FUSION PETROLEUM TECHNOLOGIES INC.

**IN THE UNITED STATES DISTRICT COURT FOR THE EASTERN DISTRICT OF LOUISIANA**

**IN RE: OIL SPILL BY THE OIL RIG MDL NO. 2179 "DEEPWATER HORIZON" IN THE GULF OF MEXICO, ON APRIL 20, 2010**

# REBUTTAL EXPERT REPORT OF DR. ALAN R. HUFFMAN SUBMITTED ON BEHALF OF THE THE UNITED STATES DEPARTMENT OF JUSTICE

This report discusses the expert findings of Dr. Alan R. Huffman relating to the drilling margins for the BP Mississippi Canyon 252 #1 well (Macondo prospect) following a review of expert reports provide by BP.

DATED: November 7, 2011

Signature: Dr. Alan R. Huffman

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Exhibit No. _____

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# Rebuttal Expert Report on Macondo Well
# U.S. Department of Justice

This rebuttal report is submitted by Dr. Alan Huffman, who has been retained by the United States Department of Justice (DOJ) to evaluate drilling margin issues relating to the BP Mississippi Canyon 252 #1 well (Macondo prospect). Dr. Huffman's initial expert report was submitted on August 26, 2011. On October 17, 2011, BP submitted expert reports from two individuals – Adam T. Bourgoyne, Jr., and Chuck Schoennagel -- that either explicitly or implicitly disputed the analysis and/or findings of Dr. Huffman's August 26th expert report. What follows is a rebuttal of Dr. Bourgoyne and Mr. Schoennagel's statements pertaining to the same issues set forth in Dr. Huffman's original report.

## I. BP'S EXPERTS HAVE MISINTEPRETED THE DRILLING MARGIN REGULATIONS TO SAP THEM OF THEIR ENFORCEABILITY

### A. BP's Experts Improperly Suggest That BP's "Latitude" to Remedy Loss of Drilling Margin Undercuts the Compulsory Nature of the Regulations

On its face, the drilling margin regulations use strong language to restrict the ability of operators to drill ahead lawfully without an adequate margin. Operators are told that "While drilling, you *must* maintain the safe drilling margin identified in the approved APD [Application for Permit to Drill]. When you cannot maintain this safe margin, you *must suspend* drilling operations and remedy the situation." 30 CFR 250.427(b) (Emphasis added). Operators are also told that "You *must* use the pressure integrity test and related hole-behavior observations ... to adjust the drilling fluid program and the setting depth of the next casing string." 30 C.F.R. 250.427(a) (Emphasis added). They are further told that if they encounter "unexpected formation pressures or conditions that warrant revising" their casing design, then they "*must* submit a revised casing program to the District Manager for approval." 30 CFR 250.428(a) (Emphasis added).

By contrast, BP's experts ignore the compulsory nature of the drilling margin regulations. Instead, in my opinion, they exaggerate the "latitude" that the regulations provide to operators who lose their safe drilling margin.

For example, Mr. Schoennagel discusses the drilling margin regulations on page 23 of his report. Immediately after setting forth the requirement to maintain a safe drilling margin, rather than explaining how that regulation must be enforced, he points out that the regulation gives the operator "the latitude to remedy the situation" in the event that it cannot maintain its margin. But the critical point, as I interpret the regulations as a practicing geophysicist, is that an operator only has the latitude to drill ahead if (a) it is able to regain its margin (either by reducing mud weight, or by increasing the weakest fracture gradient in the interval

through such methods as Loss Control Mud or Stress Cage treatments), (b) it has obtained a waiver to drill with a smaller margin from MMS, or (c) it has revised its casing design to regain its margin. Mr. Schoennagel fails to acknowledge this discrete set of remedies available to the operator and, as discussed below, he appears to ignore it when it came time to apply the regulations to the facts of this case.

BP's other drilling-margin expert, Dr. Bourgoyne, also emphasizes the latitude in the regulations, while undercutting their enforceability. At page 21 of his report, he defines a well's fracture gradient based on the pressure at which a crack in the "rock of the borehole wall ... begins to open and take mud." I have applied this same definition in my own practice. Yet, when it comes to applying this definition to determine when an operator must stop drilling because it is unable to maintain a safe drilling margin between its mud weight and its fracture gradient, Dr. Bourgoyne fails to grant the regulations any real-world enforceability.

For example, on page 33 of his report, Dr. Bourgoyne implies that even after the approval of the Macondo well's APD, BP's safe drilling margin was malleable. After acknowledging that operators are required to identify their fracture gradients in their APDs, he says that "[i]t is recognized that the approved APD is based on estimates," and that the regulations "do not specify how the estimate [of the well's fracture gradient] is made or what safety margin to use." In his report, Dr. Bourgoyne would have the reader believe that there are large errors in the estimated fracture gradients which would weaken their predictive capability.

As an expert that has been actively involved in both pre-drill and real-time pressure prediction and monitoring in the Gulf of Mexico for the past 20 years, I am of the view that Dr. Bourgoyne, in pages 22-23 of his report, has exaggerated the inability of geophysicists to predict pressures in offshore wells within a relatively limited range of error. That said, I take no issue with the assertion that the fracture gradient and mud weight figures in BP's May 2009 APD were based on estimates. Nor do I take exception to the principle that the regulations give operators the freedom to propose what their safe drilling margin should be. That does not mean, however, that any ambiguity exists as to what the safe drilling margin is once the APD is approved. As I interpret the regulations in light of my experience as a practicing geophysicist, once an operator has provided a proposed safe drilling margin between the mud weight and fracture gradient set forth in the APD (for example a 0.5 ppg difference between planned mud weight and estimated fracture gradient) and that APD is approved, the operator must maintain that margin even if the actual mud weights used and/or actual fracture gradients encountered differ from the information provided in the approved APD. I am not familiar with situations in which reputable operators unilaterally encroach on this margin without MMS approval.

