CHAPTER 3 Fluid Planning: Processes and Systems

At this point, you have chosen a clear brine fluid and made adjustments for temperature, pressure, and PCT. The volume of fluid required for the job has also been estimated.

This chapter will cover:

1. Maintenance of Clear Brine Fluid Properties
2. Corrosion Control
3. Displacement
4. Fluid Loss Control
5. Filtration and Brine Clarity

Much of the information contained in each of the following sections is applicable to all clear brine fluids. For ease of use, where information is specific, icons have been added to indicate whether it applies to one, two, or three salt brines.

Maintenance of Clear Brine Fluid Properties

This section of TETRA's *Engineered Solutions Guide for Clear Brine Fluids and Filtration* is concerned with the brine density families depicted in Figure 2 on page 11. Our goal is to focus your search upon information that is pertinent to your project. For instance, if you are planning a completion using a 3% KCl brine, you may want to skip over information that is specific to high density, three salt fluids. Brine properties also depend on composition; as the number of salts in a fluid goes up, the response to changes in brine properties such as the weight up procedure, cutback procedure, or choice of viscosifying agent to use, will differ. If you are trying to find information quickly, make use of the icons that indicate whether a section applies to one, two, or three salt brines to help narrow your search.

Objectives

- Maintain or adjust fluid density
- Control formation pressure
- Minimize fluid loss
- Maintain adequate volume

Factors Affecting

- TVD and BHP
- Sources of dilution
- Density adjustment options
- Operational constraints

Discussion

Maintaining a consistent fluid density is of primary importance in pressure control. Formation pressure is usually estimated within a narrow range. Occasionally, BHP will be different from that anticipated, and the fluid density will have to be altered to fit the actual well conditions. Adjustments may also be required due to dilution. Lower than anticipated formation pressure and fluid loss may necessitate a cutback or downward density adjustment. Conversely, higher pressure will dictate the addition of weight material to increase density.

Responding to variations in density means that a weight up or cutback procedure may be necessary. Weight material, either a concentrated liquid blending stock spike fluid or dry salt weight material, should be available on location in order to allow you to respond quickly and maintain safe working conditions.

Single Salt Brine Density Maintenance

1 SALT

With densities from 8.4 lb/gal to 11.6 lb/gal and gradients less than about 0.6 psi/ft, single salt brines are employed in lower pressure wells. Maintaining pressure control in these wells is no less important than in any others.

Unintentional Dilution. Well pressure control can be jeopardized by the unintentional dilution of a CBF with any source of lower density fluid such as rain water. The effects of this unintentional dilution will depend on the density difference between the working fluid and the diluting fluid. The greater the density difference, the more sensitive the working fluid will be to dilution.

Weight Up. A single salt brine can be reconstituted by adding dry salt weight material in the correct proportions or by adding liquid weight material or spike fluid.

- **Dry Salt Weight Material** can be used to increase the density of a single salt fluid that has been diluted, as long as adequate mixing equipment is available. Dry salt additives can also be used if additional hydrostatic pressure is needed to control the well. (See Equation 12 on page 69.) Weight up tables for the single salt fluids are provided in the "Single Salt Fluid Composition and Blending Tables" section, beginning on page 145.

When adding dry salt to increase density in a fluid, care should always be taken to monitor TCT with respect to environmental considerations.

- **Spike Fluid** is a fluid of higher density that can be added to a working fluid to raise its density. Figure 6, "Selecting and Using Spike Fluids," on page 26, illustrates the potential for increasing fluid density using a spike fluid. As the density of the working fluid approaches the density of the spike fluid, the volume of spike required to raise the density increases rapidly.

Changes in brine density, either by dilution or weight up, will change the TCT of a single salt brine. Make sure you have consulted the "Single Salt Fluid Composition and Blending Tables" section, beginning on page 145, before making any change to the fluid density.

Adding dry salts to a fluid can result in a substantial increase in brine temperature. A quick pilot test should be run to get a sense of the temperature rise that may occur. ALWAYS ADD DRY CHEMICALS SLOWLY, AND FREQUENTLY CHECK THE TEMPERATURE INCREASE.

Make an estimate of the quantity of weight material required to recover from a 0.2 lb/gal drop in density, and have at least that amount available on location.

Cutback. To reduce the hydrostatic pressure on a formation, in order to slow fluid loss for example, the density of a fluid can be cut back by adding water. Cutback tables have been provided for each of the common single salt brines in Chapter 6. (See "Single Salt Fluid Composition and Blending Tables," beginning on page 145.) The values in the tables are decimal fractions of a barrel of starting brine needed to make one barrel of final density brine when diluted with water. Alternatively, Equation 15, used for cutting a fluid back using weight percent salts, has also been provided in Chapter 4, "Field Applications and Brine Maintenance."

Seawater, due to the dissolved minerals it contains, is not recommended for use in brine cutbacks.

Two Salt Brine Density Maintenance

2 SALT

Maintaining the density of a two salt brine is more complicated than for that of a single salt fluid. Standard two salt fluids are blends of calcium chloride ($CaCl_2$), calcium bromide ($CaBr_2$), and water. The relative proportion of each component determines the density and TCT of the fluid. Any changes you make to weight a fluid up or cut a fluid back must be made carefully or your TCT will be altered.

