction in the absolute permeability of the formation near the wellbore, reduction in the relative permeability, or an increase in the viscosity of the formation fluids.

This damage can be caused by drilling, completing or working-over a well, or by producing the well. The "skin" caused by drilling fluids is usually shallow in nature, i.e., less than two feet. However, filtrate invasion can be deeper and is a function of the pressure differential, contact time, formation characteristics and fluid loss properties of the drilling fluids. This damage can take other forms such as water blocks, asphaltene damage, emulsion blocks, and $CaSO_4$ or $CaCO_3$ deposition. These forms can result in shallow to relatively deep damage. Proper chemical treatments must be designed to eliminate the skin with no adverse side effects. The following should be considered in designing a well treatment:

1. Type of formation and mineral composition
2. Type of damage and its extent
3. Physical limitations of well equipment
4. Reservoir characteristics
5. Treating fluid compatibility with contaminants and/or reservoir fluids
6. Formation properties, acid solubility, permeability and porosity.

After the above have been evaluated and a chemical treatment selected, the volumes to be used must be determined. To make this determination, the extent of damage must be estimated. One method of making this estimate is by using the damaged productivity ratio and the shape of the curves obtained by plotting the productivity ratio versus the radius of the zone of reduced permeability. The productivity ratio is the damaged production rate divided by the undamaged production rate. From this plot, the radius of damaged permeability can be approximated.

The most common indication of skin damage is a reduction in the total fluid being produced by a well. Figure 1 is a graph of the production history of a well which has been damaged. The total fluid production is declining as a result of decreasing reservoir energy. The increasing slope of the declining production is a result of some type of damage. Unfortunately, in many instances this is the only information available. From this, one must attempt to estimate the extent of damage around the wellbore. The restriction to flow will be a function of two variables; the amount of permeability reduction and the extent of this reduction. The undamaged production rate is estimated by projecting the production history to establish the production rate without damage. Sufficient production history should be plotted to determine the actual decline without the effect of early mild damage. For economic consideration, the amount the production rate can be restored will be the difference between the damaged production rate and a normally declining undamaged production rate.

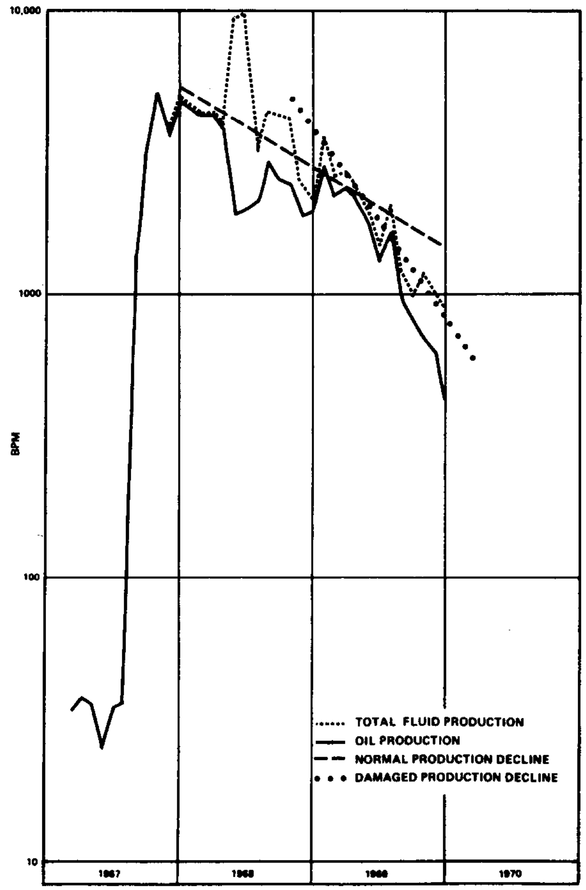

FIGURE 1

N. SQUARE LAKE NO. 16
N. SQUARE LAKE WATERFLOOD UNIT
EDDY COUNTY, N. MEXICO

If the simplest case of skin damage is assumed, it may be modeled as concentric cylinders of different permeabilities around the wellbore as shown in Fig. 2. The radius of the outer cylinder is the drainage radius of the reservoir, and this cylinder has an undamaged permeability equal to the effective permeability of the formation. The inner cylinder is the damaged portion of the reservoir. Its permeability is a fraction of the undamaged permeability, and its radius is equal to the extent of damage around the wellbore. With this model, Darcy's equations for radial flow can be solved for radial flow through series beds. From this solution