That BP's well team recognized such facts is clear from the deposition of the BP regulatory specialist assigned to that team, Ms. Scherie Douglas. She recently testified that BP needed to use a mud weight "within the 0.5 ppg that MMS policy considered to be the safe drilling margin" and that was incorporated by BP into the APD for the Macondo well (Douglas Deposition at 94, 112). She also testified that the ultimate decision as to whether BP could drill with less than the 0.5 ppg drilling margin belonged to MMS; BP had no right to make

that decision on its own. (*Ibid.* at 107) See also Cocales' March 14, 2010 e-mail, BP-HZN-MBI 0010676 (BP Drilling Engineer Brett Cocales, who was also assigned to the Macondo well team, writes that if BP wants to drill with less than a 0.5 ppg margin, "we would have to ask" MMS for a waiver, "as they require us to maintain 0.5 ppg unless a waiver is granted").

In short, as I interpret the regulations, if the operator wants to drill ahead despite the loss of a safe margin between the well's mud weight and its fracture gradient, it is free to seek MMS permission to do just that. What, in my experience, a prudent operator would not feel it is entitled to do, is to drill ahead with neither the requisite margin nor MMS approval.

### B. The Operator's Ability to Change A Well's Mud Weight to Respond to a Well Control Situation Does Not Support Further Drilling Without a Safe Margin or MMS Approval

In contrast to the explicit regulatory requirement that operators "must" maintain the safe drilling margin identified in the approved APD, Dr. Bourgoyne states at page 34 of his report that "mud weights must be allowed to deviate from the APD based on what is seen while drilling." He goes on to support this position by stating that "it is extremely important for the team on the rig to be able to change mud weights when needed for proper well control and safety without having to wait for approval." *Ibid.*

I agree with Dr. Bourgoyne's suggestion that operators need to be able to change their mud weights to respond to legitimate well control incidents. This does not, however, change or weaken in any way the requirement to maintain a safe drilling margin at all times while drilling further downhole after a well control incident occurs.

Ms. Douglas stated at her deposition (see pages 101-02, 105 and 107) that while operators are free to increase their mud weights to respond to kicks and other well control incidents, they must maintain their margin if they wish to legally drill deeper into a well after a kick. That has always been my understanding as well, and nothing that I have seen as a practicing geophysicist has contradicted it. I share Dr. Bourgoyne's view that operators need the freedom to increase or decrease their mud weights to respond to well control incidents without seeking prior MMS approval. But this does not permit them to alter their mud weight *and then unilaterally decide to continue drilling deeper into a well* once they lose their margin. To my knowledge, the act of further drilling is not needed to maintain well control, and Dr. Bourgoyne has provided no explanation of why an operator cannot wait for MMS's approval before engaging in any such drilling.

### C. The Operator May Not Drill Forward Without MMS Approval If Hole-Behavior Observations Demonstrate that the Operator Lost Its Safe Drilling Margin

Both Dr. Bourgoyne and Mr. Schoennagel challenge the conclusion in my initial report that operators must compare a well's mud weight to its weakest fracture gradient in the relevant interval to ensure that they maintain a safe drilling margin – even if hole-behavior observations indicate that the weakest fracture gradient is less than the result of the pressure

integrity test. I do not believe, however, that Dr. Bourgoyne's and Mr. Schoennagel's challenges on this topic are responsive to the key points that I raised in my initial report.

Mr. Schoennagel states, at pages 23-24 of his report, that a pressure integrity test (PIT):

> "remains as the PIT for that shoe throughout the drilling of the next segment of the well and is not updated when additional downhole data is obtained. ... For the purposes of calculating a safe drilling margin, the PIT obtained as required by 30 CFR 250.427 is not changed or updated to reflect any additional downhole data. ... In fact, there are no regulatory requirements defining what downhole data needs to be collected."

I have never suggested that the regulations direct operators to proactively collect specific types of data, other than pressure integrity test data, in order to determine its fracture gradient for purposes of ensuring that it has retained a safe drilling margin. That fact, however, does not change what I, as a practicing geophysicist, have taken to be the fundamental principle of 30 CFR 250.427 – that you must maintain a safe drilling margin at all times, and that if you learn that you cannot maintain that margin, you must take steps to regain that margin (or obtain MMS approval) before you can continue drilling.

It is notable that the language of subsection (a) of Section 250.427 does not merely require operators to use pressure integrity test results in deciding when to adjust the drilling fluid program and the setting depth of the next casing string. It explicitly requires operators additionally to use "hole-behavior observations" in determining whether they must stop drilling and set another casing string (or at least get MMS approval before they may drill ahead). I would interpret Section 250.427(a) of the MMS regulations, read in conjunction with Section 250.428(a), to require that *whenever* an operator obtains information revealing that it cannot retain the "safe" cushion (as set forth in the approved APD) between its mud weight and its fracture gradient, it must stop drilling ahead and remedy the situation. This is not to say that the operator is required to seek out such information, but I do not believe it is consistent with either the regulations or the actual practice of reputable operators to close their eyes to the information that they do acquire or open hole behavior that they observe.

I do not believe this is a safe practice, nor, based on my interpretation of the regulations, do I believe it is consistent with those regulations. From the standpoint of well control, the fundamental reason operators must maintain a margin between the mud weight and the fracture gradient is so that they can increase their mud weight in the event of a kick without inducing a fracture. Recall that operators defeat kicks by ramping up the well's mud weight enough to overbalance the pore pressure, and if they cannot do so without exceeding the well's fracture gradient, they would risk fracturing the wellbore, which could in turn add to the difficulties in subduing a kick. The rock beneath the shoe at the top of an interval is typically the weakest part of the interval and the place with the lowest fracture gradient. For that reason, the safe drilling margin is initially expressed in terms of the PIT results obtained at the shoe at the top of an interval. An operator must maintain the approved margin between its mud weight and the PIT result -- what it initially expects to be the weakest fracture gradient in the interval. However, neither of BP's expert reports denies that there are

situations in which an operator's hole-behavior observations reveal that the well's weakest fracture gradient is less than the result of the applicable PIT at the preceding shoe.