Density adjustment is most commonly required as a result of a fluid's dilution by rainwater, field brine, or simply by absorption of water from the air.

Protecting CBFs from dilution is extremely important. It takes only 3.4 bbl of fresh water to drop the density of 100 bbl of a 14.5 lb/gal CBF by 0.2 lb/gal, which represents a 50 psi drop in bottomhole hydrostatic pressure in a 5,000 ft well.

Dry Salt Weight Up. Under certain circumstances, dry salt may be used to increase fluid density; however, caution should be exercised to closely monitor TCT with respect to environmental considerations. Weight up of a two salt fluid by adding dry calcium chloride ($CaCl_2$) is not recommended, as doing so will alter the ratio of $CaCl_2$ to $CaBr_2$ and increase the fluid's TCT. It is also difficult to mix dry salts into nearly saturated brines without using specialized mixing equipment. In the event of a severe limit on fluid volume, addition of dry calcium bromide ($CaBr_2$) can be used as weight material in two salt fluids. Any composition changes should be verified using one of TETRA's proprietary fluid blending programs.

Spike Fluid Weight Up. For midrange densities, a liquid 14.2 lb/gal spike fluid can be sent to location for any necessary weight up applications. Calcium bromide 14.2 lb/gal blending stock is an effective spike fluid that can be used to weight fluids up from about 11.7 lb/gal to 13.5 lb/gal; however, if the target density is greater than 13.5 lb/gal, the volume increase with a 14.2 blending stock is more than 50%. A 15.1 lb/gal spike fluid can be used to achieve a weight up in the range of 13.6

lb/gal to 14.8 lb/gal; above that range, the volume increase would be more than 50%.

Care should be taken when utilizing a 15.1 lb/gal calcium chloride/calcium bromide ($CaCl_2/CaBr_2$) spike fluid, as it may raise the TCT of the resulting brine.

Finally, in extreme cases where the working fluid lies on the boundary of two and three salt fluids as shown on Figure 2 on page 11, a zinc containing fluid can be used to achieve density increases. In such cases, a very small amount of 19.2 lb/gal spike fluid would be required; however, it would change the nature of the working brine; it would also change the environmental regulations regarding conducting disposal activities and reporting and reacting to spills. Before making this decision, weigh the pros and cons carefully.

Estimate the type and quantity of weight material to be used on the job based on raising the density of the working fluid by 0.2 lb/gal. Make sure this amount of material is available on location. It should be kept in sealed pill tanks to prevent any contamination and/or absorption of water from the atmosphere.

Three Salt Brine Density Maintenance

3 SALT

High density three salt fluids are blended with precision to maximize performance and minimize the cost to the operator. This special attention to composition means equal care and attention should be paid to maintaining fluid properties like density, TCT, and brine clarity.

It is especially important to protect three salt fluids from dilution. To prevent contamination and absorption of water from the atmosphere, this material should be kept in closed top tanks.

There is a considerable difference between the density of a three salt fluid and most types of dilution water. Rainwater, for example, has a density of 8.3 lb/gal, and formation water has a density ranging from 8.5 lb/gal to 10 lb/gal. A small amount of contamination from either of these sources can result in a large change in the density of the working fluid. For example, it takes only 2.6 bbl of fresh water to decrease the density of 100 bbl of a 16.5 lb/gal three salt fluid to 16.3 lb/gal (a 0.2 lb/gal decrease). In a 5,000 ft well, this dilution would reduce hydrostatic pressure by more than 50 psi.

The most economical means of maintaining the prescribed density in three salt fluids is by the addition of 19.2 lb/gal zinc/calcium bromide ($ZnBr_2/CaBr_2$), a common blending stock used in formulating CBFs. For working fluids with densities higher than 16.5 lb/gal, an even more concentrated zinc bromide ($ZnBr_2$) fluid will have real economic advantages. This fluid has a density of 20.5 lb/gal. The effects are clearly shown in Figure 6, "Selecting and Using Spike Fluids," on page 26.

The advantages of using a higher density spike fluid are:

1. a much smaller volume is required to achieve the same density increase,
2. less storage volume is needed for spike material on the rig, and
3. less volume increase occurs in the working fluid when adjustments are made.

Density adjustment using solid chemicals such as dry calcium chloride is possible, but is not recommended, as it will usually result in a higher TCT. Calcium bromide dry salt can be used as weight material, especially when volume increases are not practical. Dry salts will also require vigorous agitation to achieve complete solubility in highly concentrated, heavy fluids.

The quantity of 19.2 lb/gal zinc/calcium bromide spike fluid should be estimated based on raising the working fluid density by 0.2 lb/gal. As a minimum, this amount should be maintained on the rig. To prevent contamination and absorption of water from the atmosphere, this material should be kept in sealed pill tanks.

This section is intended to briefly touch on brine maintenance. See Chapter 4, "Field Applications and Brine Maintenance," for a more in depth discussion on the subject.