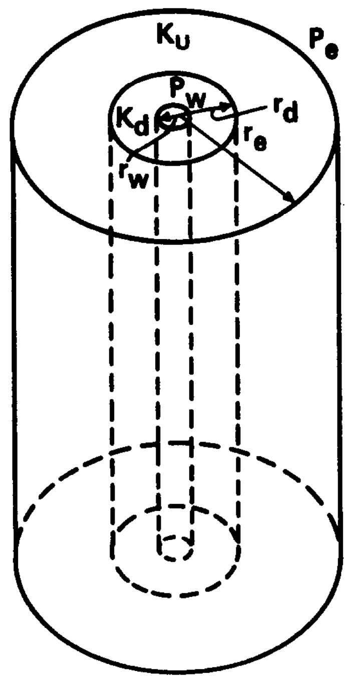

FIGURE 2
FLOW THROUGH SERIES BEDS

$$q_D = \frac{2\pi K_{avg} h (p_e - p_w)}{\mu \ln r_e/r_w}$$

where

q_D = Damaged Production Rate

h = pay thickness

p_e = pressure at the boundary of the drainage radius

p_w = pressure in the wellbore

μ = viscosity

r_e = drainage radius

r_w = wellbore radius

$$K_{avg} = \frac{\ln (r_e/r_w)}{\frac{\ln r_d/r_w}{K_d} + \frac{\ln r_e/r_d}{K_e}}$$

