From:	Perfect, Scott A. [perfect1@llnl.gov]
Sent:	Tuesday, June 01, 2010 9:56:38 AM
To:	Sharpe, Rob; Miller, Wayne O.; Havstad, Mark A.
CC:	Lane, Monya A.; Wapman, Derek
Subject:	well questions
Attachments:	Top Kill Analysis rev 51.pdf; 052810 Top Kill postercopy.xls

The third top kill attempt was conducted on May 28.

Enclosed is the pressure data from that operation (the Excel file).

Two ships were pumping mud – denoted BJ and HES.

The mud was pumped through the choke line and entered the BOP just below

The test ram.

The light blue line is the BOP "calibrated" data (the gage has an offset that they

Have corrected for). This is the pressure at the bottom of

The BOP.

The choke line pressure is the black line in the graph. Note that the choke line

Pressure is measured some distance from the BOP (thus, the BOP pressure and

Choke line pressure are different during flow).

The total mud pumping rate is the green line at the top of the graph (scale for

Rate to the right).

The mud pumping is rate limited. The third attempt ran about 78 barrels per minute

And that was pedal-to-the-metal. They can generate pressure with no problem but not

Flow.

The flow and pressure patterns have been similar for all three top kill attempts.

TREX-150303

For steady flow, the pressure at the choke/kill lines and BOP decline at a fairly Steady rate (which would seem to indicate that some head is developing in the Well and helping the fill effort) but then the effort hits a "wall" and pressure Plateaus or rises. There are theories that this indicates flow into the formation.

The period following the third attempt was furiously busy. BP had to make A decision whether to execute a fourth attempt or divert resources to "Plan B," containment via a "Top Cap" collection method.

BP concluded that the well could not be killed. Cabinet members insisted that BP present an argument as to why the top kill should be abandoned.

The pdf file is the analysis that BP scrambled to put together. Just to put some Context here - these guys had been operating with very little sleep for several days.

While nobody is contesting the conclusion to move to Plan B, Secretary Chu and Others question BP's assertion that the well cannot be closed off. We are entering Hurricane season and the BP plan is to pull the top cap assembly off the well Should a hurricane place the recovery ship in danger. Thus, the spill would Continue until they can place the top cap back on the LMRP.

We are being asked to assess what conclusions can or cannot be drawn from The kill information.

There is a telecom today with Trevor Hill (hopefully) from BP and the Sandia

Fluids guys to talk more about this topic (note message below).

Also below is a message from Dick Garwin of Secretary Chu's science team.

All,

Telecon today - same call in (and physical coordinates in Houston) as yesterday.
The telecon with be at 10:30 am ABQ time and 11:30 am Houston time.

Dial In: 866-616-1740

Conference Code: 5484388484

Sheldon's cell: 505-400-2636

Thank you,

Sheldon Tieszen

FYI - an independent analysis from Dick Garwin on Chu's science team.

FROM Dick Garwin:

Dear Team,

Here is the analysis I sketched during our science call on May 31.

Conclusions:

1. The mud cannot possibly be going primarily through the rupture disks.

2. The results seem consistent with almost all the 80 bopm going down the inside of the 9-in casing, and well fluids coming up in the annulus between the 9-in and 16-in casings.

Data:

1. As noted in the 05/31 BP brief to Salazar, there always was gas coming from the kink leaks during the heavy mudding. My observation was that there was less mud coming from those vents during the 80 bopm mudding than during the 2, 4, or 6 bopm test injections of mud with the test ram closed. Since no more than 6 bopm of mud could emerge during the tests, less than 6 of the 80 bopm could have gone UP during the 80 bopm mudding with the test ram open.

2. In his email of 05/19 regarding the rupture disks, Arun wrote:

Dick,

The disks are not 6?, at least not what I have been told. I actually held one in my hand this morning. The inner diameter of the disk, which is designed to fail, is 0.433?. It is unlikely it will fail at the thread.

The failure disk is essentially stainless steel shim stock which is welded at the circumference. Their tests have shown that it does not fail at the weld but the metal membrane fails.

BP seems to have done a lot of testing both at room T and at 200F. From that, the average burst pressure rating at 200F is 7500psi, and the 3sigma limit is 1%, i.e. 75psi. The pressures they have selected for their models is about 5% lower than average, which is how they got 7154psi (5% is actually 7125). This number was used in the BP presentation (slide 6) Sunday.

These rupture disks are essentially designed to fail inwards (collapse rating of 1600 psi), so that you prevent a cascade of pipe collapse which then leads to point loading and thereby pipe buckling. When rupture disks collapse, you get hydrostatic pressure instead, which is much better to prevent buckling.

