UNITED STATES DISTRICT COURT
EASTERN DISTRICT OF LOUISIANA

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

DOCKET NO. MDL-2179
SECTION "J"
NEW ORLEANS, LA
OCTOBER 17, 2013

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IN RE: THE COMPLAINT AND PETITION OF TRITON ASSET LEASING GMBH, ET AL

DOCKET NO. 10-CV-2771
SECTION "J"

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UNITED STATES OF AMERICA
V.
BP EXPLORATION & PRODUCTION, INC., ET AL

DOCKET NO. 10-CV-4536
SECTION "J"

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DAY 11 MORNING SESSION
TRANSCRIPT OF NONJURY TRIAL PROCEEDINGS
HEARD BEFORE THE HONORABLE CARL J. BARBIER
UNITED STATES DISTRICT JUDGE

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I N D E X

Testimony of:

P-R-O-C-E-E-D-I-N-G-S

OCTOBER 17, 2013

M O R N I N G   S E S S I O N

(COURT CALLED TO ORDER)

8:00 A.M.

08:07AM THE COURT: Good morning, everyone.

08:07AM Looks like our government workers will be paid after all. The other side of the table is probably very happy. These people down here are happy. At least until January when we have the next crisis.

08:07AM Okay.

08:07AM MR. FIELDS: Your Honor, just one administrative matter. Barry Fields on behalf of BP.

08:07AM I have in my possession a list of the exhibits that were used during the examination of Dr. Robert Zimmerman.

08:07AM That list of exhibits was circulated to the parties a couple of days ago. We did not receive an objection. So, at this time, we would offer those exhibits into evidence.

08:08AM MS. HIMMELHOCH: No objections.

08:08AM THE COURT: Very well. Without objection, those will be admitted.

08:08AM (Exhibits admitted.)

08:08AM MR. FIELDS: Thank you, Your Honor.

08:08AM MS. HIMMELHOCH: Your Honor, Sarah Himmelhoch for the

United States. Another short housekeeping matter.

Last night, BP filed an offer of proof reasserting their arguments on the surrebuttal motion. It is my understanding that we are not supposed to respond to that, but I wanted direction from the Court as to whether you expected a response.

THE COURT: I haven't even seen that, so I have no idea what that's about.

MS. HIMMELHOCH: Okay. We'll await an order from the Court before filing a response, sir.

THE COURT: All right.

MS. PENCAK: Good morning, Your Honor. Erica Pencak for the United States. Just one more preliminary matter. I have list of the United States call-outs, demonstratives, and exhibits used in the United States' examination of Drs. Merrill, Gringarten, and Zimmerman.

We've circulated these lists to the parties and received no objections.

THE COURT: Okay. Any remaining objections?

Hearing none, those are admitted.

(Exhibits admitted.)

MS. PENCAK: Thank you, Your Honor.

THE COURT: All right. According to our timekeepers, United States has used 16 hours, 33 minutes. There's 28:27 remaining. BP has used 21 hours and 49 minutes. They have

23:11 remaining.

Good morning, Dr. Zaldivar. You're still under oath.

THE WITNESS: Yes.

MR. CHAKERES: Your Honor, may it please the Court?

THE COURT: Go ahead.

CROSS EXAMINATION

BY MR. CHAKERES:

Q Nat Chakeres on behalf of the United States. Dr. Zaldivar, I have you on cross examination.

Dr. Zaldivar, your model is a one-dimensional model; correct?

A That's correct.

Q The results that come out of your modeling that will you present to the Court are mass flow rates; right?

A Those aren't the only results. What I presented to the Court yesterday were volumetric flow rates.

The model itself works in a basis of units that is mass based.

Q Are stock tank barrels a defined unit of mass or a defined unit of volume?

A That's a unit of volume. That's a volumetric flow rate.

Q You used a single stage flash process to convert the total mass flow rate in your model for stock tank barrels; correct?

A That's correct.

Q Before we get too far along, I wanted to make sure we have some terms and definitions out there. That, we're speaking the same language.

You had a demonstrative yesterday where you described different flow patterns.

Do you remember that?

A Yes, I do.

Q It included stratified flows, stratified wavy flow, slug flow, and other types of flow patterns; right?

A Yes, that's correct.

Q I might at some point call those flow regimes; that the same sort of thing?

A Flow patterns and flow regimes are two commonly used words, yes, that's correct.

Q Thank you, sir.

Now, I want to go back to this mass flow rate issue. For a single phase fluid, we'll stick with that, can we say that mass flow rate is equal to the density of the fluid times its mean velocity times the area through which it's flowing? Is that a definition of mass flow rate?

A Could you repeat that?

Q Yes.

And, actually, I've got a demonstrative just so we don't have to keep all this stuff in our head.

MR. CHAKERES: If we could pull up demonstrative

D-0221.

BY MR. CHAKERES:

Q And, again, we'll stick with single phase flow right now.

Is this an accurate representation and equation of mass flow rate along one dimension?

A Yes, that's correct.

Q Okay. And, for multiphase flow, you had multiphase flow in your model; correct?

A That's also correct.

Q We would have to make this a little bit more involved; right? We would have a mass flow rate for gas phase and a mass flow rate for the liquid phase; right?

A Yes, that's correct.

Q And the mass in both the gas phase and the liquid phase would have their own densities; right?

A Yes.

Q And both would have their own velocity; right?

A Yes, that's correct.

Q And then we would have an area for flow for each of them; right?

A Yes. That's also correct.

Q And, before we get too far along, you've spoke in your deposition about something called superficial velocity; right?

A Um-hum.

Q Is it fair to say that, if we are using the word superficial velocity, that's just the velocity of that phase, and then we don't have to worry about how much of the area is taken up for that phase?

A It's the average phase velocity.

Q The average phase velocity averaged across the entire flow area?

A Averaged across the area that it's flowing, yes.

Q So this equation is the definition of mass flow rate, but we have mass flow rates for both phases in a multiphase environment; correct?

A Yes. You also have the total mass flow rate, so that --

Q And that is the sum of the mass flow rate for each phase; right?

A Yeah. That equation could apply to the multiphase flow if the velocity itself was the average mixture velocity.

Q I appreciate that. Thanks. We can take down that demonstrative.

Now, your flow rate estimate that you presented to the Court consists of an estimate of flow out the end of the riser and an estimate of flow out of the kink leaks; correct?

A That's correct.

Q And you described yesterday how you went through arriving at both of those estimates.

For the estimate of the flow out of the riser, you used LedaFlow to predict the flow rates at which observed slug

behavior took place; right?
A That's correct.
Q You looked at two points in time, May 13th and May 16th; correct?
A Yes, that's also correct.
Q And you also looked at the period after May 20th to see what flow rates would result in the riser being flat along the floor of the ocean; correct?
A No. That's not precisely correct.
Q How is that not correct?
A I didn't model any time period past May 20th.
I did look at that period with respect to looking at ROV videos to ensure that slug flow was not present after May 20th.
Q Thanks for that clarification.
Now, you don't opine anywhere in your report that the flow out of the end of the riser was changing between May 13th and May 20th; do you?
A No, I do not.
Q You provide the same estimate for each of the days, May 13th through 20th, at the end of the riser; correct?
A I provide the same best estimated flow rate, but I do provide a range of flow rates over the full period.
Q Okay. Thank you.
Now, you testified yesterday about something

called a hydraulic diameter, and I'd like to go into that a little bit now.

Now, the diameter of the flow path in your model was what you were referring to as the hydraulic diameter; correct?

A Yes, that's correct.

Q So, in your model, the information you gave LedaFlow about the size of the flow path was the hydraulic diameter; correct?

A Yes. That's an input -- you have to input the diameter into the model, and that's the diameter that I used.

Q And you testified yesterday that the hydraulic diameter is a standard geometric transform that you use when you have a noncircular flow path; is that correct?

A A standard geometric transformation. But, yes, that's correct.

Q It's standardly used in fluid mechanics problems; correct?

A Yes.

Q And it's been used in steady state flow problems; correct?

A Yes.

Q It's been used in transient flow problems; correct?

A Yes, that's correct. Also correct.

Q It's used in single phase flow problems; correct?

A Yes, that's correct.

Q It's used in multiphase flow problems; is that correct?

A Yes, that's correct.

Q It's used in problems where there's constant density; correct?
A Most of the time that you're modeling flow, certainly if you're looking at large-scale flow phenomenon, you would expect that the density would be changing because pressure and temperature would be changing.
I am sure that it probably has been used; but, certainly, the problems that I'm most familiar looking at are large-scale problems, so you wouldn't presume that the density doesn't change over the model itself.
Q Thank you.
And my question was just, if I were to perform -- look at a problem where, say, it was an incompressible fluid and I didn't have to worry about density changes, you would expect the hydraulic diameter concept to still apply in those types of problems?
A I would expect that to be true. But, to be clear, this particular problem is compressible fluid. Gas is quite compressible, and multiphase flow is considered a compressible flow problem.
Q I appreciate that.
MR. CHAKERES: Now, if we could go to demonstrative D-22210.
BY MR. CHAKERES:
Q You talked about this a little bit yesterday, and I just

wanted to go through it again. So I have here on the left a pipe that has the drill pipe inside it.

Do you see that?

A I do.

Q And, for your model of the riser, the large -- there are several different segments that have different diameters of the drill pipe inside of it; right?

A Yes, that's correct. The drill pipe did not have the same diameter down the length of the riser.

Q The large majority of the riser, though, had 6.625 inch drill pipe inside of it; right?

