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

IN RE: OIL SPILL BY THE OIL RIG "DEEPWATER HORIZON"
IN THE GULF OF MEXICO ON APRIL 20, 2010
MDL 2179

REBUTTAL EXPERT REPORT:
RATE PREDICTION FROM THE MACONDO WELL

Prepared on Behalf of the United States

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June 10, 2013

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EXECUTIVE SUMMARY

In our initial expert report, submitted on March 22, 2013, we calculated the flow rate of oil from the Macondo well on the last day of the spill (54,000 stock tank barrels), as well as the cumulative amount of oil spilled from the reservoir over approximately 86 days (4.5 to 5.5 million stock tank barrels). In reports submitted on May 1, 2013, some of defendants' consultants challenged certain aspects of our analysis. We respond to those challenges here and adjust our cumulative flow estimates slightly based on a more detailed evaluation of the uncertainty surrounding certain input parameters.

Importantly, there were a number of aspects of our analysis that were either *not* challenged by defendants or where their analyses are consistent with ours. [redacted] Other instances where defendants' conclusions are consistent with ours are:

- Dr. Gringarten's average reservoir pressure calculations are consistent with ours: we calculated an average pressure of 10,396 psia while Dr. Gringarten obtained a range from 10,364 to 10,460 psia.
- Our average estimate of hydrocarbon pore volume in the original report was 264 million reservoir barrels. Dr. Blunt predicts a value of 258 million reservoir barrels, BP's own internal estimate is 256 million reservoir barrels, [redacted] These values show remarkable consistency among various engineers that have examined the issue.
- In our initial report we used an initial formation volume factor (Boi) value of 2.14 bbl/STB. This value is consistent with the oceanic analysis provided by Dr. Curtis Whitson on behalf of BP. Dr. Whitson predicted a value of 2.08 to 2.14 bbl/STB. This value of 2.14 was also used by BP's Phase 1 expert Morton Emilsen.[1]

Based on our evaluation of the defendant experts' reports as well as our own subsequent analysis, we have reached the following conclusions:

Rate Calculations through Capping Stack

- The oil flowing through the well on the last day before the well was finally shut-in was approximately 54,000 STB/day. In our initial report, we calculated this rate using the fluid model developed by United States' expert Dr. Aaron Zick, as well as black oil tables generated by BP in June 2010. We have now confirmed this rate using the fluids model provided by Dr. Whitson on behalf of BP.
- Our analysis and calculated rate is further confirmed by the United States' Computational Fluid Dynamics (CFD) expert Dr. Bushnell [redacted] both of whom did CFD analysis of flow through the capping stack on the last day of the spill.

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[1] TREX 7401, Morton Emilsen Expert Report (Oct. 17, 2011), p. vi, Section 1.7, 3.2 of Appendix W.

[redacted]

Macondo Fluid Analysis

- As noted above, our value of initial formation volume factor of 2.14 is consistent with that calculated by various fluids experts on behalf of BP. The United States' fluids expert Dr. Aaron Zick[2], using his own ocean separation methodology that accounts for liquid dropout, predicts a value of 1.972 to 2.045 bbl/STB. We conclude that this value is more appropriate since Dr. Whitson's analysis ignores the stock tank oil that will drop out of the gas phase as the reservoir fluid flows through the ocean.
- Dr. Blunt and Dr. Gringarten used the laboratory tests to represent B_{oi}. Because their values are based on single stage separation compared to oceanic separation (as analyzed by both Dr. Zick and Dr. Whitson), those values under-represent the stock tank oil volumes.

Estimate of Original Oil in Place in the Macondo Reservoir

- Dr. Blunt is incorrect in stating that we did not include geology in our initial report. In our original report, we relied on BP's own interpretation of geology and seismic data to estimate our original oil in place.
- In this analysis, [redacted], we use BP's original pre-drill report to determine the distribution of initial oil in place. Our analysis indicates that 60.4 MMSTB represents the 10 percentile value, 125.5 MMSTB represents the 50 percentile value and 254.1 MMSTB represents the 90 percentile value.

[redacted]

- We also show that the amount of hydrocarbon pore volume present in the reservoir based on our own values as well as Drs. Blunt, [redacted] and BP's internal experts are consistent with one another, ranging from 256 million to 264 million reservoir barrels. These reservoir barrels can be converted to standard conditions using initial B_{oi}. For example, using a B_{oi} of 2.14 and [redacted] pore volume estimate of 259 million barrels we derive an original oil in place of approximately 121 MMSTB.

Well Test Interpretation

- The work presented by Drs. Blunt and Gringarten ignores generally accepted well test interpretation practices and techniques. Moreoever, Dr. Blunt ignored actual events that took place at Macondo and therefore his analysis is unreliable.
- It is a fundamental tenet of well test analysis that one must account for the specific rate schedule that occurred just prior to the test. Here, Dr. Blunt has completely ignored the

[2] Dr. Zick, A.: "Expert Rebuttal Report," June 10, 2013.

rate variation that occurred just prior to shut-in as the choke valve closed, and Dr. Gringarten has not given adequate explanation as to how he handled this rate variation.

[redacted]

- Dr. Gringarten focuses his criticism of our average reservoir pressure calculation on the methodology we employed. This is entirely irrelevant since our calculated average reservoir pressure (10,396 psia) is in the middle of the range indicated by Dr. Gringarten (10,364 to 10,460 psia).

Total Volume of Oil Released

[redacted]

- Dr. Blunt's calculation of cumulative oil released is incorrect because he uses overly conservative inputs to his material balance calculation.
- Dr. Gringarten's cumulative oil released calculations are unreliable because his calculation of bottom hole pressures is incorrectly assumed to be independent of the rate profile. In addition, his reliance on flawed MDT permeabilities cannot be justified.

SECTION I. RATE PREDICTIONS THROUGH THE CAPPING STACK

In our original report, we calculated flow rates through the capping stack as the well was progressively shut by closing a choke valve, and concluded that the flow from the well on July 15 was approximately 54,000 STB/day. In addition, we calculated the rates through the kill line during the same time period and obtained similar rates. None of the reports submitted by defendants directly challenge our flow rate calculations through the capping stack. [redacted]

[redacted]

[redacted] We then evaluate the influence of fluid models provided by Dr. Whitson (BP) on our analysis, [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Impact of Macondo Fluid Model

Finally, although none of the defendants challenged our selection of fluid model, for purposes of completeness we have run additional sensitivities on our capping stack calculations using Dr. Whitson's EOS model.[9] In doing our original rate calculations we had used the compositional EOS developed by Zick as well as black oil tables developed by BP in 2010. The rates calculated using those two fluid models deviated by less than 0.5%. To further confirm that our rate calculations are not significantly impacted by fluid properties, we repeated our exercise using Whitson's EOS.[10] Figure 1 below shows the plot of our flow rate calculations as the choke valve is closed prior to shut-in, using the Zick and Whitson EOS models. Table 1 shows a comparison of the calculated rates. As can be seen, the differences in the two rate calculations are negligible.