If hole-behavior observations indicate the presence of a weaker point in the formation, a prudent operator would need to be concerned about preventing a fracture at this weaker point. It would be just as dangerous to maintain a tiny margin between the mud weight and a weak spot lower down in an interval as it would be to maintain the same tiny margin between the mud weight and the shoe test result at the top of the interval. This is why it is a basic principle of well control -- not to mention, as I interpret the regulations, a legal requirement -- to refrain from drilling ahead without a safe margin, regardless of whether this margin is determined based on a shoe test or based on hole-behavior observations. Indeed, this is consistent with the testimony of Kate Paine, the pore pressure/fracture gradient analyst on the rig during the drilling of the Macondo well. See Paine Deposition at 113 (indicating that a lost return event -- not the PIT at the previous casing shoe -- may provide the critical data point in determining the fracture gradient for the purposes of calculating the drilling margin); 43 ("You have no indicators that you have penetrated a weaker rock until you start having . . . minimal losses and then greater and greater losses the more you go over the fracture gradient.")

For his part, Dr. Bourgoyne takes exception to my analysis of Section 250.427(a) by contending that operators are not always able to precisely determine their fracture gradients after they fracture the wellbore, casing does not have to be run every time a loss of mud occurs in a well, and fracture gradients may, under certain circumstances, be increased by an operator. (Bourgoyne Report at 34-35.) These statements do not contradict anything I said or even implied in my original report, and any of Dr. Bourgoyne's suggestions to the contrary are simply false. More importantly, however, they ignore the critical points that I was making.

First, as Mark Alberty has acknowledged, operators are not always able to increase their well's fracture gradients, particularly when they have lost total returns in an interval. (Alberty Deposition at 74-76). Second, even though operators cannot always determine an interval's weakest fracture gradient with complete precision, they may be able to estimate that figure, as BP did in the case of this well, when it learned in drilling its final interval that the spot with the weakest fracture gradient was likely below the shoe above the interval. (BP-HZN-CEC021659; April 5th PPFG Report, BP-HZN-MBI 00118114).

Third, and most importantly, the critical issue here is whether, given BP's best understanding of the weakest fracture gradient in the relevant interval (regardless of whether that is based on a PIT or hole-behavior observations, or whether that fracture gradient has been enhanced by the available techniques), the difference between that amount and the well's mud weight was equal to or greater than the margin set forth in the approved APD and thus was large enough to support drilling further ahead without obtaining MMS approval. In my initial report, I provided specific, quantitative reasons why BP clearly did *not* retain such a safe margin when it continued to drill the final segment of this well. As referenced below, BP has made no effort to rebut the details of my analysis.

Indeed, if, in fact, the only applicable margin is based on an operator's shoe tests, rather than hole-behavior observations, there would be nothing to stop an operator from continuing to drill with mud weights that actually *exceed* a well's fracture gradient, as long as these mud weights are at least 0.5 ppg below its PIT result. In other words, under the view of BP's experts, the operator would be in compliance with the *safe* drilling margin regulations, despite using a mud weight that could fracture the wellbore and potentially cause an uncontrollable well event. This interpretation of MMS laws would make no sense from a technical or a legal perspective. It is also contrary to industry practice worldwide.

## II. BP's EXPERTS ARE WRONG IN DEFENDING THE VERACITY AND ADEQUACY OF BP's SUBMISSIONS TO MMS

Both Mr. Schoennagel and Dr. Bourgoyne squarely addressed the issue of BP's candor and/or truthfulness in submitting drilling margin information to MMS while drilling the well. In each case, these experts came to BP's defense – in my view, inappropriately.

Mr. Schoennagel stated at page 20 of his report that, after reviewing BP's filings, he has concluded that "there appears to have been full disclosure to the MMS on the activities associated with the well." He goes on to say, with respect to the revised Applications for Permit to Drill and the Applications for Permit to Modify, that "BP filed the appropriate Forms and received MMS approval prior to making changes to their initially approved casing program." *Ibid.* He also said that the Well Activity Reports (WARs) "were submitted timely and reflected a prompt and full disclosure of what was occurring as the well was being drilled" and that "BP kept MMS advised on the WARs of anything they deemed to be significant." *Ibid.* Mr. Schoennagel reinforced these general endorsements, first by providing a brief summary of each of BP's drilling permit applications and WARs (*ibid.* at 10-18), and then by giving examples of selected submissions in October 2009 and April 2010, after which he confirmed that BP submitted the "appropriate forms for MMS review and approval and kept MMS informed on the status of the well through the WARs" (*ibid.* at 21, 22).

Dr. Bourgoyne, while acknowledging the existence of errors in BP's submissions to MMS, similarly reached the conclusion that these errors were hardly disturbing. Without spelling out which of the submissions were problematic and which were not, Dr. Bourgoyne states, at page 35 of his report, that:

> "Dr. Huffman found examples of reporting errors made in documents submitted to BOEMRE (previously MMS). In my opinion, the few errors found in the large amount of material submitted to BOEMRE (previously MMS) do not warrant the leap Dr. Huffman makes to a conclusion that BP intentionally hid information so that they could operate in an unsafe and imprudent manner."

In fact, however, these expert reports fail to address many of the challenges to BP's submissions that I raised in my initial report. Also, when BP's expert reports do confront the relevant issue, they fail to do so in a persuasive way.

### A. BP Did Not Maintain A Safe Drilling Margin in the Open Hole Interval from the 22" Shoe to the 18" Shoe

BP drilled the Macondo well's open hole interval from the 22" shoe to the 18" shoe in late-October 2009. With respect to this interval, Mr. Schoennagel claimed that he confirmed that BP submitted the "appropriate forms for MMS review and approval and kept MMS informed on the status of the well through the WARs." (Schoennagel, at 21; see also Schoennagel at 11, 14-15.) Dr. Bourgoyne provides essentially no specific information about this interval in his report. Consequently, the reader of these reports, when they are taken together, is left with the impression that BP fully and properly disclosed drilling margin data to MMS and violated no margin-related laws in drilling this interval.

In fact, however, as I documented in my initial report, at pages 22-27, BP repeatedly violated drilling-margin laws in connection with this interval. Here is a summary of what was said in that portion of the report:

(1) BP conducted eight PITs in the shoe above this interval. After conducting the first seven, it drilled further down the well and performed a cement squeeze job, ensuring that the area in which BP conducted the first seven tests was placed behind cement. The final, and most relevant, test yielded a surface mud weight equivalent of 10.09 ppg.

