The Oil Drum
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

Tech Talk: Progress on the Gulf oil leak and comments on cementing pipes and well completion

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BP held a press conference a couple of days ago in which they reported on progress in trying to stop the oil leak in the Gulf of Mexico, following the blow-out and sinking of the Deepwater Horizon. The well was in the final stages of being closed down, after having been completed, so that the initial drilling rig could leave the site. This meant that the pipe that would ultimately carry the oil and gas to the surface, the production casing string, had been put into place. To hold that pipe in place, and to make sure that it is sealed so that no fluid can flow into the gaps between this tube and the rock walls left by the initial drilling of the hole, the casing had been cemented in place. I am going to repeat part of the post where I talked about that, to explain what this involves. I begin as the hole is still being drilled.

Casing a Well - (Excerpt from previous tech talk)

As the bit goes deeper we add additional lengths of drilling pipe to form the drill string, and the bit penetrates through rocks that are of different types and some of these will have fluid in them. Water, whether fresh, which might be the supply for a local community, or salt, is quite common. The hole cannot be left open any longer, because the water flowing from the surrounding rock into the well will dilute the mud, so that it no longer works as it was supposed to, plus, we might start losing some of the drilling fluid into the surrounding rock. Plus different layers of non-drinkable water can work back up the well into the drinking water aquifer.

To stop this from happening we have to stop drilling and seal off the rock on the sides of the well from the well itself. This is known as **casing the well**, and **running casing** will hopefully (but not always) be only needed once before we get to the bottom of the well.

So we pull all the drill string out of the hole, remove the drill and lower steel pipe into the well to encase the well, from the bottom of the conductor pipe down to where the bit has found (and hopefully drilled through) the rock that is giving us the problem. (Hence the name **casing**). Having this continuous length of casing in the hole will likely stop, say water, from getting in and diluting the drilling mud, but if this was all that we did, then it would still leave a problem, since the steel pipe does not completely fit up against the rock wall created by the drilling bit. In other words there will be a gap between the casing and the rock wall, that will allow fluids to travel up or down. This gap has to be filled, and the filler is normally a special form of cement.

The way that the cement is placed is simple in principle, but a fair bit more difficult to do properly and effectively. Think of the long thin tube of casing, filled with a cement that acts something like toothpaste. This cement has to be pushed down the tube so that it squeezes out of the bottom and then flows back up between the casing and the rock wall, filling all the gaps as it is pushed back up to the top or surface. (Hence the name **surface casing**). Particularly when this casing is run, it is important that the gap is fully filled. This is because this is the casing that seals the well from local groundwater, used for domestic and industrial supply. Since the cement will move more easily thorough a larger passage, than a very narrow one, this gap has to be above a certain minimum size. Small **centralizers** will be attached at points down the steel casing to keep it in the middle of the hole, rather than pressing up against one of the walls (since this might leave an open channel up through the cement). There are also "scratchers" which are put on the casing so that when it is rotated in place it will scratch the walls of the borehole and remove any mud cake that might have formed, so as to give a better bond between the cement and the rock wall.

Cementing plugs

A small plastic plug (the bottom plug) is put into the casing ahead of the cement. This separates it from the mud that is already in the hole. It is fitted with wipers, that clean mud from the walls of the casing, and it is pushed down to the bottom of the casing by the cement that is pumped into the well behind it. There are some pictures of some of the tools and descriptions of the process here, here and here.

Once the bottom plug gets to the end of the casing, there are ports it passes that allow the cement to flow out of the casing and back up the outside. Once the cement has been pumped into the casing a second, top plug, also fitted with wipers, is put into the casing and this is then pushed down by the conventional drilling mud. As it is pumped down it forces the plug down, and the cement out and back up to the surface. Because of possible variations in hole size and other possible problems, perhaps about 50% more cement might be pumped into the well than the calculations might suggest. When the top plug hits the bottom plug, then there is a pressure spike at the pumping station, telling the operator that it is finished. The rig then **waits on cement** (**WOC**) until the cement is hardened. The drill pipe can then be put back in the hole and drilling can restart.

