UNCONVENTIONAL GAS WELLBORE CLEANOUT

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ABSTRACT
Over 40% of natural gas production in the United States over the next 20 to 25 years is expected to come from "Unconventional Gas" sources. These consist of coal beds, shales and low permeability sandstones and carbonates. Unconventional gas producers are as susceptible to wellbore damage as conventional wells. Scales, formation fill and organic deposits are probable. Therefore, cleanout of these well bores is critical to maintaining production. The problem is that the loss of fluid on these reservoirs during such an operations can totally shut-down the gas production, Presented is an overview of "Unconventional Gas" sources, potential wellbore problems, the challenges to removal and solutions to the problems.

DISCUSSION
While the label, "Unconventional gas" covers a wide spectrum of natural gas producing environments, the common denominator amongst all of the various producing scenarios is an extremely low permeability, generally measured in microdarcies (0.001 mD). Coal bed methane production often comes from coal seams with permeability less than 0.01 md. Coal bed methane production is strong in the Wind River and Green River Basins of Wyoming, in Northeast New Mexico (Fruitland Coal), Southeastern Colorado (Raton Mesa) and in the Appalachians. Gas shales also have natural permeabilities in the microdarcy range and have only came into prominence in the last ten years as hydraulic fracturing technology made these wells prolific and profitable. Some of the larger gas shale plays in the U.S. are the Barnett Shale in North Texas, the Woodford Shale in Southeast Oklahoma, the Fayetteville Shale in Arkansas and the Marcellus Shale in the Northeastern U.S. Tight Gas sands and carbonates account for the largest contribution to unconventional gas production in the United States. Often, tight gas reservoirs have permeabilities measured at 0.001 md (one microdarcy). Tight gas production is prominent in the Appalachian Mountains of the Northeastern U.S., East Texas (Travis Peak and Cotton Valley formations), West Texas (Ellenberger), the DJ and Piceance Basins in Colorado, Green River and Wind River Basins in Wyoming and the San Juan Basin in Northwestern New Mexico. Production from these unconventional sources is presented in Figure 1.

While the ultra low permeability of most unconventional gas sources differentiates them from their more conventional associated and non-associated gas brethren, they tend to share many of the same wellbore damage issues when it comes to production. As with conventional gas production, much of the brine associated with unconventional gas is often over-saturated with minerals and has the ability to deposit a solid scale in the near wellbore area, wellbore or in the surface separation equipment. Calcium carbonate ($CaCO_3$) is a common problem as the mineral's solubility is affected by fluid pH, temperature and pressure changes. Barium sulfate ($BaSO_4$) is another troublesome scale found in many areas. It is usually formed as the result of incompatible waters, one with a high barium (Ba^{++}) content mixed with one containing significant quantities of sulfate ($SO_4^{=}$), but in some areas (such as Wyoming) it can be a single brine that contains barium sulfate in solution at elevated bottomhole temperatures and as the brine is produced and cools, the barium sulfate comes out of solution.

As with mineral deposits that affect both conventional and unconventional gas wells, many unconventional wells are affected by hydrocarbon deposits, much the same as their conventional relatives. These organic deposits are paraffinic waxes and / or asphaltenes that are usually constituents of condensate or oil produced in conjunction with the gas, though there are a few areas where waxes are seen though no liquid hydrocarbon is present such as the Raton Mesa coal bed production. Waxes are generally soluble at reservoir temperature, but as the fluid is produced, it tends to be cooled through gas expansion and by contact with water zones higher in the wellbore, thus resulting in the wax coming out of solution as a solid deposit. Asphaltenes are often found in a well-balanced dispersion in the produced fluids and are held in place by a complex relationship between the paraffin, resin and maltene factions in the crude or condensate. Wax deposition upsets this balance and usually is accompanied by asphaltene deposition.