A By large majority, about three-quarters of the riser, or near that amount, had that specific drill pipe diameter.

Q We'll take that.

And the general form of the equation for a hydraulic diameter is four times the area through which the fluid is flowing divided by perimeter, the wetted perimeter; correct?

A That's correct.

Q And you describe that in your report; correct?

A I do.

Q And, specifically for an annular flow, you derived sort of a shortcut, which is true for all annular flows, which the hydraulic diameter is equal to the diameter of the big pipe, the inner diameter of the big pipe, minus the outer diameter of the

little pipe; is that correct?
A Yeah. I wouldn't describe it as a shortcut. If you apply the formula 4A over P and you simplify that formula, you can simplify it to that specific relationship for flow in any annulus.
Q It means the exact same thing as 4A over P for annular flow path; doesn't it?
A Yes, that's correct.
Q And, if we were to pretend the drill pipe were perfectly centered in the riser, the hydraulic diameter is equal to double the gap between the inner pipe and the outer pipe; isn't it?
A Could you repeat that?
Q Yes.
So presuming the drill pipe is perfectly centered, there's a gap between the drill pipe and the riser; right?
A That's correct.
Q And the hydraulic diameter would be double that gap; right?
A So, if you're asking me in this specific example that if 12.875 minus 6.625 is approximately two-thirds, so there would be half of it on both sides, yes, that's correct.
Q That wasn't quite my question.
My question was, so you have -- the derivation of the hydraulic diameter is the big pipe diameter minus the small pipe diameter; right?
A That's correct.

Q Half of that would then be the big pipe radius minus the small pipe radius; right?
A Half of what specifically?
Q Half of the hydraulic diameter.
A Half of 12.875 is 6.4 something.
Q And I'm not trying to say that this is one-third of the whole thing.

I'm saying, for any annular flow path, the gap between the drill pipe and the riser times two is the hydraulic diameter; right?
A I am not sure that that's generally true without deriving it. Certainly, you could imagine a pipe that's very small -- yeah, it might be true, though.
Q So this formula -- and we'll look at that again. So this formula, it's not true just for the annular flow path that you modeled; right? It's true for any annular flow path. That's the hydraulic diameter for that annular flow path; right?
A That is true.
Q Okay. We can pull that demonstrative. We'll come back to that in a minute.

Now, you testified in your deposition that the reason why you use a hydraulic diameter as opposed to the actual -- or the diameter relating to the actual flow area is because you want to maintain the ratio between the cross-sectional area of the flow and the wetted perimeter; correct?

A That's correct.
Q And is it correct to say that the reason you do this is because the cross-sectional area for flow is proportional to the driving force, there's a pressure drop for the pipe, and the wetted perimeter is proportional to the frictional force acting against flow?
A Yes. I would generally agree with that. I don't know that I would say that they're directly proportional, but there is a relationship between those.
Q And that relationship is why you need to maintain the ratio between the area in the wetted perimeter; right?
A Yeah. In order to correctly capture the relationship between pressure drop and volumetric flow rate or flow rate period.
Q Now, you testified in your deposition that LedaFlow uses the hydraulic diameter and calculates the pressure drop based on velocities and frictional losses associated with those velocities; correct?
A That's correct.
Q And so the fluid velocities in the system are used in conjunction with the hydraulic diameter to calculate pressure drops; correct?
A Yes, that's correct.
Q You want to accurately capture the pressure drops in the system; right?

A That's correct.
Q And that's why you used the hydraulic diameter; correct?
A That's also correct.
Q You also want the velocities in your model to be correct; correct?
A No, that's not correct.
Q You do not want the velocities in your model to be accurate?
A I think, ideally, I would want to capture the correct two representation of the velocities.
However, when you make a geometric transformation, such as the hydraulic diameter geometric transformation, essentially what you're doing is you're narrowing the area of the pipe itself.
When you do that, you increase the speed of the fluid in that pipe in order to correctly capture the relationship between pressure dropping and flow rate.
Essentially, if you think of his demonstrative where you have a drill pipe flowing through the center of it, that drill pipe has -- exerts extra frictional resistance to flow.
And what the hydraulic diameter does, is it takes a smaller pipe so that you get the same resistance to flow and then the fluid flows faster.
Q So it's your testimony that the velocities in your model were not the accurate velocities that were present in the

Macondo riser?

A Yes, that's correct. What my model captures correctly is the volumetric flow rate and pressure drops.

Q Now, you testified in your deposition that you ran your model for a while, an hour, two hours, to stabilize the velocity profiles, the pressure profiles, temperature profiles, and the density profiles before you imposed the oscillation of the riser. Do you remember that?

A I do.

Q And you testified that you wanted to have your velocity profiles that were as near as the actual conditions as possible before starting to move the riser; do you recall that?

A I do.

MR. FIELDS: Your Honor, may I be heard? Barry Fields.

The one issue I have is, it's not really appropriate to talk about what he testified in his deposition. You can ask a question and get an answer here, but that's not a proper --

THE COURT: That's correct. Wait a minute. Ask the witness a question, and obviously you can phrase your question based on something that was said in the deposition. But phrase it as a question.

If he gives an answer that you think is contrary to what he said in his deposition, then you can use his deposition; okay?

MR. CHAKERES: I will do so, Your Honor.
BY MR. CHAKERES:
Q So, when you ran your model, you ran it at a steady state for a certain period of time in order to allow it to stabilize before oscillating the riser; correct?
A That's correct.
Q And the reason you did that was because you wanted to get representative temperature profiles, pressure profiles, density profiles and velocity profiles that were as near the actual conditions as possible before you started to move the riser; correct?
A Yes. So, when you start one of these models, you have to spend some time allowing the model to stabilize. Because, when you jump into the Macondo well on May 13th, well, it had been flowing for some time, which means that it had temperature profiles across the walls. As I described earlier, you have the riser, and there's a temperature gradient; and then there's the buoyancy model, and there's a temperature gradient. And all of those materials hold heat.
And so, when you build a model, you run it to steady state or you run it until all the conditions stabilize so that you do have these stable representative pressure profiles and temperature profiles throughout the model.
Q But your testimony now is that your velocity profile is not representative of what was actually in the riser; correct?

A It wasn't the true velocity. It was a representative profile of a stable profile for those conditions. Yes, that's correct.
Q And those conditions means a smaller pipe than what was actually in the Macondo riser; right?
A It means, yeah, I used the geometric transformation for hydraulic diameter. And, in doing so, I have to allow my model to stabilize. I have to allow it to start from something that would represent those conditions that Macondo was in, yes.
Q Now, yesterday you testified a little bit about flow patterns; right?
A I did.
Q And you stated -- and if we could pull up -- well, we'll keep going along.
You stated that if you have stratified flow, that corresponds to slow gas flow and slow liquid flow; right?
A I don't think I used those exact words.
Stratified flow is the velocities, we're talking about superficial velocities or average phase velocities, and it generally is present when the ratio between the gas velocities and the liquid velocities are near each other.
It could be moving quite fast. But, if the gas is moving faster than the liquid, you would see waves or ripples on the surface of the liquid.
If they're moving at the same speed, you're going

to see liquid at the bottom of the pipe with gas on the top of the pipe, and you won't see much rippling in the surface.

THE COURT: No matter what the speed?

THE WITNESS: No matter what the speed.

BY MR. CHAKERES:

Q So, if both of them were moving, say, one meter per year, very, very slowly, right, you would not see the ripples on the waves; right?

A Not if they were moving at the same speed, no.

Q Then let's double the gas to two meters per year. That's still very, very slow; right?

A Just the gas portions of the liquid?

Q The liquid is still moving at one meter per year.

A Yes.

Q And the gas is now moving at two meters per year. Very, very slow. Are you going to be seeing waves kicking up there?

A I would guess not likely.

Of course, to know the answer to that, you would need to model the specifics of the fluid. You'd need to know something about the interfacial friction; you'd need to know something about the particular fluid viscosity. The thicker fluids tend not to ripple as easily.

So there's lots of sophistication and complexity to multiphase flow. In that particular example with very slow-moving fluids, I would say it's unlikely. But, without a specific example, I don't know that.

I can generally answer that question for all problems.

Q Now let's assume the fluids were moving at 10 meters per second. Both the gas and the liquid are moving at 10 meters per second. Are you with me?

A I am.

Q Much faster flow through the riser; right?

A That's correct.

Q Now we double the gas velocity there from 10 meters per second to 20 meters per second.

Do you think it's going to be the same change in flow patterns as you had when the flows were thousands of times smaller?

A No, probably not. Again, you have to look specifically at the fluid conditions in order to draw general conclusions.

MR. CHAKERES: Let's look at demonstrative D-2205.

BY MR. CHAKERES:

Q Now, we have here -- over here on the left is the actual riser. We have the outer diameter of 915.5 inches, or diameter of the outer pipe 915.5 inches, diameter of the inner pipe 6.625 inches.

Do you see that?

A I do.

Q And now we have your model. It's got a hydraulic diameter

of 12.875 inches; right?
A That's correct.
Q Now, I'll just throw out a hypothetical here. I've multiplied my -- the riser by 3, but I've maintained the difference between the diameter of the outer pipe and the inner pipe. So I have the same hydraulic diameter. And we can subtract these if you want. But those should come out to 12.875 inches.
Do you see that?
A I do.
Q The flow area for this large pipe is about 1050 square inches.
Do you see that?
A I do.
Q The flow area for your model is about 130 square inches.
Do you see that?
A I do.
Q Now, we have the same hydraulic diameter in both of these cases; don't we?
A Yes. That's precisely the point.
Q Precisely the point. I'm sorry. Let you finish.
A You can't think of this in terms of -- I mentioned this as a counterintuitive phenomenon. I mean, if you think about it -- unfortunately, everything in science isn't intuitive. This is one of those situations where it's not the most intuitive

situation.