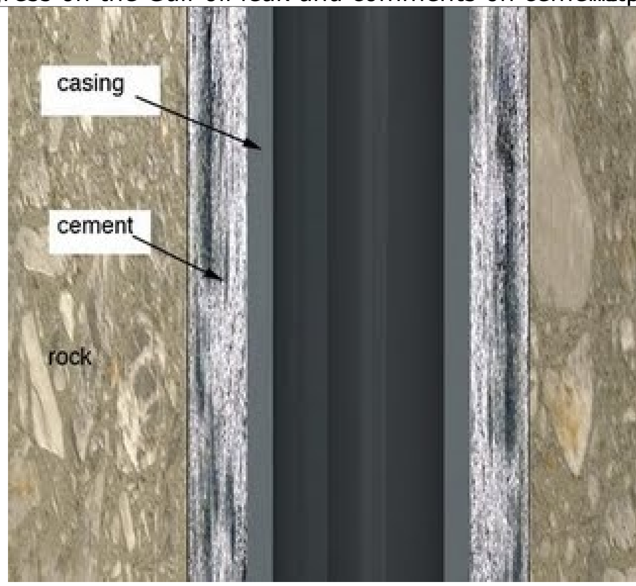


Illustration of a cased well

But whoops, the bit won't fit in the hole any longer! For the sake of discussion lets say we ran half-inch thick casing. And that we had an inch of cement behind it all around the casing. Then the hole we have available to get the drill through down to the bottom is now only 6-7/8th inches in diameter. So we now might use a 6-5/8th inch diameter bit to continue drilling (since we don't want it rubbing against the casing wall).

If we run into another layer of problem rock as we drill down to the bottom of the hole, then we are going to have to run another set of casing. This is known as **intermediate casing**, and the process is the same, and it leaves us with an even smaller hole through which to get a drill bit through.

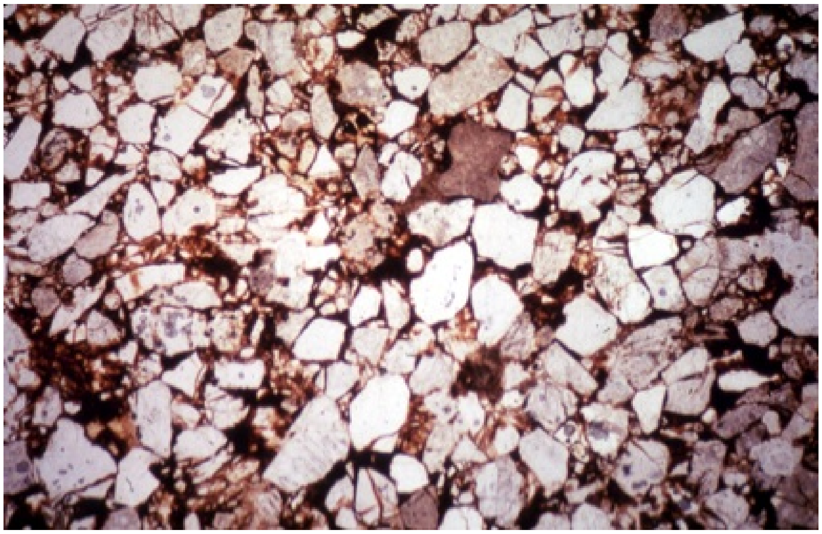
Completing and Perforating a Well (Excerpt from previous tech talk)

That describes a little of the process of how a casing is cemented in position. The well that the Deepwater Horizon had drilled had reached the zone where the oil was, and in preparation for leaving the site had, as I mentioned above, run in the production casing. Let me add the post on well completion to explain this a little more.

There are a number of different steps that we have yet to go through before we can finish what is commonly called, the **completion**, of the well.

And one of the first things that we do is to flush out the drilling fluid, and then clean the walls of the well – firstly by washing the remaining mud from the well down in the production zone. That means that the rock wall is exposed, just as it was drilled. There are several issues that can come about as a result of this. The first is that the rock we have drilled into can be fairly weak. This is one of the peculiarities of geology. To a degree the richer in oil the rock is, the weaker the rock will be. (And that also holds true for oil shale - of which more at a later date). Why is that?

Well let's talk a little about the rock structure, particularly in this post the porosity that it has. (I'll talk about permeability next time). There are, simplistically, two types of rock, that oil is usually found in and for now, to make a simple generalization, I am going to call them **sandstone** and **carbonate** (as I said holding shale until a later time). Sandstone rock is made up of relatively large grains that are glued together at the edges with various different types of natural cement. The grains do not fit that well together (think apples filling up a room, and connected where they touch). We call the gaps between the grains, the **pore space** of the rock, and it is these gaps that the oil fills up to form the reservoir. And so we can calculate the "free volume", as it were, of the rock as the (relative amount of free space in the rock, you can get this by subtracting the weight of the rock from the weight of the same sized piece cut from solid quartz and it will tell you how much empty space there is in the rock, and thus, how much oil there could be in that volume.