(2) Nevertheless, in seeking a waiver to drill with a margin of only 0.3 ppg, BP reported to MMS that its PIT was 10.25 ppg – the highest number it obtained in the first seven tests. Alberty testified at his deposition that it is not appropriate to report the result of any PIT other than the final test, meaning that BP should have reported the 10.09 ppg figure, not the 10.25 ppg figure.

(3) After BP began drilling the interval, the well took a kick. BP increased its mud weight in order to control the kick. A BP internal document indicates that it faced a choice of safety versus economics. The document indicates that if BP stopped drilling and set casing above the spot of the kick, it may have to use an additional casing string, and thus "sacrifice hole-diameter in the reservoir interval." By contrast, if BP continued to drill further down the hole, it could risk "drilling through another over-pressured sand package" which "would initiate a potentially uncontrollable well control event."

(4) Despite the fact that MMS did not grant BP a waiver to drill with more than a 9.95 ppg mud weight (meaning it needed a margin of at least 0.3 ppg), BP chose to drill ahead – putting economics over safety – at a mud weight of 10.1 ppg. Thus, BP illegally drilled ahead with *literally no margin at all* over its last PIT score (10.09 ppg), and a margin of only 0.15 ppg over the highest PIT score it obtained in any of the eight tests (10.25 ppg).

(5) There was no safety reason why BP could not have set casing before drilling ahead after the kick, or at least seek MMS approval before drilling ahead without the approved margin. It did neither.

(6) In the October 29 drilling permit application, filed *after* BP drilled ahead without the approved margin, BP improperly and repeatedly identified its fracture gradient and/or formation test for the shoe above this interval at 11.1 ppg – a gross exaggeration.

Neither Mr. Schoennagel nor Dr. Bourgoyne raises any facts that challenge the above narrative. Instead, they offer only generalities – like the comment that MMS was "kept informed on the status of the well through the WARs." In fact, I reviewed the WARs that Mr. Schoennagel cites for the relevant weeks (October 18-24 2009 and October 25-3, 2009) and found that, even though MMS includes a place in the WAR to identify the relevant "casing shoe test" figure, BP left that place completely blank. (See also Douglas Deposition at 118-120, Exhibit 5838) I found nothing in those WARs that would have given the impression that BP drilled the interval without the required margin – let alone that it knowingly risked initiating an "uncontrollable well control event."

Weeks after my report was filed, Scherie Douglas was deposed and asked to talk about this interval. She testified that:

(1) BP was obligated to report the final PIT score that it obtained before drilling the interval (Douglas Deposition at 133-135);

(2) While it is lawful for an operator to increase its mud weight to control the kick, it would not be lawful for the operator to then drill further down a well with less than the approved drilling margin and without MMS permission (*Ibid.* at 101-2, 105, 107); and

(3) The October WARs for the Macondo should have contained the actual PIT score BP obtained and she had no explanation as to why that figure was omitted (*Ibid.* at 120).

In short, BP's own regulatory specialist for this well testified in a manner that is completely consistent with my own perspective on this interval, and inconsistent with the conclusory statements BP is offering in its expert reports to defend its conduct.

### B. BP Did Not Maintain a Safe Drilling Margin in the Open Hole Interval from the 16" Shoe to the 13 5/8" Shoe

BP drilled the Macondo well's open hole interval from the 16" shoe to the 13 5/8" shoe in early and mid-March 2010. Mr. Schoennagel referenced drilling permit applications and WARs that related to this interval on pages 12-13 and 17 of his report, but he made no attempt to specifically evaluate the findings in my report challenging BP's conduct involving this interval (other than the general statements, at page 20 of his report, that "there appears to have been full disclosure to the MMS on the activities associated with the well" and that the "WARs ... reflected a prompt and full disclosure of what was occurring as the well was being drilled ... [and] BP kept MMS advised on the WARs of anything they deemed to be significant."). Dr. Bourgoyne, by contrast, did explicitly challenge my findings on this interval with respect to the issue of whether BP properly reported the results of the relevant PIT to MMS. (Bourgoyne Report at 36) After reviewing both Mr. Schoennagel's and Dr.

Bourgoyne's reports, I stand behind the analysis in my initial report indicating that BP repeatedly made false statements to MMS and drilled ahead without the required margin.

I documented BP's margin-related violations involving this interval in pages 28-30 of my initial report. Here is a summary of what was said in that portion of the report:

(1) The only PIT result for this interval was 12.55 ppg. BP's records indicate that it records its PIT results to the hundredth of a ppg, and in fact it reported to MMS the PIT results for October 2009 to the hundredth of a ppg.

(2) Nevertheless, when Scherie Douglas orally spoke to MMS' Frank Patton to seek a waiver of the drilling margin in March 2010, she said that the PIT result was "12.6" ppg. (After I filed my report, Douglas explained at her deposition, at pages 136 and 142-44, that she was relaying the figure that she received from others at BP and would have relayed a more precise figure if they had provided one.)

(3) Relying on BP's representation that the PIT result was 12.6 ppg, and thinking that it was being asked to grant a waiver to drill with a 0.3 ppg margin, MMS granted BP permission to drill with a 12.3 ppg mud weight.

(4) BP's internal records included an e-mail from a BP drilling engineer, Brett Cocales, expressing concern about drilling a mud weight that falls just short of the margin because the PIT score was 12.55 ppg and not 12.6 ppg.

(5) In reporting PIT scores in drilling permit applications and in WARs that were submitted *after* it conducted the relevant PIT, BP repeatedly rounded the number all the way up to 13.0 ppg. Specifically, it identified the PIT result/fracture gradient/shoe test for the relevant interval as 13.0:

a. Four different times in the March 15th Application for Bypass;
b. Once in the WAR for the week ending March 20, 2010; and
c. Once again in the WAR for the week ending March 27, 2010.

(Additionally, I did not note in my initial report, but certainly could have, that BP continued to report the fictional "13.0" ppg figure two more times in its March 26, 2010 Application for Revised Bypass. (BP-HZN-OGR000709))

(6) In short, many of BP's statements to MMS created the impression that it was drilling with a margin of 0.3 ppg or higher when, in fact, this was not the case.

