The invention adds a friction reducing agent or agents to gravel slurry to decrease pressure required for proper fluid velocities so as to obtain the desired gravel propagation in an annular space around a screen assembly.
Fresh Water

Friction Pressure psfi1,000ft

Injection Rate-BPM

A - 1 1/4" 2.4 lb tubing  
B - 2 3/8" 4.7 lb tubing  
C - 2 7/8" 8.6 lb tubing  
D - 2 7/8" 7.9 lb tubing  
E - 2 7/8" 6.5 lb tubing  
F - 3 1/2" 15.8 lb tubing  
G - 2 3/8" x 4 1/2" 9.5 lb annulus  
H - 3 1/2" 9.3 lb tubing  
I - 2 7/8" x 5 1/2" 15.5 lb annulus  
J - 4" 11 lb tubing  
K - 2 3/8" x 5 1/2" 15.5 lb annulus  
L - 4 1/2" 9.5 lb casing  
M - 5" 18 lb casing  
N - 5 1/2" 15.5 lb casing  
O - 2 7/8" x 7" 23 lb annulus  
P - 2 3/8" x 7" 23 lb annulus  
Q - 7" 23 lb casing  
R - 7 5/8" 29.7 lb casing

FIG. 1
FIG. 2

10 lb/gal Brine

<table>
<thead>
<tr>
<th>Friction Pressure psi/1,000ft</th>
<th>Injection Rate-BPM</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
</tbody>
</table>

A - 1 1/4" 2.4 lb tubing  
B - 2 3/8" 4.7 lb tubing  
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P - 2 3/8" x 7" 23 lb annulus  
Q - 7" 23 lb casing  
R - 7 5/8" 29.7 lb casing
Friction Reducer in Fresh Water

![Graph showing friction pressure vs. injection rate for different tubing and casing sizes.]

A - 1 1/4" 2.4 lb tubing  
B - 2 3/8" 4.7 lb tubing  
C - 2 7/8" 8.6 lb tubing  
D - 2 7/8" 7.9 lb tubing  
E - 2 7/8" 6.5 lb tubing  
F - 3 1/2" 15.8 lb tubing  
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O - 2 7/8" x 7" 23 lb annulus  
P - 2 3/8" x 7" 23 lb annulus  
Q - 7" 23 lb casing  
R - 7 5/8" 29.7 lb casing

FIG. 3
10 lb/1000 gallons HEC Polymer

Friction Pressure (psi)/1,000ft

Injection Rate-BPM

A - 2 3/8" 4.7 lb tubing
B - 2 7/8" 6.5 lb tubing
C - 3 1/2" 9.3 lb tubing
D - 4 1/2" 11.6 lb casing
E - 5 1/2" 15.5 lb casing
F - 7" 23 lb casing
G - 2 3/8" x 4 1/2" 11.6 lb annulus
H - 2 7/8" x 5 1/2" 15.5 lb annulus
I - 2 3/8" x 5 1/2" 15.5 lb annulus
J - 3 1/2" x 7" 23 lb annulus
K - 2 7/8" x 7" 23 lb annulus
L - 2 3/8" x 7" 23 lb annulus

FIG. 4
20 lb/1000 gallons Baker Clean Gel I

<table>
<thead>
<tr>
<th>Injection Rate-BPM</th>
<th>Friction Pressure (psi)</th>
<th>1,000ft</th>
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<tbody>
<tr>
<td>1</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>1000</td>
<td></td>
</tr>
</tbody>
</table>

A - 2 3/8" 4.7 lb tubing
B - 2 7/8" 6.5 lb tubing
C - 3 1/2" 9.3 lb tubing
D - 4 1/2" 11.6 lb casing
E - 5 1/2" 15.5 lb casing
F - 7" 23 lb casing
G - 2 3/8" x 4 1/2" 11.6 lb annulus
H - 2 7/8" x 5 1/2" 15.5 lb annulus
I - 2 3/8" x 5 1/2" 15.5 lb annulus
J - 3 1/2" x 7" 23 lb annulus
K - 2 7/8" x 7" 23 lb annulus
L - 2 3/8" x 7" 23 lb annulus

FIG. 5
20 lb/1000 gallons Guar Polymer

Injection Rate-BPM

Friction Pressure (psi)/1,000 ft

A - 1 1/4" 2.4 lb tubing
B - 2 3/8" 4.7 lb tubing
C - 2 7/8" 8.6 lb tubing
D - 2 7/8" 7.9 lb tubing
E - 2 7/8" 6.5 lb tubing
F - 3 1/2" 15.8 lb tubing
G - 2 3/8" x 4 1/2" 9.5 lb annulus
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L - 4 1/2" 9.5 lb casing
M - 5" 18 lb casing
N - 5 1/2" 15.5 lb casing
O - 2 7/8" x 7" 23 lb annulus
P - 2 3/8" x 7" 23 lb annulus
Q - 7" 23 lb casing
R - 7 5/8" 29.7 lb casing

FIG. 6
30 lb/1000 gallons Guar Polymer

<table>
<thead>
<tr>
<th>Friction Pressure (ps)</th>
<th>Injection Rate-BPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>D</td>
<td>E</td>
</tr>
<tr>
<td>E</td>
<td>F</td>
</tr>
<tr>
<td>F</td>
<td>G</td>
</tr>
<tr>
<td>G</td>
<td>H</td>
</tr>
<tr>
<td>H</td>
<td>I</td>
</tr>
</tbody>
</table>

A - 1 1/4" 2.4 lb tubing  J - 4" 11 lb tubing
B - 2 3/8" 4.7 lb tubing  K - 2 3/8" x 5 1/2" 15.5 lb annulus
C - 2 7/8" 8.6 lb tubing  L - 4 1/2" 9.5 lb casing
D - 2 7/8" 7.9 lb tubing  M - 5" 18 lb casing
E - 2 7/8" 6.5 lb tubing  N - 5 1/2" 15.5 lb casing
F - 3 1/2" 15.8 lb tubing  O - 2 7/8" x 7" 23 lb annulus
G - 2 3/8" x 4 1/2" 9.5 lb annulus  P - 2 3/8" x 7" 23 lb annulus
H - 3 1/2" 9.3 lb tubing  Q - 7" 23 lb casing
I - 2 7/8" x 5 1/2" 15.5 lb annulus  R - 7 5/8" 29.7 lb casing

FIG. 7
REDUCED FRICTION PRESSURE GRAVEL PACK SLURRY

FIELD OF THE INVENTION

[0001] The field of the invention comprises the use of friction pressure reducing agents to extend the length of vertical, deviated, highly deviated or horizontal intervals that may be gravel packed by means of gravel packing sand (specific gravity of approximately 2.65), man made ceramic propants (specific gravity 2.65-3.5) or with Low Density Proppant, LDP, also called Low Density Gravel, LDG, and/or by mechanical valves known as Beta Breaker Valves which effectively shorten the fluid path of the wash pipe. The friction pressure reducing agent may be used with either of the LDP/ LDG or Beta Breaker Valves or combination of the two.

BACKGROUND OF THE INVENTION

[0002] In the practice of gravel packing long vertical, deviated, highly deviated and horizontal completions, the gravel pack itself may be placed inside a casing or inside an open hole, i.e., no casing completion. The gravel is normally placed in the completion interval by pumping slurry from the surface through a tubing or work-string. The completion typically has a gravel pack screen assembly equipped with a crossover tool that permits the slurry to cross over from the work-string into the annulus between the gravel pack screen and open hole or cased hole.

[0003] The gravel pack screen assembly is located across the zone to be produced and is usually equipped with a wash pipe or inner flow tube. The wash pipe is run almost to the bottom of the screen assembly and is used to take returns through the screen and conduct them back to the casing work-string annulus above the gravel pack packer. Fluids from the slurry travel the path of least resistance, flowing in the annulus between the screen and open hole or casing and inside the screen—wash pipe annulus to enter the end of the wash pipe. The fluids are then returned to the work-string—casing annulus above the gravel pack packer through a fluid by-pass in the gravel pack packer service tool, to be circulated back to surface.

[0004] In deviated, highly deviated and horizontal wells the pump rate is normally controlled so that the gravel, proppant or filtering material forms a self-propagating dune down the screen. The height of the sand dune is controlled by the fluid velocity across the top of the dune, the viscosity of the carrier fluid, the density difference between the solid particulate filter medium as well as the settling velocity of the gravel, proppant or filter particulate material in the carrier fluid. This initial sand dune normally propagates from the gravel pack packer located inside the casing, down the blank pipe to the screen until it reaches the end of the screen furthest away from the packer.

[0005] The section of the horizontal well at the casing shoe is frequently called the “heel” of the well and the end of the screen furthest from the casing shoe is called the “toe” of the well. This initial dune propagation is commonly referred to as the Alpha Wave.

[0006] When the Alpha Wave reaches the toe of the well the annular area between the top of the screen and the inside diameter, ID, of the casing or open hole is backfilled by fluid entering the screen and depositing the gravel, proppant or filtration material in the void or unfilled area completing the gravel pack. The back filling of the annular area is accomplished by the carrier fluid entering the screen—washpipe annulus, as close to the end of the wash pipe as possible, because of the fluid dynamics seeking the path of least resistance, and depositing the gravel or filtration media in the annular area. The back filling of the top part of the annular area is commonly known in the industry as the Beta Wave.

[0007] In vertical wells and deviated wells the gravel or filtration material may not form an Alpha or Beta wave and may fall or be transported vertically with the carrier fluid to the bottom of the well and fill from the bottom up.