Section of sand with oil in the pores-–this is actually an oil sand, so the grains aren't that well cemented together. (Syncrude)

So say we had a core that weighed 144 lb/cu ft and the weight of solid quartz (flint) is 220 lb/cu ft. Then only 65% of the rock (144/220) is solid rock and the remainder is what is known as **pore space**. Now these holes can be connected or totally separated, with each pore surrounded by a solid piece of rock. Normally the percentage given is reversed, i.e **porosity** = **proportion of void space to total volume**, or in this case 35% of the total volume is not rock. (Another picture showing porosity of a sandstone can be found here. Now in the reservoir rock this space is going to be filled with a fluid, either gas, oil or water. For now let us assume that it is filled with oil.

What I have described so far is known as primary porosity,i.e. that which is created by this initial structure of the rock. With carbonates more than sandstone there is a **secondary porosity**, and this is the porosity induced by rock movement and the dissolving of channels and holes in the rock by the movement of fluid over the rock through the millennia. Again put simply the oil found in a sandstone will occur between the grains of the rock. In the case of the carbonates, which normally have a much smaller individual particle size, the oil is more often usefully found in the cracks and joints formed were the rock bedding planes were created (and which can be seen in exposed rock in a lot of road cuts along the highway).

The voids and spaces in the rock are also formed from the spaces from what might have been old coral reefs, or where water dissolved holes through the rock. But sometimes the two methods of formation mix, and I would like to quote from Kenneth Deffeyes book "Hubbert's Peak" (my favorite text as an explanation of the geological case).

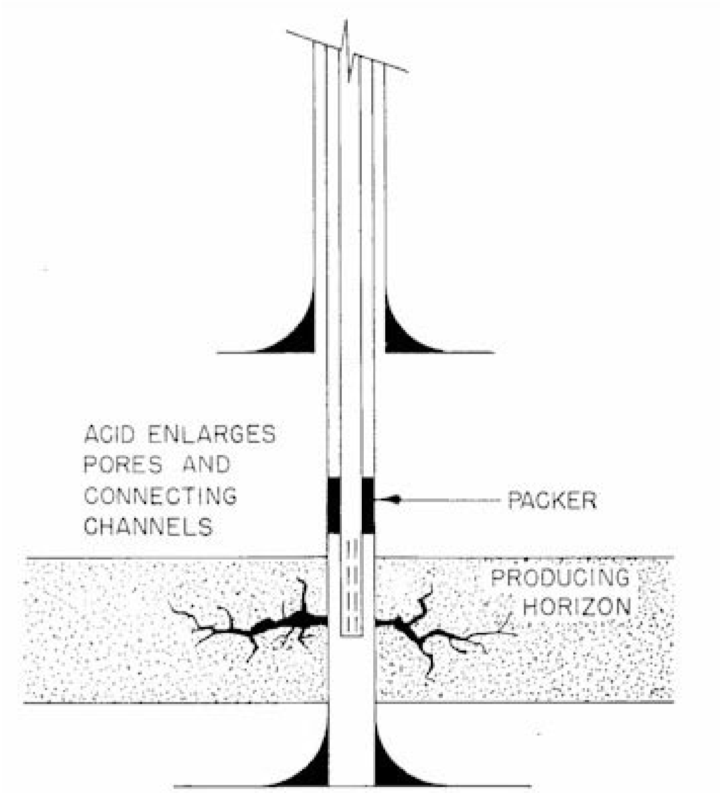
> Fine grained calcium carbonate mud usually gets consolidated into massive limestones, usually with little or no porosity. . . . . . . .About 10 percent of ancient limestones do have

> porosity. . . . . . .Most massive and nonporous limestones contain textures made by invertebrate animals that ingest sediment and turn out fecal pellets. Usually the pellets get squished into the mud. Rarely do the fecal pellets themselves form a porous sedimentary rock. . . .I twisted Aramco's collective arm for samples from the supergiant Ghawar field. . . . .Examining the reservoir rock of the world's biggest oil field . . .a small part of the reservoir was dolomite, but most of it turned out to be fecal pellet limestone. I had to go home that evening and explain to my family that the reservoir rock in the world's biggest oil field was made of shit.

