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МАГИСТЕРСКАЯ ДИССЕРТАЦИЯ

Тема работы
Оценка эффективности применений обработок призабойной зоны на «Σ» месторождении

УДК 622.245.54(571.16)

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Оглавление

Введение

Использование кислот для стимулирования или улучшения добычи нефти из карбонатных коллекторов было впервые предпринято в 1895 году. Тогда были выпущены патенты на использование как соляной, так и серной кислот. Хотя было проведено несколько «обработок скважин», этот процесс не вызвал всеобщего интереса из-за сильной коррозии обсадной колонны и другого металлического оборудования. Следующие попытки использовать кислоту произошли между 1925 и 1930 годами. Они состояли в использовании соляной кислоты (HCl) для растворения солевых отложений в скважинах на месторождении Гленпуль в штате Оклахома и увеличить добычу из карбонатных пород формации Джефферсона (девон) в Кентукки. Ни одна из этих усилий не была успешной, и «кислотная обработка» снова была оставлена.

Открытие ингибиторов мышьяка, которые позволили HCl взаимодействовать с породой пласта без серьезного повреждения оборудования из металлической скважины, возродило интерес к кислотной обработке нефти в 1932 году. В то время Pure Oil Co. и Dow Chemical Co. использовали эти ингибиторы с HCl для обработки скважин, добывающую из известнякового пласта в округе Изабелла, штат Мичиган. Результаты этого подхода были выдающимися. Когда подобные обработки в соседних скважинах дали еще более впечатляющие результаты, родилась кисловатая промышленность. В течение лет, прошедших с тех ранних обработок, индустрия кислотной обработки выросла до одной, используя сотни миллионов галлонов кислоты, применяемой в десятках тысяч скважин в год. Технология развивалась с нарастающей быстротой, и было сделано много изменений и нововведений для повышения эффективности кислотной обработки. Из-за новых методов применения и разработки добавок для изменения характеристик самой кислоты кислотная обработка стала

высококвалифицированной наукой. Для разработки эффективной кислотной обработки требуется знание доступных материалов, химических реакций при обработке и условий эксплуатации, свойств коллектора и характеристик горных пород.

Данная проблема кислотных обработок и по настоящее время является *актуальной*, так как на месторождениях с системой ППД возникает эффект набухания глинистых частиц в результате чего, снижается проницаемость и как следствие продуктивность и приемистость нагнетательных скважин.

Целью исследования являтся оценка эффективности проведенных работ по глинокислотным обработкам скважин как добывающих так и нагнетательных.

Для достижения поставленной цели будут решены следующие задачи:

– Изучить геологическое строение месторождения и его особенности разработки;

– Рассмотреть и изучить технологии ОПЗ и их кинетику;

– Провести анализ эффективности проведенных ОПЗ на данном месторождении;

– Произвести расчет для средней скважины месторождения объемов хим. реагентов, необходимых для ОПЗ.

– Сделать выводы и рекомендации.

АННОТАЦИЯ

Оценка эффективности от кислотных обработок призабойной зоны скважин на месторождении «Σ» (Томская обл.)

Геологический разрез месторождения «Σ» представлен терригенными отложениями различного литолого-фациального состава мезозойскокайнозойского платформенного чехла и в разной степени метаморфизованными и дислоцированными образованиями доюрского (палеозойского) фундамента.

Характерной особенностью геологического сторония осадочного чехла и кровли доюрского основания на изучаемой территории является широкое развитие тектонических нарушений. Основные разломы, контролирующие залежи нефти и газа, имеют субмеридиональное простирание и затрагивают почти всю осадочную толщу. По мере накопления осадочных отложений в нижней части платформенного чехла тектоническая активность затухает. Дизъюнктивы становятся менее протяженными, малоамплитудными, но ориентировка остается унаследованной. При анализе вертикальных временных срезов на уровне отражающих горизонтов Iб и IIб отмечается, что практически отсутствуют основные признаки амплитудных дизъюнктивов – видимые смещения осей синфазности. О наличии тектонических нарушений на уровне верхнеюрских отложений свидетельствуют только локальные изменения динамических характеристик отраженных волн.

Основным нефтегазоносным объектом является пласт $Ю_1$. Он имеет сложное строение, представлен разнофациальными песчано-глинистыми пропластками, в ряде разрезов скважин – с преобладанием песчаников.

Пласт $Ю_1$ на месторождении вскрыт всеми скважинами. Несмотря на свою довольно резкую литологическую изменчивость по простиранию, в

целом он хорошо выдержан и четко прослеживается по площади. В нем выделяют три толщи – подугольную, межугольную и надугольную.

По результатам интерпретации геофизические исследования скважин коэффициент проницаемости пласта Ю$_1^1$ составляет в среднем 6.6×10^{-3} мкм^2. Средневзвешенное значение по скважинным данным коэффициента пористости пласта составило >0,1 долей единиц. Коэффициент начальной нефтенасыщенности рассчитан как средневзвешенное значение по всей эффективной нефтенасыщенной толщине и принят равным 0,53 доли единиц.

Объектом разработки на месторождении «Σ» является пласт Ю$_1^1$, приуроченный к верхневасюганской подсвите васюганского горизонта оксфордского яруса верхнего отдела юрской системы. Продуктивный пласт сложен песчаниками светло-серыми, мелко-среднезернистыми, среднемелкозернистыми и мелкозернистыми, алевритистыми и алевритовыми, с намывами и прослоями слюдисто-углисто–глинистого материала.

(37%) работают с обводненностью продукции выше 60%.

Коэффициент эксплуатации добывающего фонда скважин составляет 0,7–0,98, коэффициент использования от 0,8 до 0,99.

Весь добывающий фонд объекта Ю$_1^1$ эксплуатируется механизированным способом (ЭЦН). Среднее забойное давление по всему фонду составляет около 5,5 МПа, что ниже давления насыщения (менее 12 МПа).

Ввиду низких фильтрационно-емкостных свойств коллектора на всех скважинах выполняются операции больше объемного гидравлический разрыв пласта, как одного из самых эффективных методов повышения нефтяной отдачи. Применяемые профили и конструкции скважин, методы вскрытия пластов и освоения скважин на месторождении «Σ» являются

апробированными для условий данного месторождения и практически не вызывают осложнений. Месторождение полностью обустроено с точки зрения системы сбора, учета и подготовки продукции скважин.

Кислотная обработка карбонатов и силикатов – это две совершенно различные области. Карбонатные породы, включающие главным образом известняки и доломиты, быстро растворяются в соляной кислоте и создают продукты реакции, легко растворяющиеся в воде.

