

From: Marcia K McNutt/DO/USGS/DOI
Sent: Tuesday, January 11, 2011 6:09 PM
To: aratzel@sandia.gov
Subject: FW: FW: FW: USGS Director McNutt would like to discuss BOP forensics

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From: R. Camilli <rcamilli@whoi.edu> [mailto:R. Camilli <rcamilli@whoi.edu>]
Sent: Friday, January 07, 2011 11:01 AM
To: Marcia K McNutt <mcnutt@usgs.gov>
Cc: Tom Hunter [REDACTED] <dyoerger@whoi.edu>; Mark K Sogge <mark_sogge@usgs.gov>
Subject: Re: FW: FW: USGS Director McNutt would like to discuss BOP forensics

Hi Marcia,

I'm glad to see that assumptions #2 and #3 appear valid. As for assumption #1, pumping rate does not need to be constant. I probably should have used a more specific description, maybe 'flow path shape' instead of 'source shape.' Dana, any thoughts?

Thanks,
Rich

On 1/7/2011 10:05 AM, Marcia K McNutt wrote:

Forgot to copy to Tom.... doing so now....

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From: Marcia K McNutt/DO/USGS/DOI
Sent: Friday, January 07, 2011 10:03 AM
To: 'R. Camilli'
Cc: 'Dana Yoerger <dyoerger@whoi.edu>'; 'Mark K Sogge <mark_sogge@usgs.gov>'
Subject: RE: FW: USGS Director McNutt would like to discuss BOP forensics

Rich and Dana,

Please see some comments below. I am copying this email to Tom Hunter who was also in the room during Top Kill and spent the most time thinking deeply about the implications of the pressure data, not so much for its flow rate implications, but more so for its implications as to where the restrictions were within the BOP. Of course, that mystery has now been answered for us. One of the biggest concerns that we wrestled with during various phases of the operations was the flakiness of that pressure gauge. Tom can perhaps comment on what sort of faith we want to put in its performance during Top Kill.

Marcia

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From: R. Camilli <rcamilli@whoi.edu> [mailto:R. Camilli <rcamilli@whoi.edu>]
Sent: Friday, January 07, 2011 12:02 AM
To: Marcia K McNutt <mcnutt@usgs.gov>
Cc: Dana Yoerger <dyoerger@whoi.edu>; Mark K Sogge <mark_sogge@usgs.gov>
Subject: Re: FW: USGS Director McNutt would like to discuss BOP forensics



Hi Marcia,

I've sent this as an update to my earlier email because Dana Yoerger and I found some pressure data recoded during top kill that allows us to make another independent flow rate estimate. I wouldn't be surprised though if others have already examined this information more closely than we have.

A document on the DoE website* states that during the top kill the maximum drill mud input rate was 80bpm (0.21 m³/s) and the maximum pressure was 6,000 psi. Another document** lists the 'post kill' BOP pressure (with test ram open) at 3320 psi (+/-50 psi). These measurements were recorded within hours of each other on May 28.

If we make the following assumptions:

1) source shape was unchanged during these measurements

Do you mean by this the hydrocarbon flow source? If so, this is probably a very safe assumption. If you mean the pumping rate, it did vary during top kill, although not sure over the time period of these particular pressure measurements.

2) drill mud viscosity >= well hydrocarbon fluid viscosity

Safe assumption. It was designed as such.

3) the maximum pumping rate failed to overcome the well flow, and at best achieved equilibrium (i.e., mud input rate = total outflow rate from the downstream leaks)

BP's interpretation of the Top Kill data, based on the pressure curve, is that during each attempt at Top Kill the mud was able to force the hydrocarbons only a short distance down into the well bore (the observed 700 psi drop is about equal to replacing a gas column with 16.4 ppg mud down to the first rupture disk in the 18" casing). The same behavior was seen regardless of pumping rate.

4) fluids in the well (upstream of the BOP rams) were single phase liquid and incompressible

5) GOR is 1606

6) flow through the restrictions was turbulent

7) pressure scales as velocity to the power of 1.75 (from F. White, *Fluid Mechanics*, 1979)

We can derive the expression

$$Q_1^{1.75}/p_1 = Q_2^{1.75}/p_2$$

where:

p₁ = maximum recorded pressure during top kill

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Q_1 = mud outflow rate during top kill

p_2 = recorded pressure after top kill

Q_2 = calculated single phase (liquid) well fluid flow rate

Solving for Q_2 , yields a well fluid flow rate of $0.15 \text{ m}^3/\text{s}$ after top kill

Using assumptions #4 & #5, the single phase hydrocarbon fluids within the well would by volume be approximately 72% oil and 28% natural gas condensates, yielding an oil flow rate of $0.11 \text{ m}^3/\text{s}$, or 59,000 BOPD on May 28.