But, in this particular example, yes, it's exactly the same hydraulic diameter. If you have a straw with an obstruction and you're trying to suck fluid into your mouth, that straw requires you to exert more effort.

You can take a smaller straw and exert the same amount of effort and get the exact same amount of fluid in your mouth.

If you have a big, big straw with a big, big straw in the center of it, in terms of the amount of force to get the same fluid, or the volumetric flow rate, it's the exact same force.

Q Well, it's not really counterintuitive when we say that we're maintaining the velocities across these; is it?

Because we have here about the same distance from, you know, the inner wall and the outer wall, so we're maintaining the relationship between the area for flow and the wetted perimeter.

So, if we say that the frictional pressure drop versus velocity relationship stays the same across all of these, it's not so counterintuitive; is it?

A It may not be counterintuitive to you, but it would also be incorrect to do so.

Q So is it your testimony that, for a given pressure drop, same pressure drop across each of these three examples -- same fluid, same temperature, everything -- for the same pressure drop, you are going to get the same amount of flow through each of these?

A Not the same velocity; but you will get the same volumetric flow rate, yes, that's correct.

Q So I can keep expanding this riser over here. I can push this riser out to a thousand; and, as long as I have the same hydraulic diameter, just by pushing my inner pipe out in the same way, I can increase my area for flow up to a thousand.

I have the same pressure drop pushing flow through this giant riser as I do through your little model, and I'm going to get the same amount of flow through there?

A Well, I don't agree with the premise that you can extend this model to infinity. At some point, and you might actually be approaching that point in this particular example, you approach what's called flow between two parallel plates.

But, in general, despite the fact that it's counterintuitive, it is correct.

Q If I extend this thing out to a thousand, if I am maintaining a relationship between the velocity and the pressure drop, because every bit of flow has got a similar amount of drag because it's got a similar amount of space to flow through, it's not really counterintuitive if I maintain the velocity but I allow my mass flow rates or volumetric flow rates to vary in this case; is it?

A Yeah. But, unfortunately, that's not what the science tells us to be true.
Q So you think the hydraulic diameter concept breaks down around here, but it's still okay over here?
A No. I think it's probably okay in the 3X scenario; however, you cannot extend this riser out bigger and bigger and bigger. Eventually, you're going to get to a situation where the fluid, for instance at the top of the pipe, has no interaction with the fluid at the bottom of the pipe.
It would be the equivalent of imaging a pipe the size of the earth with a tiny little layer. Well of course the fluid here would have no idea what the fluid there is doing.
There are specific ratios where when you extend this out to large, large system with very large inner pipes where hydraulic diameter is not considered the correct geometric transformation.
But, for the purpose of the demonstration, I'm going with it. It is counterintuitive; and, yes, this model is the correct answer.
Unfortunately, no, it doesn't give you the true velocities, but it does give you the correct relationship between pressure drop and flow rate.
Q So let's go to an expert report from one of your colleagues. It's Exhibit 11488. Page 24.
BY MR. CHAKERES: If we could call out figure 9.

BY MR. CHAKERES:
Q Did you read the expert report of Adrian Johnson?
A I did not.
Q Do you recognize this as a flow regime map?
A I do.
Q Now, this represents where flows are going to be in different flow regimes, which we described earlier is going to be something similar to flow patterns.
Do you see that?
A I do.
Q It's a little hard to read, so we can pull out some of the language if we need to.
Now, let's look at the axes.
We have here on the bottom something called, I believe it's rho liquid/*v* liquid squares.
Do you see that?
A I do.
Q And then, on the y-axis, we have a rho gas/*v* gas squared; right?
A I do.
Q And we can pull out the page. Dr. Johnson was kind enough to define for us what rho and *v* represent here.
If we could go out to the main page. We see here, rho liquid is density of the liquid. *v* liquid is the superficial liquid velocity. UG is the superficial gas

velocity. Right?

Do you see that?

A I do.

Q Let's go back to the flow regime map. This map tells us what flow regime we're in based on the velocities and the densities that we have, not a ratio of them that you're allowed to scale by whatever factor you want; right?

It's the actual velocities and the actual densities of each fluid that determine what flow regime you're in; isn't it true?

A It's, in fact, kind of the ratio. But, yes. I'm not sure exactly where this map was taken from. I'm not familiar with Hewitt-Roberts.

But these maps, generally speaking, are built for particular angles. They have a very specific. You often see the x-axis and y-axis to be a series of nondimensional terms.

But, in general, what you're comparing is what is the relative gas velocity to the relative liquid velocity, and that says something about the flow regime.

Q Right. The relative velocities. It's not the ratios of the velocities. If both of them are one meter per year, you are going to wind up somewhere way down here, even if one of them is ten times the other.

But, if you start getting over in the actual velocity of the gas is something much greater, then the same

ratio might do something different in terms of what flow regime you're in; won't it?
A Yeah, that's correct. And that's consistent with what I said earlier. If I have used the term ratio, I've used it to represent this chart itself.
But, in your specific example, you asked me if a ratio at a very low speed was likely to be stratified smooth, and then you took that same ratio and scaled it up to a high speed. Then I said it is likely to result in stratified wavy. So it is consistent with what I've said to you.
MR. CHAERES: If we could go back to demonstrative D-2205.
MR. CHAERES:
Q So, in this case, you're saying that, for a given pressure drop, the velocity up here is going to be different from your model by a factor of 8; right?
For a given pressure drop, same hydraulic diameter. You're saying the velocity in this larger shape is going to be 8 times less than the velocity in the model; right?
A I didn't say anything about velocity.
Q Well, for a given pressure drop, what do you think is going to happen to the velocities between, say, a model with the same hydraulic diameter as this shape right here?
A I would need to do some math here. I'm presuming that the ratio of 1053 to 130 is somewhere near 8, which is how you're

coming up with this 8 times velocity.

Surely, what I'm saying is that the velocity and modeled riser in this example would result in a substantially higher velocity than the velocity in 3 times the riser.

And, again, we're really talking about the average mixture velocity. Remember, in multiphase flow, there are multiple different velocities. The gas is moving at a different speed.

But, yes, the average velocity certainly is going to be significantly faster in the modeled riser, as you've got it termed.

Q The very crux of what you're trying to do in this case is you're trying to provide the Court with an estimate of flow rates based on what flow patterns you observed; correct?

A That's correct.

Q And the flow patterns that you're determining are based on the velocities, among other things, are based on the relative velocities of each phase; correct?

A In general, that is a true statement. But you have to be very careful with these flow regime maps.

So what these flow regime maps focus on specifically is what I was talking about, hydrodynamic slugging, which is when slug flow is determined based on those ratio. And, when I described slug flow at the beginning, that's the way I described it.

But one of the other mechanisms for slug flow is terrain-induced slugging, which is slugging that's determined based on the position of the riser. So liquid tends to move to the low spots in the riser, and it accumulates there; and then, occasionally, it will burp out liquid in these system.

What we have in this particular case is sort of a modification of terrain-induced slugging. So you wouldn't see on a flow map that it would be in the slug flow regime. What would you see is it would likely be in the stratified flow regime.

If we can put up video -- I don't know if we can do this. But, yesterday, one of the slugs actually looks quite like stratified flow. It is oil dominant, but it does still have a gas layer flowing across the top.

And so we're really talking about a very unique mechanism of slug flow behavior. We're certainly not talking about hydrodynamic slugging or these flow regime maps or what you get from these flow regime maps.

Q Appreciate that. You are still -- you need to wind up in the stratified flow regime ballpark upstream of the buoyant riser in order to model the slugs that you observed; correct?

A That's correct.

Q The relative velocities of the phases are still relevant to whether you're in a stratified flow regime or flow pattern upstream of the buoyant riser; correct?

A That's also correct.
Q And the relative velocities of the phases is also important in determining whether the gas can push the oil slugs all the way up the buoyant riser, or you get something to break and you create a double peak; isn't that correct?
A That's also correct.
Q So the actual relative velocities of both phases is very important in determining whether the slug behavior observed matches your flow rates; right?
A Yes, that's correct. We looked specifically at the flow regimes in this particular case. We see almost the entire riser sits in -- when you look at that traditional flow regime map, almost the entire riser sits in a stratified flow.
Q And it's your testimony, just so I'm clear, that instead of using the hydraulic diameter to get the right velocity profile, you believe that the hydraulic diameter maintains mass flow rates or volumetric flow rates, and so your model will predict velocities that are incorrect; right?
A It's not just what I believe. That's what the science tells us. But, yes, that's also what I believe.
Q Okay. Now, let's look at another example. Let's go to the kink leaks for a little while.
Now, you also use hydraulic diameters for the kink leaks; correct?
A That's correct.