Corrosion Control

Inhibiting or minimizing corrosion is extremely important when planning a well. This section provides a brief overview of the topic. A more complete discussion can be found in Chapter 8 in the "Corrosion Control" section, beginning on page 185.

Objectives

- Protect casing, liner, and downhole tools
- Minimize corrosion promoters
- Render corrosion products nondamaging to the formation
- Protect packer and production tubing

Factors Affecting

- Temperature
- Brine acidity (pH)
- Surface aeration and air entrainment
- Acid formation gases (CO_2, H_2S)
- Metallurgy
- Bacteria

Discussion

The factors affecting corrosion are very complex. The information presented here is intended as a brief introduction. TETRA has done extensive testing in the area of corrosion, especially as it relates to environmentally assisted cracking (EAC) in HPHT wells. A TETRA fluids specialist will be happy to assist in developing solutions aimed at reducing the probability of corrosion in your well.

Temperature. Most chemical reactions proceed more rapidly at higher temperatures. This is also true for the various reactions involved in the corrosion process. Temperature conditions in the well will provide the basis for choosing a corrosion program. With proper protection, by means of a thoroughly planned corrosion control program, brines are routinely used at temperatures as high as 350°F with corrosion rates of less than 15 mils per year (mpy). Recommended application rates for TETRAHib™ and CORSAF™ corrosion inhibitors, OxBan™ oxygen scavengers, and biological control additives are provided in Table 7, "Typical Corrosion Control System Applications," on page 44 at the end of this section.

Brine Acidity (pH). Single salt fluids range from neutral to slightly basic when they are manufactured. They can be treated to increase alkalinity and reduce the presence of the corrosion promoting hydrogen ion (H^+) with the careful addition of a base such as sodium hydroxide or lime.

1 SALT

Two salt calcium chloride/calcium bromide fluids are neutral to slightly basic in nature. Alkalinity can be adjusted to further reduce the presence of the corrosion promoting hydrogen ion (H^+). This adjustment, however, is not easily accomplished in the field. Because of this, all TETRA two salt fluids are carefully blended to eliminate the presence of corrosion promoters.

2 SALT

Three salt fluids are prepared using calcium chloride ($CaCl_2$), calcium bromide ($CaBr_2$), and zinc bromide ($ZnBr_2$). When zinc is dissolved, it has a tendency to create acidic conditions. If a

3 SALT

solution is made more alkaline, then zinc may begin to precipitate as zinc hydroxide ($Zn(OH)_2$). In order to maintain the physical properties of zinc bromide brines, the pH must be kept at a relatively low level. Because corrosion is accelerated by low pH, special attention should be given to minimizing corrosion in three salt fluids. TETRA has a long history of manufacturing zinc bromide and formulates all of its zinc products to minimize acidity and corrosion.

Contact a TETRA fluids specialist if you have concerns about zinc precipitation. TETRA has developed a number of solutions to address this problem.

Surface Aeration and Air Entrainment. Oxygen derived from the air is a major corrosion accelerator. Oxygen solubility in concentrated salt solutions is extremely low and becomes even lower as brine temperatures rise. Oxygen can, however, be introduced into the circulating system if fluids are allowed to freefall into tanks. Other possible sources for oxygen are leaking pump seals, agitators, and suction pumps. Small air bubbles can be entrained in more viscous brines and carried down into the well. With increasing pressure, the entrained air will eventually dissolve and react with casing, tubing, or downhole tools. To reduce the impact of surface aeration, it is prudent to add a small amount of oxygen scavenger.

OxBan HB can be used at the level of five gal/100 bbl and up, depending on oxygen entrainment. If not supervised, this course of action can lead to overtreatment. Preventative measures should be taken to eliminate air entrainment to reduce such overtreatment.

The presence of trace amounts of oxygen with sulfur containing species can be a dangerous combination with respect to EAC. For more information, see the "Corrosion Control" section in Chapter 8, beginning on page 185.

Acid Formation Gases. More common in a completion fluid situation, gases such as carbon dioxide (CO_2) and hydrogen sulfide (H_2S) can accelerate corrosion. Both gases are slightly acidic in nature and will contribute to the acidity of a brine.

Metallurgy. It is essential that information concerning the metallurgy of casing and tubing be considered in the planning and design of any completion. If carbon steel tubing is to be used, the issue of general corrosion must be adequately addressed. If CRA tubing is to be used, the issues of EAC must be addressed, with the compatibility between the fluids and tubing being carefully evaluated, especially if the fluid is to be used as a packer fluid. Through participation in extensive scientific test studies in the area of CBFs, metallurgy, and EAC, TETRA has developed a software program called the MatchWell fluid compatibility selector. It can be used to predict tubing/fluid compatibility and performance and make fluid recommendations based on specific well conditions. For more information about EAC, read the "Environmentally Assisted Cracking" section, beginning on page 189 in Chapter 8.

Consult your TETRA representative to take advantage of this technology and receive a customer recommendation report from the MatchWell fluid compatibility selector to assist you in planning your next HPHT well completion.