There are a few caveats to this estimate:

- 1) the precision of the 6,000 psi and 80 bpm values recorded during top kill (these one sig fig values might skew the estimate either way by 10% or so),
- 2) if the viscosity of the well fluids is less than the drilling mud, this would cause the calculated oil flow rate to increase,
- 3) if flow equilibrium was not reached during the top kill (i.e., mud input rate < total outflow rate from the downstream leaks) this would also cause the calculated oil flow to increase.

I find it comforting that in general these issues make your calculation a lower bound.

This analysis does not address the possible increasing flow path cross section within the BOP because the pressure readings were taken within hours of each other. However, the erosion and pitting on and around the blind shear ram elements are suggestive of cavitation occurring at this flow restriction and causing single phase well fluids to transition into to a two phase fluid in the downstream region. This scenario is consistent with observations of two phase fluids exiting the leak source and the theoretical bubble point for methane.

*http://www.energy.gov/open/documents/5.3_Item_01_Top_Kill_Operation_Status_09_June_1400.pdf

** http://www.energy.gov/open/documents/2.2.3_Item_08_Data_Diagnostics.xls

Thanks, Rick and Dana. Very helpful.

Marcia

Best regards,
Rich

On 1/6/2011 3:42 PM, Marcia K McNutt wrote:

Better views.

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From: Marcia K McNutt/DO/USGS/DOI

To: rcamilli@whoi.edu, Paul A Hsieh/WRD/USGS/DOI, Bill.Lehr@noaa.gov, acratze@sandia.gov, Donald.Maclay@mms.gov, tohunte@sandia.gov, George.Guthrie@NETL.DC

Cc: Mark K Sogge/DO/USGS/DOI, Lori_Caramanias@sol.doi.gov, Rachel.Jacobson@sol.doi.gov, Jason.Mathews@boemre.gov, David.Dykes@boemre.gov

Date: 01/06/2011 12:11 AM

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Dear Friends of Flow Rate:

I just want to give you a heads up on some new information that I just learned about today that will have great bearing on the flow rate. We do not yet have sufficient information to act, but I will be passing along the information to you once I receive it. Please keep this information confidential, although I understand that some of these views are available (although their significance may not be widely appreciated).

Basically the forensics that have been accomplished to date by the Norwegian firm DNV have determined that the blind shear rams were closed and that the flow path is through limited areas (washed out areas? channels created by stuck pipes?) around the blades. DNV is conducting at this point in time an exact laser scan to get the cross-sectional area of the region through which flow could have occurred. Seems to me on first blush that this new evidence affects our work in the following manner:

- (1) We can get yet another estimate of initial versus final flow rate using the area of the opening and the initial bottom-hole pressure/final shut-in pressure. This will be an upper bound on the initial flow rate as it would assume that the opening has not increased in size through time.
- (2) Does anyone have any ideas for how to model the erosion of the opening with time? This might be very difficult. In addition, Both of the blind shears are above where the mud was pumped during top kill. Mud wasn't bullheaded down through the blind shears, producing erosion that way. However, we did see quite a bit of mud exiting out the riser, clearly mud was coming back up from below. But that was just for a few days.
- (3) Whatever the restriction of the blind shears, it can't be a lot, otherwise top kill would have worked. Tom: I know you spent a lot of time thinking about where the main restrictions were during top kill.
- (4) In looking at our final curve for flow rate as a function of time, we do need to consider carefully the competing processes of depletion of the reservoir, which causes flow rate to decrease, and possible widening of the flow path, which causes the flow to increase. The final curve may be peaked in the middle for all I know.

Anyway, this is just food for thought. More to come.

Marcia

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From: Mathews, Jason <Jason.Mathews@boemre.gov> [mailto:Mathews, Jason <Jason.Mathews@boemre.gov>]
Sent: Wednesday, January 05, 2011 1:20 PM
To: "Dykes, David" <David.Dykes@boemre.gov>; "McNutt, Marcia" <mcnutt@usgs.gov>
Cc: "Murphy, Silvia" <Silvia.Murphy@sol.doi.gov>; "Maclay, Don" <Donald.Maclay@boemre.gov>; "Sogge, Mark" <mark_sogge@usgs.gov>
Subject: RE: USGS Director McNutt would like to discuss BOP forensics

Also, here are some additional shots of the washout areas. (please don't distribute these documents outside of your workgroup)

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From: Dykes, David
Sent: Wednesday, January 05, 2011 11:59 AM
To: McNutt, Marcia
Cc: Murphy, Silvia; Maclay, Don; Mathews, Jason; Sogge, Mark
Subject: RE: USGS Director McNutt would like to discuss BOP forensics

Ms McNutt,

I am available to discuss the BOP forensics with you or anyone else today. In short, we found (during the initial recovery and confirmed during the forensic work) that the blind shear rams were in the closed position. The flow path appeared to be washed out areas around the blind ram elements (at right angle to the direction of element travel) on both sides and around/between the blades (in the closed position). See attached file of BOP internals. As you can see, the flow path was limited to this area and was not an open 18 3/4" bore flow path. We are having DNV laser-map this area to determine the total open cross sectional area. Knowing this area now, with known pressures, one could now calculate an actual flow rate, within a small margin of error.