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[7] PROSPER – System Analysis Program, V. 11.5, Petroleum Experts, Edinburgh, U.K.

[redacted]

[9] Dr. Whitson, C.: "Expert Report of Curtis Hays Whitson, PhD," May 1, 2013.

[10] We wanted to compare the two EOS models; one generated by our expert Zick and one generated by Dr. Whitson for BP. Since we ran our initial analysis with Dr. Zick's compositional model, we compared the results with Whitson's compositional model rather than the black oil tables he generated for PROSPER. Indeed, Dr. Whitson's report included a warning to those using his PROSPER black oil tables: "Any Prosper applications using black-oil PVT tables for the DWH Incident will, as a result, be uncertain when the fluid at issue is near-critcal, and should be validated using an EOS-based compositional version of Prosper." Whitson Report, p. 34.

Figure 1: Comparison of Zick and Whitson Models in Calculating Rates through the Choke Line

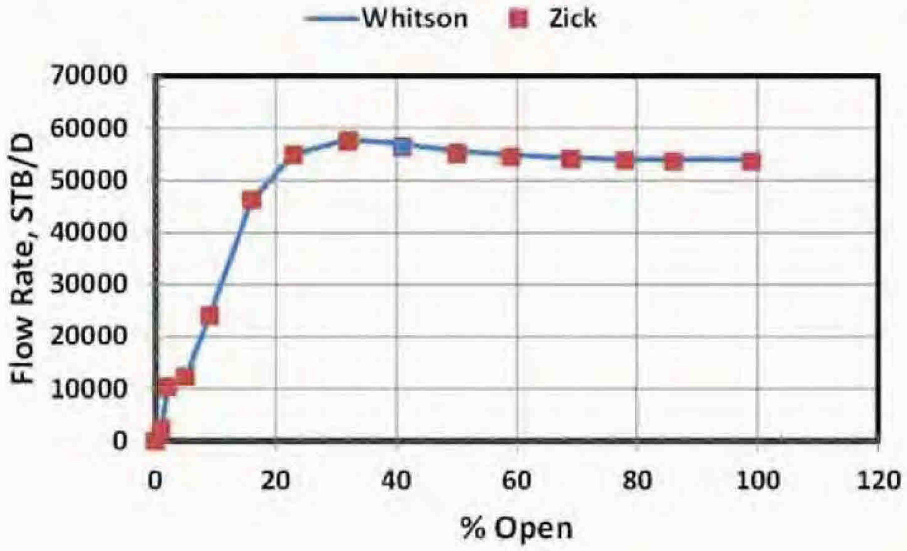

Table 1: Rate Comparison for different Choke Settings – Zick vs. Whitson EOS Models

% Open Choke	p(PT-3K-2) (psig)	Zick K-Factor (STB/d)	Whitson K-Factor (STB/d)
99	3074	54000	53500
86	3075	54000	53500
78	3099	54000	53750
69	3138	54300	54000
59	3230	54900	54400
50	3384	55600	55100
41	3671	56900	56400
32	4149	57800	57400
23	4748	55000	54840
16	5606	46350	46175
9	6220	24000	24000
5	6408	12420	12350
2	6553	10850	10400
1	6581	2320	2310
0	6600	0	0

In generating Figure 1, we used the PROSPER wellbore modeling program. According to Dr. Whitson's report, he created his EOS by defining binary coefficients as a function of temperature.[11] PROSPER can only accept one set of binary coefficients. In Figure 1 we used the binary coefficients corresponding to 243 F (reservoir temperature). To ensure that this effect is not significant, we also calculated the rates by setting Dr. Whitson's binary coefficients to correspond to 180 F, the lowest wellhead temperature used in the sensitivity analysis in our initial report. Figure 2 below shows the comparison of flow rates calculated using Dr. Whitson's EOS with binary coefficients set at 243 F and at 180 F. As shown in Figure 2, the difference is negligible.

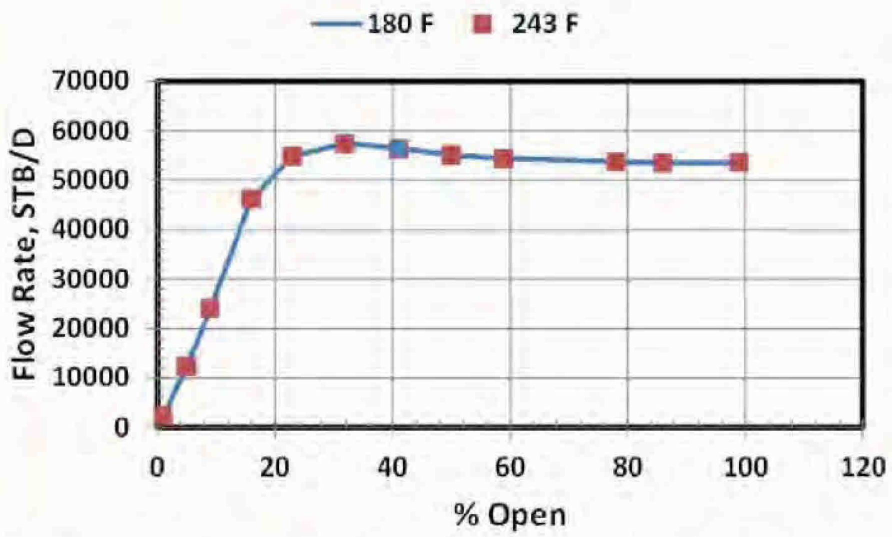

Figure 2: Effect of Temperature Dependent Binary Coefficients on Rate Calculations through Choke Line

We also compared the flow rates through the kill line using Whitson's model. As expected, we found that the difference between the Zick model and the Whitson model was negligible (52,000 STB/day for Zick's model versus 51,250 STB/day for Whitson's model).

[redacted]

[11] Dr. Whitson, C.: "Expert Report of Curtis Hayes Whitson, PhD," May 1, 2013, p. 16.