Bacteria. In spite of the salinity and high temperatures found in the subsurface environment, bacteria have been found to exist in some of the world's most extreme environments. Especially adaptable are iron bacteria, sulfur oxidizing bacteria, and sulfate reducing bacteria. The presence of these microorganisms can dramatically increase the corrosivity of the environment, especially if H_2S is generated from the bacteria. Brines that are properly formulated with biocides can eliminate these bacterial problems.

Recommendations

1. Use a properly formulated TETRA clear brine fluid that has been manufactured to the highest specifications.
2. Select a corrosion inhibitor package that is compatible with the metallurgy at the expected bottomhole temperature.
3. Try to reduce all sources of entrained air such as freefalls, excessive agitation, leaking pump seals, and suction vortices.
4. Do not run jet hoppers unless a polymer is being added.
5. Whenever possible, minimize the contact between CBFs and acidic gases such as carbon dioxide (CO_2) and hydrogen sulfide (H_2S).
6. Select a brine formulation to help neutralize acidic gases.

Table 7 provides recommended application rates for TETRAHib™ and CORSAF™ SF corrosion inhibitors, OxBan™ oxygen scavengers, and biological control additives for different brine density ranges.

TABLE 7. Typical Corrosion Control System Applications

Fluid	Density	Temperature	Corrosion Inhibitor	Dose[1]	Oxygen Scavenger	Dose[1]	Biocide	Dose[1]
KCl, 3%	8.6	200°F	TETRAHib	10	OxBan	1.5	Antimicrobial Biocide	1
		300°F	TETRAHib	15	OxBan	1.5	Antimicrobial Biocide	1
KCl	9.7	200°F	TETRAHib	15	OxBan	1	Antimicrobial Biocide	1
		300°F	TETRAHib	20	OxBan	1	Antimicrobial Biocide	1
NaCl	10.0	200°F	TETRAHib	15	OxBan	1	Antimicrobial Biocide	1
		300°F	TETRAHib	20	OxBan	1	Antimicrobial Biocide	1
NaBr	12.0	200°F	TETRAHib	15	OxBan	1	Antimicrobial Biocide	1
		300°F	TETRAHib	20	OxBan	1	Antimicrobial Biocide	1
$CaCl_2$	10.0	200°F	TETRAHib	15	OxBan HB	10	Antimicrobial Biocide	1
		300°F	TETRAHib	20	OxBan HB	10	Antimicrobial Biocide	1
$CaCl_2$	11.6	200°F	TETRAHib Plus	5	OxBan HB	10	Antimicrobial Biocide	1
		300°F	TETRAHib Plus	7.5	OxBan HB	10	Antimicrobial Biocide	1
$CaCl_2$ + CRA[2]	11.6	200°F	CORSAF SF	20	OxBan HB	10	Antimicrobial Biocide	1
		300°F	CORSAF SF	30	OxBan HB	10	Antimicrobial Biocide	1
$CaCl_2/Br_2$	14.5	200°F	TETRAHib Plus	10	OxBan HB	10	Antimicrobial Biocide	1
		300°F	TETRAHib Plus	15	OxBan HB	10	Antimicrobial Biocide	1
$CaCl_2/Br_2$ + CRA[2]	14.5	200°F	CORSAF SF	20	OxBan HB	10	Antimicrobial Biocide	1
		300°F	CORSAF SF	30	OxBan HB	10	Antimicrobial Biocide	1

[1]Dose quantities are in U.S. gallons per 100 barrels of brine, gal/100 bbl
[2]Corrosion Resistant Alloy (e.g., 13 Chrome)

TABLE 7. Typical Corrosion Control System Applications

Fluid	Density	Temperature	Corrosion Inhibitor	Dose[1]	Oxygen Scavenger	Dose[1]	Biocide	Dose[1]
$CaCl_2/Br_2$	15.2	200°F	TETRAHib Plus	10	OxBan HB	10	Antimicrobial Biocide	1
		300°F	TETRAHib Plus	15	OxBan HB	10	Antimicrobial Biocide	1
$CaCl_2/Br_2$ + CRA[2]	15.2	200°F	CORSAF SF	20	OxBan HB	10	Antimicrobial Biocide	1
		300°F	CORSAF SF	30	OxBan HB	10	Antimicrobial Biocide	1
$Zn/CaCl_2/Br_2$	16.0	200°F	TETRAHib Plus	15	OxBan HB	10	Antimicrobial Biocide	1
		300°F	TETRAHib Plus	20	OxBan HB	10	Antimicrobial Biocide	1
$Zn/CaCl_2/Br_2$ + CRA[2]	16.0	200°F	CORSAF SF	20	OxBan HB	10	Antimicrobial Biocide	1
		300°F	CORSAF SF	30	OxBan HB	10	Antimicrobial Biocide	1
$Zn/CaCl_2/Br_2$	19.0	200°F	TETRAHib Plus	15	OxBan HB	10-15	Antimicrobial Biocide	1
		300°F	TETRAHib Plus	20	OxBan HB	10-15	Antimicrobial Biocide	1
$Zn/CaCl_2/Br_2$ + CRA[2]	19.0	200°F	CORSAF SF	20	OxBan HB	10-15	Antimicrobial Biocide	1
		300°F	CORSAF SF	30	OxBan HB	10-15	Antimicrobial Biocide	1

[1]Dose quantities are in U.S. gallons per 100 barrels of brine, gal/100 bbl
[2]Corrosion Resistant Alloy (e.g., 13 Chrome)

Displacement

Introducing a clear brine fluid to a well after drilling operations can be a critical step in a successful well completion. This section is designed to provide an overview of the topic. For more information, consult the "Displacement" section in Chapter 8, beginning on page 193.