Q And, before we get too much farther, there were several leaks that you modeled. There was the leak that you called leak B; correct?
A Yes.
Q And there was leak D; correct?
A Yes.
Q And then there are two other leaks that you combined; isn't that right?
A No, that's not correct.
Q How did you model the other two leaks?
A Well, just to be clear, the three leaks or four potential holes that were present were holes B and C. And then D and E were the holes that were, if you remember the drawing, they're almost touching each other. There's a very small sliver of the riser between the two holes.
Q Okay. And how did you model those two that were very close to each other?
A So I consulted Nesic, and he provided area and wetted perimeter for those holes so that I could calculate the hydraulic diameter for those holes.
Q Did you sum the areas and sum the perimeters?
A Again, Nesic provided that information.
Q Understood.
A I got a total area for those holes and a wetted perimeter.
Q Okay. And, the total area, did you understand that to be

the area of one hole plus the area of the other hole?
A   I have presumed so, yes.
Q   And, likewise for the perimeter, it was the perimeter on one hole plus the perimeter of the other hole?
A   Again, I presume so.
Q   I'd like to flip to the ELMO and ask you about another hypothetical.
And, again, it's your understanding that, using the hydraulic diameter, that will -- well, let me rephrase that.
It's your testimony that, for a given pressure drop, two flow paths with the same hydraulic diameter will give the same flow rate; right?
A   Could you just repeat it just to make sure that I understand?
Q   Yes.
For a given pressure drop, two flow paths with the same hydraulic diameter will give the same flow rate.
That's your testimony; right?
A   Yeah, that the relationship between pressure drop and flow rate is the same.
Q   It's not your testimony. You're rejecting the idea that, for a given pressure drop, two shapes of the same hydraulic diameter provide the same velocity; right?
A   Yes, that's correct.
Q   Okay. I'd like to go through another example.

So I'm attempting to draw a water tank. Do you see that? And let's put a little leak at the bottom of the water tank. We'll make it a square of 1 inch area on the side.

And so, for this square, the hydraulic diameter is 4 times the area over the perimeter; correct?

A That's correct.

Q And the area would be 1 inch times 1 inch; right?

A That's correct.

Q And the perimeter would be 4 inches; right?

A That's correct.

Q Okay. So that comes out to 1 inch for the hydraulic diameter; right?

A That's correct.

Q And, assuming this is water, if we know the height of the water, we can calculate the flow rate out of that leak. That's a straightforward calculation; right?

A I'm sorry. What's the premise, that the tank is --

Q We know the height of the fluid, we know the size of the leak, we can calculate the flow out of the leak; right?

A Yes.

Q What if I were to go in there with a grinder and I'm going to expand the size of this leak into a circle that had a diameter of 1.

What's the hydraulic diameter of the circle of diameter 1?

A 1.
Q So those two shapes have the same hydraulic diameter, the square and the circle; right?
A That's correct.
Q And, putting aside jokes about squares and circles, the area of the circle is more than 20 percent greater than the area of the square; right?
A I will take your word that it's 20 percent. I would have to do calculations to be certain of that.
Q It's roughly something related to the ratio between Pi and 4.
Now, is it your testimony that the flow rate out of the circle is going to be the same as the flow rate out of the square?
A In this particular case, if you were using the hydraulic diameter, they would result in the same flow rate given the same pressure drop, yes.
Q Well, I understand that if you're using the hydraulic diameter, because we just stated that they have the same hydraulic diameter.
My question to you is, what's happening in reality. Do these two orifices have the same flow rate coming out of them for the given pressure drop?
A I think the answer is yes. I haven't looked specifically at this problem; but, when you have a square hole, you've

introduced a very different frictional relationship between flow out the bottom of that tank.

What the science says is that, yes, they would result in the same fundamental flow rate despite the fact that the area is bigger. I know it's counterintuitive, but that doesn't make it incorrect.

Q Okay. It's not so counterintuitive if we just say that the velocities through both of these are the same, and the area change is changing the flow rates; is it? That's not so counterintuitive?

A It may not be counterintuitive to you, but it would be incorrect.

MR. CHAERES: We're going to label this as demonstrative D-22485.

I'd like to draw one more water tank, with the Court's indulgence.

BY MR. CHAERES:

Q Again, we have a gap, a leak, with a 1 inch square. Do you see that?

A I do.

Q And we've established the hydraulic diameter of this leak is 1 inch; right?

A Yes.

Q Okay. Now, let's say we plunk a hole on the opposite side of this tank, same size. Hole's on the opposite side of the tank.

Is the flow rate going to stay the same?

A When you mean on the opposite side of the tank --

Q On the other side of the tank, a hole of the same size.

A Is that whole hole at the bottom?

Q Both of these holes are at the bottom of the tanks of water.

A I guess, if you could draw it. I'm not sure what you mean.

But, yes, if you add another hole --

Q We'll add another hole here on the side.

A -- you'll have additional volume or fluid leaking out of the tank.

Q Okay. What if I move that hole right next to our hole? Would we have additional flow coming out of the tank?

A Yes, you do.

Q Okay. And, this hole, let's say this is 1 inch. Okay?

Now, if we wanted to use a hydraulic diameter to calculate the flow out of these orifices, if they're right next to each other, we can use a hydraulic diameter to do that.

That's what you did with two of the leaks on the kink; right?

A I did.

Q Okay.

A Now, please bear in mind, this was an exceptionally conservative assumption of mine. Again, when we looked at the kink leaks, we were focused on maximum flow rates. We used very conservatively -- since it wasn't clear which hole or if both holes were present, we used both holes in that scenario or the area and wetted perimeter for both holes.

Q Appreciate that.

But the use of the hydraulic diameter for two holes that were near each and saying they're combined areas and they're combined perimeters, could be used to make one hydraulic diameter. That's what you did in your model for those holes; right?

A I did.

Q And you believe that the science supports you in that; right?

A It does.

Q Now, let's figure out what the hydraulic diameter of these two holes is. It's 4 times the area over the perimeter; right?

You agree?

A Yeah. That's the formula for hydraulic diameters.

Q Now, the area we multiply by 2, so it's going to be 2 square inches now; right?

A You're calculating -- sorry, the hydraulic diameter for those combined holes?

Q Yes. Yes.

A That's not what was provided to me.

Q That's not what was provide to you.

A I was provided a combined area and a combined wetted perimeter. I then took the irregular-shaped hole and converted that into a circular hole which is required by the models in order to accurately characterize the volume of flow out of the riser in this case.

Q So you created a diameter of the actual -- you created a hole with a diameter corresponding to the actual area for flow for those depths?

A Yeah. Again, I was provided an actual area of those two holes and an actual combined perimeter for those two holes. I did not take those two holes, combine them with the hydraulic diameter.

Q Let's walk through what you did; okay? So the area of hole 1 and the area of hole 2, you were given those as a combined number; right?

A That's correct. I was given a combined area and a combined wetted perimeter for those two holes. I then take that combined area -- so, in this case, the 4A. The A is already given and the wetted perimeter is also given -- that is the combined area and the combined wetted perimeter for those two holes.

Then I convert using the hydraulic diameter those holes into a circular geometry, which is what the hydraulic diameter transformation does. And then I was able to calculate the flow rate using those holes.

Q Let's do that -- sorry, I didn't mean to cut you off. Were you done?

A Yeah.

I was able to calculate the flow rate using those holes using a multiphase flow simulator.

Q So let's walk through -- if what I'm doing over here is incorrect, so what's the combined area of the two holes here? If both holes have a size of 1 inch.

A I think it would be 2 inches.

Q Squared; correct?

A That's correct.

Q And what's the combined perimeter of both of these holes?

A It's going to be 8.

Q And so you took the combined area and combined perimeter and then you calculated a hydraulic diameter using the combined area and the combined perimeter?

A That's correct.

Q So the combined area we just said was 2 square inches; right?

A That's correct.

Q And the perimeter you said was 8 inches; right?

A Yes, that's correct.

Q And that equals 1 inch; doesn't it? Right? For this example, the hydraulic diameter is 1 inch; right?

A Yes, that's correct.

Q So we just doubled the size of our flow path. You just said that if we double it we're going to increase our flow. Yet, we

have the exact same hydraulic diameters we had with just one hole there; don't we?
A Right. But you have all of this additional frictional force associated with the additional walls. It is unintuitive, but it is the correct thing to do. It is the best available geometric transformation for the modeling of the these problems.
There are numerous texts. You arguing with me doesn't take away from the fact that there is decades of scientists looking specifically at this geometric transformation, and they all conclude it is the correct geometric transformation.
Q You say it's the correct geometric transformation to get the right velocities of out the holes; don't they?
A That is absolutely not correct.
Q I can keep on drawing these things; right? I can draw another one over here; right?
A If you can show me one paper that says that the hydraulic diameter, one text or any sort of body, because the science -- and I went to school studying these things -- and, really, the science does tell you, despite the fact its unintuitive, it is the correct answer.
Q With all due respect, sir, just answer my question.
I can put another leak over here, right next to these other leaks; right? Same size, we'll pretend. And these three leaks combined will have the same hydraulic diameter;

right?
A But I did not combine the holes. So, when I modeled the kink section of the riser outside of D and E, which was provided to me by Dr. Nesic as a combined area and perimeter.
All of the other holes were modeled independent of one another.
Q Now --
A Now, each of those holes were converted to a circular geometry, but they were all independently modeled.
Q But you just said that, if the holes had been close to each other, as in fact D and E were, it would be appropriate to combine their areas, combine their perimeters, and get a hydraulic diameter corresponding to those areas and perimeters; right?
A I believe that's what I said. I didn't catch the full question. If you could repeat it just to make sure.
Q Just wanted to confirm, you said if the holes are close to each other, you can use their combined areas and the combined perimeters and come up with a hydraulic diameter corresponding to the combined area and the combined perimeter; correct?
A I don't know that I made any general statements. What I specifically did is I was provided the area and perimeter by Dr. Nesic. It was a combined area and perimeter because these holes were so close to one another.
I then took that area and used the hydraulic

diameter for D/E, which I correctly labeled, and I treated that as one hole in this case.