Для сравнения: реакция между плавиковой кислотой и песчаником проходит гораздо медленнее. Целью обработки глинокислотой является скорее разблокировка существущих каналов путем растворения загрязнения скважины и минералов, заполнящих промежуточное поровое пространство, чем создание новых каналов. Плавиковая кислота быстрее реагирует с минералами из серии песчаников, чем с кварцем. Кислотные реакции, вызываемые сопутствующими минералами – глинами, полевыми шпатами и слюдами, могут создавать отложения, приводящие к закупориванию. Значительная часть проектирования кислотной обработки песчаника обычно направлена на возможность предотвращения этого процесса.

Для обработанных скважин проводилась оценка эффективности обработки призабойной зоны с использованием факторного анализа. Оценка показала, что в 80% процентов случаев обработки глинокислотой на месторождении «Σ» были успешными, то есть наблюдался прирост добычи нефти на протяжении 6 мес и увеличение Кпрод белее чем на 1 т/сут/атм.

Операции ОПЗ значительно повышают добычу нефти, которая в свою очередь увеличивает ЧДД на 14%, что показывает очень хорошие результаты для данного типа обработок.ЧДД более 5000 млн. руб накопленных затрат практически не увеличивается, это говорит о том, что основная масса денежных средств образуется в начальный период. Таким образом чем

раньше будут проводиться ОПЗ на скважинах, тем эффективней они будут как для экономики предприятия так и для выполнения плана по добыче.

Acidizing

Introduction

The use of acids to stimulate or to improve oil production from carbonate reservoirs was first attempted in 1895. Patents covering the use of both hydrochloric and sulfuric acids for this purpose were issued at that time. Although several "well treatments" were conducted, the process failed to arouse general interest because of severe corrosion of well casing and other metal equipment, The next attempts to use acid occurred between 1925 and 1930. These consisted of using hydrochloric acid (HCl) to dissolve scale in wells in the Glenpool field of Oklahoma and to increase production from the Jefferson Limestone (Devonian) in Kentucky. None of these efforts were successful and "acidizing" once again was abandoned.

The discovery of arsenic inhibitors, which allowed HCl to react with the formation rock without seriously damaging the metal well equipment, revived interest in oilwell acidizing in 1932. At that time, Pure Oil Co. and Dow Chemical Co. used these inhibitors with HCl to treat a well producing from a limestone formation in Isabella County, MI. Results of this treatment were outstanding. When similar treatments in neighboring wells produced even more spectacular results, the acidizing industry was born. Throughout the years following those early treatments, the acidizing industry has grown to one using hundreds of millions of gallons of acid applied in tens of thousands of wells each year. Technology has developed with increasing rapidity, and many changes and innovations have been made to improve the effectiveness of acidizing treatments. Because of new techniques of application and development of additives to alter the characteristics of the acid itself, acidizing has become a highly skilled science. A knowledge of available materials, chemical reactions at treating and well conditions, reservoir properties, and rock characteristics are required to design an effective and efficient acidizing treatment. Since it is beyond the scope of this text to cover all aspects of

acidizing in detail, this discussion will be limited to a general description of materials, techniques, and design considerations. A bibliography is provided for those requiring a more detailed discussion of a particular subject. Also, the major well stimulation companies providing acidizing services offer literature and technical assistance for problem analysis and treatment design.

General Principles

The primary purpose of any acidizing treatment is to dissolve either the formation rock or materials, natural or induced, within the pore spaces of the rock. Originally, acidizing was applied to carbonate formations to dissolve the rock itself. Over a period of time, special acid formulations were developed for use in sandstone formations to remove damaging materials induced by drilling or completion fluids or by production practices.

There are two primary requirements that an acid must meet to be acceptable as a treating fluid: (1) it must react with carbonates or other minerals to form soluble products, and (2) it must be capable of being inhibited to prevent excessive reaction with metal goods in the well. Other important considerations are availability, cost, and safety in handling. While there are many formulations available, only four major types of acid have found extensive application in well treatments: hydrochloric, hydrofluoric, acetic, and formic acids.

Hydrochloric Acid (HCl)

An aqeuous solution of HCl is most commonly used for acidizing treatments, for reasons of economy and because it leaves no insoluble reaction product. When HCl is pumped into a limestone formation, a chemical reaction takes place, producing calcium chloride, CO*, and water. This reaction is represented by the following equation:

One thousand gallons of 15% HCI will dissolve approximately 10.8 cu ft (1,840 lbm) of limestone. It will liberate approximately 7,000 cu ft of CO1 , measured at atmospheric conditions, and produce 2,042.4 lbm of calcium chloride.

This salt is dissolved in the original water of the acid solution, plus 39.75 gal of water formed during the reaction. The specific gravity of this solution will be 1.181 (20.4% calcium chloride). While 15 wt% HCI has been the most commonly used, concentrations of 20 and 28% have become extremely popular over the past 2 decades. Regardless of the acid strength used, the reaction is the same and equivalent amounts of carbonate rock are dissolved. For example, 10,000 gal of 3% HCl solution will dissolve the same amount of rock as 1,000 gal of 28% HCl. Fig. 54.1 shows the effect of acid concentration on the amount of limestone dissolved. The main differences between the two solutions are their reaction rates (or spending times) and their physical volumes. Although lower concentrations of acid have greater equivalent volumes, their reaction times and depth of penetration into the reservoir, from the wellbore, are considerably less than those of the higher-strength solutions. Reaction rates and penetration will be discussed later.

Similar reactions occur when dolomite or impure limestone is treated with HCI. Dolomitic lime contains a large percentage of magnesium combined as calcium magnesium carbonate. Although it reacts more slowly, this mineral also dissolves in HCl, and the resulting magnesium chloride is soluble in the spent acid. Other impurities occurring in limestone and dolomite are often insoluble in acid, and if appreciable percentages of such components are present, special additives must be included in the acid solution to ensure their removal.

HCl ordinarily is manufactured in concentrations of 32 to 36 wt% HCl and is diluted at service company stations to 15, 20, or 28% for field use. The concentrated acid, the various chemical additives, and water are mixed in the tank truck used to haul the acid to the wellsite. Table 54.1 lists the weights of various concentrations of HCI. These data are useful in calculating mixing proportions for acid dilution, using the following equation:

$$V_{ca} = \frac{V_{da} C_{da} \gamma_{da}}{C_{ca(HCl)} \gamma_{ca}},$$

where

Vda = final volume of dilute acid, Cda = desired

concentration of dilute acid, λda = specific gravity of

dilute acid, Vca = volume of concentrated acid

required, Cca(HCI) = percent of HCI in concentrated

acid, and γca = specific gravity of concentrated acid.

Approximate proportions of concentrated acid and water required for dilution .