Objectives

- Protect the formation by developing a completely solid free environment in which to carry out well completion or workover operations
- Ensure that drilling fluid constituents do not come into contact with CBFs
- Separate the two systems to maintain the integrity of the drilling fluid and the CBF
- Reduce standby rig costs caused by unnecessary filtration time

Factors Affecting

- Mud type
- Pressure constraints
- Environmental discharge limitations
- Time constraints due to rig operations or cost

Discussion

Clear brine fluids are incompatible with water based, diesel oil based, and synthetic oil based muds. When they are mixed, this incompatibility generally produces a viscous, unpumpable mass due to flocculation of the mud by high salt content of the brines. Should this reaction take place downhole during the displacement, the flow resistance and pump pressure will increase dramatically, and pumping operations may have to be suspended due to excessive pressures. To avoid this reaction, drilling muds and CBFs must be separated when the mud is being displaced from the well.

Carefully preparing surface equipment for the change from a drilling fluid to a clear brine fluid is always important, but is even more critical when a three salt fluid is being used. It is important to avoid cross-contamination of drilling fluids with zinc. Even small amounts of zinc can make a drilling fluid unacceptable for conventional disposal.

The two general methods by which drilling fluids are removed from the well prior to the introduction of a CBF are *indirect displacement* and *direct displacement*.

Predisplacement Activities. There are seven major activities that must be performed prior to conducting displacement operations. These predisplacement activities must be undertaken in the case of both indirect and direct displacements.

The seven major predisplacement activities are as follows:

1. **Selecting Displacement System.** Pay careful attention to the design of the displacement system chosen. TETRA has developed two chemical systems—TDSP™ and TETRAClean™—both of which can be configured for use in either direct or indirect displacements.
2. **Cleaning Surface Equipment.** Clean all surface equipment so that it is completely free of solids and residual water. Active pits should be cleaned, completely dried, and covered.
3. **Verifying Rheology.** Check the drilling fluid rheology and thin the mud to promote complete removal of solids.
4. **Ensuring Flow Path is Clear.** Ensure that the flow path is clear by circulating or drilling out settled solids.
5. **Calculating Pressure Differentials.** Calculate pressure differentials along the flow path to reduce overpressuring casing or tubing. Reverse circulating during displacement will also result in a large pressure drop at the base of the working string due to the highly turbulent flow conditions at that point. Higher pumping pressures may be required.

With single salt brines, large differentials are less likely in lower pressure wells using lightweight mud and brines. But spacer densities should be carefully designed to minimize these pressure effects.

1 SALT

With two salt and three salt brines, pressure differentials between heavier brines and the lightweight surfactant rinse stage of a displacement system can result in large pressure differentials between tubing and casing.

2 SALT 3 SALT

6. **Running Wellbore Cleanup Tools.** Run brush and scraper tools to the casing bottom.

7. **Maintaining Flow.** Do not stop pumping at any time during displacement until the returns indicate a continuous flow of the CBF.

When planning displacement operations for our customers, TETRA's fluids specialists use displacement modeling software to perform necessary calculations and model specific displacement operations. These software programs and their uses are explained in the "Displacement Modeling Software" section in Chapter 8, beginning on page 198.

Water Based Mud

In order to develop a completely solid free environment in the well prior to completion operations, all traces of solid laden drilling fluids must be removed. Two options, direct and indirect displacement, are available to the operator when a water based mud has been used.

If CRA tubing is to be used, it is essential that all of the potential sulfur contaminations, e.g., lignin sulfonates, be removed, as they may form sulfides which can contribute to EAC.

Indirect Displacement. This technique can be used with water based muds or sometimes with synthetic oil based muds because of the need to discharge rinse water containing residual mud constituents.

An indirect displacement technique consists of:

1. displacing the mud from the hole by making a single pass with seawater or lease water,
2. circulating seawater with a surfactant added to remove the final mud residue, and
3. installing the clear brine fluid with a spacer separating it from the seawater.

Indirect displacements are carried out when drilling fluid constituents can be safely jettisoned to the ocean and adequate rig time is available to allow for recirculation until returns are clean. Sufficient circulation time must be expended to avoid contact between residual drilling solids and the CBF. Contamination of the CBF by solids will cause delays, as the solids will have to be filtered from the CBF. If solids are not entirely removed, the completion could be jeopardized if solids are allowed to invade the perforations and/or producing zone. Solids may also settle around the packer, making it difficult to remove.

Additionally, the presence of solids can induce a form of concentration cell corrosion known as crevice corrosion, which can lead to EAC issues. A further consideration is the possible generation of H_2S or sulfur from additives associated with the mud solids. These sulfur containing contaminants can lead to sulfide stress cracking (SSC).