The other holes, B and C, were modeled independently.

Q Understood.

But, here, if all these holes are very close to each other, I can keep on drawing holes that are very close to each other; right? I can keep doing that for a long time. I can put holes all the way around the bottom of our water tank, and the combined areas and the combined perimeters will give you a hydraulic diameter that's the same for -- it's the same as just one hole; won't it?

A In this particular example, I did not do that. You're asking me to indulge in your hypothetical here. If you're asking me, if you continue to draw holes and then try to combine them into one hydraulic diameter, yes, that's the case.

That's not what I did.

Q All I was asking you is, if you keep drawing holes, you're not going to increase your hydraulic diameter; will you?

A In this particular case or in the *Deepwater*/Macondo/*Horizon?*

Q In this particular case.

A In this particular case, if you keep drawing the holes and you keep trying to combine them and to create one hydraulic diameter, yes, that's what will occur.

Q All right. We are going to put this as D-22486.

Let me give you one more water tank. I want to be clean here.

So what if, instead of drawing the holes separate, I actually bring them together, just a little bit, so it's one hole.

You see that?

A I do.

Q And so now it's one hole with this complex geometry you're talking about. There's all sorts of frictional interactions going on with this complex geometry.

If I bring these holes together -- again, I can still do the same thing. One hole now, essentially the same hydraulic diameter is just one square; isn't it? Because the ratio between the areas of all this space and the perimeter stays the same; doesn't it?

A I think that would be correct, yes.

Q And is it your testimony that the flow -- I can put a ring around the whole bottom of the tank. Is the flow rate out of the bottom of the tank with our little daisy-chain of holes here as it would just a 1 inch square hole?

A Again, I didn't --

THE COURT: Or a 1 inch round hole; is that what you're equating this to?

THE WITNESS: Yes. It would be -- if you were to take this string of holes and you were to compute the area, and then you would take the wetted perimeter, a 1 inch round hole would roughly calculate to be the same flow rate out of the bottom of the tank.

Despite the fact that it's unintuitive, that would be correct.

BY MR. CHAKERES:

Q   And is that what would actually happen if I took a water tank and I punched all these holes around slightly overlapping with each other? Would I have the same flow rate out of the tank as if I just punched one hole?

A   Again, I've not studied this particular problem. Intuitively, it sounds counterintuitive, but the science would tell you that's what would happen.

Q   Okay. We're going to label this as D-22487.

MR. CHAERES: Now, if we could pull up Exhibit 10650.

BY MR. CHAERES:

Q   You were provided in your considered materials some calculations that BP performed of flow out of the kink leaks during the response; weren't you?

Let's blow up the top half of this. Call-out 10650.1.1.US.

You were provided this as part of your consideration materials; weren't you?

A   Yeah. I recognize the material.

Q   Do you understand that Tim Lockett was calculating flow out

of kink leaks here?
A He appears to be, yes.
Q And he's calculating flow out of a circular orifice; right? He's converting the original geometry to a circular flow path; right?
A He appears to be, yes.
Q And the area of that circular flow path is not an area corresponding to the hydraulic diameter, but it's actually a circle that has the same area as what he believed the kink leaks to have; isn't that true?
A Could you repeat the question one more time?
Q Isn't it true that the circular flow path that Tim Lockett modeled had the same area as he believed the kink leaks actually had?
A He seems to be taking irregular geometry holes, calculating the cross-sectional area for those, and then converting them into what's called an equivalent area transformation.
Q And an equivalent area transformation will give you a circle or the diameter corresponding to a circle with the same area as the regular geometry; right?
A That's correct.
Q Okay. We can pull that down.
And, again, it's your testimony that any two geometries with the same hydraulic diameter will, for the same pressure drop, give you the same flow rate; right?

A Yes, That's correct.
Q It's not your testimony that the velocities will stay the same.
A No. The velocities certainly will not stay the same.
MR. CHAERES: Okay. Let's go to Exhibit 130712. 130712. Might be 130713.
BY MR. CHAERES:
Q Ever seen this book before?
A I have.
Q You have?
A Yes.
Q What is it?
A It's a book on flow. It's a textbook.
Q And, for your demonstrative yesterday where you posited that hydraulic diameter maintains the relationship between flow rates and pressure drops, this book was one of the sources that you cited for that proposition; wasn't it?
A That's correct.
Q All right. Let's see what this book has to say about the topic.
MR. CHAERES: If we could go to 130713, page 35.
BY MR. CHAERES:
Q Now, we're in chapter 3, calculation of system pressure flow or size. Do you see that? It's a chapter where they tell you how to calculate flow?

A I see this, yes.
Q Let's pull out the portion of the page under Equations For Losses.
Now, we see here, we have equations for losses. And you recognize delta H represents head; is that what it appears to you?
And delta PR represents pressure?
A Yes, that's what it says.
Q Okay. And it says that delta P is equal to K times rho times *v* squared over 2; right?
A That's correct.
Q And rho typically denotes density; right?
A Typically, it's density, yes, that's correct.
Q And *v* -- that's a term for velocity; isn't it?
A It could be.
Q Is that your understanding? Are you familiar with this equation?
A Yeah. In this context, I suspect that it is the velocity.
Q And then we've got K over here; right? And they say K is a loss coefficient; don't they?
A They do.
Q And, under the Loss Coefficient, they say K is equal to FL over D; right?
A Right.
Q And D, in that loss coefficient -- if we could pull out --

let's actually go down to the equation below it.
They're talking about the hydraulic diameter with that D with the loss coefficient; right?
A Yes, that's correct.
Q And we can actually go on to the next page, just to confirm it.
Up here at the top, D is equal to hydraulic diameter 4 times the cross-sectional area divided by the perimeter; right?
A That's correct.
Q So, sure enough, as you stated, the hydraulic diameter is an accepted principle in fluid dynamics; right?
A That's correct.
Q And it's used in this context, again, in equation relating pressure drops to velocities; right?
A Specifically used in the frictional relationship.
Q Right.
Now, let's go ahead to page 44, 130713.44.
All right. Now let's see what the book says about noncircular cross-sections.
MR. CHAERES: We can call out all the way down to the bottom? Thank you.
BY MR. CHAERES:
Q Here, again, they introduce the concept of a hydraulic diameter; don't they?

A They do.
Q And they say above it: For many noncircular cross-sections a satisfactory procedure for calculating head losses is to replace the pipe diameter in the friction and Reynolds number equations by the hydraulic diameter.
You see that?
A I do.
Q And, again, this book is saying that you use the hydraulic diameter when you want to get your frictional pressure losses right and in the Reynolds number equation; right?
A Yes, that's correct.
Q And, the Reynolds number equation, that's one of those dimensionless parameters you mentioned a while back; isn't it?
A Yes.
Q And the dimensionless parameters help tell you what flow regime or flow pattern you're in if you're in multiphase flow; right?
A The Reynolds number specifically focuses on the difference between laminar and turbulent follow. It is not associated with the flow patterns that we were discussing earlier.
THE COURT: Pull the microphone a little closer.
BY MR. CHAKERES:
Q Take that correction. The Reynolds number tells you how turbulent your flow is?
A That's correct. I mean, this is all focused on single phase

flow as a context.

Q And you testified before, the hydraulic diameter concept should apply to single phase flow just like it should apply to multiphase flow; right?

A It's used in single phase flow, that's correct.

Q And this is a book that you cited in support of the proposition that every geometry with the same hydraulic diameter will have the same flow rate for a given pressure drop; isn't it?

A I have referred to this book with regards to the use of hydraulic diameter in industry, yes.

Q Let's skip ahead to page 46 now?

45 is a bunch of pictures with noncircular geometries.

Let's go down here to section, all the way up to Substituting. So, here, they're solving H - and, again, that's head -- and they say substitute -- again, Q, that's flow rate; right? Q is typically flow rate in these kind of equations?

A That should be the volumetric flow rate, yes.

Q And, A, we just saw in our hydraulic diameter derivation that A is the actual cross-section area available for flow; didn't we? It's the same A as we saw in the hydraulic diameter equation; right?

A Yeah, that's correct. I don't know if it's the actual cross-section in this particular section without reading it.

But I think it is; yes, that's correct.
Q They say substituting *v* -- which is velocity, we decided; right?
A Yes.
So that's the definition between in single phase flow the velocity and volumetric flow in an area.
Q When you want to solve for the flow rate instead of the velocity in that equation we saw before, you don't divide by an area corresponding to the hydraulic diameter, you divide by the actual cross-sectional area; don't you?
A No, that's not correct. This is what's referred to in science as a definition. This relates variables to one and the other inside the context of whatever assumptions that you've made.
So, in my model, when I used the hydraulic diameter, you could take the velocity in that model, you could take the area calculated by the hydraulic diameter and you could come to the volumetric flow rate.
It's just the relationship between variables. This is not a formula that you would use then to determine something.
Q This is the formula you'd use to determine something; isn't it?
A In this particular case, this is a formula that looks to be calculating -- I'm surprised it's delta H -- but some sort of

pressure drop with frictional and flow rate, yes.

Q And, when you stick in the flow rate, you stick in the flow rate based on the velocity in the actual cross-sectional area; don't you?

A No. I think, if you go back a page, actually what's happening is they've taken a frictional relationship. Now what they're doing is saying, Hey, we now have a relationship or a definition between volumetric flow rate and area, and if you substitute that in to this previous frictional relationship then you now have a calculation for pressure drop.