Determination of acid strength can be estimated in the field using either a hydrometer or a field titration kit. The accuracy of hydrometer readings depends on the care and technique used by the field engineer. Both the hydrometer and the glass cylinder in which the test is made should be free from oil or dirt. The spindle should float freely in the acid, and all readings should be made at the lowest level of the acid meniscus. The temperature of the acid sample should be taken and the hydrometer reading corrected to 60°F.

Determination of acid strength by titration is simplified by the use of 0.59 N standard sodium hydroxide solution. If a 2-mL sample of the acid is titrated with this standard solution to a methyl orange end point, the burette reading (milliliters of sodium hydroxide used) will be equal to the acid strength (percent HCI).

Acetic and Formic Acids

Acetic acid (CH3COOH) and formic acid (HCOOH) are weakly ionized, slowly reacting, organic acids. They are used much less frequently than HCI and are suitable primarily for wells with high bottomhole temperatures (BHT's above 250°F) or where prolonged reaction times are desired. The reaction of these acids with limestone is described by the following equation:

2HOrg+CaCOj +CaOrgz +HzO+CO,.

HAc is available in concentrations up to 100% as glacial HAc. while HCOOH is available in 70 to 90% concentrations. For field use, HAc solutions normally are diluted to I5 % or less.

Above this concentration, one of the reaction products, calcium acetate, can precipitate from its "spent acid" solution because of its limited solubility. Similarly, the concentration of HCOOH normally is limited to 9 to 10% because of the limited solubility of calcium formate. At a 10% concentration, 1,000 gal HAc will dissolve 740 Ibm of limestone, whereas 1,000 gal HCOOH dissolves 970 lbm. Where more dissolving power per gallon of acid is desired, HCI is sometimes mixed with HCOOH or HAc. Such blends still provide extended reaction times. when compared with HCl. HCOOH and HAc also may be blended together. Table 54.2 illustrates some of the more common acid strengths and blends.

Hydrofluoric Acid (HF)

HF is used in combination with HCI and has been referred to as "intensified acid" or "mud removal" acid. Depending on the formulation and use. HF is used primarily to remove clay-particle damage in sandstone formations, to improve permeability of clay-containing formations, and to increase solubility of dolomitic formations. Its utility is based on the fact that some clays. silica, and other materials normally insoluble in HCI have some degree of solubility in HF. For example, 1000 gal of an acid solution containing 3% HF and 12% HCI will dissolve 500 lbm of clay and up to I .450 lbm of $CaCO_3$.

In carbonates, application of HF/HCl mixtures must be controlled carefully because of cost and possible precipitation of reaction products such as calcium fluorides or complex fluosilicates, which have a very limited solubility. For reaction with silicates, such as natural clays or clays in drilling fluids, the blends usually contain 2 to 10% HF and 5 to 26% HCl. The concentration of HCl used in the blend should be equal to or greater than that of the HF.
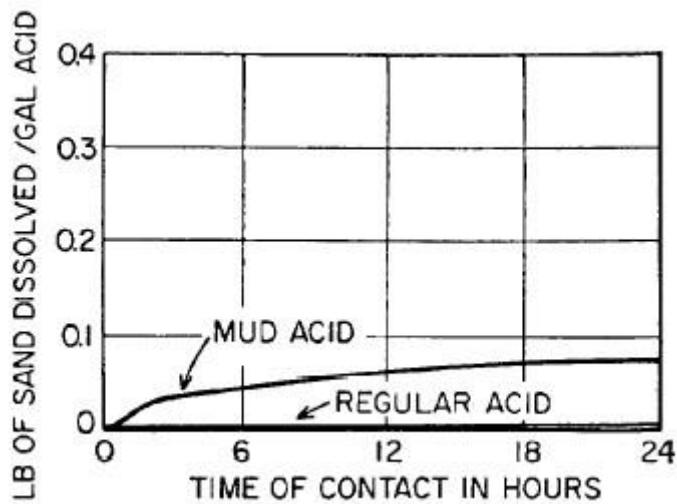
Figure 1 Solubility of silicas and in mud removal acid.

The so-called "intensified acids" used in dolomitic formations are mainly HCl containing small concentrations of HF, usually about 0.25 % Intercrystalline films of silica, insoluble in HCl, often occur in the crystal structure of dolomite. When such are present, they prevent the acid from contacting the soluble portions of the rock. The presence of fluoride intensifier in the acid will destroy such films, allowing the acid to react more completely with the soluble portions of the rock. Illustrates the comparative reaction rates of HCI and intensified acid on dolomite formations.

More recent developments of HF involve the use of delayed-action agents in sandstone acidizing. The first of these was a self-generating mud acid system, reported by Templeton et al. ' The system provides slow generation of acid from the hydrolysis of methyl formate. Yielding methyl alcohol and HCOOH acid. The acid then reacts with ammonium fluoride to yield HF in situ. They attribute the success of the system to getting the HF reaction away from the wellbore into areas that conventional HF solutions normally do not reach before spending. Equally important factors are the techniques of application and of returning the well to production following treatment. The treatment technique mvolves use of an aromatic solvent and mud acid preflush, along with the self-generating mud acid (SGMA). The wells are returned to production by opening the choke gradually

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over a 90–day period and never allowing an excessive drawdown. The process is available from most service companies as SGMA.

A significant development in this area of slow-reacting, HF-supplying, claydissolving acid has been the fluoboric acid system reported by Thomas and Crowe.' This acid hydrolyzes to form hydroxyfluoboric acid and HF, which will dissolve clays.

$$HBF4 + HZO - HBF30H + HF.$$
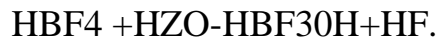
This reaction provides a slow-release source of HF, which can penetrate deeply before spending. Perhaps more important, the slowly generated hydroxyfluoboric acid reacts with clays to form a nonswelling, nondispersing product that stabilizes fine clays and holds fine particles of silica in place.

Acid Reaction Rates

A knowledge of the factors affecting the reaction rate of acids is important for several reasons. First, these factors, correlated with reservoir and formation characteristics, form a guide for the selection of acid type and volume for a given treatment. Next, a study of these factors can furnish an understanding of what parameters govern spending time, which will determine how far a given formulation can penetrate into the formation before spending. Many factors govern the reaction rate of an acid, such as pressure, temperature, flow velocity, acid concentration, reaction products, viscosity, acid type, area/volume ratio, and formation composition (physical and chemical). These factors have been the subject of extensively reported research for many years. Details of such studies are available in published literature.
Only a brief general discussion will be presented here.