As for Dr. Bourgoyne's discussion regarding the propriety of rounding PIT results to the nearest tenth of a ppg, not hundredth, his analysis leaves out some salient facts. For example, he pointed out that MMS's electronic e-Wells system requires data to be reported in tenths of a ppg (Bourgoyne Report at 36), and yet this has no bearing on why Scherie Douglas, when she was orally discussing the PIT result with an MMS engineer, failed to report the 12.55 ppg figure. As another example, Dr. Bourgoyne suggested that in measuring PITs, BP used a tool

named "Pressure While Drilling" that yields figures that are more precise than what MMS requires to be used. But this is just another example of the principle that there is no valid reason to refrain from reporting the same information to MMS that an operator uses in its own internal records. For its internal purposes, BP routinely recorded its PITs to the one-hundredth of a ppg, and it was more than capable of reporting the figure of 12.55 when asking MMS for a waiver down to 0.3 ppg.

Finally, as noted, I raised in my earlier report many more issues than simply whether operators are permitted to report PITs to the nearest hundredth of a ppg. For example, BP was hardly rounding up to the nearest tenth when it reported a 12.55 ppg PIT result as "13.0" ppg. Yet, this figure was provided to MMS numerous times in several different documents, even though BP never conducted a PIT that yielded this figure.

### C. The Pressure Integrity Tests at the 13 5/8" Shoe and the 9 7/8" Shoe Were Invalid

In my initial report, on pages 30-36, I explained why it was inappropriate for BP to drill ahead in these two intervals despite its lack of confidence in the validity of the respective PITs that it conducted at the top of these intervals. In response, Dr. Bourgoyne provides an analysis on pages 38-47 of his report, taking exception to my conclusions. (See also his discussion on pages 20-28, which provides the background information he believes to be relevant to the issue at hand.) For the reasons explained below, however, I continue to maintain that BP was obliged to re-conduct the relevant PITs so as to gain more confidence in the tests' validity before drilling ahead.

*The PIT at the 13 5/8" Casing Shoe*

BP drilled the Macondo well's open hole interval from the 13 5/8" shoe to the 11 7/8" shoe in late-March 2010. It drilled the well's open hole interval from the 9 7/8" shoe to the bottom of the well in April 2010.

Dr. Bourgoyne contends that the PIT results were entirely consistent with the hypothesis that, in both cases, BP simply drilled into low permeability rock with no pre-existing fractures. (Bourgoyne Report at 40, 44). Dr. Bourgoyne notes that the sharp break over on the curve is indicative of what he calls breakout of "an impermeable smooth borehole with no pre-existing defects or cracks and significant tensile strength and stress concentration near the borehole wall." However, he offers no physical basis for this interpretation. As part of my analysis of the Macondo data, I undertook a detailed petrophysical analysis of the available well log data. This included the gamma ray, resistivity, density, neutron porosity, compressional sonic, shear sonic, Stoneley wave sonic, and other logs made available to me. (The details underlying the well log data that I reviewed are set forth in Appendix A to this report. Note that the wireline well log data was not available to BP until after it completed drilling the well to its total depth.) These logs were also used to calculate the rock moduli, including the bulk modulus, shear modulus, Young's modulus, Poisson's Ratio, Vp/Vs ratio and brittleness, all of which can also be used to estimate other properties including the compressive and tensile strength of the rocks. These properties can be used to infer the rock

strength and other key properties that are germane to this discussion. In fact, the well log data for this interval show no evidence of an anomalously strong layer at the casing shoe. Quite the contrary, the well log data suggest that the shale at this depth has essentially the same physical properties as the shales tested at the Macondo well's 11 7/8" shoe (the next deeper shoe in the well). Dr. Bourgoyne fails to mention, let alone discuss, this fact in his analysis.

Moreover, leaving aside the well log data, if we were to accept Dr. Bourgoyne's assertion that the rocks at issue were unusually strong, there would be no way to explain how the pressures reflected on the PIT curve rapidly dropped by over 200 psi during the shut-in period (the period after the pumps are stopped). This is in sharp contrast to the relatively small pressure increase from the point where the fracture initiation began to the point where maximum pressure was reached. In fact, a careful comparison of all of the PIT tests at Macondo shows that the PIT from 13 5/8" shoe had by far the greatest pressure drop during shut in of any test, which is incompatible with the rock properties that Dr. Bourgoyne attempts to attribute to the shales at the particular casing shoe.

Furthermore, the PIT at the shoe just below this interval, the 11 7/8" shoe, appears to be a valid test of the same rocks with the same log properties. Yet despite the fact that the 11 7/8" shoe test took place thousands of feet further down the well, the PIT result for the 13 5/8" shoe test was virtually identical to that of the 11 7/8" test result. Moreover, the 11 7/8" shoe test curve shows a much smaller pressure drop than the PIT at the 13 5/8" shoe. This relatively small pressure drop suggests that the rock BP tested at the 11 7/8" shoe, which did achieve leak off, would appear to be *stiffer* during fracture closure than the material exposed at the 13 5/8" shoe. Yet if it were stiffer, and it was measured thousands of feet further down the well, it is difficult to understand how it did not yield a higher PIT value than the 13 5/8" test, unless of course the 13 5/8" test was not valid.

On page 41 of his report, Dr. Bourgoyne attempts to refute my opinion that the 13 5/8" PIT is invalid. He claims that the volumes of mud used in the Casing Integrity Test and the PIT are virtually the same. He uses this argument to claim that that pressurization curves should look the same because the rocks are so strong. If this is true, however, then the shut-in curves should *also* show the same behavior because the rocks and steel pipe are both retaining the fluid. This is clearly *not* the case, as the PIT shows more than a 200 psi decline during the shut in period. The only way that the pressure decline during shut in can be explained under his assumptions is if the mud is being lost through the shoe in a cement channel, or other flaw that was exposed during the test, which would also invalidate the test and require a retest of the shoe. This observation is direct evidence that Dr. Bourgoyne's assertions about the validity of the test are simply wrong.