Or that's what I assume the H is here. This actually emphasizes the point that the ratio here of perimeter to area is quite important. And that comes directly from the hydraulic diameter, and it is that ratio that is important.

Q All right. We can do some addition, subtraction, multiplication over here and see if the hydraulic diameter is really what the area you're flowing that flow rate through there.

But we don't have to do that up here, because the flow rate, area Q, is flowing through A; isn't it?

A So, I think, if you just go back to the previous equation, we could walk you through how they get here. But this really is, if my memory is right from the equation that you showed me earlier, this is just a substitution of the hydraulic diameter into that previous equation.

This in fact emphasizes that the ratio of wetted perimeter and area are what is important, despite the fact that it's counterintuitive.

Q What's important is to get the right frictional coefficient; isn't it?

A In this case, it's what's important to get the right pressure drop. That's the equation we're looking at.

Q So it's your testimony -- you got to get the right pressure drop -- you got to use the hydraulic diameter to get the right pressure drop; right?

A Yeah, that's correct. And specifically, I mean, when you think about this pipeline, pressure drop is very important, resistance to flow is very important. It determines how the pressure and temperature change down the length of the pipe.

In multiphase flow, that changes the ratio of gas to liquid, that changes the velocities as they move down the pipes.

It's very important.

Q Okay. But it's your testimony that the hydraulic diameter concept, everything with the same hydraulic diameter, no matter how large the actual area is, even if the modeled area -- let me start that question again.

It's your testimony that, no matter how large the actual area is, if you have the same hydraulic diameter and the same pressure drop, you're going to get the same flow rate;

right?

MR. FIELDS: Objection. Asked and answered, Your Honor.

THE COURT: Overruled.

BY MR. CHAERES:

A Yes, that's correct. I mean, again, we put some bounds when we were talking about it and you were talking about infinitely large riser pipes. You start to get in a very specialized situation where now the fluid doesn't interact with certain -- the other fluid in the pipe.

But, yes, in the examples you gave, despite the fact there's a large difference in cross-sectional area, yes, it will result in the same pressure drop and the same volumetric flow rate.

Q If that's the definition of flow rate, how does that thing change with your hydraulic diameter? That thing is your velocity times your actual area; right?

A Again, so this *v* equals QA. This is a definition. So this is just an interrelationship between variables calculated from the same model. This is not something that could be then used to calculate a new number.

So, for example, in my model you can't calculate a velocity and then say, oh, I want to take the velocity out of this model, and then use that relationship to calculate a new volumetric flow rate using a bigger cross-sectional area.

What this tells you is that, given a solution to the equations, that that's how those variables are related. So a velocity using the hydraulic diameter is related to the volumetric flow rate by the velocity equals Q over A.

And, in the construct of a model that is all using the hydraulic diameter, that will be exactly true.

MR. CHAERES: Okay. If we could pull down the call-out.

BY MR. CHAERES:

Q Now, let's go back to page -- actually, I'll hold this down for a moment.

So it's not counterintuitive if you have the same -- if you maintain the velocities to pressure drop's relationship across all shapes of the same hydraulic diameter; is it? That's not a counterintuitive thing; is it?

A To me, it is, as an expert. I've read the literature. I'm now a believer in hydraulic diameter. I've used it multiple times throughout my career. It matches and is accepted in industry.

Q And after your model is predicting velocities that are one-half the actual velocities in this -- excuse me -- your model would have to model velocities, or double the velocities in the system; wouldn't it?

A They'll be faster.

Q They'll be double.

A Well, this is multiphase flow. So, again, we've tried to simplify this, and probably for the sake of this conversation that's probably best.

But multiphase flow is really incredibly complicated. You have multiple velocities. You have a gas velocity; you have a liquid velocity. They're moving at different speeds at different portions of the pipe. You have an average mixture velocity.

But, yes, probably -- or the average measured of velocities should be faster in general than the measured velocity in the true system.

Q And it would have to be double if your area is off by half; wouldn't it?

A It's not exactly half, and there are different area drill pipes. So, no, it's not an exact 2:1 ratio. Remember, you know, the drill pipe example that you've used, which is a large section of the riser. There's also a drill pipe upstream of that which is much smaller which results in a different ratio.

Q And then there's another segment upstream of that which results in a larger ratio; isn't there?

A A 22-foot section, yes, of a 45,000 foot riser.

Q So 75 percent of your riser has 2.03, as I think the ratio of the area of the -- the area in the actual system to the area in your model.

Does that sound about right?

A There were 264 over 130, yes.
Q Now, you also testified yesterday that the user manuals say what you did with the hydraulic diameter is correct.
MR. CHAERES: I'd like to look at Exhibit 130544.
BY MR. CHAERES:
Q This is the most recent OLGA user manual I can get my hands on. Do you recognize this document?
A Yeah, this is -- it's certainly not the most recent user manual. There's version 7.2, which I used in this particular investigation. And now, just recently, a few days ago, 7.3 was released.
Q Okay. Now, let's go to page 444 of this document.
All right. If we could call out the table beginning with pipes.
This is telling me how to input various inputs; right? And it says here: For diameter for pipe.
Again, hydraulic diameter. That's what's used to input for your pipe; right?
A Sorry, where are you specifically?
Q Diameter. It says input the hydraulic diameter of the pipe; right?
A Yep, that's correct.
Q And then, above that -- and, again, this is consistent if you want to maintain a relationship between pressure drops and velocities; right?

A Yes. This is for the pipe keyword in OLGA. This is a specific keyword when you're modeling the pipe. This particular input in diameter is one of the inputs, and this manual is confirming the use of hydraulic diameter.
Q And, again, you need the hydraulic diameter because you want to maintain your relationship between the wetted perimeter and the area; right?
A Yes, that's correct.
Q And that will get you the right pressure drops for a given velocity; correct?
A No. That will give me the right pressure drops or the right relationships between flow rate and pressure drop.
Q It's more intuitive if you say that it gives you the right relationship between the pressure drop and the velocity; isn't it?
A No, I don't believe that it is.
Q Okay. Now, let's look up above diameter to this area entry. So this area 1. It gives you an opportunity to enter correct total flow area; doesn't it?
A So this particular keyword is when you're using multiple pipes. They call them equivalent pipes that are flowing in parallel with one another.
This particular keyword is only used, again, in a special case where you have multiple pipes flowing in parallel. This keyword is not used for a single pipe situation.

Q What's the real number? Is it -- well, let me withdraw that question.

So an integer is where you're counting 1, 2, 3, 4, 5; right?

A That's correct.

Q With a real number, you can have decimals. You can say 1.5, 1.75, that kind of thing; right?

A Yes.

Q 2.03.

Now, the number of equivalent pipes down here, you can input a real number for that; can't you?

A Again, this is a section of the manual that's referring to parallel pipes flowing next to each other. This would not be the correct use of the software in this particular case. This would take a real number input, or that's what it says in the manual.

Q Like a half a pipe or, you know, sort of a like a Pacman shape of a pipe, that's not something you'd actually be modeling in reality; right?

You would only input a real number for the number of equivalent pipes in a fraction form if you from were transforming something that was different from what was going on in your model; wouldn't you?

A Again, the situation that they're trying to address in this particular section with these particular keywords -- so what you shouldn't take from this is that all of these keywords are used at any given time. It depends very specifically on the model that you create.

And, when they say number of equivalent pipes, in production fields you oftentimes have three or five pipes running in parallel. This is -- the area and the number of equivalent pipe is what they're referring to.

Q You ever have 2.5 pipes running in parallel in reality?

A No. And, in general, I've never seen it used that way. I mean, it does say that it would accept a real number, but there are numerous problems with this manual.

It could in fact accept a real number, but I have never seen it used that way.

Q Okay. Let's look at page 429 of this document, and let's call out the table beginning with leak.

So we were just talking about how to input pipes; right?

Now we're talking about how to input leaks. Do you see that?

A Yes. So this is the section of a model that looks like it's focused on the leak key, yes.

Q Okay. Now, let's go down to see what they say about diameter in the leak key.

Maximum equivalent diameter of leak area. There's no mention of hydraulic diameter there; is there?

A No. So what they're asking you to input is the maximum equivalent diameter.

Now, the equivalent diameter is, again, this transformation. In this case, hydraulic diameter.

Q It said hydraulic diameter in the pipe thing; didn't it?

A Yeah. There was no definition per maximum equivalent diameter. So what they are asking you to do is calculate an equivalent diameter, hydraulic diameter.

Hydraulic diameter is one such diameter, and then put that into the model.

Q So you think that they meant hydraulic diameter when they wrote equivalent diameter here?

A No, I'm not saying that. I'm saying equivalent diameter is a word that refers to these geometric transformations. They were not specific about which transformation that they were asking users to use.

There are of a number of empirically derived transformations when you're looking at irregularly shaped holes. So, an example as, sometimes they're much smaller than the hydraulic diameter.

But, in this particular case, we used the hydraulic diameter as the equivalent diameter in this section.

Q And they specified what geometric transformation they wanted you to use in the pipe section when they said hydraulic diameter; didn't they?