[redacted]

SECTION II. MATERIAL BALANCE ANALYSIS

Material balance analysis is a method based on conservation of mass. The unique advantage of this technique is in its simplicity. For oil reservoirs, to apply the material balance technique, we need to know how much oil volume was present in the reservoir at the beginning and how much oil volume was present at the end. Knowing the two, we can calculate the amount of oil produced from the reservoir. The input parameters needed to apply material balance are volume of oil in place at the beginning, the initial and final reservoir pressures and the total compressibility of the reservoir.[13] In addition, if an underlying aquifer is influencing the production, we will need to know also the size, shape and other properties of the aquifer.

In our original report, we applied the material balance technique to calculate the amount of oil released. We explained that the amount of oil released – based on a sensitivity study – was in the range of 4.5 to 5.5 million stock tank barrels. We did not explicitly consider the impact of an aquifer in our analysis; however, we did state in our report that our predicted results are conservative because any influence from an aquifer would result in an additional volume of oil released.

[redacted]

Conversion of Reservoir Fluid to Stock Tank Barrels

In our original report, we used the equation of state (EOS) developed by United States fluids expert Dr. Aaron Zick to represent the Macondo fluid properties in our analysis of calculation of flow rates through choke as well as kill line. We compared our results with black oil model generated by BP in June of 2010, which was also based on compositional modeling. As discussed above, we compared our flow rate results using Whitson's compositional model and our results are similar.

What is common in these three models is the assumption that the oil is separated using a multi-stage process. Both Dr. Blunt and Dr. Gringarten use single stage separation properties to calculate the formation volume factor for oil.[14] Dr. Blunt claims that it is better to use single

[13] Because of the simple nature of material balance analysis, it can be greatly influenced by uncertainty in the input parameters.
[14] Dr. Blunt, M.: "A Calculation of the volume of Oil Released during the Deepwater Horizon Accident," May 1, 2013, p. 27; Dr. Gringarten, A.: "Well Test Analysis," May 1, 2013, p. 58.

stage separation in the analysis to avoid the actual complexity of the process. This is odd considering that Dr. Whitson, BP expert, constructs a very detailed process of oil and gas separation as the oil is released to the bottom of the ocean, which he calls his "oceanic separation" process, and also provides a simplified, five-stage "oceanic proxy" process which is certainly simple enough for Drs. Blunt and Gringarten to use in their modeling.[15]

Based on his analysis, Dr. Whitson finds the results stated in Table 2 below. In Table 2, Dr. Whitson assumes that the reservoir contains 100 barrels of oil. He then proceeds with the assumption about how this oil will be released into the ocean. He considers a process he terms "oceanic separation" at two exit temperatures: 210 F and 130 F. Using these assumptions, Dr. Whitson states that 100 barrels of reservoir fluid will result in either 46.7 barrels of oil or 48.0 barrels of oil, respectively. Knowing the formation volume factor is the ratio of oil at reservoir conditions to oil at surface conditions, the formation volume factor at initial conditions is either (100/46.7 = 2.08 bbl/STB) or (100/48 = 2.14 bbl/STB). BP's black oil table calculates the initial formation volume factor to be 2.14 bbl/STB, which is consistent with the conservative end of Dr. Whitson's predictions. We used a value of 2.14 bbl/STB in our original report, based on the black oil tables provided by BP in June 2010 and as further supported by Dr. Zick's multistage separation analysis. In contrast, Dr. Blunt uses a value between 2.3 to 2.4 bbl/STB in his analysis.[16]

Table 2: Data of Oil Released starting with 100 barrels of Reservoir Fluid (Whitson)

1. **Single Stage Flash:**	**43.3 barrels**
2. **Oceanic Separator (T_{exit}=210°):**	**46.7 barrels**
3. **Oceanic Separator (T_{exit}=130°):**	**48.0 barrels**
4. **4-Stage Separator:**	**47.9 barrels**

The United States' fluids expert, Dr. Zick, conducted his own oceanic separation analysis, using a more refined method than that proposed by Dr. Whitson. In addition to assuming separation of oil and gas at different pressures and temperatures as the Macondo fluid move through the ocean after it is released at the seafloor, Dr. Zick also concludes that oil will drop from the gas phase as the gas phase moves through the ocean and condensation occurs. Using this methodology, Dr. Zick predicted an initial formation volume factor value of 1.972 bbl/STB using his own equation of state, and 2.045 bbl/STB using Dr. Whitson's equation of state.[17] We believe that the process described by Dr. Zick is more representative of what actually

[15] Dr. Whitson, C.: "Expert Report of Curtis Hayes Whitson, PhD," May 1, 2013, p. 17
[16] Dr. Blunt, M.: "A Calculation of the Volume of Oil Released during the Deepwater Horizon Accident," May 1, 2013, p. 27.
[17] Dr. Zick, A.: "Rebuttal Report," June 10, 2013.

happened in the ocean because it accounts for all of the oil that is present in the ocean, unlike Dr. Whitson's analysis which ignored oil that condenses out of the gas phase.

Although both Dr. Zick and Dr. Whitson have simulated the oceanic separation process, Dr. Whitson then goes on in his report and says that 10% of the oil released into the Gulf of Mexico is dissolved in the ocean and, therefore, it should not be included in the calculation of stock tank barrels. We do not agree with this statement since it assumes that if certain oil components are dissolved in water, that oil is not released in the ocean. This is even more nonsensical than failing to include oil dropout from the gas phase as the fluid moves through the ocean. The fact is that the oil is indeed released into the ocean and it simply went into the water phase. It did not disappear. Using this argument under extreme condition, we can assume that all the components in oil phase have certain solubility in sea water and sea water volume is large; therefore, eventually, all the oil will be dissolved in water and no oil is released into the ocean. Intuitively, this argument does not make any sense.

In brief, the initial formation volume factor we have used in our calculations is consistent with what BP's consultant – Dr. Whitson – predicts. For the type of oil which is produced from Macondo, we are indeed using appropriate values of formation volume factors. The initial formation volume factor values used by Dr. Blunt are not consistent with what the three compositional models (Zick model, Whitson model, and BP's 2010 model) predict.

Estimate of Original Oil in Place

One critical element of material balance analysis is the amount of oil in place in the reservoir (STOIIP). The value of STOIIP is calculated by dividing the reservoir hydrocarbon pore volume (HCPV) by the initial formation volume factor (B_{oi}). HCPV is the produce of pore volume multiplied by oil saturation. As we discussed in the previous section, there is some dispute (even among the opinions put forward by BP) regarding what value should be used for B_{oi}. Dr. Blunt uses a value that is significantly higher than what Dr. Whitson calculated and what we used in our initial report. As demonstrated in the previous section, our value is more appropriate based on what happened in the ocean as oil is released, and is consistent with the B_{oi} value calculated by BP's Dr. Whitson by simulating discharge of oil to the Gulf of Mexico.