Hope this helps.

= Arun

At each level there are at most two broken disks (agree with BP that they would have broken inward at 1600 psi). Therefore we have a maximum of 6 open apertures of diameter 0.433 inches, so an area (each) of 0.95 sq cm, for a total of 5.7 sq cm.

The velocity, V, of a jet through an aperture bounding two pressures is limited by 100% conversion of pressure energy into kinetic energy. The pressure below the BOP was about 5500 psia during the mudding, and the pressure on the exit of the "disk" could not have been less than ambient of 2250 psia. So the pressure drop P is less than 3250 psi. The pressure energy expended on each cc of mud going through the jet(s) is P erg/cc, and the kinetic energy in that jet thus cannot exceed P erg/cc. The kinetic energy is 0.5 rho V^2. With a rho = 2 g/cc we thus have V^2 less than P.

At 3250 psi or 216 atm, this is 2.16 x 10^8 erg/cc so that V is less than 147 m/s. The mud flow rate thus cannot exceed 83.7 liter/second or

5.02 cubic m/min. A 42-gal barrel of oil is 159 liters or 0.159 cu m. So the maximum flow through all 6 rupture disks (assumed open) is 5.02/0.159 = 31.6 bopm. If only 2 rupture disks, then the mud flow is 10.5 bopm.

3. What would be the consequence of a flow pattern in which mud could go down the 9-inch tube? If the test ram is open and the C and K lines just above the test ram opened, no mud flow will occur until the pressure of mud at the see floor exceeds the below-BOP static pressure of 3800 psia.

The bore of the 9-inch tubing is open to the mud and IF the bottom of the tube is open, mud can go down and into the formation at the foot of the well with a pressure at the foot of the 5500 psia PLUS the hydrostatic pressure of the mud, which for a bore length o 13,000 feet (3.9 km) and a density twice that of water is (rho g h) = 7.8 x 10^8 dyne/sq cm or 780 atm or 11700 psi (plus the 6000 psi at BOP) for a total of 17,700 psi.-- enough to fracture the formation unless the rock is very dense. The measured formation pressure was given to us as 11, 850 psia.

Incidentally, hydrostatic pressure (fresh water in the rock pores in a column of 3.9 km height below the mudline at 2250 psia) would be 5850 psi PLUS the 2250 psi at mudline-- so 8100 psia. Since the measured pressure is 11,850 psia, the reservoir is GEOPRESSURED and not simply hydropressured.

After the mud flow is stopped, mud will continue to flow into the formation until the mud column exerts a pressure of 11,850 psia, below which pressure the reservoir fluid supports the mud. Thus the mudostatic pressure will be (11,850 psia - 3850 psia) = 8000 psi, or a column 3.9 km x (8000/11700) = 2.67 km high (beginning 1230 m below the seabottom).

IF the oil/gas is rising from the annulus between 9 and 16-inch casings, perhaps through an impaired casing hanger, we ask what happens when the mudding begins and the pressure above the test ram rises from 3850 to 6000 psia. Recall that I assume that the oil/gas flow is driven by reservoir pressure of 11,850 psia through an impedance that drops the pressure in the BOP to 3850 psia at the normal well flow. Raising the BOP pressure to 6000 psia with mud will momentarily stop the gas/oil flow through the assumed gap in the 9-inch casing hanger. Some mud will enter that gap (unless it acts as a diode/one-way valve). For how long will the pressure at the top of the annulus remain below 6000 psia?

Oil/gas is still streaming into the amnulus, and the pressure will rise ultimately to the shut-in pressure of about 8000 psia (with mixture rho =

0.5 g/cc), so the gas/oil will resume and bubble through the heavy mud in the BOP, going through the gaps in the rams while entraining little mud.

How long the oil/gas stream takes to recover simply depends on the compressibility of gas/oil column, which is negligible at pressures above the bubble point.

If the flow is 20,000 bopd or 14 bopm, it will take some minutes (NEEDS TO BE ESTIMATED, but I must finish this in crude form).

Then the flow of oil/gas through the hanger at the new 6000 psia or 5500 psia will be driven at much the same rate as without the mud.

When the mudding stops, mud flow out the vents will cease almost immediately, as the 80 bbl of mud per minute clears the BOP space in a few seconds. The mud shooting down the 9-in casing will rapidly reduce the BOP pressure to the "static value"

That's a scenario that seems to fit.

Dick Garwin, June 1 at 12:17 am Eastern Time

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As you gain experience, you will realize that all logical
questions are considered insubordination -Dilbert-
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Top Kill Analysis rev 51.pdf (490 kB)

052810 Top Kill postercopy.xls (15 MB)