K_d = permeability of the damaged zone

r_d = radius of the damaged zone

K_e = permeability of the formation

The ratio of K_{avg} to K_e, the undamaged per-

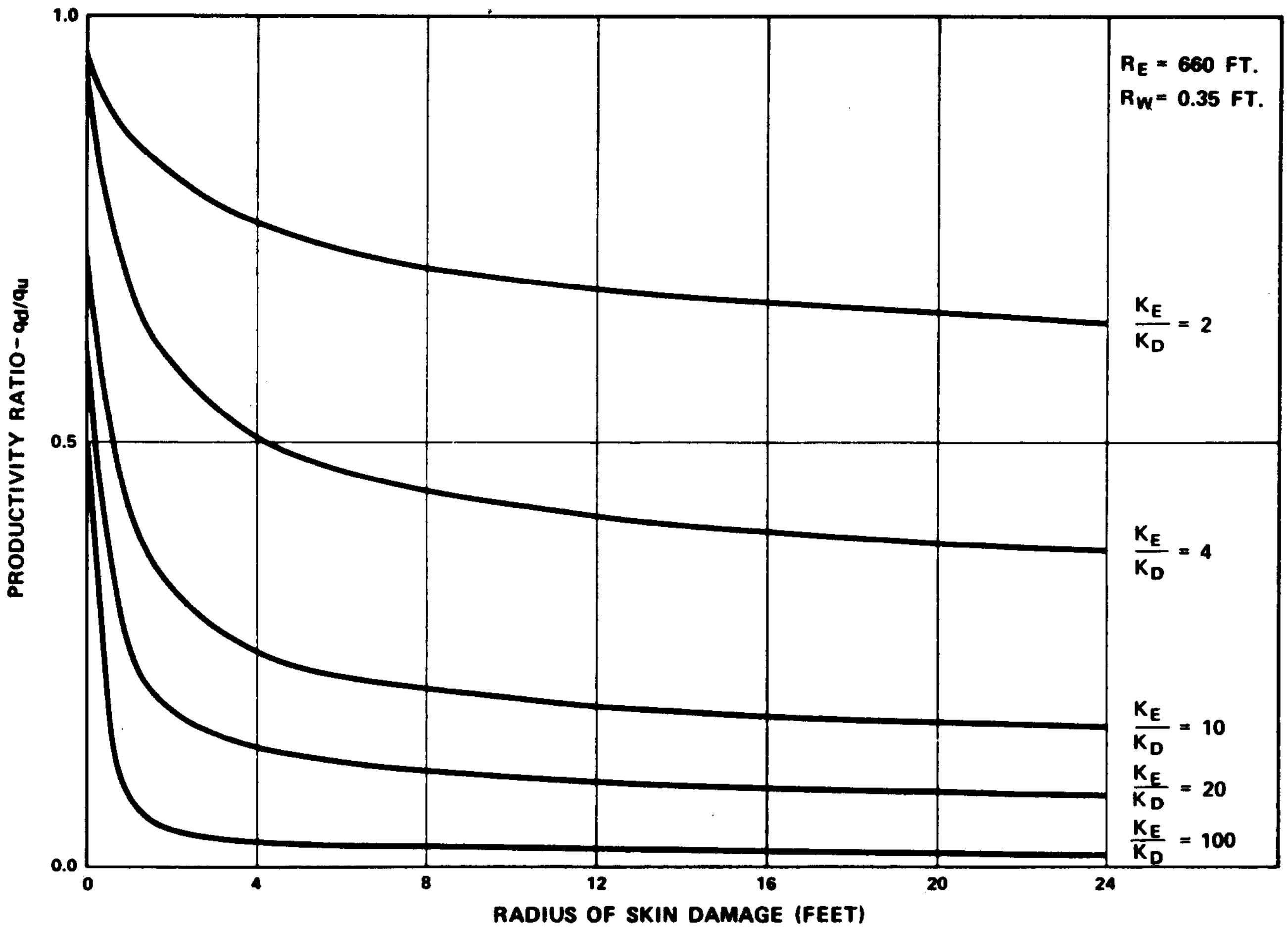

FIGURE 3

meability, is also equal to the productivity ratio; therefore,

$$PR = \frac{\ln (r_e/r_w)}{\ln (r_e/r_d) + \frac{K_e}{K_d} \ln (r_d/r_w)}$$

relating the extent of the damaged area to the productivity ratio, Fig. 3. Hawkin's derivation of the above equation can be found in Ref. 1.

In observing the shape of the above curves, it appears that beyond a radius of approximately 10 ft the curve becomes relatively flat. From this observation it appears that the area of the most severe restriction to production is within this radius. Therefore, the most significant improvements in production rate will be obtained by effectively treating this zone to remove the damage. The amount of increase in production rate obtained by attempting to treat beyond 10 feet does not appear to be justified. If significant damage is known to exist at greater distances, it would probably be more effective to try a fracture treatment rather than attempting to treat with chemicals. The largest pressure and temperature drops occur relatively close to the wellbore enforcing the proposition that significant skin damage is shallow in extent. Figure 3 is a tool to determine the extent of damaged permeability. From prior treatments in the subject well or offset wells it may be possible to estimate the damaged permeability ratio. Then Fig. 3 can be used to predict the extent of damage.

With the radius of damage, porosity, and net pay from sources such as logs or cores, the volume of treatment can be estimated from charts such as Fig. 4. The volume can be determined by calculating the volume of pore space to be filled by treating chemical using the equation:

$$\text{pore volume} = \pi r_d^2 h \phi S_{xo}$$

Usually pump rates and injection pressures

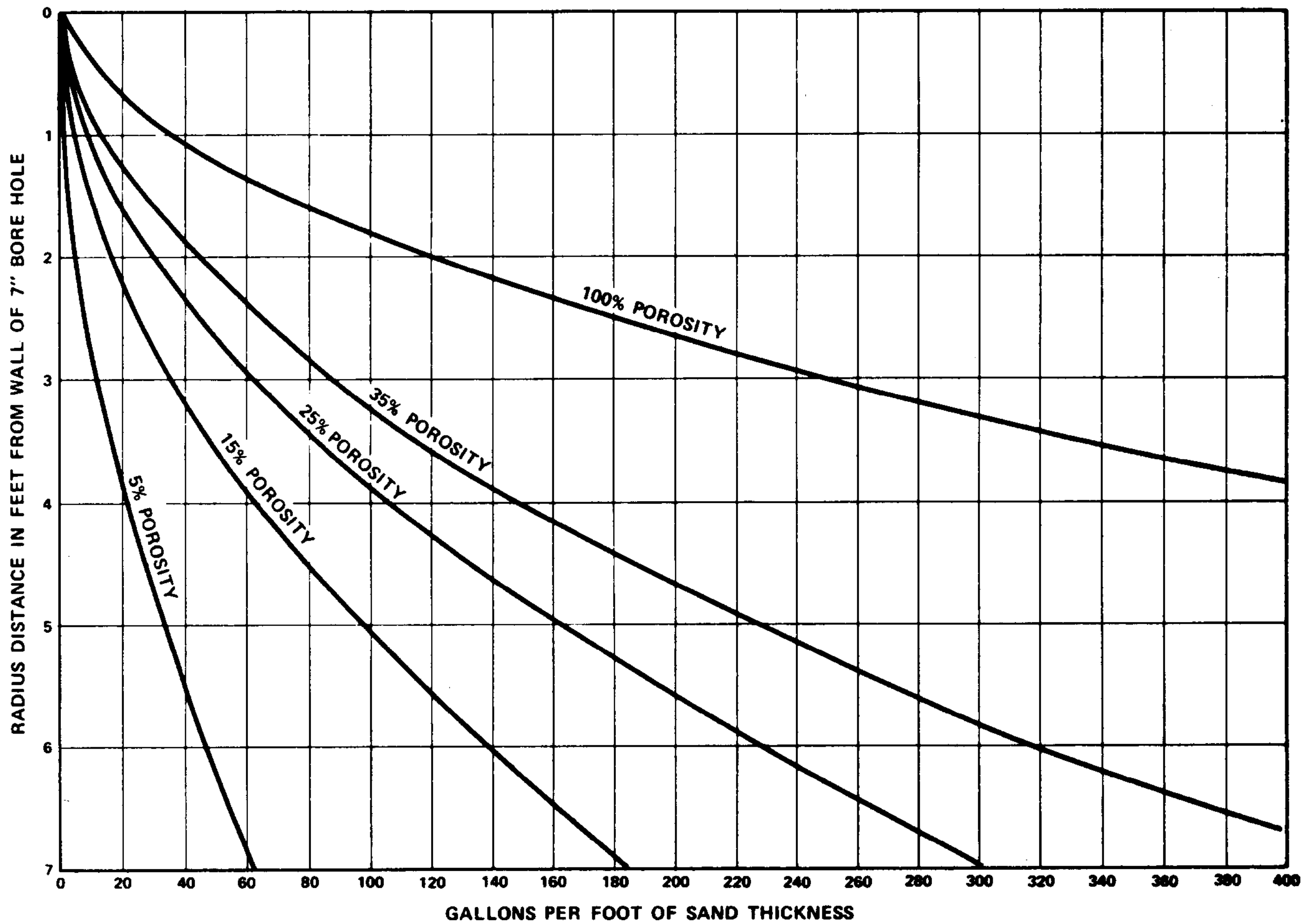

FIGURE 4

should be low to allow the treating fluid to move radially as uniformly as possible.

For example, this approach was used in treating Sealy Smith No. 62 in the Monahans Clearfork water flood. A supratidal and marine dolomite, the Clearfork flood has been troubled with $CaSO_4$ deposition restricting fluid flow. An offset well with similar geologic parameters was treated with 1500 gal. of 15 per cent HC1 acid. Before treating, the productivity ratio was 0.03. Stimulation restored the well to its undamaged productive capacity. The offset well had 75 ft of 10 per cent porosity pay. From Fig. 4 the treated radius was approximately 3 ft. From Fig. 3, Ke/Kd is approximately 100. The productivity ratio in Sealy Smith No. 62 was 0.05 when it was considered for stimulation. With this PR and Ke/Kd equal to 100, the damaged radius (from Fig. 3), is approximately 1.5 ft. Treatment was calculated using a treating radius of 2 ft. The Clearfork in Well No. 62 was 60 ft thick with about 12 per cent porosity. From Fig. 4, treating 2 ft from the wellbore requires about 15 gal. per foot of pay. With 60 ft of pay, the required treatment would be 900 gal. The recommended treatment volume for this well was 1000 gal. The well was restored to the undamaged production rate as established from production history. Other treatments in this field were evaluated in the manner described above. All of these evaluations seem to confirm that $CaSO_4$ damage in this flood results in high permeability damage that is shallow in extent.

The above example used information from an offset well. Many wells exhibit a "saw-tooth" production history where the well must be treated periodically. These prior stimulations can be evaluated in the same manner.

This approach assumes that wells which are impaired as a result of production will usually experience the same type of damage periodically. Therefore, this approach is particularly applicable in supplementary recovery projects. The method cannot be used if a well has not produced in an undamaged state.

The simplest case of skin damage is considered above. In West Texas, many wells have been fractured, complicating the damage picture. There is permeability restriction in both the fracture and formation. The pressure in the fracture will essentially be equal to wellbore pressure; therefore, the pressure profile into the fracture will be similar to the pressure profile into the wellbore. This being the case, skin damage exists in the formation as well as in the fracture. In these cases, it may be necessary to stage treatments with the second stage being overflushed.

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