Dr. Blunt criticizes our use of STOIIP in our report because he claims we did not properly consider geology. Dr. Blunt claims that we did not properly account for connected volume in the reservoir which can be explained by proper use of geology. If what he stated was true, we would expect the hydrocarbon volumes connected to the Macondo well to be significantly different based on one's interpretation of geology. We can therefore refute his argument by showing the values of hydrocarbon pore volumes used by four different people. By comparing HCPV, we are also able to avoid the debate associated with B_{oi}. In Table 3 below, we compare these results.

Table 3. HCPV Used by Different Experts[18]

	HCPV
	MM res bbls
Blunt	258
BP	256
Kelkar and Raghavan	264
[redacted]	[redacted]

These numbers are remarkably – and, we believe, indisputably – close to each other, and illustrate that the hydrocarbon pore volume we used in our original report is consistent with what BP engineers have used.

[redacted]

[18] Dr. Blunt, M.: "A Calculation of the Volume of Oil Released during the Deepwater Horizon Incident," May 1, 2013; we calculated HCPV in Blunt's report by multiplying STOIIP for mid-case on p. 51 with appropriate value of B_{oi} for each lab. The average is 258 MM reservoir barrels. BP "PIE Matches of 25-July," BP-HZN-2179MDL04923120; for the most commonly used value of 110 MMSTB, BP reported the value of reservoir barrels to be 256 MM. Kelkar, M. and Raghavan, R.: "Rate Prediction from Macondo Well," March 22, 2013; in our original report, we used two values of STOIIP, 110 MMSTB and 137 MMSTB. We took the average of the two and multiplied by 2.14 bbl/STB to convert it to reservoir barrels. [redacted]

[redacted]

Therefore, [redacted] we conclude that it is most reasonable to use BP's original bulk volume estimates to bound our estimate of the original oil in place. In fact, as stated by Dr. Huffman in his expert report, BP's own seismic interpretation and the associated areal coverage of the reservoir is [redacted] reasonable [redacted]. For completeness, we reproduce data from BP's pre-drill report. We multiplied the reservoir size by the thickness, and then multiplied by 90% to determine the bulk volume of the reservoir connected to the Macondo well. This 90% connectivity value is also used by Dr. Blunt in his analysis.[23]

Table 4: Bulk Volume Uncertainty as reported in BP's Macondo Pre-Drill Report

	90	50	10
Reservoir Size (acres)	3639	4498	8697
thickness (ft)	25	42	44
% Connectivity	90%	90%	90%
Connected Bulk Volume (Acre-ft)	81,878	170,024	344,401

Formation Compressibility

[redacted]

[22] BP Macondo Technical Assessment Memorandum, April 2009.
[23] Dr. Blunt, M.: "A Calculation of Volume Released during Deepwater Horizon Accident," May 1, 2013, p. 25.
[24] BP Powerpoint Presentation, Reservoir Response, 8_july-2010, BP-HZN-2179MDL07033641.

[redacted]

Response to "Well Test" Analyses by Drs. Blunt and Gringarten

Drs. Blunt and Gringarten recognize the need for reliable rate measurements. There are a few things that are common to the approaches taken by them and a few that are distinct. Both experts use identical bottom-hole pressure measurements calculated by Dr. Blunt for the final buildup period that lasted approximately 20 days. Both analyses are based on the estimate of MDT permeability obtained by Dr. Gringarten. Similar to the conclusions of the government experts, both Dr. Blunt and Dr. Gringarten conclude that the Macondo well is located in a rectangular reservoir of a finite size. However, the estimates of average pressure determined by Drs. Blunt and Gringarten are distinct: Dr. Gringarten concludes that the average pressure is in the range 10,364 to 10,460 psi, and Dr. Blunt concludes that it is in the range 10,433 to 10,531 psi.

[redacted] The principal observation to be derived from the work of Drs. Blunt and Gringarten is that many rate schedules will fit the buildup pressures equally well. Dr. Gringarten is also particularly critical of average pressure estimates we obtained in our initial report, principally in terms of provenance; we show his criticism is unfounded. Indeed, our analysis of average reservoir pressure using the Mead method obtained a value in the middle of the range calculated by Dr. Gringarten. Below we provide specific observations and critiques of the methods employed by Drs. Blunt and Gringarten based on generally accepted petroleum engineering principles.

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[25] Dr. Blunt, M.: "A Calculation of the Volume of Oil Released during the Deepwater Horizon Incident," May 1, 2013; p. 30.
[26] Dr. Roegiers, J.C.: "Rebuttal to the Report of Dr. Robert Zimmerman," June 10, 2013; Dr. Huffman, A.: "Expert Report," June 10, 2013.

Dr. Blunt. Credence cannot be given to the Blunt report for the following reasons: (i) the analysis is not based on the events that actually took place at Macondo; (ii) the report does not address issues concerning support volume; and (iii) [redacted]

The errors in Dr. Blunt's analysis are plainly apparent from the language of his own report. It is a basic tenet of pressure data analysis that flow rate information is critical to that analysis. Footnote 86 of the Blunt report acknowledges the need for flow rate information and indicates that a rate was not used where he notes "I … have not relied on commercial pressure transient analysis software. Such software requires an assumed flow rate…" On page 49, this refrain is repeated when Dr. Blunt notes that his analysis is based on "…a mathematical model that assumed a fixed (albeit unspecified) flow rate." Later, on page 115, Dr. Blunt acknowledges: "My pressure analysis has assumed a constant flow rate, followed by an instant stopping of the flow. In contrast, in Macondo, there was a complex sequence of changes in flow rate as the choke was closed." Further, page 117 of the report acknowledges "I must emphasize though that *the flow rates I have used are for illustrative purposes only…*" (emphasis added).

Analysis of pressure data is authentic only if the rate schedule that actually occurred is used. The statements excerpted from the Blunt report acknowledge that he only models hypothetical events that have no meaning to reality and do not reflect the events that took place at Macondo.

Interpretations using the pressure derivative curve depend on the rate schedule prior to a test, and any conclusions drawn from that interpretation in Dr. Blunt's report are suspect; see Page 41of the Blunt report ("…flow rate history does impact the pressure response"). As already noted, however, Dr. Blunt asserts that he can analyze the pressure buildup test by assuming a "fixed" (and "unspecified") rate, which ignores the choke valve changes that occurred just prior to the start of the pressure buildup. By doing so, he tacitly acknowledges that he does not know the flow rate schedule immediately prior to shut in, and therefore that many rate schedules will fit the buildup pressure equally well. Dr. Blunt attempts to compensate for the fact that he ignores the choke valve turns – and the corresponding rate changes – just prior to shut in by also ignoring the first 10,000 seconds (2.78 hours) of the buildup period after the Macondo well was shut in. It is generally agreed among experts in the field of well test analysis that knowledge of the well response for a few minutes prior to and after the onset of pressure buildup are crucial to the analysis. Dr. Blunt's exclusion of the first 2.78 hours of data ignores almost 2 log cycles of the data that are available; that is, Dr. Blunt completely ignores almost one-half the number of log cycles of data that that are available for evaluation. It is this early part of a test that helps one identify the segment of the pressure buildup curve that should be used to estimate the permeability-thickness product and identify other features of the reservoir such as faults and boundaries that may be useful in proceeding with the analysis.