Please call me to discuss.

J. David Dykes

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From: Marcia K McNutt [<mailto:mcnutt@usgs.gov>]
Sent: Tuesday, January 04, 2011 7:22 PM
To: Mathews, Jason; Sogge, Mark
Cc: Dykes, David; Murphy, Silvia; Maclay, Don
Subject: RE: USGS Director McNutt would like to discuss BOP forensics

Thanks for getting back to us, Jason. I look forward to speaking to someone who knows the results of the investigation of the BOP as I believe that they could be very crucial to the interpretation of the flow rate data as a function of time.

Thanks.

Marcia

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From: Mathews, Jason <Jason.Mathews@boemre.gov> [<mailto:Jason.Mathews@boemre.gov>]
Sent: Tuesday, January 04, 2011 8:17 PM
To: "Sogge, Mark" <mark_sogge@usgs.gov>
Cc: "McNutt, Marcia" <mcnutt@usgs.gov>; "Dykes, David" <David.Dykes@boemre.gov>; "Murphy, Silvia" <Silvia.Murphy@sol.doi.gov>; "Maclay, Don" <Donald.Maclay@boemre.gov>; "Mathews, Jason" <Jason.Mathews@boemre.gov>

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Subject: RE: USGS Director McNutt would like to discuss BOP forensics
Mark

Thanks for the update. Unfortunately, I am on leave (though checking my emails), and I won't be able to talk with Marcia until next week. I have cc'd some of the people I work with in case they can speak with her earlier, but I would prefer to speak with her early next week.

Have a nice evening -

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From: Mark K Sogge [mailto:mark_sogge@usgs.gov]
Sent: Tuesday, January 04, 2011 3:58 PM
To: Mathews, Jason
Subject: USGS Director McNutt would like to discuss BOP forensics
Importance: High
Hi Jason,

You and I spoke on December 20, when you inquired whether BOP forensic results might affect our Flow Rate Technical Group estimates for the spill rate from the Macondo Well. As we discussed, the estimates from the plume video analysis, plume acoustics analysis, and mass balance teams would not be affected. After checking with one of our reservoir model experts (Paul Hsieh, USGS) and the lead of our Nodal Analysis Team (George Guthrie, DOE), it also appeared that their estimates would also not be significantly affected.

However, Dr. Marcia McNutt (USGS Director, and Chair of the Flow Rate Technical Group) informed me today that she believes that the BOP forensic results may have bearing on the pattern of flow rate over time. So she would very much like to speak with you at the earliest opportunity. Her contact information is:

Marcia McNutt; mcnutt@usgs.gov; mobile # [REDACTED]

She can generally be reached at this number throughout the day and into the evening. I know that Marcia will greatly appreciate the opportunity to talk with you in the next day or two, if at all possible.

Thank you very much.

Mark

Mark Sogge
Senior Science Advisor (acting)
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mark_sogge@usgs.gov [attachment "Exhibit I-4_BP-HZN-MBI00208235.pdf" deleted by Marcia K McNutt/DO/USGS/DOI] [attachment "Exhibit I-1_BP-HZN-MBI00208232.pdf" deleted by Marcia K McNutt/DO/USGS/DOI] [attachment "Exhibit I-2_BP-HZN-MBI00208233.pdf" deleted by Marcia K McNutt/DO/USGS/DOI] [attachment "Exhibit I-3_BP-HZN-MBI00208234.pdf" deleted by Marcia K McNutt/DO/USGS/DOI] [attachment "Exhibit I-4_BP-HZN-MBI00208235.pdf" deleted by Marcia K McNutt/DO/USGS/DOI] [attachment "Exhibit I-1_BP-HZN-MBI00208232.pdf" deleted by Marcia K McNutt/DO/USGS/DOI] [attachment "Exhibit I-2_BP-HZN-MBI00208233.pdf" deleted by Marcia K McNutt/DO/USGS/DOI] [attachment "Exhibit I-3_BP-HZN-MBI00208234.pdf" deleted by Marcia K McNutt/DO/USGS/DOI]

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