A Yes. Specifically, in that section, they confirmed the use of hydraulic diameter.
Q And they didn't here; did they?
A No. Again, I think this has to do with a context. So a leak hole can be very irregularly shaped. And there's a large body of research around characterizing leak holes and the specific diameter or transformation that would correctly characterize that, some of which are smaller than the hydraulic diameter.
This is just, we don't know which correlation you're going to use. We don't know enough about the leak holes. Certainly, pipes aren't star-shaped or anything like that, so they can safely say hydraulic diameter. When you're looking at a hole, it could be any irregular shape.
So, at this particular section, I think they stayed safely more generic.
Q When Tim Lockett was modeling the leak, he did not use a hydraulic diameter; did he?
A I didn't see Tim Lockett modeling anything. I just saw an email where he was calculating an equivalent area diameter. I don't know what he actually used in his calculations.
MR. FIELDS: Your Honor, I'm sorry. May I approach and give the witness some water?
THE COURT: Sure.
BY MR. CHAKERES:

Q In the email that Tim Lockett -- from Tim Lockett that you saw, he was discussing calculating leaks; right? Calculating flow through leaks; wasn't he?
A Yes. That's what he was discussing.
Q And the area transform that he used for that was an area transform that was going to give him the equivalent of the area as was actually flowing through leaks; wasn't it?
A So, as I think in this email, he's again trying to transform, and he uses a transform that would calculate the diameter of the equivalent area of that leak, yes.
MR. CHAERES: Okay. We can pull this down.
So if we could just go real quickly back to demonstrative D-22201.
BY MR. CHAERES:
Q Again, we were talking here about at the beginning, this is approximation for multiphase flow, but it actually holds true for each phase. Mass flow rate with a density times the velocity times the area; right?
A Yeah, that's correct. If the velocity is an average mixture velocity, that would hold true.
Q Okay. And the difference between your model and reality, at least for the sake of the -- the large majority of the riser, is that the area available flow through the riser with a 6'65" drill pipe is about double what the area was in your model; isn't that true?

09:29AM A That's correct.

09:29AM Q And the velocity, you state, drops by an equivalent amount in order to keep the mass flow rate the same; isn't that true?

09:29AM A It changes. I think the velocity in my model would be faster than the velocity.

09:29AM Q I stand corrected.

09:29AM The area drops in your model so the velocity increases in your model; correct?

09:29AM A That's correct.

09:29AM Q Now, if the velocity were to have stayed the same and your model was within reality, then the mass flow rate in reality would have been double what the mass flow rate was in your model?

09:30AM A No. Again, that's really incorrect. Again, you're now taking definitions and you're trying to make them predictive.

09:30AM What I've used is the best available technology. I've made an approximation that's based on science and that's backed by a large body of literature. You cannot then cherry-pick one number that you like out of my model and then plug it into a relationship. This is just the definition. And then try to predict something else. It's just not correct to do that.

09:30AM Q So, to sum up, you claim that for any -- well, you claim that this definition is being taken out of context. This definition has to hold true; right?

A Yeah. The definition holds true given the construct of a particular model. So, if you were to take my model and you were to use my area, my velocity, and my density, of course then you would get the same mass flow rate that my model's predicting.

What I am saying is that you can say, Oh, I like this one result from your model, let me take that and let me take an area that wasn't used in the model, and then expect to get the correct mass flow rate. That's just not the way it's done.

There's nothing in the literature that would say that. There's nothing in the OLGA manual that says: Oh, by the way, you need to scale your numbers by a factor of 2. It's just not correct.

Q The OLGA manual allows you to input real numbers for equivalent pipes in order get the total correct area for flow; right?

A No. Again, equivalent pipes is a scenario where you have multiple pipes flowing in parallel. This is quite common in the oil and gas industry, and that's why that was introduced.

What the manual says, quite clearly, is use the hydraulic diameter when you're modeling flow through a pipe.

Q And you use the hydraulic diameter to get the right pressure drops and the right velocities; isn't that true?

A No. That's not what the manual says, and that's not the purpose of the hydraulic diameter. The hydraulic diameter is intended to correctly relate flow rates and pressure drops.

It's not intended to correctly relate velocities and pressure drops.

MR. CHAERES: Dr. Zaldivar, I have no further questions.

THE COURT: Redirect.

REDIRECT EXAMINATION

BY MR. FIELDS:

Q Good morning, Dr. Zaldivar. Barry Fields, and I have you on redirect examination on behalf of BP and Anadarko.

Just us a few questions to follow-up.

MR. FIELDS: If we pull up TREX-130544.444.

BY MR. FIELDS:

Q We were just looking at this.

I want to specifically look at the example that you were asked about equivalent pipes. And that's under Area. Do you see that?

A Yes, I do.

MR. FIELDS: If Your Honor doesn't mind, just so that we're clear, could Dr. Zaldivar go down to the chart and sort of draw an example of equivalent pipes as compared to the situation we're dealing with here?

THE COURT: Okay.

BY MR. FIELDS:

Q So would you draw what -- when you talk about what are equivalent pipes, what is that and what we're dealing with in an equivalent pipe situation?

THE COURT: He'll need a microphone because nobody will be able to hear him where he is.

THE WITNESS: Can you hear me?

MR. FIELDS: Yes.

THE WITNESS: So just go ahead?

So, again, what we're describing here -- didn't work very well.

What we're describing here is a single pipe. This is the riser with a drill pipe flowing through it. What they're referring to in the manual is multiple pipes flowing in parallel.

This is quite common in the oil and gas industry. As they find new oil, they might lay another pipe identical to the one right next to it. So, oftentimes, you see this where you have multiple pipes.

It wouldn't be convenient to model each pipe independently. It would result in bigger models. So this is a shortcut that allows you to combine these pipes together.

BY MR. FIELDS:

Q In the situation that you were modeling, were you modeling a situation that involved equivalent pipes?

A No.

Q Now, on cross examination, you were asked a series of questions regarding a water tower. And I guess my first question was, was that hypothetical example, was that dealing with a single phase fluid or a multiphase fluid?

A I understood it to be a single phase fluid.

Q And, when you're dealing with multiphase flow or multiphase fluids, are there other factors beyond the hydraulic diameter that matter?

A Yes.

Q What are other examples or factors that matter?

A So, again, the ratio of gas to oil, the gas moves a little bit faster. It can create a choking affect on the liquid. There's lots of complexity here. The extent that the liquid touches the particular surface.

But, yeah, there's lots of complexity here.

Q Is one of the factors that matters something called a discharge coefficient?

A Oh, yes.

Q And what is a discharge coefficient?

A Discharge coefficient is a characterization of the pressure recovery through a particular diameter.

Q And did you use discharge coefficients in your work?

A I did.

MR. FIELDS: Pull up TREX-11683.57 and 58.

BY MR. FIELDS:

Q What discharge coefficient did you use, if you recall, in

dealing with the kink leaks?
A So I used 0.84 for the kink leaks.
Q Okay. We don't need that then. Good memory.
Is that for a circular hole, or was it for a rectangular hole?
A No. It's a circular hole. If you were to use a rectangular hole, you would have to use a much lower discharge coefficient, something on the order between 0.61 and 0.5.
Q And, in your view, was it a conservative assumption, to use a discharge coefficient in that manner?
A Yes. To assume discharge coefficient of 0.84, it was a conservative assumption. Actually, it's a consistent assumption with the use of hydraulic diameter.
Had I taken a different approach and used the equivalent area, then I would have had to greatly reduce the discharge coefficient by almost 40 percent actually.
Q Now, you indicated on cross examination that the velocities in your model, or that were predicted by your models, are not the correct velocities when you use the hydraulic diameter?
A That's correct.
Q Now, is that something that's unique to your model, or is that something that occurs whenever you're using the hydraulic diameter in a multiphase flow simulator?
A No, this isn't unique to my model. The use of hydraulic diameter is standard transformation. It would be used in any

situation like this.

Q And why do these models generate velocities that are different than the actual velocities in the pipe?

A The purpose, again, is to accurately capture the relationship between pressure drop and flow rate. You have an increased velocity to get the correct pressure drop or to get that correct resistance to flow.

Q And why can't you take the velocities out of your model or the velocities that are generated from a multiphase flow simulator when you're using the hydraulic diameter, and use that velocity in another equation or in another model?

A Well, at least in the context -- I mean, in general, your models are self-consistent. You're solving many equations. And all of those equations relate the variables inside that model.

It would be very incorrect to then take one parameter and then try to use that in another situation. In particular, with like definitional sort of things, which is just the relations of variables.

MR. FIELDS: Can we pull up D-24688.

BY MR. FIELDS:

Q You indicated on cross examination that you're aware of literature out there that talks about why it's appropriate to use the hydraulic diameter, and this is a slide you helped us prepare.

Can you just provide the Court briefly with what this shows about the use of hydraulic diameter in multiphase flow modeling?

A Yes. So, on the left, this is an excerpt of the OLGA manual that specifically focuses on flow in an annulus exactly like the situation we have in the *Deepwater Horizon*.

It says the correct thing to do is to use the hydraulic diameter. In the center, we have the textbook that the government placed before us, the Miller textbook, also recommending the use of hydraulic diameter.

And then last we have an article by Koch which has a very strong statement which says: Until a proven relationship for equivalent diameter is forthcoming, there is to other choice than to use the hydraulic diameter.

Q Thank you.

MR. FIELDS: No further questions, Your Honor.

THE COURT: Thank you, sir, you're done.

Who is your next witness?

MR. BROCK: Our next witness is Dr. Nesic.

THE COURT: Who is next, Mr. Brock?

MR. BROCK: Dr. Nesic.

THE COURT: Let's go ahead and take a 15 minute recess.

(Proceedings in recess.)

THE COURT: Please be seated.

Go ahead, Mr. Brock.