[redacted]

[redacted]

If indeed the Blunt report had included the influence of the choke valve turns that really took place at Macondo and replaced the unspecified rate schedule, and considered the entire duration of the test that was actually conducted at Macondo, then he would have found that the derivative curve shown in the "centre-piece" of the analysis to be located in a much different place. We illustrate this matter in Figure 3.

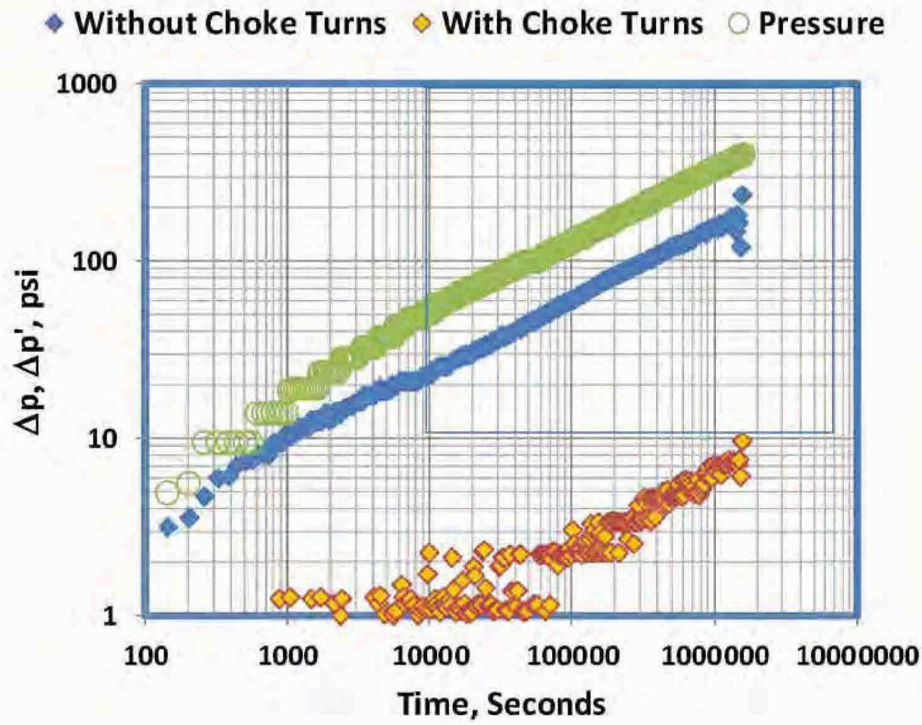

Figure 3: Pressure Responses Including Convolved Derivatives by Including and Ignoring Choke Valve Changes

In the above Figure, the topmost curve (green circles) represents the change in the pressure response that occurred during the pressure buildup test. The bottommost curve (orange diamonds) represents the corresponding convolved derivative curve for the rate schedule that we used in our initial report, and reflects the influence of the choke valve turns that occurred prior to shut-in using our calculated shut in rate of 54,000 stb/day. The middle curve (blue diamonds) represents the convolved derivative curve ignoring that the choke turns; that is, it assumes, as Dr. Blunt has done, that the rate was held constant during the choking period and equal to the rate before choking commenced. We simply note that the two derivative curves are distinct for the entire time range of the pressure buildup test, and Dr. Blunt's assumption that the choke valve turns can be ignored is not justified. The shaded area of the above figure presents data after

10,000 seconds and displays the portion of the response used by Dr. Blunt. The portion of the figure that is not shaded illustrates that Dr. Blunt has ignored almost half of the data (2 log cycles) that are available to him.

We note that the results shown in Figure 3 above is a generic observation for the situation that occurred in Macondo; that is, other rate values will result in similar curves. For example, in Figure 4 below we show the derivative curve for two rate values taking into account the choke changes that occurred at Macondo: the curve in blue is the same curve shown in Figure 3 and the curve in green is the derivative curve for the rate of 45,000 stb/day assumed by Dr. Blunt. We see that our observation will also hold for the rate assumed by Dr. Blunt. This point may be understood by comparing the derivative curves used by Dr. Blunt with those given in Dr. Gringarten's report.

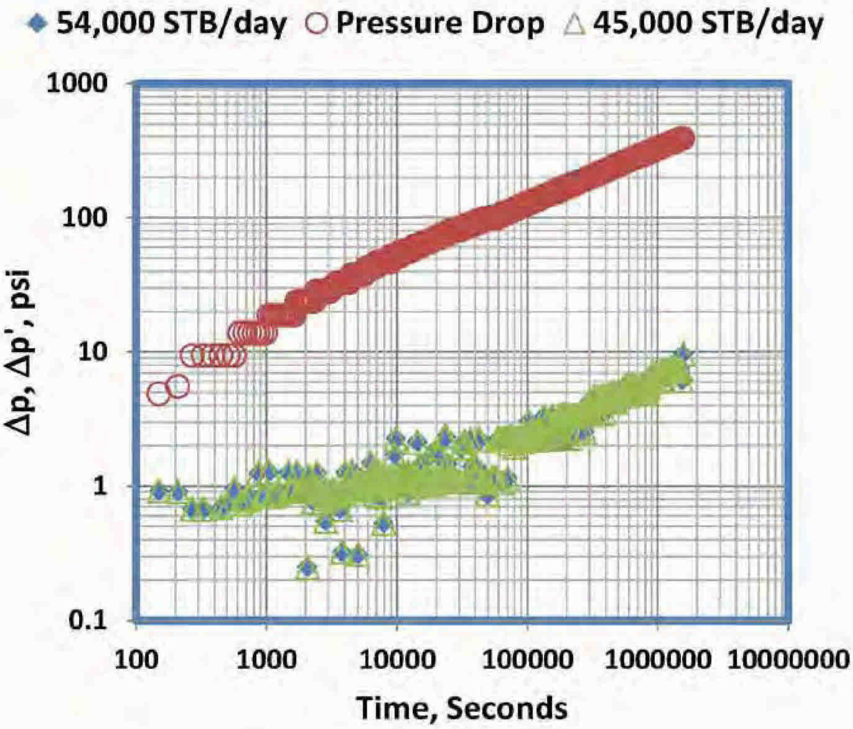

Figure 4: Influence of the Magnitude (54,000 vs. 45,000 STB/day)