While many of the wellbore problems that can be found in unconventional gas production are the same as those found in conventional gas wells, the efforts to remediate those problems and stimulate gas production can differ greatly. In conventional gas production, downhole scale deposits are often removed by spotting an organic acid or chelating solution across the area of deposition (e.g. – the perforated interval) and sometimes into the formation(s). Unconventional gas wells can suffer production impairment if this fluid is lost to the reservoir and while the clean-up procedure may not include fluid entering the reservoir, fluid often finds its way into the formation through the effect of hydrostatic pressure or through imbibition. In Figure 2, the effect of water saturation on the relative permeability to gas in a low-perm reservoir is depicted. As can be seen, as little as 50% water saturation in a low-perm rock can effectively result in a near-zero permeability to gas. To prevent this potential impairment to production, it is extremely important that water entering the formation during workover operations be kept to as minimal amount as possible. Two ways of accomplishing this are through wellbore remediation using coiled tubing and minimizing the effect of hydrostatic pressure by utilizing foam to carry scale dissolving and inhibiting chemicals downhole.

Coiled Tubing Wellbore Cleanout

Wellbore cleanouts using jointed tubing are common but with a great deal of risk that fluid may be lost to the formation. Use of coiled tubing reduces this risk considerably and as listed in Table 1 is able to remove many wellbore contaminates. The use of coiled tubing allows a well to be worked on in an underbalanced state and with movement of the bottomhole assembly through the area to be cleaned, Figure 3. Wellbore configuration greatly limits the effectiveness of cleanouts using jointed tubulars, since coiled tubing can be used in both vertical and highly deviated holes this minimizes these limits. The bottomhole assembly utilizes nozzles to jet materials out of the wellbore using a minimum amount of liquid and nitrogen. By virtue of this mechanical impact the process is efficient, Figure 4. This process insures efficient coverage and minimal losses of liquids to a reservoir.

The heart of coiled tubing cleanout designs is the prediction software that can evaluate pressures and velocities at over 200 nodes along the path the coil is going to take in the wellbore. Parameter adjustments can be made to insure continued circulation of the wellbore without losses to the formation. Surface treating pressure, nitrogen rate, liquid rate, wellhead pressure, choke size and foam quality can all be adjusted to accomplish the optimum design. The ability to make these evaluations using a two phase flow analysis, looking at effective viscosity, shear rate, Reynolds Numbers, friction factors and hydrostatic gradients is critical to this process and makes this software package unique.

Foamed Chemical Applications

Unconventional, tight gas sands in the Appalachian Mountains of West Virginia and Kentucky were found to suffer from production loss due to calcium carbonate deposition in and around the perforations. While the deposits are easily removed with inorganic acid, these treatments were often lost to the formation due to the low bottomhole pressure in the wells. Any fluids lost to the reservoir would result in a total production loss of these low volume, low permeability wells. Often, mechanical removal of the treatment fluids (swabbing) would be required to return the wells to production. Because of this, the standard procedure for applying an acid for downhole scale removal involved placing a swab unit on the well to aid with fluid recovery. This, along with the remote location of most of the wells, drastically increased the cost of the remediation efforts.

In late 2006, a method of creating a stable, acidified foam was developed using compressed nitrogen as the carrier gas for the foam. Three drums of inorganic acid were foamed into the annulus of three test wells and the wells shut-in overnight. In Figure 5, the production response for the three wells is presented. All of the wells indicated production increases similar to those treated with conventional liquid acids and none demonstrated the production loss issues noted when treated with liquid acids. In addition to the success of these treatments, it should be noted that mechanical fluid removal was not necessary saving the Operator significant additional expenses. Figure 6 details the average cost of remediation for scaled wells in this area for the last three years as compared to the average cost of the foamed treatments. To further document the performance of these treatments, a wireline conveyed camera was used to film the perforations before and after one of the foamed acid treatments. This film clearly documented the removal of the downhole scale deposits.