Putting this analysis in perspective, I have been evaluating PIT data in the GOM for the last 20 years, including several recent projects for other clients close to the Macondo well, and I rarely see cases where a valid PIT was shown to exceed the overburden gradient in the Mississippi Canyon area. BP's internal records indicate that the anomalous nature of this test result, and the possibility that the test was invalid, was clearly understood by the BP geophysicist assigned to this well team, Martin Albertin. (Exhibit 3733) See also the

following evidence of the BP Macondo team's contemporaneous concerns relevant to the validity of the PIT: Exhibit 1311 (BP Drilling Engineer Mark Hafle questions whether it is worth doing a second formation test in this interval); BP-HZN-2179MDL00292629 (Albertin reports that a review of nearby wells indicate that "all appear to behave normally," meaning "below overburden"); and BP-HZN-2179MDL01213209 (well site geologist Gord Bennett suggests that the relevant PIT curve "looked kinda odd"). For the reasons discussed above and in my initial report, there is no documentary evidence here to suggest that this anomalous result stemmed from something unusual in the formation. Under these circumstances, before it could justify drilling any significant amount of new open hole, BP should have drilled out a bit and then conducted an additional PIT, just like it did back in October and February when it repeatedly re-tested the casing shoe when it was looking to obtain a higher result because of anomalously low LOT values.

*The PIT at the 9 7/8" Casing Shoe*

With respect to the pressure integrity test at the 9 7/8" casing shoe, Dr. Bourgoyne recognizes that the fracture gradient that resulted from this test was significantly above the overburden gradient, and once again attributes this anomalous result to unusually strong rocks. Yet Dr. Bourgoyne offers no explanation for why the PIT curve for this later test and the curve for the test at the 13 5/8" shoe were so dramatically different, at least during their bleed-off phases. Stated simply, one such test revealed an unusually rapid bleed off whereas the other revealed no bleed off whatsoever. Yet the impression one would get from Dr. Bourgoyne's report is that we are talking about more or less the same rock and that the only difference between the two tests is that one test initiated a few small fractures before shut in. This analysis seems inadequate to say the least.

Dr. Bourgoyne noted that the formation integrity test (FIT) value of the 9 7/8" casing shoe test was 698 psi above the calculated overburden stress, but persists in his claim that this result is consistent with "an impermeable smooth borehole with no pre-existing defects or cracks and significant tensile strength and stress concentration near the borehole wall." Leaving aside that Dr. Bourgoyne is merely speculating about the rock that was tested, the fact remains that this test never achieved leak off; in other words, the rate of pressure buildup showed no sign of decreasing. Thus, if in fact, BP had continued on with this test to determine the point where a fracture was actually initiated (i.e., where mud began to leak out of the wellbore), there is no telling how high the result would have been.

Moreover, in reacting to my statement that the 9 7/8" PIT curve looked more like a casing test result than a formation test result, Dr. Bourgoyne did not dispute that the test curve resembled a casing test. Instead, he responded, at pages 45-46 of his report, that certain types of rock "would be expected to behave much like steel pipe from the standpoint of allowing fluid to enter the borehole wall when no cracks are present." I will grant that some kinds of rock will yield a smaller pressure bleed off than other rocks, but the fact that this particular test yielded literally a zero bleed off is anything but expected – unless the operator tested casing by mistake.

Dr. Bourgoyne's analysis of the casing test at the 9 7/8" shoe reflected a lack of understanding of critical events involving this well. Although Dr. Bourgoyne provided a detailed analysis of the first casing test on the 9 7/8" shoe (conducted to 950 psi), he completely failed to acknowledge that BP conducted a second casing test to 1500 psi, as documented in Figure 1 of my report. BP staff's comments concerning this second casing test are important to understanding why its PIT was invalid.

Drilling Engineer Brian Morel, in an e-mail dated April 3, 2010, when asked about the tests conducted at that shoe, stated that "we did a second test on the casing to 1500 [psi] ..., [but] as we were not expecting to get anywhere close to 16.0 ppg with the lot [i.e., the PIT], we decided not to test any higher than 1500 psi." (Exh. 4090) In other words, BP only tested the casing to 1500 psi because it did not expect the rock formation to withstand even close to that level of pressure during the PIT. Morel went on to say in the April 3, 2010 email: "So when pressure did get that high on the lot we opted to shut down without going to leak off because we wouldn't know if it was casing or formation." (Exh 4090). Typically, the rock formation begins to fracture at a pressure lower than the pressure at which the casing has been tested – this allows the operator to know that the rock, and not the casing, has fractured. Here, however, the casing had not been tested above 1500 psi. As a result, had BP continued to exert pressure above 1500 psi, it would not have been sure whether the rock or the casing was failing. And yet, by stopping at 1500 psi, BP's attempt to conduct a PIT generated a result that looked like a casing test and could not possibly have generated confidence that BP had tested rock rather than steel. Nevertheless, instead of drilling another 10 feet of formation and then conducting a second PIT so that it could be confident in its results, BP decided to stick with the original test. By ignoring this second casing test entirely, Dr. Bourgoyne failed to address the fact that BP's employees could not tell whether they had been testing rock or casing at the shoe above the Macondo's final interval. Any serious attempt to address the issue of whether BP was obliged to re-test the PIT at that shoe would necessarily involve confronting the written statements of the Macondo team when they received a PIT result that was so hard to believe.

What is more, a careful evaluation of the strength of the relevant rocks determined from well log data in the last part of the Macondo well calls into question Dr. Bourgoyne's assertion that the rocks at the 9 7/8" shoe are anomalous. Rather, the well log data suggests that the rocks at the 9 7/8" shoe are very similar in their properties to the shales in the rest of the open hole section below the shoe. In fact, these data suggest that there are areas below the shoe that are weaker and some that are stronger than the shales allegedly tested at the shoe. The upshot of my analysis of the well log data is that the shale properties are sufficiently different (and much weaker) than the properties of steel pipe such that there should have been a significant drop in pressure during the shut-in period. The fact that the pressure didn't drop even 1 psi at shut in makes this test impossible to accept as a valid FIT in an open hole and further suggests that BP tested casing, rather than the formation. The rocks are simply not incompressible enough to allow for the kind of response reflected in this test curve.

In short, it is still my expert opinion that the test at the 9 7/8" shoe was so anomalous that BP most likely did not test the shales that are represented in the well logs at this depth. Under the MMS regulations, as I understand them, operators were required to get a valid test before

drilling forward. A prudent operator would have drilled out another 10 or so feet of shale and retested the shoe to determine a valid LOT result before drilling the next open hole segment, especially given the difficult nature of the Macondo well up to that time.

Finally, Dr. Bourgoyne's discussion, in the way that it characterized my own analysis, glossed over a critical point. I did not say in my report that there is no possible way for one or both of these tests to have actually measured formation, rather than casing or cement. What I said was that neither of these tests possessed sufficient indications of a valid PIT that is mandatory before an operator can justify drilling ahead without re-testing the shoe. To support that conclusion, I marshaled various types of information – including contemporaneous e-mails from BP employees questioning the tests' validity, the anomalous test curves, and the anomalous results – that would reasonably lead an operator to question the validity of the tests. I have duly noted Mr. Albertin's recent statements indicating that he grew to believe that these PITs were valid (Bourgoyne Report at 47), but I have seen no contemporaneous accounts that would confirm that self-serving testimony, let alone establish the tests' reliability.

### D. BP Did Not Maintain a Safe Drilling Margin in the Open Hole Interval from the 9 7/8" Shoe to 18,360' (TD)

As was made clear in my initial report, from a drilling margin standpoint, I have two sets of issues with BP's conduct in drilling the Macondo well's final interval. First, as discussed above, I do not believe that the PIT conducted at the top of the interval had sufficient indication that the test was valid to justify drilling ahead. And second, BP's hole-behavior observations when drilling this interval required it to stop drilling before it reached the total depth of 18,360'. (See Huffman Report at 36-39)

To support this latter conclusion, I provided a detailed analysis of the tight squeeze that BP encountered between its best estimates of the highest pore pressure at the bottom of the interval and the weakest fracture gradient in the interval. As I explained, far from having the required 0.5 ppg margin (as set forth in the approved APD) between its mud weight and its fracture gradient, BP continued to drill ahead even after reaching the point where it believed that a decrease in mud weight of only 0.1 ppg would leave the well underbalanced (beneath the pore pressure in the most highly pressured sand in the open hole) but an increase of only 0.1 ppg would fracture the wellbore (exceed the weakest fracture gradient in the open hole). It is notable that neither Mr. Schoennagel nor Dr. Bourgoyne made an effort to challenge my specific findings concerning the total lack of a drilling window at the bottom of the well. Rather, they confined their responses to generalizations, discussed in Section I above, concerning the latitude given to drillers when their hole-behavior observations reveal a loss of margin. In other words, they skirted critical issues that I raised in my initial report as to why BP's conduct was both illegal and unsafe.[1]

[1] Perhaps the one instance in which Dr. Bourgoyne addressed the specifics of my analysis was in response to my comments that BP should have known that it lost its drilling margin in part because of the results of its GeoTap tests. In response, Dr. Bourgoyne states at page 34 of his report that "Geo-Tap tools can measure pore pressure but do not measure fracture pressure. BP has specialists for calculating fracture

While Dr. Bourgoyne offers little analysis of whether we should be concerned about the size of the drilling margin near the bottom of the Macondo well, his report's background discussion of drilling margins does recognize the need for a well's mud weight both to exceed its pore pressure and be less than its fracture gradient. (Bourgoyne Report at 30) Dr. Bourgoyne never specifies the amount of such cushions that are needed to ensure adequate well control. Yet one of BP's documents, a 2008 Tubular Design Manual, talks about BP's practice of maintaining at least a 0.3-0.5 ppg cushion between the formation pore pressure and mud weight, and another 0.3-0.5 ppg cushion between the mud weight and the fracture gradient. (Exhibit 5839, at BP-HZN-OIG00039969) The latter cushion is called a "kick and cementing margin," and BP explains that it is necessary "as an approximate allowance for swab during pipe movement, well control and ECD during cementing." *Ibid.* Similarly, in its March 26, 2010 Application for Revised Bypass for the Macondo well, BP provided a plot that includes a 0.2 ppg cushion between its pore pressure and its mud weight, and a 0.5 ppg cushion between its mud weight and its fracture gradient. There is a dramatic difference between the above cushions, on the one hand, and the miniscule cushions of less than 0.1 ppg on each side that were actually experienced as BP approached the bottom of this well, on the other. Based on both my experiences in participating in drilling operations for numerous clients worldwide and my interpretation of the regulations, I am confident in saying that if BP wanted to drill ahead under these circumstances and in the face of 30 CFR. 250.427 and 250.428 (not to mention its own APD), it needed to apprise MMS of the situation and seek MMS' prior approval.

Finally, there are two relevant internal inconsistencies in BP's expert reports that bear mention here. First, the spirit of the BP expert reports is internally inconsistent when it comes to these experts' treatment of BP's PITs and its drill-ahead decisions at the bottom of the well. My sense after reading the report of Mr. Schoennagel, at pages 23-24, is that he takes the position that an operator need not take hole-behavior observations into account in determining whether it has retained its "safe drilling margin." All that the operator must do, he appears to suggest, is ensure that it keeps its mud weight at least 0.5 ppg from its PIT result, even if the hole-behavior observations indicate that the actual fracture gradient has dropped to significantly less than that PIT result. By contrast, Dr. Bourgoyne, as discussed above, would have us believe that an operator is justified in drilling ahead after conducting a PIT that: (a) yields a result that is unusually high, to say the least; (b) is likely not to be representative of the interval about to be drilled; and (c) yielded a curve that is indistinguishable in any way from a casing test. Taken together, BP's experts would have one believe that the MMS regulations allow a driller to make mud weight decisions, which are vital for well control, based upon highly questionable and clearly unrepresentative PIT results and then continue to drill ahead with little regard for how the hole actually responds to the mud weight in the well. In my opinion, this is contrary to both the letter and the spirit of

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gradients from other observations, but these are just estimated and are often inaccurate." In fact, however, Mark Alberty, BP's in-house authority on pore pressure/fracture gradient issues when the Macondo was drilled, testified that a downhole GeoTap estimate of a well's fracture gradient in sandstone would be more accurate than what you might learn from a PIT up hole. (Alberty Deposition at 307)

30 CFR 250.427 and 30 CFR 250.428(a) as well as worldwide industry practice, and defies common sense.

Second, Dr. Bourgoyne's report is internally inconsistent insofar as he states, on page 9, that the well was "drilled to total depth safely and successfully with consistent industry practices," but then discusses on page 30 how important it is "to prevent the development of a very large fracture" that could potentially lead to an "underground blowout." In fact, BP drilled the bottom of this well in a manner that gravely risked just such a blowout. This can arise in extreme cases of pressure differences between two adjacent reservoirs. In this scenario, the reservoir with the lower pore pressure can actually have a sand fracture gradient that is similar to (and potentially even less than) the mud weight required to control the pore pressure of the higher pressured reservoir. As discussed in my previous report, at 37, in the case of the Macondo, the reservoir at roughly 17,713' had a GeoTap pore pressure gradient of 14.14-14.16 ppg, whereas the reservoir a few hundred feet further down the hole had a GeoTap pore pressure gradient of 12.58 ppg, corresponding to an estimated fracture gradient of 14.34-14.35 ppg – creating an extremely tight squeeze. BP's internal communications confirm that they were gravely concerned about this lack of a drilling window between the pore pressure in the higher reservoir and the fracture gradient in the lower reservoir. This is what led the BP geologist to say that there was essentially only a single surface mud weight – 14.0 ppg, not 13.9 and not 14.1 – in which the well could be stable. BP had a choice of plugging up the bottom of its hole with cement and attempting to find a higher, stable point at which to set casing that would isolate the high-pressure sand behind pipe and protect the hydrocarbon-bearing reservoirs below it. Nevertheless, despite that option, despite the possibility of encountering sands with even higher pore pressures than what it had already encountered, and despite its staff's understanding of 30 CFR 250.427, when BP had drilled to the depth of 18,260', it elected to drill an additional 100' further without obtaining MMS' prior approval in doing so. In any event, it left its well in a position where it had but a tiny margin available to cement the well's final interval.

## III. DR. BOURGOYNE'S ASSERTION THAT BP DID NOT INTEND TO HIDE INFORMATION FROM MMS IS BASELESS

On page 35 of his report, Dr. Bourgoyne made the following statement: "In my opinion, the few errors found in the large amount of material submitted to BOEMRE (previously MMS) do not warrant the leap Dr. Huffman makes to a conclusion that BP intentionally hid information so that they could operate in an unsafe and imprudent manner." I have multiple difficulties with this statement.

To begin, I made no effort in my initial report to weigh in on the issue of whether BP's submission of false information or failure to disclose required information reflected an "intent" to mislead MMS. When I spoke of "misrepresentations," for example, I was simply reporting on instances when BP made representations to MMS that were false, rather than passing judgment on whether BP made such representations with fraudulent intent. Secondly, in making the above statement, Dr. Bourgoyne offers no facts to support his conclusion about BP's intent. If I am asked to evaluate the accuracy of his conclusion, I would have to say that Dr. Bourgoyne would have difficulty supporting such a position.

While I did not set out to include all relevant documents that prove this point, my report contains various references to internal BP documents suggesting that its well team was quite sophisticated as to the drilling margin laws and the specific duty to seek an MMS waiver before drilling ahead without the required margin. Clearly, that duty was violated on multiple occasions, a problem that was exacerbated by the frequent misreporting of drilling-margin data to MMS shortly after BP drilled ahead without the required margin.

In addition, the record I have reviewed indicates that the two individuals who may have played the most critical roles in BP's drilling margin decisions (including decisions as to what information to report to MMS) were Drilling Engineers Mark Hafle and Brian Morel. (Douglas Deposition at 25-26; Vinson Deposition at 313; Guide Deposition at 334) Both of these individuals asserted their 5th Amendment rights in response to any drilling margin question that they were asked. (Hafle Deposition at 21, 62-65, 72-73, 89, 115-128, 154-55, 158, 226-29; Morel Deposition at 20, 26-27, 42-45, 59-61, 103-110, 176, 235-36). Thus, unless Dr. Bourgoyne has access to information that I do not, I fail to see how he has the confidence to make the statement he did about BP's "intent" underlying its repeated failures to speak truthfully to MMS and/or make all required disclosures, or its repeated decisions to drill ahead without the required cushion between its mud weight and its fracture gradient.

## Appendix 1

## Log Plot and Description

The .pdf display in Appendix 1 consists of (1) raw wireline (W/L) log data and (2) calculated log curves that are derived from the raw wireline log data. The raw wireline data was received in .las file format and loaded from the following specific filenames:

- **BP_OCS-G_32306_001_ST00BP01_P_and_S_in-casing_17240-11770.las,**
- **BP_Macondo_OCSG_32306_001_ST00BP01_OBMI_DSI_Main_Pass_MD_125PUP.las and**
- **BP_Macondo_OCSG_32306_001_ST00BP01_TCOM_Main_Pass_Quick_Look_LAS_file_071PUP.las.**

BP produced the wireline files on four DVDs labeled BP-HZN-2179MDL269688 – BP-2179MDL00269691. Logging while drilling (LWD) data were loaded and reviewed but were not included in this presentation footage interval of 16700 ft MD to 18360ft MD. Minor raw data editing consisted of merging logging runs and removal of non-appropriate data quality such as density recording through casing. The .pdf presentation consists of 18 tracks where the left side of the presentation generally displays the raw logs and the right side illustrates the derived curves including the following:

- track 1: the gamma ray,
- track 2: the measured depth,
- track 3: the casing shoe depth,
- track 4: the resistivity,
- track 5: the wireline tension and borehole diameter,
- track 6: the density correction,
- track 7: the neutron and density,
- track 8: the edited density,
- track 9: the edited compressional interval transit time and
- track 10: the edited shear interval transit time.

The remaining tracks 11-18 are generally derived curves characterizing rock geomechanical properties and petrophysical properties.

- track 11 Poisson's ratio and compressional-to-shear velocity ratio,
- track 12 bulk, shear and Young's modulus,
- track 13 shear, compressional velocity and acoustic impedance,
- track 14 raw Stoneley transit time and rock brittleness,
- track 15 total and effective porosity,

- track 16 water saturation,
- track 17 measured depth,
- track 18 the volume of shale and fluids bulk volume.

In track 18 the hydrocarbon bearing zones are indicated by the red shaded color which correlates to the water saturation in track 16.