[redacted]

The reasoning Dr. Blunt gives in his report is circular because, by assuming both a flow rate and the duration of the production period, the cumulative oil produced may simply be obtained by multiplying the two numbers. Ironically, this is exactly the (unfounded) criticism that Dr. Blunt leveled against certain of the United States' experts ("… and then assumed a fixed outflow performance over the period of the spill. This pre-determined – within narrow bands – the cumulative flow").[27]

The second crucial shortcoming in Blunt's analysis is that, by assuming a permeability of the reservoir from the MDT analysis that has withdrawn at most a few barrels of oil from the reservoir, Dr. Blunt ignores the influence of support volume. [redacted] As a result of the lack of consideration of the issue of support volume, Dr. Blunt's analysis is suspect.

[redacted]

[27] Dr. Blunt, M.: "A Calculation of the Volume of Oil Released during the Deepwater Horizon Incident," May 1, 2013; p. 137.

[redacted]

[redacted]

Dr. Gringarten. Credence cannot be given to the Gringarten report for the following reasons: (i) The analysis is not based on rate measurements that actually took place at Macondo, [redacted] (iii) the report uses a permeability estimates based on production of a few barrels or less and does not address the issues concerning support volume and ignores upscaling of estimates of permeability based on reconstructed MDT data.

The Gringarten report begins by recognizing the importance of rate for pressure analysis by noting that "well testing cannot be used to infer the critical parameter of permeability reliably unless flow rate history is known"; see page 9. Further on page 25, the report notes the principal limitation of well testing by the statement "and that is exactly what a well test can tell us, *provided we know the flow rate*." That reliable rate measurements are part and parcel of a viable pressure analysis is undeniable. Through a series of steps, Dr. Gringarten uses a technique known as deconvolution to arrive at the results shown in Figure 5.10. In the process, in the legend of Figure 5.8 the Gringarten report notes that resolution of the gauge PT-3K-2 is 5 psi. The value of 5 psi is also noted in the Blunt report. This resolution is quite poor in terms of our current expectations for undertaking a pressure analysis in the modern context. These days we expect the resolution to be 0.0001% of full scale;[31] thus if we wish to measure pressures in the range of 0 to 10,000 psi (as at Macondo), we require a gauge resolution of 0.01 psi. This observation is not unusual for as noted in Whittle *et al.* (of which Dr. Gringarten is a coauthor) the gauge resolution should be 0.01 psi.[32] This observation suggests that BP probably had no intention of using this gauge except to ascertain the magnitude of pressure.

The procedure used by Dr. Gringarten for his deconvolution process is outlined on Page 36, Section 5.1 of his report. Here he acknowledges that a rate must be known to begin the deconvolution process where he notes that "I must first assume a flow-rate history as a starting point." He also recognizes that his assumed rates are approximate. In outlining his philosophy of calculating rates, Dr. Gringarten starts with two hypothetical profiles for the flow rate, provides these two rate profiles to Dr. Johnson and asks him, Dr. Johnson, to calculate the bottom-hole pressure corresponding to these profiles. The pressures determined by Dr. Johnson are then used in the deconvolution process to calculate the rate profile that may have occurred during the blow out. But Dr. Johnson does not provide a pressure profile for the entire duration of the blowout and thus Dr. Gringarten must make additional assumptions, for on Page 36 he notes that the "pressure decreases linearly" from the instant of blowout until "the first pressure

[31] Kamal, M. M. (2009), Transient Well Testing, Monograph 23, Society of Petroleum Engineers, Richardson, Texas (page 38).
[32] Whittle, T. M., J. Lee, and A. C. Gringarten, Will Wireline Formation Tests Replace Well Tests? Paper presented at the SPE Annual Technical Conference and Exhibition held in Denver, Colorado, U.S.A., 5-8 October 2003.

measurement on May 10." This is an ad hoc assumption and has no basis. In his model, this hypothetical, calculated and assumed pressure profile is the force that drives the reservoir to produce. Technically, for a given system, this pressure profile can yield one and only one rate profile, so if the rate profile is changed during the deconvolution process the pressures must be recalculated. [redacted] If, at the end of the analysis, he were to make adjustments to the results of his analysis, then his revised estimates would not honor the picture he paints.

The results obtained by deconvolution in the Gringarten report are not tailored to a specific rate schedule. Any number of rate schedules could fit this data because, as Dr. Gringarten himself notes, deconvolution "does not provide absolute values" (of rate); see page 45. This means that the value of permeability obtained through deconvolution does not represent the permeability of the Macondo reservoir and may be adjusted in any manner should the engineer so desire (downwards or upwards). Basically, the reader must understand that as noted in Houze, *et al* deconvolution "can be extremely misleading if not handled with care and proper understanding of the underlying hypotheses and limitations." And here Houze, *et al*, are talking about situations where there is no concern about the rate schedule. The final step in Dr. Gringarten's analysis is the scaling of the deconvolution results to MDT estimates of permeability. Consideration of the MDT responses suggests that these results should be used only qualitatively to obtain an order of magnitude estimate of permeability. [redacted]

The implications of Dr. Gringarten's conclusion that the Macondo well is located in a reservoir with negligible aquifer support are subtle in two ways. First, the universe of models used by Dr. Gringarten does appear to include the existence of aquifer support. [redacted]

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[33] Houze, O., Tauzin, E. Olivier A. (2010), New Method to Deconvolve Well-Test Data Under Changing Well Conditions, Paper SPE 132478, presented at the SPE Annual Technical Conference and Exhibition held in Florence, Italy, 19–22 September.

As the end product of his deconvolution process, Dr. Gringarten arrives at a model, which is that of a well in a single-layer, rectangular-drainage region, quite unlike that used by all other United States and BP experts, despite the recognition in the report that "information from geology, geophysics and petrophysics" (page 24) be included. This model is also quite unlike any of the cartoons suggested in the Blunt report concerning the geological setting of this turbidite reservoir.

In summary, credence cannot be given to the analysis in the Gringarten report, for the arbitrary assumptions made and failure to provide or honor any constraints except those chosen by Dr. Gringarten. In essence, Dr. Gringarten says that the permeability cannot be any value including the value he obtained by methods of his choosing, except the one he wills it to be. The absence of any attempt to measure rate precludes constraining rate predictions, the assumption of the reservoir model to conduct the deconvolution process does not represent the geological setting.