[0008] As the completion interval lengthens the friction pressure increases in the open hole—screen annulus, the screen—washpipe annulus and the washpipe. The increased completion length results in an increase in friction pressure for a given pump rate. Eventually the increase in pressure may reach a level that exceeds the formation parting pressure, also called the formation fracturing pressure, which then prevents further placement of gravel and causes an incomplete fill up of the screen— casing or screen—open hole annulus.

[0009] The fluid pressure working at various points is sum of all of the friction pressure components and the hydrostatic pressure. The hydrostatic pressure is the sum of the carrier fluid density plus the density the gravel or filtration media added to the carrier fluid.

[0010] The term “Equivalent Circulating Density”, ECD, is applied to describe the combination of friction pressure and hydrostatic pressure component of the fluid flow paths. Computer modeling is frequently performed to calculate the ECD at various critical points in a placement of the gravel or filtration media.

[0011] Another method practiced to extend the reach of placing gravel, proppant or filtration media (the term “gravel as used herein intending to cover all these terms) in long sections of highly deviated or horizontal gravel packed wells is to use light weight (low density) gravel, proppant or filtration material.

[0012] When the gravel is added to the completion brine carrier fluid, it will increase the apparent density of the carrier fluid by the relationship of:

\[ \text{Density of the slurry} = \left( \text{Density of the carrier fluid} \times \text{Volume of the gravel} \right) \left( \text{Density of the gravel} - 1 \right) \]

[0013] Reducing the specific gravity of the gravel will produce a lower slurry density at a given concentration as demonstrated in Table 1 below of Slurry Density for Various Gravel Mix Ratios and Gravel Densities:

| TABLE 1 |
|------------------|------------------|------------------|------------------|
|                 | **Gravel s.g. 2.65** | **Gravel s.g. 1.67** |
| **Lbs. added**   | **1 ppa**       | **10 ppa**      | **1 ppa**       | **10 ppa**      |
| Base Fluid       | 8.5 ppg         | 9.9 ppg         | 11.0 ppg        | 12.3 ppg        |
|                  | 10.04 ppg       | 13.42 ppg       | 14.50 ppg       | 16.73 ppg       |
| 8.5 ppg          | 9.80 ppg        | 11.34 ppg       | 11.83 ppg       | 14.05 ppg       |
| 10.5 ppg         | 11.00 ppg       | 14.11 ppg       | 15.57 ppg       | 17.79 ppg       |
|                  | 12.73 ppg       | 15.60 ppg       | 18.03 ppg       | 21.36 ppg       |
|                  | 14.11 ppg       | 17.52 ppg       | 19.94 ppg       | 23.35 ppg       |

[0014] The use of Low Density Proppant, LDP, or Gravel for gravel packing has several advantages. It helps to reduce the Hydrostatic Pressure (HP) of the slurry. The use of LDP permits the placement of a large volume of gravel at the same slurry density, thereby reducing the time required to gravel pack.
pack the annular volume, and lower the pump rates needed to propagate the Alpha and Beta Waves, which in turn, reduces the friction pressure of the gravel packing operation.

[0015] Technology using mechanical valves to shorten the length of the washpipe as the Beta Wave is placed has been patented and is known as a Beta Breaker and is disclosed under U.S. Pat. No. 6,311,722. Other references to this device and its application are found as follows: "Beta-wave Pressure Control Enables Extended-Reach Horizontal Gravel Packs," Martin P. Coronado, SPE, and T. Gary Corbett, SPE, both of Baker Oil Tools Society of Petroleum Engineers Inc., 2001.

SUMMARY OF THE INVENTION

[0016] The invention adds a friction reducing agent or agents to a gravel slurry in order to decrease the pumping pressure required for the desired gravel propagation in an annular space around a screen assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] FIG. 1 is a graph of friction pressure loss versus flow rate for a variety of conduit sizes for fresh water;
[0018] FIG. 2 is a graph of friction pressure loss versus flow rate for a variety of conduit sizes for 10 pounds per gallon brine;
[0019] FIG. 3 is a graph of friction pressure loss versus flow rate for a variety of conduit sizes for fresh water with friction reducer;
[0020] FIG. 4 is a graph of friction pressure loss versus flow rate for a variety of conduit sizes for 1000 gallons mixture of HEC in water;
[0021] FIG. 5 is a graph of friction pressure loss versus flow rate for a variety of conduit sizes for 20 pounds per 1000 gallons mixture of Baker Clean Gel in water;
[0022] FIG. 6 is a graph of friction pressure loss versus flow rate for a variety of conduit sizes for 20 pounds per 1000 gallons of Guar Polymer in water;
[0023] FIG. 7 is a graph of friction pressure loss versus flow rate for a variety of conduit sizes for 30 pounds per 1000 gallons of Guar Polymer in water and;
[0024] FIG. 8 is a comparison graph of pressure loss versus flow in a 0.43 inch inside diameter tube comparing water to 36 pounds per thousand gallons of Xanvis in water.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0025] Friction pressure for Newtonian fluids is normally displayed as a logarithmic function of fluid velocity and friction pressure. FIG. 4 demonstrates typical friction pressures for fresh water and fluid conditioned with 10 lbs/1000 gal of HEC (hydroxy ethyl cellulose) gel.
[0026] Inspection of Curve "I" for the annulus of 2½ tubing inside a 5½, 15.5 pounds per foot (ppf) casing at 10 barrels per minute (bpm) indicates a friction pressure of 100 psi/1000 ft. The addition of 10 lbs/1000 gal of HEC, Baker Clean Gel, reduces the friction pressure to approximately 35 psi/1,000 ft., or a 65% reduction in friction pressure.
[0027] The invention uses any of several friction reducing agents. These include polyacrylamides and co-polymers of acrylamides, and polymers, including guar, and derivatized guar, such as hydroxypropyl guar (HPG), carboxymethylhydroxypropyl guar (CMHGP), and others, cellulose polymers including hydroxyethylcellulose (HEC), carboxymethylhydroxyethyl cellulose (CMHEC), starch and starch derivatives, biopolymers such as XC and Xanvis and derivatives of biopolymers, and surfactant based systems such as Viscoelastic Surfactant fluids commonly known in the industry as Clear frac offered by Schlumberger and Surffrac offered by Baker Oil Tools.
[0028] Some friction reducers may be preferred over others based on the specific conditions of the gravel pack completion. The type of friction reducer may be selected based on compatibility issues with the completion brine, compatibility issues with the filter cake, the formation temperature and the circulating temperature, the desired shear stability, the ability to form an alpha and beta wave and control the dune height or the ability to transport gravel down alternate flow path tubes, (Shunt Tubes offered by Schlumberger and Direct Pack Tubes offered by Baker Oil Tools).
[0029] The use of a HEC or biopolymers known as XC or Xanvis may provide the desired combination of friction pressure and compatibility characteristics with completion brine and filter cakes to make them preferred in many but not all applications.
[0030] The use of Viscoelastic Surfactants, VES, may be desired in other applications to reduce friction pressure and transport the gravel or filtration media and their use is disclosed in this invention.
[0031] The concentration of the polymers in the industry is usually referred to in pounds of polymer per thousand gallons (pppg), but other concentrations such as weight percent or in the case of Viscoelastic Surfactants, which are liquids their dosage is generally referred to as percent volume to volume (v/v).
[0032] The invention generally uses a preferred range of polymers in a low concentration range of one or less to twenty ppg, but concentrations outside of this range are also seen as having benefit.
[0033] The concentration of the VES is generally preferred in low concentrations of less than 1 percent (v/v), but higher concentrations may be used to achieve the desired friction pressure reduction.
[0034] The above description is illustrative of the preferred embodiment and many modifications may be made by those skilled in the art without departing from the invention whose scope is to be determined from the literal and equivalent scope of the claims below.

1. A gravel packing method comprising:
   mixing a slurry of gravel in a carrier fluid;
   adding a friction reducer to the slurry;
   using the addition of a friction reducer to allow an increase in gravel concentration without having to increase surface or downhole slurry pressure; and
   delivering the slurry downhole.
2. The method of claim 1, comprising:
   reducing surface pressure for slurry circulation to deposit the gravel as a result of said friction reducer.
3. (canceled)
4. The method of claim 1, comprising:
   increasing slurry circulation rates for the same surface or downhole pressure because of said friction reducer.
5. The method of claim 1, comprising:
   increasing the interval length that is gravel packed using the same surface or downhole pressures due to the addition of a friction reducer.
6. The method of claim 1, comprising:
   using at least one Beta Breaker Valve in a bottom hole
   assembly to deposit the gravel in the well.
7. The method of claim 1, comprising:
   using Low Density Gravel as the gravel.
8. The method of claim 1, comprising:
   using the addition of said friction reducer to enable the
   deposition of gravel without exceeding the formation
   fracturing pressure under conditions where it otherwise
   would have exceeded the formation fracturing pressure
   without said friction reducer.
9. The method of claim 1, comprising:
   using as said friction reducer at least one of polyacryla-
   mides and co-polymer of acrylamides and polymers,
   including guar, and derivatized guar such as hydroxy-
   propyl guar (HPG), carboxymethylhydroxypropyl guar
   (CMHPG), cellulose polymers including hydroxyethyl-
   cellulose (HEC), carboxymethylhydroxyethyl cellulose
   (CMHEC), starch and starch derivatives, biopolymers or
   a surfactant.

* * * * *