Direct Displacement. This technique requires slightly more attention to detail; however, because it can be carried out in a much shorter period of time, it reduces rig time lost while circulating.

TETRA's TDSP direct displacement system is a three stage process:

1. **TDSP I—Mud Removal Stage.** This first stage consists of a weighted spacer designed to push the mud from the hole. This spacer is very viscous and should have a higher yield point than the mud being displaced, which will ensure separation of incompatible fluids and maximize the hole cleaning ability. The density of the TDSP I phase will be determined by the density of the drilling mud.

The volume of TDSP I should provide for at least 1,000 feet of coverage in the largest annular section of casing.

2. **TDSP II—Surfactant Wash Stage.** Stage two consists of a turbulent flow spacer with a concentrated surfactant which disperses any residual mud from casing and tubing surfaces.

The annular velocity should be greater than 180 ft/min, and the volume of TDSP II should provide at least 2,000 feet of coverage in the largest annular section of casing.

3. **TDSP III—Viscosified Sweep Stage.** The third stage consists of a spacer used between the surfactant wash spacer and the completion fluid. This stage promotes the removal of residual materials dispersed by the surfactant wash. The rheology of this stage is designed to maximize lifting capacity.

The volume of TDSP III should provide for at least 1,000 feet of coverage in the largest annular section of casing.

Diesel Oil Based Muds and Synthetic Oil Based Muds

Diesel oil based and synthetic oil based drilling fluid systems often require the use of direct displacement. An additional oil based pad should be placed between the mud and TDSP I when a CBF is to follow an oil based mud system; however, other than this, the procedures are the same.

In a diesel oil based mud displacement where CRA tubing is used, it is vital to eliminate the potential for sulfur or sulfide contamination, which can lead to EAC. An in depth discussion of corrosion can be found in the "Corrosion Control" section in Chapter 8, beginning on page 185.

TETRAClean Displacement System

Developed for use under the stringent environmental regulations of the North Sea, the versatile TETRAClean displacement system is used for well cleanup after water based, diesel oil based, or synthetic oil based drilling muds. For ease of use, the TETRAClean system is mixed as a single viscous pill, usually in the range of 200 to 250 bbl. The highly effective, concentrated pill reduces the need for additional pit volume. Depending on brine chemistry, TETRAVis HEC polymer or BioPol polymer may be used to build viscosity. The TETRAClean 105 surfactant package and TETRAClean 106 activator are added to the viscosified brine. The pill is run after a compatible spacer and pumped at a rate high enough to achieve turbulent conditions.

The TETRAClean system can be used without restriction in the UK North Sea, as the system has an environmental Chemical Hazard Assessment and Risk Management (CHARM) rating of *Gold*. An in depth discussion of displacement and the TETRAClean system can be found in the "Displacement" section in Chapter 8, beginning on page 193.

Fluid Loss Control

Controlling fluid loss should be an integral part of planning for any completion operation. Prior to bringing any CBF to the location, provisions should be made to deal with any potential fluid loss situation. This section is designed to provide a brief overview of the topic. For a more in depth discussion, see the "Reduction of Fluid Loss" section in Chapter 8, beginning on page 203.

Objectives

- Maintain well control—ensure a full column of adequate density brine
- Minimize seepage losses that may contribute to formation damage
- Reduce relative permeability effects
- Stop lost circulation conditions

Factors Affecting

- Fluid density and pressure differential
- Formation permeability and porosity
- Formation pressure and temperature
- Completion fluid type
- Length of thief zone

Discussion

Clear brine fluids are designed to minimize formation damage. Despite their low potential for damage, these fluids are still foreign to oil and gas producing formations; for this reason, their introduction to the wellbore may have adverse effects if large quantities of fluid escape the wellbore and enter the formation, mixing with formation fluids.

Knowledge of reservoir characteristics should give some indication as to the potential for movement of fluids from the well into the formation.

Generally there are two types of fluid loss:

1. Seepage is the migration of wellbore fluids into the formation under the influence of hydrostatic pressure; it is controlled by formation permeability. With light seepage, penetration may be a matter of only a few inches.
2. Lost circulation is severe fluid loss that has reached a rate at which circulation can no longer be maintained. It is wholesale loss of fluid to highly fractured or very porous formations and requires immediate action.

Between these two extremes, there is a continuum that spans the full range. Completion engineers can choose between technologies designed to address three broad categories: (1) light seepage, (2) moderate seepage due to a relatively permeable formation, and (3) lost circulation, which is severe and requires immediate and decisive action.

Light Seepage. In cases of light seepage, consider lowering the density of the fluid to reduce flow into the formation. Well control and safety considerations should both be carefully weighed. If lowering the density is not feasible, a solid free, viscosified pill should be placed across the producing zone to slow the loss. The ability of a viscosified pill to control seepage will depend on the wellbore temperature, as the viscosifying properties of most polymers are reduced at higher temperatures.

Polymer pills are generally applicable in formations with permeabilities of less than one darcy. Most common polymer pills are made using BioPol, TETRAVis, or a combination of the two. A decision as to which polymer to use should be based on temperature stability, salt system, and damage characteristics. For most general brine applications, the TETRAVis products are most widely used, since the polymer is considered less damaging and easier to clean up.