Despite incorporation of sophisticated procedures, Dr. Gringarten has had to admit that deconvolution is inadequate. The values for average pressure he arrives at are given on page 35 of his report indicate that the average pressure is in the range of 10,364 to 10,460 psi. The value we obtained using the Mead method (which Dr. Gringarten criticizes as unsophisticated and out of date) is 10,395 psi, which compares extremely favorably with the values Dr. Gringarten derives. The various issues pertaining to the absence of a reliable rate schedule so eloquently noted by Dr. Gringarten have not escaped our attention. We considered attempting a well test analysis. However, recognizing the limitations and challenges where all theoretical developments in well testing have presumed a reliable rate schedule is available, we have explored methods that do not rest primarily upon the existence of a reliable and unequivocal rate schedule. Fortuitously, methods do appear to exist whereby average pressure may be determined and not many assumptions need to be made regarding the flow rate, particularly in light of the absence of reliable and unequivocal measurements of rate. We found one method that does not depend on a rate schedule and this was considered in our initial report. In particular, Dr. Gringarten criticized our use of the Mead method. Criticisms of the Mead method are acceptable only if we were to ignore modern data mining techniques. The viability of this method may be tested with examples that are available in the literature, so that its range of applicability may be better understood. We searched the literature and compared Mead estimates with what other analysts had done using conventional well test methods. Here, we present two examples. In Dr. Lee's textbook first edition (Table 2.3), he calculates an average pressure of 4,411 psi for a particular reservoir. For the same reservoir, using Mead, we calculate 4,413 psi, a difference of just 2 psi. The second example is from the Earlougher monograph. He calculates a pressure of 3,342 psig for the reservoir in question. Using Mead, we calculate 3,326 psig, a difference of just 16 psi. These examples demonstrate how favorably the Mead method compares with more complex well test analysis methodologies. [redacted] Based on the observations given here,

[34] Lee, W. J. (1982) Well Testing, SPE Textbook Series (1), Society of Petroleum Engineers of AIME, New York, NY and Dallas. TX., 159 pp; Earlougher, R. C. Jr. (1977) Advances in Well Testing, SPE Monograph Series (5) Society of Petroleum Engineers, Dallas TX, 264 pp.

we believe that a disinterested evaluation makes clear that a blanket disregard of our approach by Dr. Gringarten is unfounded.

[redacted]

[redacted]

[redacted]

[redacted]

INFORMATION REQUIRED BY THE FEDERAL RULES OF CIVIL PROCEDURE

Together with our original report, this report contains our opinions, conclusions, and the reasons therefore. The information required by the Federal Rules of Civil Procedure was set forth in our original report.

The opinions expressed in this report are our own and are based on the data and facts available to us at the time of writing. Should additional relevant or pertinent information become available, we reserve the right to supplement the discussion and findings in this report.

Appendix A. Response to Critiques of Choke Calculation

[redacted]

[redacted] In our calculations of rate through choke for various choke valve settings, we observed that the rate goes through a maximum as choke is progressively closed. In our original report, we cautioned that the rate calculations for certain choke interval should be treated with caution since those observations are inconsistent with what we would expect to observe. We note that this same observation has been made by every engineer that has modeled flow through the capping stack, [redacted]

[redacted]

APPENDIX B. RESPONSE TO DR. STRICKLAND'S PRESSURE DROP ANALYSIS

[redacted]

[redacted]

[redacted]

CONFIDENTIAL

[redacted]

[redacted]

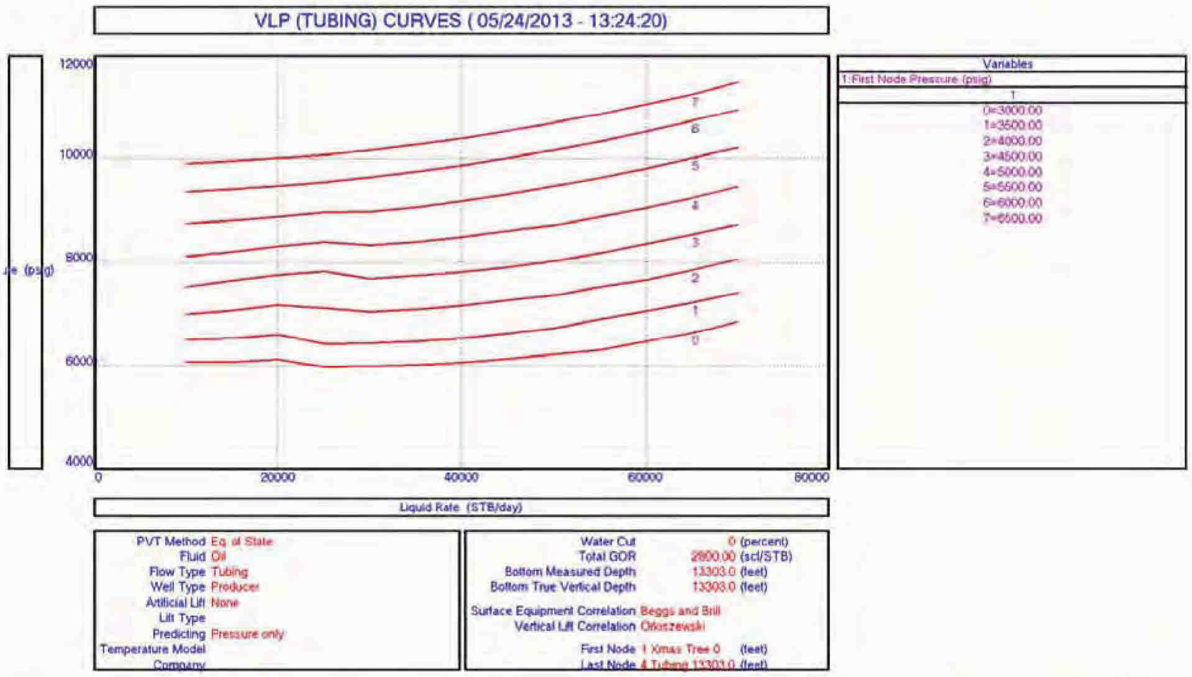

Figure 9: Calculation of Bottom Hole Pressure using PROSPER program for different BOP pressures (more realistic flow configuration than Stickland's configuration)

We also compared our results with Dr. Johnson (BP) who considered the case of the drill pipe being connected to the capping stack where flow is both inside and outside the drill pipe. This result is reproduced by Dr. Gringarten in his report.[42] Dr. Gringarten also assumes that the BOP pressure at the time of shut-in was 4,000 psia. Using that value, he reproduces the results of Dr. Johnson. For the assumption of drill pipe connected to the capping stack, Dr. Gringarten shows the BHP is in the range of 7,800 psia to 8,200 psia at a rate of 45,000 STB/day. These values are consistent with our Figure 9 above.