To maintain the production increases seen in the foamed acid applications and to attempt to prevent further scale deposition, a similar treatment regime was designed where a scale inhibitor was applied to the annulus of the treated wells in a foamed “package”. The average treatment would involve 15 gallons of a scale inhibitor in a stable foam applied to the annulus and allowed to “fall” over-night. Scale inhibitor residuals performed on the treated wells have indicated that scale inhibitor is present in the produced brine in quantities sufficient to inhibit scale for three or more months after the treatment. With the exception of the overnight shut-in period, the treated well's production rate is not affected by the treatment.

CONCLUSIONS

Wellbore deposits are often the same regardless of whether the well is a conventional or unconventional gas producer. These deposits may be organic (wax, asphaltenes) or inorganic (scale, iron solids, formation fines or sand) in nature. The biggest difference in conventional and unconventional gas sources is the ultra low permeability seen in many unconventional gas reservoirs. This affects how we remediate downhole wellbore deposits as fluid entry into the near-wellbore area can be extremely detrimental to low-perm, unconventional gas wells. Fluid loss to the reservoir can be prevented in many cases by use of Coiled Tubing and foamed chemical application technologies.

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Table 1
Wellbore Contaminates Coiled Tubing Can Remove

Particulates	Iron Sulfide
Muds & Gels	Calcium Sulfate
Waxes & Complexes	Sulfur
Coke & Tar	Calcium Carbonate
Barium Sulfate	Filter Cake

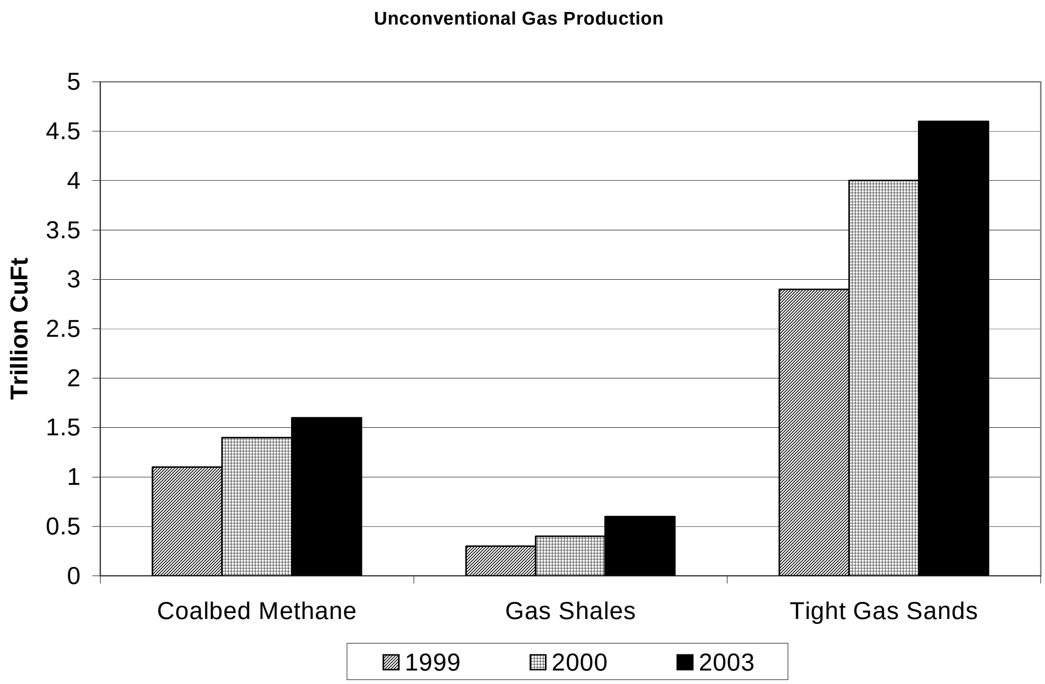

Figure 1 – Unconventional Gas Production

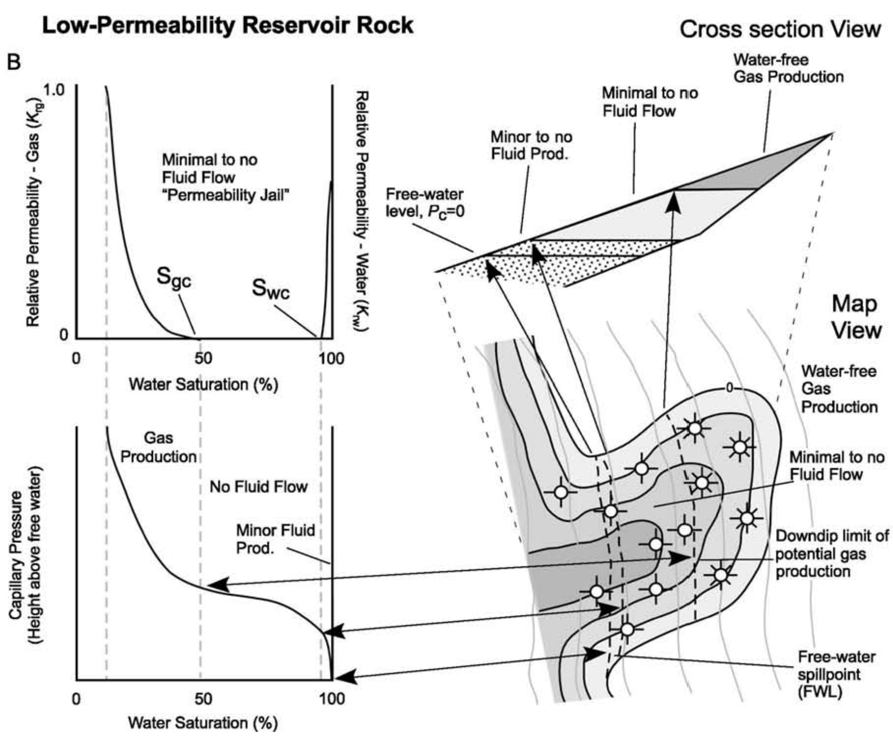

Figure 2 – Effect of Water Saturation on Relative Perm in Low Perm Reservoir

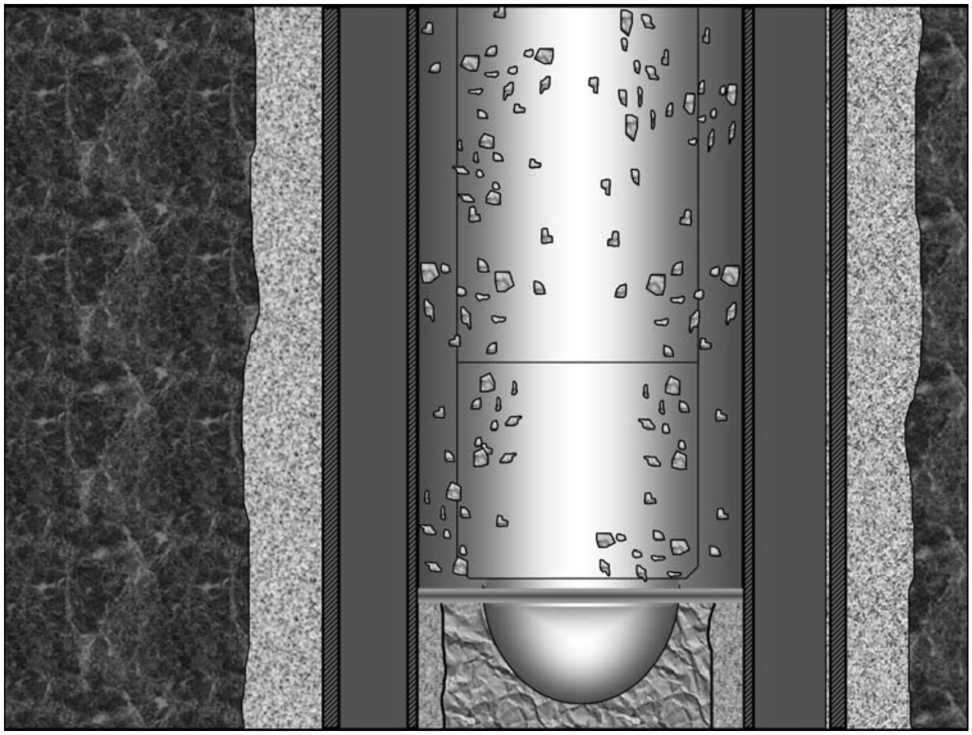

Figure 3 – Coiled Tubing Cleanouts With Jetting

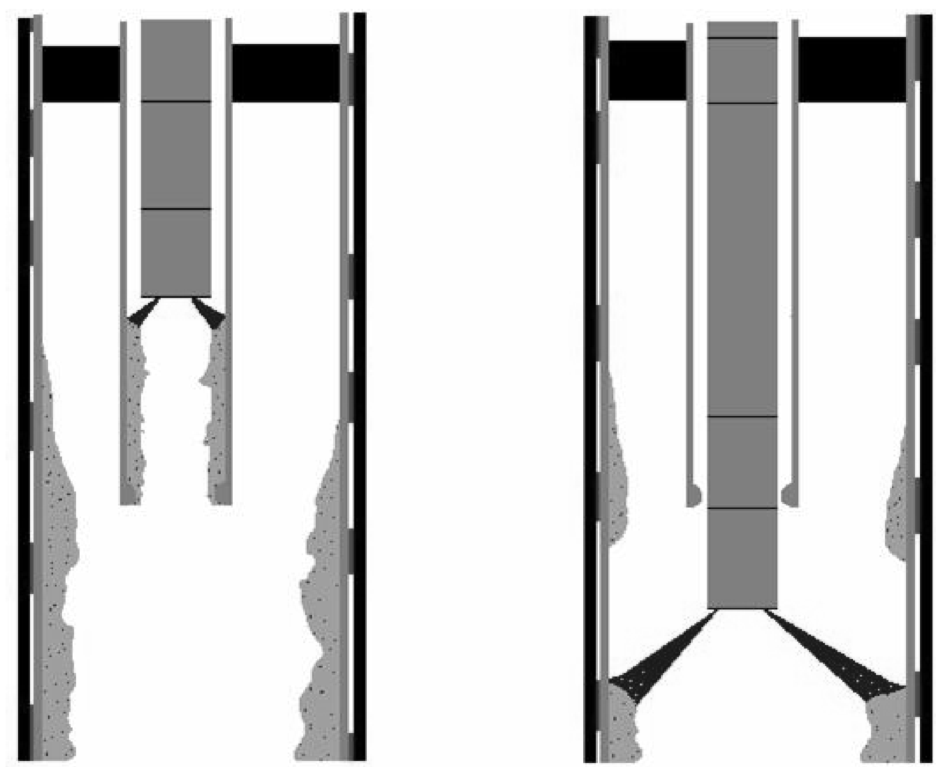

Figure 4 – Bottomhole Assembly Jetting on Coiled Tubing