1. **Single Salt Fluid Polymer Pills.** TETRAVis and BioPol L are both commonly used to viscosify single salt fluids. BioPol L is often chosen when bottomhole temperatures exceed 225°F. 1 SALT
2. **Two Salt Fluid Polymer Pills.** The most common viscosifying agent for use in two salt calcium chloride/calcium bromide brines is TETRAVis L Plus. 2 SALT

3. **Three Salt Fluid Polymer Pills.** TETRAVis L Plus is the most common viscosifying agent used for three salt systems. It will not hydrate in three salt fluids containing more than 1% $ZnBr_2$ (0.3% Zn) and less than about 30% $ZnBr_2$ (9% Zn). This range covers three salt fluids with densities up to 17.2 lb/gal. In order to viscosify a heavy fluid between 15.2 lb/gal and 17.3 lb/gal, a special cutback fluid must be made from 19.2 lb/gal $Zn/CaBr_2$ and fresh water.

3 SALT

A weighted pill containing zinc bromide can be formulated by using a fluid made by cutting back 19.2 lb/gal spike fluid with fresh water. This method will work throughout the range of three salt fluids. (See "Mixing Viscosified Pills," beginning on page 74.)

Moderate Seepage. At moderate loss rates, you will want to approach the problem using a mixture of viscosifying agents and bridging material. There are four options available when dealing with moderate loss situations. They are:

1. **TETRACarb Sized Calcium Carbonate ($CaCO_3$).** TETRA's sized calcium carbonate ($CaCO_3$) pills provide a reversible means of quickly shutting off rapid fluid loss to the formation. Carefully ground and sized particles of $CaCO_3$ are suspended in a viscosified pill and placed across the thief zone. The procedure for building a viscosified pill is given in Chapter 4. (See "Mixing Viscosified Pills," beginning on page 74.)

When completion operations are finished, a mild acid treatment may be required to dissolve calcium carbonate solids.

2. **TETRA SS Sized Sodium Chloride (NaCl).** Another reversible means of stopping fluid loss is by using a viscous pill with sized particles of sodium chloride (NaCl) suspended in it. Sodium chloride particles can be used to bridge formation pores and reduce fluid loss. Application is limited to situations where a saturated salt (NaCl) solution can be maintained; otherwise, the particles will dissolve. There are generally sufficient chloride ions from calcium chloride in three salt fluids to keep the salt crystals from dissolving.

The advantage of sized sodium chloride crystals is that they will dissolve during flowback operations, provided formation fluids are not saturated with respect to sodium chloride. Salt crystals can be removed by using an undersaturated potassium or sodium chloride brine or a fresh water rinse.

3. **TETRAFlex FLC Seal.** For moderate losses, this sized, shredded crosslinked polymer mixed with a brine can be used for fluid loss control. The treatment is completely and rapidly reversible with a mild acid treatment.

4. **TETRA SmartSeal.** In the late stages of completion, especially after a screen and gravel pack emplacement, a TETRA SmartSeal pill will enable fluid loss control while running the final production tubing. SmartSeal is a viscosified pill with a carefully chosen blend of TETRA-Carb calcium carbonate bridging material. SmartSeal pills are usually small in volume, approximately five bbl, and can be designed to maintain viscosity at temperatures above 300°F. To ensure integrity of the SmartSeal pill and facilitate removal of the calcium carbonate filter cake, a TETRA SmartSeal Pad should be run in front of and behind the SmartSeal pill. In addition to guarding against dilution of the pill, the SmartSeal Pads play an active role by treating the screen to reduce adhesion of the TETRACarb particles, thus making cleanup easier and more complete.

Lost Circulation. For situations involving lost circulation, the primary objective is to seal off the thief zone. Coarse sized calcium carbonate or sodium chloride bridging materials should be used.

A TETRA fluids representative can help with these decisions. Whichever situation is anticipated, fluid loss control should be an integral part of planning for any completion operation. Provisions should be made to deal with fluid loss prior to bringing any CBF to the location. For more information regarding this topic, see the "Reduction of Fluid Loss" section in Chapter 8, beginning on page 203.

Filtration and Brine Clarity

Brine filtration is another component in TETRA's integrated productivity protection system which encompasses more than just the fluid. Workover and completion operations often generate solids that are picked up and transported by the CBF. These solids can be carried into the formation or perforations. Such solids can be difficult to remove and their presence often results in lower productivity. In order to eliminate the possibility of production impairment, brine filtration is used to remove solids from the system. Another important aspect to consider when planning a filtration operation is the potential impact that solids can have on corrosion within the annulus, especially with the use of CRAs. Effectively removing these solids is one more way to reduce the probability of corrosion.

Filtration equipment is operated continuously during all phases of completion operations as long as the CBF is in the hole. The primary goal of this section is to assist you in selecting the correctly sized filtration equipment. Chapter 8, "Special Topics," also includes a section on filtration, which provides a better understanding of the filtration process.