Pressure

Fig. 3 shows the effect of pressure on the reaction rate of 15% HCl with limestone and dolomite at 80°F. Above 500 psi, pressure has little effect on reaction rate. At bottomhole treating pressures, there is only a small difference (a

factor of 1.5 to 2) in the comparative reaction of acid with limestone and dolomite compared to the rather large difference (a factor of about 10) at atmospheric pressure.
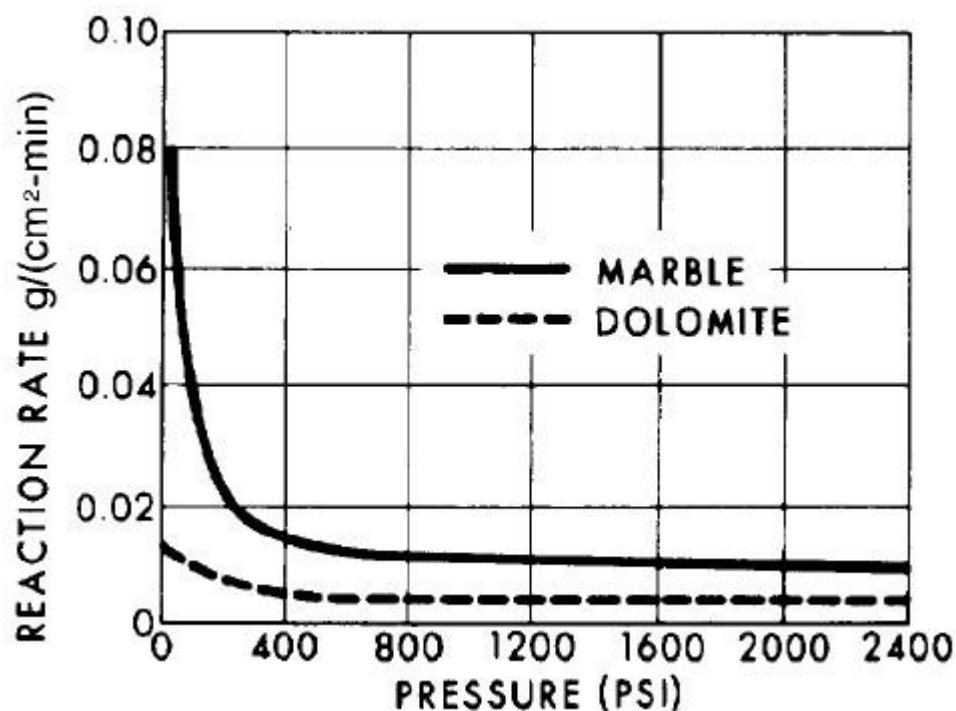

Figrure 2-Effect of pressureo n reaction rate (15% HCI tit8 0°F).

Temperature

Acid reaction rate increases directly with temperature. At 140 to 150"F, the reaction rate of HCI and limestone is approximately twice that at 80°F. It must be recognized that the temperature controlling the reaction is affected by the injection temperature of the acid (a major factor), and by the heat liberated by the reaction itself (a minor factor). Computerized programs are used to estimate the bottomhole fluid temperature at various stages, allowing more effective acid treatment design.

Flow Velocity

Fig. 4 shows that increased flow velocity increases the reaction rate of 15 % HCl with CaCO 3. This velocity effect is more pronounced in narrower fractures. Reaction rate is a function of shear rate, 6 v/b, set - ' as illustrated by the following equation:

$$R=[(28.5 \ v/b)^{0.8}+184]\times 10^{-6}, \quad \ldots\ldots\ldots\ldots\ldots(1)$$

where R is the reaction rate in lbmisq ft-set, v is the flow velocity in fracture, ft/sec, and b is the fracture width, ft. (The reaction rate is for 15% HCl with marble at 80°F under 1,100 psi pressure.)
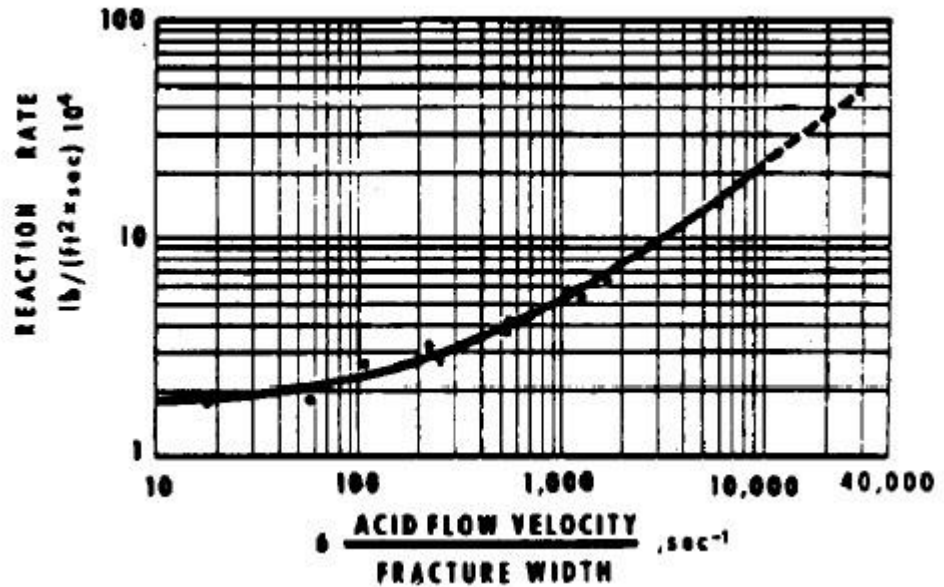

Figure 3-Effect of flow on reaction rate (15% HCI with CaCO3).

The flow velocity in fractures and channels depends on injection rate and actual geometry of the flow path.

$$v_{rf}=0.18i_{ac}/(r_f b) \quad \text{(radial fracture)}, \quad \ldots\ldots\ldots(2a)$$

$$v_{lf}=1.15i_{ac}/(hb) \quad \text{(linear fracture)}, \quad \ldots\ldots\ldots(2b)$$

$$v_{cc}=17.2i_{ac}/d^2 \quad \text{(cylindrical channel)}. \quad \ldots\ldots\ldots(2c)$$

where
v = flow velocity in fractures and channels, ft/sec,
i_{ac} = acid injection rate, bbl/min,
r_f = fracture radius, ft,
h = fracture height, ft,
d = channel diameter, in., and
b = fracture width, in.

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Acid Concentration

Reaction rate increases with acid concentration up to 24 to 25% HCl, but not proportionally, as shown in Fig. 54.8. Above 25% HCl, the reaction rate actually decreases because of reduced acid activity. As acid spends, the reaction rate decreases as a result of reduced acid concentration and the retarding effect of dissolved reaction products, such as calcium or magnesium chloride.
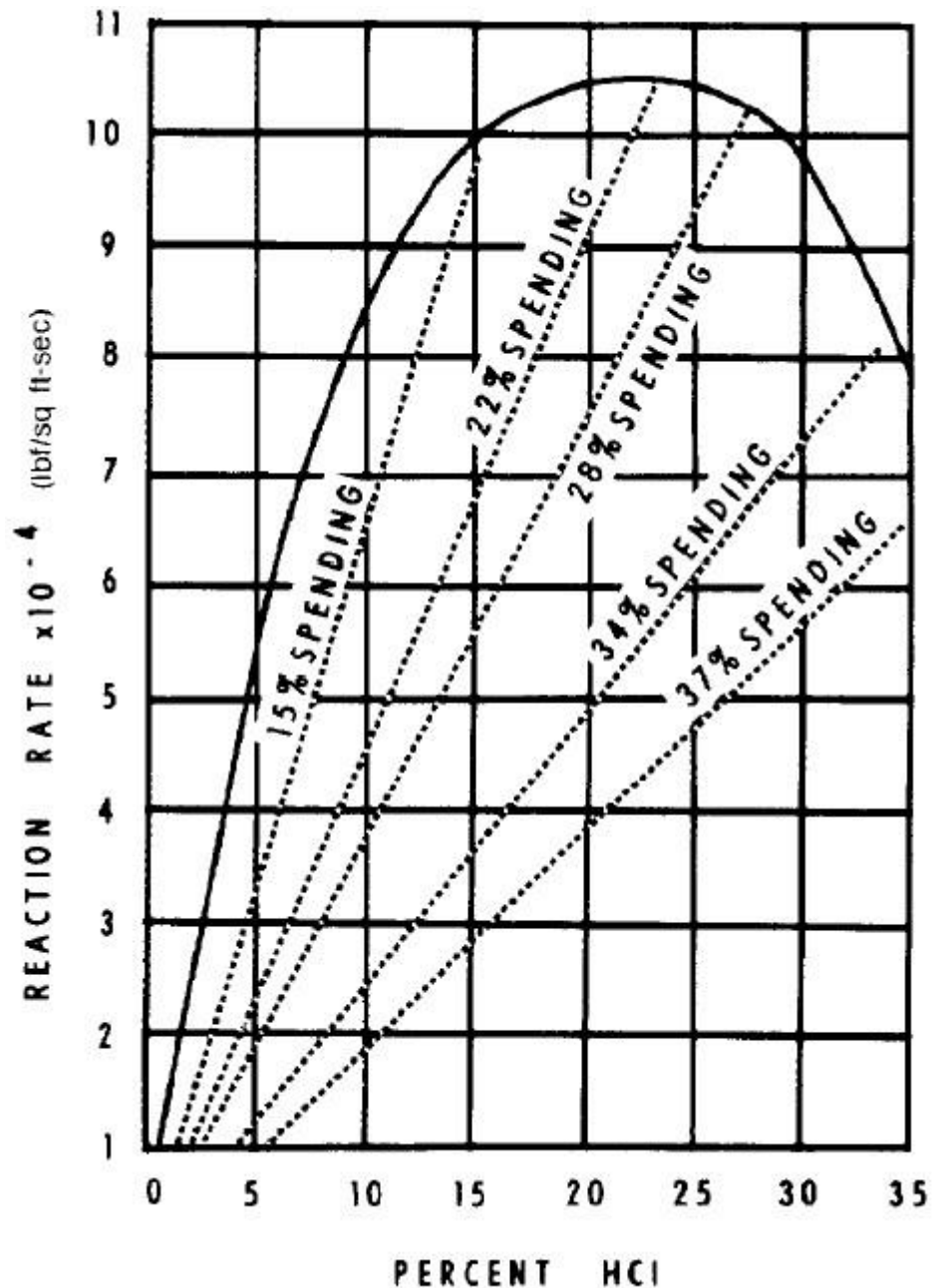

Figure 4-Effect of concentration on reaction rate and spending rate.

Area/Volume Ratio

Area/volume (A/V) ratio is one of the major factors affecting reaction rate spending time, and may vary over a wide range. This ratio, the area in contact with a given volume of acid, is inversely proportional to pore radius or fracture width. Fig. 6 shows the time required for 15% HCl to spend on marble, at 80°F and 1,100 psi, for three different A/V ratios.
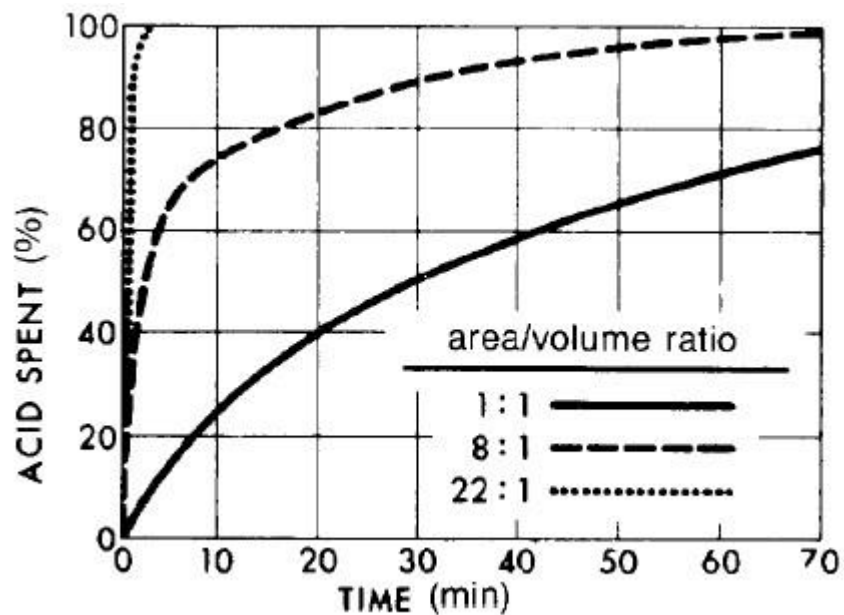

Figure. 5-Effect of A/V ratio on spending time (15% HCI, 80°F and 1,100 psi).

The term "spending time" has very little meaning or value by itself. It must be related to flow geometry and, thus, to the distance the acid penetrates before it is spent. In matrix acidizing, extremely high A/V ratios may be encountered. For example, a IO-md, 20%-porosity limestone may have an A/V ratio of 28,000 to 1. In such a formation, it would be very difficult to obtain significant penetration before spending. A natural fracture, 0.00 1 in. wide, has an A/V ratio of 3,200: 1. A 0. l-in. fracture has an A/V ratio of 32: 1. The smaller ratios in wider fractures allow greater penetration of the acid into the reservoir before spending is complete.

Formation Composition

Probably the most important factor that governs effectiveness of an acidizing treatment is the rock composition. Its chemical and physical characteristics determine how and where the acid will react with and dissolve the rock.

From the standpoint of chemical composition, there is little difference in the reaction rate of HCI on most limestones, all other factors remaining constant. The physical rock texture. however, can control pore size distribution. A/V ratio, pore geometry, and other properties. This, in turn, influences the type of flow channels created by acid reaction and is the key to acid response. Two formations having the same acid solubility and permeability may respond differently to acid treatment because of variances in physical structure.

Acid Additives

The use of a corrosion inhibitor as an additive made possible the first commercially feasible acidizing treatments. Since that time, many auxiliary chemicals have been developed to modify acid solutions, influencing their application and recovery.

Corrosion Inhibitors

Inhibitors are chemical materials that, when dissolved in acid solutions, greatly retard the reaction rate of the acid with metals. They are used in acidizing to avoid damage to casing, tubing, pumps, valves. and other well equipment. Inhibitors cannot completely stop all reaction between the acid and metal; however, they do slow the reaction, eliminating 95 to 98% of the metal loss that would otherwise occur. Most inhibitors have practically no effect on the reaction rate of acid with limestone, dolomite, or acid-soluble scale deposits.

The length of time that an inhibitor is effective depends on the acid temperature, type of acid, acid concentration, type of steel, and the inhibitor concentration.

Organic inhibitors in HCI are effective up to 400"F, but above 200°F relatively large concentrations are required. The effect of temperature on corrosion inhibition. Equations have been developed for estimating BHT's during acid treatments. By knowing these temperatures, adequate corrosion protection can be provided, even in wells with static BHT's up to 400°F.

Surfactants

Surfactants are chemicals used to lower the surface terlsion or interfacial tension of fresh acid or spent acid solutions. The use of a surfactant improves the treating efficiency in a number of ways. The presence of a surfactant improves the penetrating ability of the acid solution entering a formation. This is extremely desirable in matrix acidizing treatments. Because it provides deeper penetration of acid into the formation. In addition, surfactants permit the acid to penetrate oily films clinging to the surface of the rock and lining the pores, so that the acid can come in contact with the rock and dissolve it.

The use of surfactants also facilitates the return of spent acid following the treatment (Fig. 6). Wetting of the formation is more nearly complete and there is less resistance to flow of the acid, so that the spent acid is readily returned through the treated section. This is especially important in low-pressure wells.
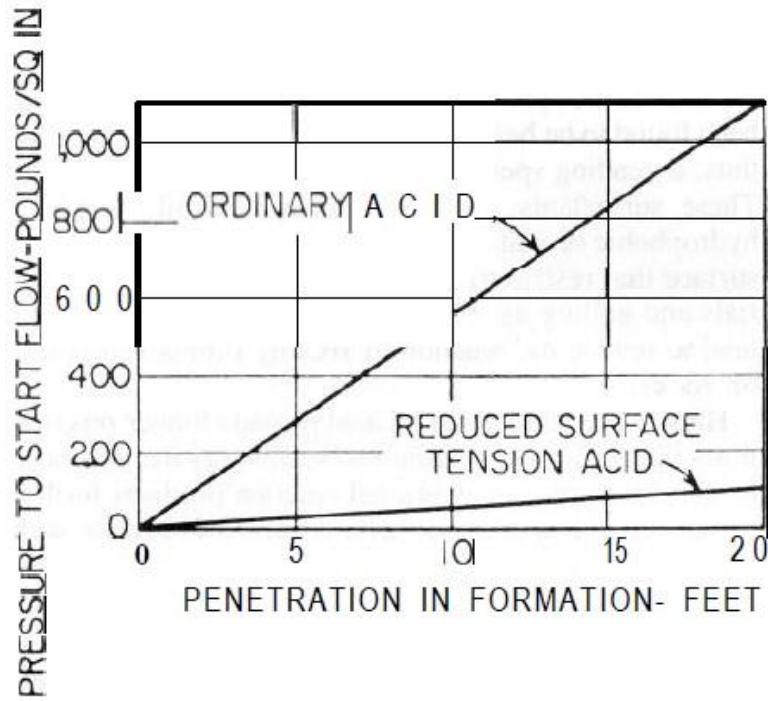
Figure 6—Effect of surface-tension-reducing agent in facilitating return of spent acid.

Another advantage in the use of surfactants in acid is the demulsifying action obtained. Many surfactants are capable of inhibiting the occurrence of emulsions or destroying those already formed.

Surfactants also promote dispersion and suspension of fine solids to provide better cleanup following treatment. These solids may be either mud solids or natural fines released from the formation. They are suspended and physically removed from the formation.

Special surfactants are used as antisludge agents. Some crudes form an insoluble sludge when in contact with acid. The sludge consists of asphaltenes, resin, paraffin, and other complex hydrocarbons. The acid reacts with the crude at the interface, forming an insoluble film. The coalescence of this film, which results on the sludge particles, can be avoided by use of proper additives. Ethylene glycol monobutyl ether is a mutual solvent surfactant used in matrix sandstone acidizing to water-wet the formation. This agent prevents particle migration and subsequent particle plugging. It improves cleanup by preventing the stabilization of emulsions

by fine particles. Many different surfactants are used in acidizing. Type and concentration for a particular application should be selected on the basis of laboratory testing.

Silicate-Control Agents

Various silicate compounds, commonly known as clays and silts, usually are present in most limestones and dolomites. One of the characteristics of these silicates is that they will swell in spent acid. Naturally, this is undesirable because swollen silicate particles may block formation flow channels, reducing well production.

Silicate-control additives are chemicals that prevent released silicate particles from adsorbing water. Some buffer the pH of the solution near the isoelectric point (where the volume of the swelled clays is at a minimum). Others cause shrinkage of the silicate particles by replacing the adsorbed water molecules with a waterrepellent organic film. Thus, possible formation plugging is prevented, treating pressures are lowered, faster cleanup is provided, and the occurrence of particlestabilized emulsions is minimized.

Iron-Control Agents

Iron control is approached two ways. The oldest and most common approach is to use sequestering agents, which act by complexing iron ions, thereby preventing precipitation when the acid spends. A second method is use of reducing agents that reduce any ferric ions (Fe^{3+}) to ferrous ions (Fe^{2+}), which do not precipitate as the hydroxide or hydrous oxide until the pH of the system is above 7. Since acids in contact with the formation rock will not spend to a pH that high, the hydroxide will not damage the well. Spent acid usually has a pH between 4.5 and 6.5, no higher.

Erythorbic acid is one of the most effective reducing agents that can be used for this purpose. The reduction of all the ferric iron to ferrous iron, however, does not prevent the precipitation of ferrous sulfide (FeS), which precipitates when the

acid spends to a pH of 2, as it will readily in almost any formation. To protect fully against iron precipitation in a sour well, a complexing agent is needed. Citric, lactic, and acetic acids as well as EDTA or NTA are popular sequestrants. In some wells where H2S can become mixed with the acid it also may be advisable to use both the reducing agent and the sequestering agents, since ferric iron can react with H2S to precipitate free sulfur, which itself can damage permeability The loss of effectiveness of acetic acid at temperatures above 125°F and the possibility of precipitating calcium citrate also are factors that should be considered in guarding against iron precipitates.

Alcohols

Methyl and isopropyl alcohols sometimes are used at concentrations of 5 to 20 ~01% of acid to reduce surface tension. Methyl alcohol is sometimes used at concentrations, up to 66 % to increase vapor pressure of the acid and spent acid solution. Use of alcohols thus improves both rate and degree of cleanup, which can be particularly helpful in dry gas wells.

Gelling and Fluid Loss Agents

Natural gums and synthetic polymers are added to acid to increase the viscosity of the acid solution. 3 This reduces leakoff into large pore spaces and, to some extent, into natural hairline fractures. It also provides some degree of reaction rate retardation.

Other materials used to control leakoff are fine (IOOmesh) sand and fine salt These materials bridge in hairline fractures to reduce fluid flow out of the main fracture during fracture acidizing treatments.

Another successful fluid-loss control agent is a mixture of finely ground, oilsoluble resins. Originally designed as a diverting agent for use through gravel packs during sandstone matrix acidizing treatments, this agent was later shown to be effective as a fluid-loss agent in fracture acidizing, when used at higher concentrations. '

Liquefied Gases

Liquid nitrogen and liquid CO2 sometimes are used in acid solutions to provide added energy for better well cleanup. Nitrogen also is used to make foamed acid, which provides excellent leakoff control in low permeability rock.

Retarded Acids

It is often desirable in acid fracturing treatments to retard the reaction rate of the acid to provide deeper penetration of active acid into the formation. Retardation may be accomplished by use of slower-reacting acids (HAc and HCOOH), by adding chemicals to reduce reaction rate, or by increasing concentration to extend spending time.

HAc and HCOOH are weakly ionized and sometimes are used to obtain longer reaction time. The additional cost of these acids may prohibit extensive use in certain formations. Deeper matrix penetration than would be obtained by HAc or HCOOH is obtained by the fasterreacting HCl because the channeling or wormhole effect produced by the HCl reduces the A/V ratio, thus prolonging reaction time. In fractures, the HAc and HCOOH would obtain deeper penetration than HCl; however, larger volumes would be required to dissolve an equivalent amount of rock.

Some chemicals, added to HCl, form a barrier on the rock surface, which interferes with its normal contact and "retards" the reaction rate of the acid. Acidin-oil emulsions generally exhibit retarded reaction rates. The acid in the emulsion does not completely contact the rock surface because of the presence of an interfering oil film. This is particularly true for emulsions with at least 20% oil as the outer phase. Certain surfactants recently have been found to be beneficial in reducing reaction rate and, thus, extending spending time and penetration distance. These surfactants, in the presence of oil, provide a hydrophobic or water-repellent, oil-like film on the rock surface that restricts acid/rock contact. Fluid-loss materials

and gelling agents (acid-thickening additives) also tend to reduce the reaction of HCl by film development on rocks.

Acidizing Techniques

There are three fundamental techniques used in acidizing treatments.

1. Wellbore Cleanup. This entails fill-up and soak of acid in the wellbore. Fluid movement is at a minimum, unless some mechanical means of agitation is used.

2. Matrix Acidiz,ing. This is done by injecting acid into the matrix pore structure of the formation, below the hydraulic fracturing pressure. Flow pattern is essentially through the natural permeability structure.

3. Acid Fmcturing. This is injection into the formation above hydraulic fracturing pressure. Flow pattern is essentially through hydraulic fractures: however, much of the fluid does leak off into the matrix along the fracture faces.

The technique selected will depend on what the operator wishes to accomplish with the treatment.

Matrix acidizing may be selected as a proper technique for one or more of the following reasons: (1) to remove either natural or induced formation damage, (2) to achieve low-pressure breakdown of the formation before fracturing, (3) to achieve uniform breakdown of all perforations, (4) to leave zone barriers intact, or (5) to achieve reduced treating costs.

The principal types of formation damage are mud invasion, cement, precipitates, saturation changes, and migration of fines. The effect of damage on injectivity or productivity is shown in Fig. 7. It can be seen that the greatest flow increase results from restoring the natural rock permeability. The magnitude of this primary flow increase depends on the extent (radius) of the damage. Further increase in pore size by matrix acidizing results in only a limited increase in flow (stimulation).

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If the producing formation does not have enough natural permeability, then a hydraulic fracturing treatment should be considered. The primary purpose of fracturing is to achieve injectivity or productivity beyond the natural reservoir capability. An effective fracture may create a new permeability path, interconnect existing permeability streaks, or break into an untapped portion of the reservoir.
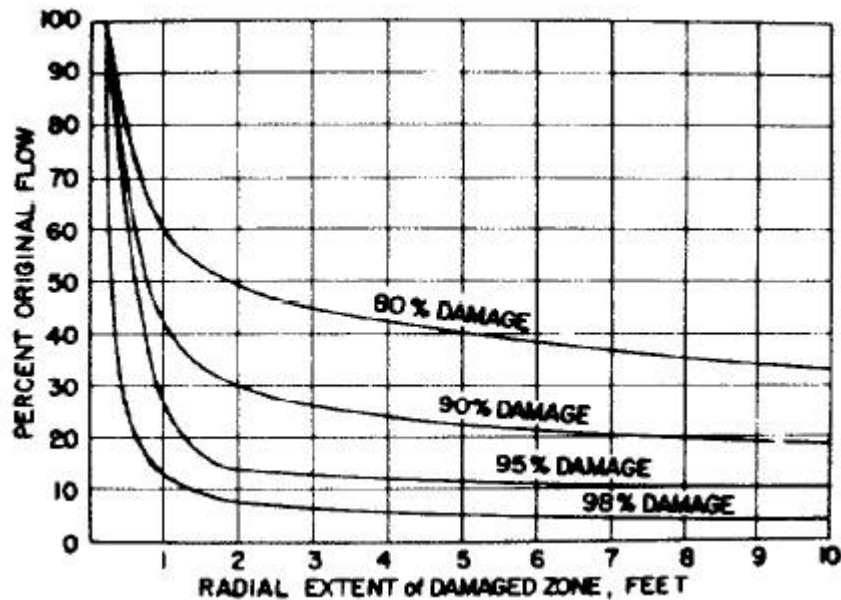

Figure 7 – Effect of damaged zone on flow.

The success of any fracturing treatment depends on two factors: fracture conductivity and effective penetration, as illustrated in Fig. 8. If enough etched fracture conductivity can be achieved, then increased penetration becomes important. For any given formation, there will be an optimum conductivity and penetration, which will be controlled by cost. In other words, there will be some point where production increase per dollar spent will be a maximum. This must be determined by pretreatment design.
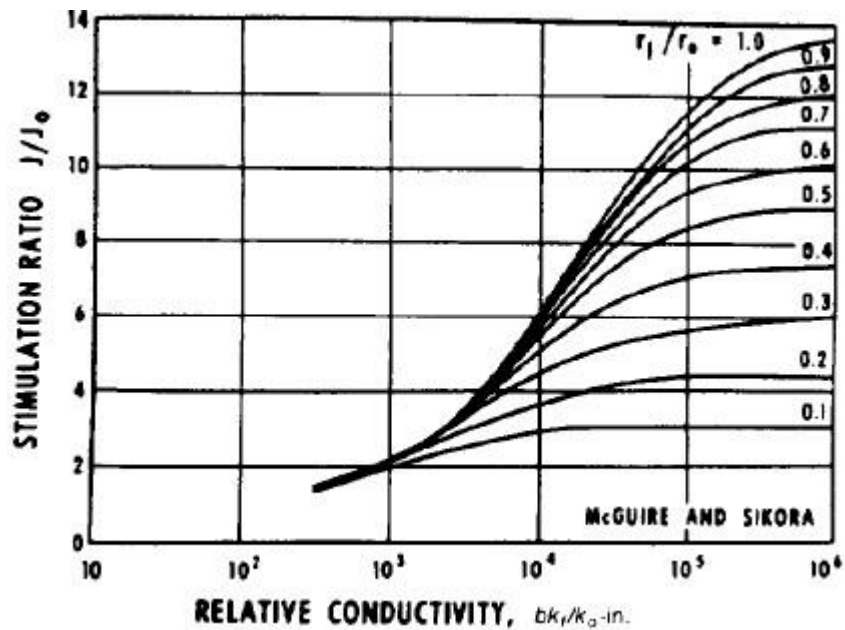
Figure. 8 - Relationship of conductivity and penetration to productivitiy crease.J = productivitiyn dex of well after stimulation, J, = productivity index before stimulationr,i = radiuso f fracture(ft)r,e = drainage radius (ft). k,=permeability of fracture (md), k, = permeability of formation (md), and b = fracture width (in.).

Laboratory Testing

The physical and chemical characteristics of the formation rock often affect the results of an acidizing treatment. In some cases, the use of special additive chemicals will improve the action of the acid or avoid cleanup difficulties in returning the spent acid following the job. It is important, therefore, that samples of the formation rock (either cores or cuttings) and, if possible, samples of the crude oil and formation brine be subjected to laboratory testing before acidizing to design the most effective treatment.

Customarily, permeability. porosity, and oil- and watersaturation tests are run on formation core samples, using standardized core-analysis procedures. In addition, acidsolubility tests are run to determine to what extent the formation will respond to an acidizing treatment.

Formation solubility may be determined two different ways. In the first method, a weighed chunk of the rock is immersed in an excess of acid and

maintained at formation temperature. After an hour, any insoluble residue is washed. dried, and weighed. With samples known to contain silicates, additional tests may be run in which the rock is exposed to the dissolving action of combined HCl and HF.

Заключение

Геологический разрез месторождения «Σ» представлен терригенными отложениями различного литолого-фациального состава мезозойскокайнозойского платформенного чехла и в разной степени метаморфизованными и дислоцированными образованиями доюрского (палеозойского) фундамента.

Характерной особенностью геологического сторооения осадочного чехла и кровли доюрского основания на изучаемой территории является широкое развитие тектонических нарушений. Основные разломы, контролирующие залежи нефти и газа, имеют субмеридиональное простирание и затрагивают почти всю осадочную толщу. По мере накопления осадочных отложений в нижней части платформенного чехла тектоническая активность затухает.

Основным нефтегазоносным объектом является пласт $Ю_1$. Он имеет сложное строение, представлен разнофациальными песчано-глинистыми пропластками, в ряде разрезов скважин – с преобладанием песчаников.

Пласт $Ю_1$ на месторождении вскрыт всеми скважинами. Несмотря на свою довольно резкую литологическую изменчивость по простиранию, в целом он хорошо выдержан и четко прослеживается по площади. В нем выделяют три толщи – *подугольную, межугольную и надугольную*.

На текущий момент месторождение «Σ» находится в промышленной разработке – II стадия разработки;

Дебиты вновь вводимых скважин неуклонно снижаются по геологическим причинам (бурение в зонах максимальных нефтенасыщенных толщин закончено);

Наибольшие потери базовой добычи связаны с энергетикой пласта и прогрессирующим обводнением скважин, одной из причин которого является приближение фронта нагнетаемой воды к добывающим скважинам;

Выработка запасов составила 31%, текущий КИН – 0,107;

Система разработки на месторождении является практически сформированной - в зонах активного бурения перевод скважин в подъёме пластового давления не соответствует проектным решениям.

На месторадени Σ применяют два вида обработки призабойной зоны: солянокислотные (редко) и глинокислотные. Наибольший эффект достигается от ГКО, так как карбонатного материала в продуктивных пластах незначительно, а разбухание глинистого материла из-за осуществления подъёма пластового давления наиболее значительно влияет на фильтрационно-ёмкостные свойства призабойной зоны скважин.

Проведена оценка эффективности проведенных Обработок призабойной зоны при помощи факторного анализа положительный эффект на добывающем фонде, 12 из 14 скважин дали прирост по нефти. Увеличение Кпрод наблюдается в среднем на 1.2 .

На нагнетательном фонде также были проведены 5 операций обработок призабойной зоны, которые дали положительный эффект – увеличение приемистости каждой нагнетательной скважины.

Рассчитан объем кислоты (HCl+HF -12%) для обработки не более 30м^3 и не менее 10 м^3.

По результатам оценки экономической эффективности от обработок призабойной зоны было выявлено, что чистый дисконтированный доход в среднем увеличивается до 14% – что показывается значимость проводимых обработок призабойной зоны на месторождении.

В главе социальная ответственность выявлены вредные факторы, влияющие на окружающую среду, при операциях обработок призабойной зоны и меры безопасности по работе с химреагентами, а также меры по предотвращению попадания химических веществ в водоемы и почву.