So there you have it. And the reason for the quote is that the rock at the bottom of our well can be very weak, and may be left in poor shape by the oil drilling bit that just passed it by. Now remember it is this wall around the hole that is the barrier through which all the oil in that rock must pass to get into the well. So before we leave it we have to ensure that it is in as good a condition to allow that flow as possible. (Hence the reason for the removal of the mud and the cleaning of the wall). We also have to isolate the production zone from the rest of the well, and we do this with what is known as a completion or production packer.

Production packer (B.J. Services) - the three rings swell out and fill the gap (pack it) between the tool and the rock wall of the hole acting as a seal to separate the well below, from the well above – note the internal pipe to allow flow from the underlying part of the well.

One of the problems is that the drill bit may have overly crushed the rock, so that fine carbonate particles are pushed into the cracks and pores of the rock, right around the bore. These can block the passages that will allow the oil to enter the well. And so, in order to get rid of these particles, a strong acid can be poured into the bottom of the well. This **acidizing** dissolves these fine particles and opens up the cracks leading out into the surrounding rock, so that the oil can flow into the **well bore** more easily.



Acidizing operations involve the introduction of acids into the formation crevices to increase the flow capacity of the pay zone. (From *Primer of Oil and Gas Production*, Book 1 of the Vocational Training Series, 3rd ed., API.)

Process of isolating and acidizing the formation.

Another problem is that the rock may be very weak, since a lot of its strength comes from the oil that fills the holes within it. This oil only provides strength as long as the rock is totally confined on all sides, but when the pressure is removed on one side (think of popping a champagne cork) then the oil can flow away, taking the support for the surrounding rock with it. If the rock bridges that are left are weak then they can crush. This will cause the crushed rock (**sand**) to mix with the oil, which will require a **de-sanding process** at the surface, but it will also close some of the passages through which the oil is flowing to the well. A well operator that speeds the flow of oil out from the rock around the well, can reduce the support that the oil gives to the surrounding rock to the point that it crushes, and permanently reduces oil flow into the well. We can put in a screen that will hold the rock in place, but allow the oil to seep through slots in the screen wall.

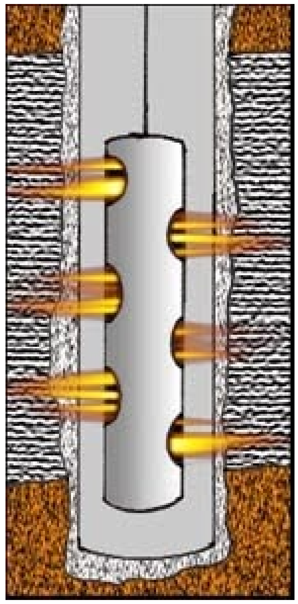
Completion screen

Or, to stop that rock crushing from happening and to reinforce the rock, we can pump a layer of concrete into the bottom of the well, cementing a steel liner into the rock, just as we cased the well higher up the well. The steel liner, or **production casing**, has, however, one problem. Once it is cemented into place, there is this hollow tube all the way to the surface, but there is no way that the oil can get through the cement and the steel into that passage.

And this is where Her Majesty's Explosive comes in. Small, specially designed, explosive charges, known as **shaped charges** are now put together into specifically designed charge packages, and lowered down into the well into the completion zone.

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)

Here they are detonated, sending small jets of metal against the wall of the casing and **perforating** the steel and concrete into the surrounding rock. There is an animation that shows the jet being produced (see also information here) .



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

Update for Deepwater Horizon

At the time that the explosion occurred on the oil rig, it appears that they had cemented the production casing in place, and were cleaning the mud from the well, prior to putting a temporary cement cap at the top of the well. This would allow them to leave the site (abandon the well), with the well ready to be connected to the pipes that would more permanently carry the oil and gas from the well.

Thus this rig would not carry out the perforation of the well that I have just described, and the production casing should have been surrounded by a cement jacket, that would help seal, temporarily, the bottom of the well. It is the condition of this cement that is, I gather, why Haliburton, who were responsible for that part of the operation, are now in the picture.

The latest report from Upstream, suggests that there have been a number of attempts to get the current BOPs on the well to work, and that they may be providing some restriction to the flow, or this may be coming from the kinks in the riser above the BOP. However they have cut off the riser to give a better target, and they will do this again before lowering a new BOP arrangement that will "stab" onto the initial structure, and allow them to possibly seal the well with that (depending on how good a seal they can achieve with the stabbing operation – these are normally fairly tight).

They will still have to drill the relief wells, and are apparently already drilling the first well, while a second rig is completing another well in the Gulf, and then will come over and provide a back-up to the first in drilling a second relief well.