Objectives

- Protect the producing formation
- Remove solids from completion fluid
- Remove potential contaminants for CRA applications
- Assure an uninterrupted supply of filtered, solid free completion fluid
- Ensure tool operability

Factors Affecting

- Hole volume and available tankage
- Efficiency and type of displacement
- Type of completion
- Anticipated flow rates
- Deck space
- Brine density and viscosity

Discussion

Protection of the formation should always be the primary objective of filtration. To optimize filtration operations, the following factors should be considered.

Hole Volume. Simply put, the larger the hole, the larger the filtering equipment should be. Typical flow rates for plate and frame filter presses range from 0.8 bbl/min to 1.2 bbl/min per 100 square feet of filter area. A hole with a volume of 800 barrels and appropriately sized surface tankage may have a circulating volume of as much as 1,800 barrels. Using the above range of 0.8 bbl/min to 1.2 bbl/min per 100 square feet, a 1,100 square foot filter unit would operate in the range from 8.8 bbl/min to 13.2 bbl/min. Using an average value, it would take 2.7 hours to filter the entire fluid volume once.

Drilling Fluid Displacement. Brine filtration is primarily a means of removing potentially damaging particulate matter. It is not designed to remove large amounts of solids resulting from incomplete mud displacement or tank cleaning operations. For the best utilization of filtration equipment, and to minimize downtime, other strategies should be employed for the removal of bulk solids. The upper limit for an efficient plate and frame operation is a solid level of around 2% by volume. Fluids with solid content above 2% should be displaced with clean fluid.

Downtime may become significant if the filter is not correctly sized for both flow rate and solid content. As an example, a fluid with a solid content of 0.25% would have a filtration unit operating time of 2.6 hours using a 600 square foot filter unit. Filtration unit operating time would increase to 4.7 hours with an 1,100 square foot unit. Each precoat cycle may require up to 60 minutes. Downtime would be greatly reduced from 7.2 hr/day to 4.4 hr/day with the larger unit. There is a distinct advantage in using a larger unit.

Type of Completion. Some downhole activities like gravel packing or milling operations are likely to generate a larger volume of solids, which will influence the size of the filtration unit required. The rate at which solids accumulate in the filter will determine the active filtration time. This subject is discussed in more detail in Chapter 8. (See "Filtration," beginning on page 205.)

Available Tankage. Efficient filtration requires an available brine holding tank capacity of about 0.75 to 1.0 times the hole volume. The filter feed tank and clean brine tank should be about the same size. This allows larger particles to settle and increases the active filtration time for the filter unit. This is an advantage, because the filter press must be broken down, washed out, and precoated each time the chambers are filled.

Larger tanks provide a wide spot in the circulating path, allowing some settling and taking some of the load off the filter. If rig space is limited and tankage is small, more solids must be captured by the filter. If settling is limited, the filter chambers will fill more rapidly and a larger filter would be advisable. A smaller filter feed tank, for example 75 bbl, will reduce settling time. This also means a shorter interval for dumping and precoating, only 10 minutes at a circulating rate of 7.5 bbl/min, before rig operations would have to be suspended until filtration equipment could be brought back online.

Deck Space. Available floor space on the rig may dictate the size of the filter unit used. All TETRA filter units are specifically designed for completion fluid applications.

TABLE 8. Filtration Equipment

TETRA Filtration Equipment			
Unit	Filter Area	Flow Rate	Footprint
	ft^2	bbl/min	L x W
SafeDEflo 600	600	6 - 8	22 x 15 feet
SafeDEflo C600	600	8 - 10	16 x 15 feet
SafeDEflo 1100	1,100	8 - 12	24 x 15 feet
SafeDEflo 1300	1,300	12 - 14	26 x 15 feet
SafeDEflo 1500	1,500	14 - 20	26 x 15 feet

Some general specifications of TETRA's filtration equipment are shown in Table 8 to assist you in making your selection. The Filtration section in Chapter 8, "Special Topics," explores the subject in greater detail.

Viscosity. Lightweight, single salt fluids typically have a viscosity of less than 10 centipoise (cp), which will generally result in lower head losses through the circulating system. Both the density and the viscosity of a completion fluid should be considered when determining the filter unit size required for a specific job.

Above 10.0 lb/gal, the viscosity of CBFs can range up to 30 cp. The effect of viscosity is most noticeable in the case of two salt summer blends which may be saturated with calcium chloride. The increased viscosity will also cause compression of the filter cake, reducing its permeability. This will lower flow rates and decrease operating times. In cases such as these, a slightly larger filtration unit is recommended.

Recommendations

1. Plan and carefully execute a complete displacement of drilling mud to reduce CBF contamination.
2. As a general guideline, plan a filtration unit that will provide 0.8 bbl/min to 1.0 bbl/min per 100 ft^2 of filter area.
3. Select filtration equipment that will minimize downtime by estimating solid loading and filtration unit operating time; where settling time is limited by pit volume, a larger filter unit should be selected.
4. Provide adequate tankage; 100% of the hole volume is ideal, but at least 75% is recommended to maintain an uninterrupted supply of clean completion fluid at all times.
5. Establish a baseline nephelometric turbidity unit (NTU) value for the fluid at the rig site as the reference turbidity value for filtered brine.

Notes:

Notes: