The Oil Drum
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

Making holes and cracks around oil and gas wells

Posted by Heading Out on November 22, 2009 - 4:42pm
Topic: Geology/Exploration
Tags: gas, oil [list all tags]

This is a continuation of the tech talks, discussing technical topics, that I write on Sundays. For the past few weeks I have been writing about some of the techniques used in producing the gas from shales, and that will likely continue for another week or two. Because of the need to condense the topic into a relatively short post I would ask those familiar with the topics to understand that I have had to shorten the description and gloss over some details in order to keep the main theme clear. But further comments to help readers understand the techniques better (or questions when it isn't) are appreciated.

Equipment used for hydraulic fracturing a well (Primer)

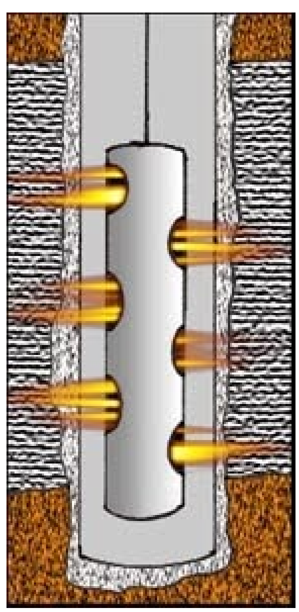
There is a simple test that I use in one of my introductory classes, where I give the students a rectangle of paper and ask them to pull it apart, then I give them a rectangle with a cut half way through it perpendicular to the length, and half-way down, and ask them to pull that apart. It tears apart much more easily, and it is how I start a lecture on the role of cracks in causing materials to fail. You apply that principle about every time you pull open a package with a serrated top. The deeper cuts focus the force you are pulling with over a small area, making it easier to part the package and extract the candy, nuts or whatever without having to pull so hard that, when the package tears, you throw the contents around the neighborhood.

Today I want to talk a little more about perforating the wall of a well, and a bit more about hydrofracing. They are not necessarily used together, but both are ways of getting cracks out from the immediate wall of the wellbore so that the valuable fluid on the other side can have an easier path into the well.

To begin with the topic of perforating a well, I have written about this earlier, but more from the point of the tools used to do the job. What I'd like to do here is to talk a little more about it from the rock point of view. As I mentioned [last time](#) the rock right around the well can be subject to a high enough pressure that it will partially fail, or crush, and this can lower the amount of fluid that can get through, or alternately it might have been damaged in some other way. By bringing in a tool with a set of shaped charges in it, and then firing these at the appropriate place this problem can be overcome.

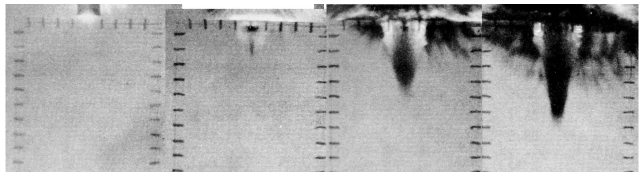
Arrangement of shaped charges (the yellow cylinders) – when the explosive goes off the cones collapse and small liquid metal jets shoot out of the open end, through the casing, concrete and into the rock, creating a channel. ([Core Labs](#))

The charges aren't all necessarily fired at one time or place, even though, for the illustration below, they appear to be.



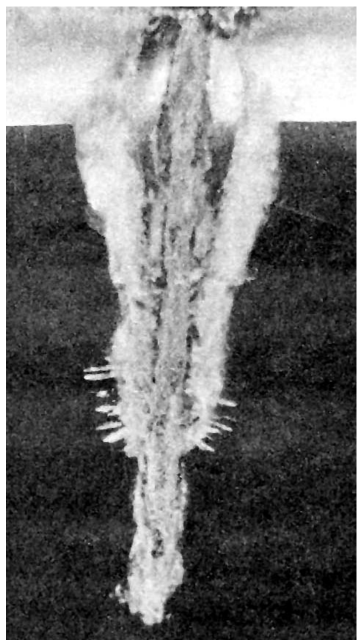
Representation of shaped charges firing and penetrating the casing, cement and wall ([OSHA](#))

The jet of metal that shoots out of the cone will travel into the rock roughly 10 cone diameters, as a rough rule of thumb, and this carries a channel, or tunnel, out through the damaged rock into the surrounding reservoir. The collapse and creation of the channel happens very fast:



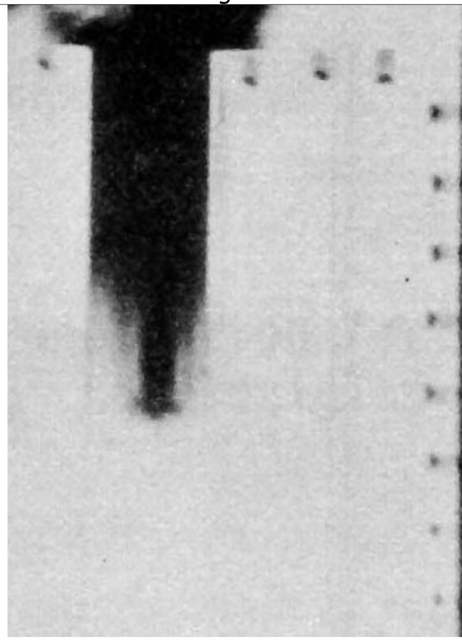
Penetration of a perforating charge into Plexiglas after 3, 12, 21 and 30 microseconds. Marks are in cone diameters. (after Konya)*

The channel is initially hollow, and drives a set of small and large cracks out into the rock around the line of the charge.



Jet penetration through Plexiglas (note the lateral cracks away from the line of penetration. The dark section is due to a change in background. (after Konya)*

However, while it is easier to show the damage that the jet does by showing how it penetrates Plexiglas, this is not rock, but it does show some of the events that occur. When, for example, (vide the discussion on jointed shale last week) the jet shoots into rock where there are clear joint planes defined, then these act to stop the crack growth (perhaps in the way that those who used to remember stopping cracks growing in old cars by drilling a hole at the end of the crack. It distributes the stress that was causing the crack to grow when focused on the tip, over a larger area so that it drops below the critical level). Or the stress is high enough to cause cracks to form and be reflected back at the jet.



Jet damage confined between two adjacent planes when the charge is fired into plates that run parallel to the direction of the jet. (after Konya)*

If the charge is not carefully designed and used, therefore, it might not be as effective as initially hoped, and this becomes even more true if the pieces of metal that are formed when the cone collapses are carried into the channel and partially block it. There are different strategies, depending on the well and the surrounding rock and it is one of those things in life where, if you got it right the results are almost immediately obvious – as is the converse.

Creating cracks that go out into the surrounding rock has become a vital part of the economic production of gas from the shales around the country, as we have discussed, and having a starting crack in the right direction, whether it is a natural joint in the rock, or a crack that has been deliberately created helps control where the crack starts and how it grows.

Crack growing out from a drilled hole in Plexiglas, the small notch at the top of the hole *controlled the direction of the growth of the crack (We put ink in the hole to show how the fluid goes into the crack).*

In the above picture you can see that when the hole was pressurized, a crack grew, and ink flowed into the crack, as it formed, but, when the pressure came off, the crack closed and most of the ink was forced back out of the crack. (We created the pressure by firing an air rifle pellet into the hole).

So if we are going to have a useful crack we need to have it open after we take the pressure back off – after all we need to get the fluid back out of the well, so that the gas can pass up the well for collection.

Now it is not quite as easy to grow the crack, or prop it open as I may have suggested earlier, and to explain some of the issues in a little more detail I am going to use an example and some details from the Modern Shale Gas Primer.

When you decide to frac the well, and each well is different, as is just about every location, so there is a significant amount of preparation and knowledge required to work out the procedure required at that particular point. Bear in mind that the crack that you are going to have to grow needs to stay in the shale layer, and not go out beyond it into the surrounding rock. One of the reasons for this is, apart from giving the gas a path to the well, if it goes outside the reservoir rock then the gas can escape, or, alternately, other fluids can gain access to the well. This is particularly true of the Barnett where the rock immediately below it, the Ellenberger limestones, can hold a lot of water that can muck up the gas recovery if it gets into the fractures. (Given this degree of control and the large distance below the ground to the reservoir rock, this is why a lot of the fears that the frac job will damage the ground water tend to be dramatically overstated).

In the example cited, which is from the Marcellus shale, the treatment of the frac takes a total of 18 steps, and because some of these are fairly similar I am going to go through them in groups. First the hole is treated with an acid, to clean away any remaining debris and mud from the drilling operation and to clean any fractures around the hole, so that they can be used to help the frac grow. After the acid the hole is filled with an initial polymeric fluid, largely water, but containing the "Banana Water" that I referred to in an earlier post. This is a friction reducing agent and will help carry the particles used to hold the crack open into the crack in the first place. The problem with that polymer is that some of the choices available, while good at reducing the friction to help move the particles, aren't that good at holding the particles in suspension, and the last thing we need is for them to settle out in the bottom of the well, and so in the subsequent steps in the process as the particles (or proppants) are added, there is usually a second polymer in the mix to hold them in suspension.

Once the hole is full of the slickwater (the official term for the first polymer solution) the initial frac is made with a fine sand suspended in the fluid. To keep the crack open all along its length we need sand along the path and the crack gets narrower as it grows deeper. So for the first several stages of the crack growth the fluid is filled with successively greater concentrations of the fine sand, so that, in this way, it can penetrate to the deepest part of the fracture.

In the example cited there are some seven of these sub-stages with the fluid being pumped into the well at some 3,000 gpm but varying the fluid:proppant density to carry more and more of the particles into the fracture. Once these stages have been completed, then the job is finished by pumping an additional eight sub-stages of fluid, with this second set containing a larger size of proppant particles. In this way the area closest to the mouth of the fracture will be held wider apart to make it easier for the gas to escape. As with the first set of sub-stages, the concentration of proppant in the fluid increases as the stages progress. In total, in the example given, some 450,000 lb of proppant was used to make the fracture, together with some 578,000 gallons of water.

Once the fracture is created, then the well is flushed to clean out the different fluids, and make it easier for the gas to get out out of the rock and into the well. (It also removes any loose and ineffective proppant so that it doesn't later become a nuisance). If you think that this would need a lot of equipment you are right!

Equipment used for hydraulic fracturing a well (Primer)

Since there is some discussion of the effects of the different constituents of the fracing fluid on local waters I thought I would end with the listing of common chemicals used in that liquid, which is provided in the Primer.

As usual this has had to be a very brief review of the technology and may have oversimplified to the point of not being clear, so all technical comments and questions are appreciated.

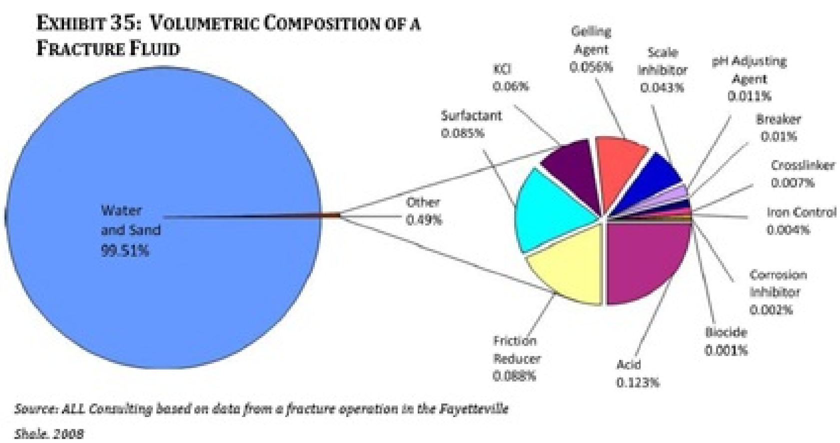


EXHIBIT 36: FRACTURING FLUID ADDITIVES, MAIN COMPOUNDS, AND COMMON USES.

Additive Type	Main Compound(s)	Purpose	Common Use of Main Compound
Diluted Acid (15%)	Hydrochloric acid or muriatic acid	Help dissolve minerals and initiate cracks in the rock	Swimming pool chemical and cleaner
Biocide	Glutaraldehyde	Eliminates bacteria in the water that produce corrosive byproducts	Disinfectant; sterilize medical and dental equipment
Breaker	Ammonium persulfate	Allows a delayed break down of the gel polymer chains	Bleaching agent in detergent and hair cosmetics, manufacture of household plastics
Corrosion Inhibitor	N,n-dimethyl formamide	Prevents the corrosion of the pipe	Used in pharmaceuticals, acrylic fibers, plastics
Crosslinker	Borate salts	Maintains fluid viscosity as temperature increases	Laundry detergents, hand soaps, and cosmetics
Friction Reducer	Polyacrylamide	Minimizes friction between the fluid and the pipe	Water treatment, soil conditioner
	Mineral oil		Make-up remover, laxatives, and candy
Gel	Guar gum or hydroxyethyl cellulose	Thickens the water in order to suspend the sand	Cosmetics, toothpaste, sauces, baked goods, ice cream
Iron Control	Citric acid	Prevents precipitation of metal oxides	Food additive, flavoring in food and beverages; Lemon Juice ~7% Citric Acid
KCl	Potassium chloride	Creates a brine carrier fluid	Low sodium table salt substitute
Oxygen Scavenger	Ammonium bisulfite	Removes oxygen from the water to protect the pipe from corrosion	Cosmetics, food and beverage processing, water treatment
pH Adjusting Agent	Sodium or potassium carbonate	Maintains the effectiveness of other components, such as crosslinkers	Washing soda, detergents, soap, water softener, glass and ceramics
Proppant	Silica, quartz sand	Allows the fractures to remain open so the gas can escape	Drinking water filtration, play sand, concrete, brick mortar
Scale Inhibitor	Ethylene glycol	Prevents scale deposits in the pipe	Automotive antifreeze, household cleansers, and de-icing agent
Surfactant	Isopropanol	Used to increase the viscosity of the fracture fluid	Glass cleaner, antiperspirant, and hair color

Note: The specific compounds used in a given fracturing operation will vary depending on company preference, source water quality and site-specific characteristics of the target formation. The compounds shown above are representative of the major compounds used in hydraulic fracturing of gas shales.

* The initial photos in this post were taken as part of the dissertation of Dr Konya, "The use of Shaped Explosive Charges to Investigate Permeability, Penetration and Fracture Formation in Coal, Dolomite and Plexiglas" Missouri S&T, 1972.