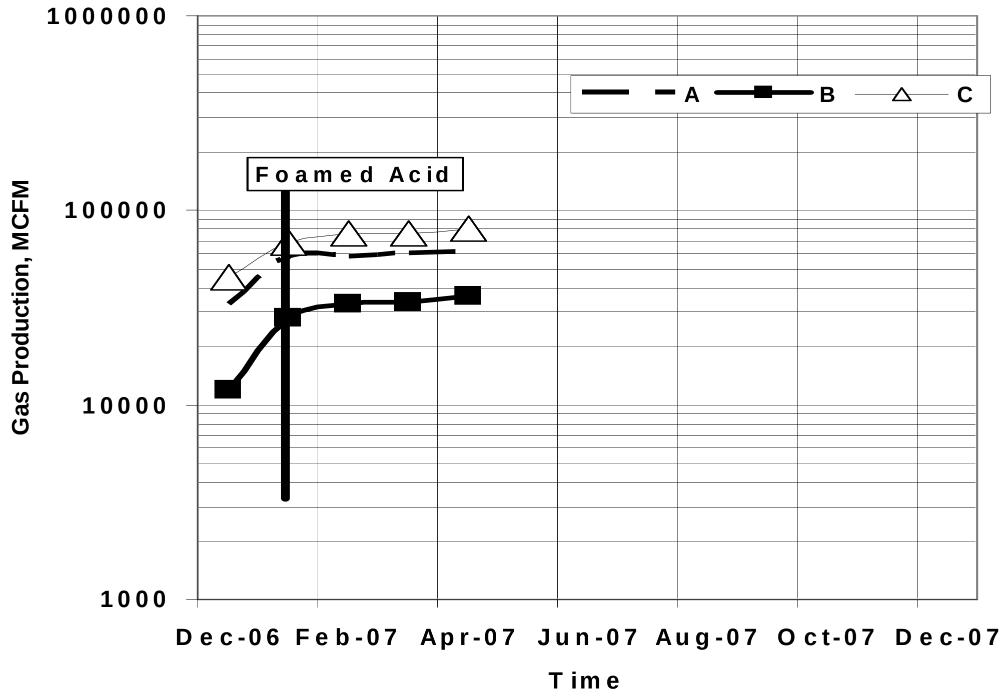

Figure 5 – Effect on Production from Foamed Acid Jobs

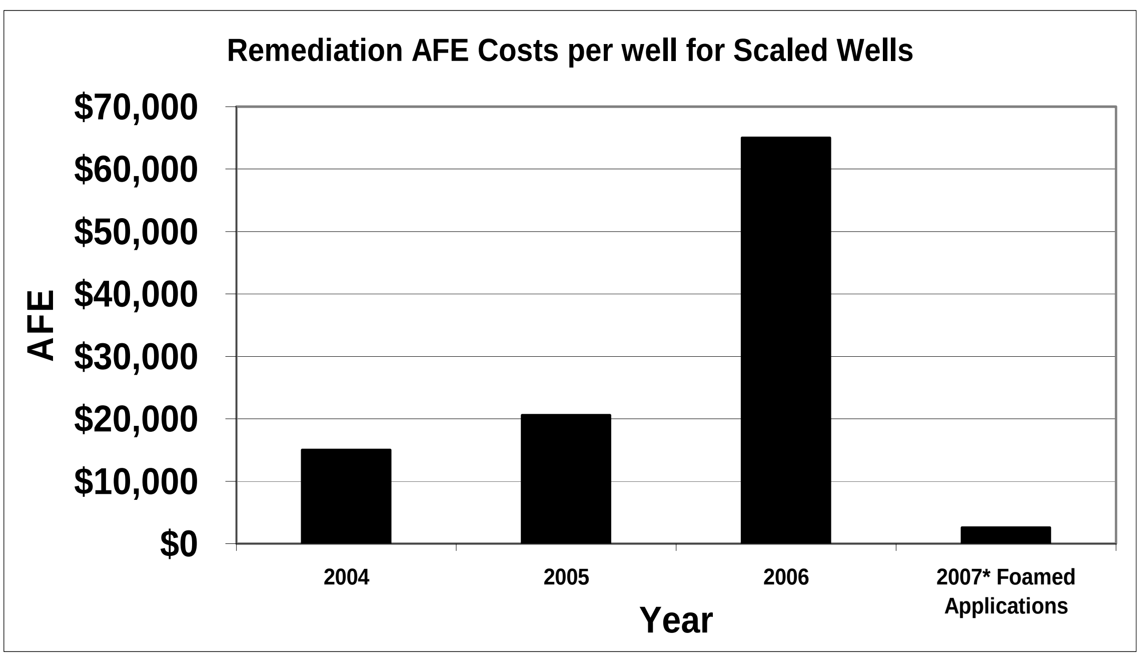

Figure 6 – Average Cost Per Well for Scale Remediation