[redacted]

[42] Dr. Gringarten, A.: "Well Test Analysis," May 1, 2013, Appendix F, p. 23, Figure 25.

[redacted]

[redacted]

APPENDIX C. ANALYSIS OF THE IMPACT OF AQUIFER ON TOTAL VOLUME RELEASED

[redacted] However, during the spill, while trying to understand how the reservoir will behave, BP examined the possibility that an aquifer may be present and used different sizes of aquifers to study the impact.[47] The presence of an aquifer in most Gulf of Mexico reservoirs is not uncommon, so it is common practice to investigate the impact of aquifer. So, what BP did during the spill is what any oil company would do under the circumstances. [redacted] Although both Dr. Blunt[48] and Dr. Gringarten claim that an aquifer is absent based on their pressure derivative analysis, as we have discussed in the previous section, the derivative analysis is extremely sensitive to the rate profile assumed prior to shut-in. In the absence of reliable rate data, the derivative values can be significantly influenced by assumed rates just prior to shut-in. [redacted]

[redacted]

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[47] BP Macondo Technical Note, June 15, 2010, BP-HZN-2179MDL01945306; BP Preliminary Reservoir Model, July 6, 2010, BP-HZN-2179MDL04804766.

[48] Dr. Blunt, M.: "A Calculation of the Volume of Oil Released during the Deepwater Horizon Incident," May 1, 2013; p. 47; Dr. Gringarten, A.: "Well Test Analysis," May 1, 2013, p. 35.

[redacted]

[redacted]

[redacted]

APPENDIX D. SUPPLEMENTAL FACTS AND DATA CONSIDERED IN FORMING OUR OPINIONS

The following list supplements the consideration list produced with our initial report.

BP-HZN-2179MDL04440804
Ex 141219
Ex 141235
Ex 141204
Ex 141207
Ex 141231
Ex 141197
Ex 141244
Ex 141234
Ex 141228
Ex 141200
Ex 141196
Ex 141237
Ex 141218
Ex 141224
Ex 141220
Ex 141208
Ex 141239
Ex 141215
Ex 141230
Ex 141226
Ex 141199
Ex 141206
Ex 141216
Ex 141214
Ex 141241
Ex 141203
Ex 141242
Ex 141238
BP-HZN-2179MDL06745929
Ex 141217
Ex 141209
Ex 141198
Ex 141212
Ex 141222
Ex 141229
Ex 141210
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BP-HZN-2179MDL06744203
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BP-HZN-2179MDL06745330
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BP-HZN-2179MDL06743286
BP-HZN-2179MDL01872218
BP-HZN-MBI00193341
Ex 07511
Reliance Modeling Material of Defendant Expert Strickland
Reliance Modeling Material of Defendant Expert Blunt
Reliance Modeling Material of Defendant Expert Gringarten
Expert Report of Adrian Johnson PhD, May 1, 2013
Expert Report of Alain Gringarten, May 1, 2013
Expert Report of Dr. Carlos Torres-Verdin, May 1, 2013
Expert Report of Curtis Hays Whitson, PhD, May 1, 2013
Expert Report of Martin J. Blunt, May 1, 2013
Expert Report of J.P. Martin Trusler, PhD, May 1, 2013
Expert Report of Robert W. Zimmerman, May 1, 2013
Expert Report of Dr. Sankaran Sundaresan, May 1, 2013
Expert Report of Dr. Simon Lo, May 1, 2013
Expert Report of Richard F. Strickland, PhD, P.E., May 1, 2013
Reliance Modeling Material of Defendant Expert Trusler
Reliance Modeling Material of Defendant Expert Whitson
Modular Formation Dynamics Tester
Polaris Plots Results
Laser Scanning Tracking Sheet
2013_05_10_R_Gasaway_Letter_re_Expert Reports
BP-HZN-2179MDL02508352
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Ex 130240
Ex 130275
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Ex 9577
Ex 8669
Ex 141195

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BP-HZN-2179MDL07805896
BP-HZN-2179MDL07796900
BP-HZN-2179MDL07033641
Tidwell, W. C., and J. L. Wilson (2000), Heterogeneity, permeability patterns, and permeability upscaling: Physical characteristics of a block of Massillon sandstone exhibiting nested scales of heterogeneity, *SPE Res. Eval. Eng.*, 3(4), 283–291
Raghavan, R., and F. Kuchuck (2009), Multilayer reservoirs, in Transient Well Testing, edited by M. M. Kamal, Monograph 23, Society of Petroleum Engineers, Richardson, Texas
Whittle, T. M., J. Lee, and A. C. Gringarten, Will Wireline Formation Tests Replace Well Tests? Paper presented at the SPE Annual Technical Conference and Exhibition held in Denver, Colorado, U.S.A., 5-8 October 2003
Al-Harbi, A., A. Gringarten, R. Akkurt (2007), A Practical Approach to Determine Permeability from Wireline Measurements, SPE Saudi Arabia Section Technical Symposium, 7-8 May, Dhahran, Saudi Arabia
Kamal, M. M. (2009), Transient Well Testing, Monograph 23, Society of Petroleum Engineers, Richardson, Texas
Houze, O., Tauzin, E. Olivier A. (2010), New Method to Deconvolve Well-Test Data Under Changing Well Conditions, Paper SPE 132478, presented at the SPE Annual Technical Conference and Exhibition held in Florence, Italy, 19–22 September
Lee, W. J. (1982) Well Testing, SPE Textbook Series (1), Society of Petroleum Engineers of AIME, New York, NY and Dallas. TX
Earlougher, R. C. Jr. (1977) Advances in Well Testing, SPE Monograph Series (5) Society of Petroleum Engineers, Dallas TX
AE-HZN-2179MDL00064585
Gao, C., Jones, J.R., Raghavan, R., and Lee, W.J. 1994. Interpretation of Responses of Commingled Systems with Mixed Inner and Outer Boundary Conditions Using Derivatives. SPE Formation Evaluation, 9(4), 264-271

Dake, L.P. (1994) The Practice of Reservoir Engineering, Developments in Petroleum Science, 36, Elsevier Science, B. V. Amsterdam
BP-HZN-2179MDL01945306
BP-HZN-2179MDL04804766
BP-HZN-2179MDL01945308
Dake, L.P.: "Principles of Reservoir Engineering," Elsevier Publications, 1978, chapter 9