SRDJAN NESIC, Ph.D., being first duly sworn, testified as follows:

THE CLERK: Will you take a seat. State and spell your name for the record, please.

THE WITNESS: My name is Srdjan Nesic, S-R-D-J-A-N, last name N-E-S-I-C.

MS. CROSS: Your Honor, Anna Cross on behalf of the United States.

I just want to remind the Court that there is a *Daubert* motion pending against Dr. Nesic. It's Docket No. 11508. And we're happy to argue it or leave it on the papers.

THE COURT: Yeah, I've looked at it. I'm going to deny the -- I think the issues that you raise in your motion are more properly subject of cross examination and will go to the weight of this expert's testimony.

So I'll deny the motion.

MS. CROSS: Understood. Thank you.

MR. BROCK: Can I proceed now?

THE COURT: Yes.

DIRECT EXAMINATION

BY MR. BROCK:

Q Mike Brock on behalf of BP and Anadarko. And this will be your direct examination, Dr. Nesic.

Would you begin by stating your full name for the record and tell Judge Barbier where you live and work.

A My name is Srdjan Nesic, and I live and work in Athens, Ohio.

Q What were you asked to do by BP, Dr. Nesic?

A I was asked by BP to offer my opinions as to what were the effects of erosion on the change of flow rate through the BOP.

MR. BROCK: I'm going to call up now D-23626. And could I have the first slide, please.

BY MR. BROCK:

Q Dr. Nesic, can you use this slide to describe for Judge Barbier your educational background, please?

A I have a Bachelors and Masters in mechanical engineering from the University of Belgrade. And I also have a Ph.D. in chemical engineering from the University of Saskatchewan in Canada.

Q Did you study the issue of erosion as part of your graduate degrees?

A I have. And, actually, erosion was one of the key topics in the course of my Ph.D. work.

Q Now, after you received your Ph.D. degree, where did you work?

A Straight after my Ph.D., I went and worked for the Institute For Energy Technology in Norway, in Oslo, Norway.

Q What is the Institute For Energy and Technology?

A It is the largest research institute in the country, and used to be a nuclear institute. But, when I was there, it had already switched and did all its work almost on problems related

to oil and gas production in the North Sea.
Q What was your position with the Institute For Energy Technology?
A I was a principal research scientist over there.
Q What does that mean?
A That means I was a project leader on numerous projects which mostly related to the issues of multiphase flow and metal loss by erosion and corrosion in the facilities in the North Sea. That is, the oil and gas facilities in the North Sea.
Q Can you describe the work that you were doing in the area of erosion during the period of time that you were with the Institute For Energy Technology?
A There were a number of different projects that dealt with the various modes of metal loss, and all of them were exclusively related to so-called internal metal loss. That means from the inside of the pipe. And most of them were related to offshore oil and gas production.
Q Why is this an issue that's of importance to the oil and gas industry?
A Well, it is hugely important to the oil and gas industry because, whether in the design stage or the operational stage of any given field, there is an enormous pressure on all the engineers to design things and operate things in a way that there aren't any breaches of the pipe wall, whatever the mechanism is, so there is no uncontrolled release. And they

have to make sure that doesn't happen for 30 to 50 years, typically.

Q Now, you show here on this slide that you were with the Institute For Energy Technology from 1991 to 1996, and then you went to the University of Queensland. And we list here senior lecturer of mechanical engineering.

Can you describe for Judge Barbier what you did during this time and how that work is relevant to your opinions here today.

A Sure.

Your Honor, I moved from a pure research position in Norway to a combined teaching-research position in the University of Queensland. There, I had shared duties. I taught courses on fluid mechanics, corrosion, erosion, computation of fluid dynamics.

I also guided Ph.D. students to do their research projects on the Master's and Ph.D. level in those exact same fields. So I had computation of fluid dynamics thesis; I had erosion thesis, et cetera.

Q Will you be using your knowledge and experience with regard to erosion and computational fluid dynamics to present to the Court today your opinions about erosion within the BOP and the kink riser?

A Yes, I will.

Q Now, at the end of your tenure at the University of

Queensland, we show here that you moved to Ohio University in 2002.

Would you describe for Judge Barbier what your position is at Ohio University? And maybe just start with some of the courses that you teach and the work that do you in the field of erosion.

A I moved in 2002. January 2nd, I started at Ohio University as a full professor there. So, I had my share of teaching duties.

But I also took at the same time a directorship of the Institute For Corrosion and Multiphase Technology. On the teaching side, I continued with courses along the fluid mechanics, computation of fluid mechanics, corrosion, erosion type of classes that I taught at both undergraduate and graduate level.

And, on the research side, I was directing work at the Institute For Corrosion and Multiphase Technology.

Q Now, you mentioned this briefly in that answer, the Institute For Corrosion and Multiphase Technology. Can you describe for Judge Barbier what that institute is and what it does.

A The institute is the largest, and I would say one of the leading institutes, for studying problem of metal loss by erosion and corrosion in the world. That's the main reason actually I moved to Ohio University.

We have the biggest projects and lots of different industrial sponsors. Whereas, all our activities are directed towards problems seen in the oil and gas industry. We are hundred percent sponsored by the industry, and all my graduate students and other research staff are focused on problems of metal loss in multiphase flow in that industry.

Q What type of research does the institute do for major oil companies and engineering companies that support the oil companies?

A We do research that is sounding very narrow, but it's a very important area. We focus on various modes of metal loss within the different pipes and other equipment they have.

So it's so-called internal corrosion in the oil and gas industry, starting from corrosion down -- and erosion as well -- down in the well. Then erosion and corrosion in the so-called surface equipment. Then in the very long pipelines. So we exclusively do that kind of work.

Our sponsors are, as I already alluded, oil and gas companies, engineering companies, as well as chemical companies that support the previous ones.

Q Does your role as the director of the institute give you expertise to help answer the question of erosion in the Macondo BOP end riser?

A Oh, indeed, yes.

Q And why is that so?

A Because, starting even with my Masters about 30 years ago, I have worked with issues of computation fluid dynamics. Actually, my Ph.D. thesis was the pioneering work in application of computation of fluid dynamics in erosion. That was the first time that was ever done.

And I've continued since to be active in that area. I have conducted many research studies myself. I've guided numerous students who looked at this combination of affect -- how flow affects erosion.

So, therefore, I feel I'm directly applying all that knowledge in my opinions when I offer them to the Court here.

Q Thank you.

We've used this term here in the slide with regard to your qualifications, computational fluid dynamics, and you've just mentioned that to the Court.

What is computational fluid dynamics, and how does it assist you in evaluating a case like the one we're looking at here?

A Your Honor, I know you heard a lot about very sophisticated computer-based techniques to resolve problems, and this is one of them.

Computational fluid dynamics is a mathematical technique that's then implemented in computers to solve equations of fluid flow and any associated effect in a way that we cannot do otherwise.

Using this technique, we can get very detailed information of what flow does through complicated geometries. And, in the case that we're looking at here in the Macondo well, we are having very complex geometries. So the computational fluid dynamics is the only way that can give us the insight of what the fluid did, the hydrocarbons did, as well as any particles that were carried with it.

Q Thank you.

Now, just last question on this topic. We've listed here on this slide: Co-authored over 70 peer-reviewed papers, 100 conference papers and book articles in the field.

In terms of your work with regard to corrosion, erosion, and CFD, are you published in all of those areas?

A Yes. Those three topics you mentioned were the main topics that I ever published about.

Q Right. Thank you.

MR. BROCK: Your Honor, at this point, we would tender Dr. Nesic as an expert witness in the computational fluid dynamics and metal erosion.

MS. CROSS: Under our *Daubert* motion and on cross examination, no objection.

THE COURT: All right. He's accepted.

BY MR. BROCK:

Q Let's go now, Dr. Nesic, to an overview of just the basic concept of erosion, what we're talking about. I've called up D-24603, and I'll just ask you, first of all, what is metal erosion? What are we talking about when we talk about the concept of erosion?

A Metal erosion is a name for a phenomena where metallic surface is mechanically removed by repeated impact of solid particles. Very frequently, those solid particles are sand.

I have a little animation here that I would like to start. It is a simplification of the situation, but I think it illustrates the point. Here, it shows one individual particle striking the surface and causing damage by these repeated impacts. In reality, we have large numbers of particles impacting any given area and causing the metal to be lost.

So, again, to summarize, it's a mechanical mode of metal loss that's often seen in the field.

Q What are the factors that must be present in order for erosion to occur?

A They stem directly from this animation. As you can imagine just by looking at this still picture, we have to have enough particles there, enough sand in this case, to cause erosion.

The second important parameter is that those particles, the sand, must impact the surface with sufficient energy. Translated into simple terms, it has to move fast enough so that it can dig into the surface.

And the third condition is the particles have to come at a right angle. It's not enough that they're there and they're moving fast. They have to come at a right angle so they can chisel out a piece of metal surface.

So, therefore, it's not sufficient to say in a straight line you could have a lot of particles moving fast, but if they just barely scrape the surface and roll over they don't cause erosion. Erosion is caused when particles hit at a particular angle with a particular intensity.

Q You have described that to us before as angle of impact.

A Correct.

Q And that has significance in terms of evaluating how much erosion will occur given other conditions?

A That is true.

Q Okay. Now, based on your knowledge, education, and experience, does erosion occur as long as solid particles are moving in the system?

A One can say that. Given that the conditions are conducive to corrosion -- that is, the angle of impact is there and the velocity is there -- one can then safely assume that as long as the particles are there, corrosion -- sorry -- erosion is going to continue. That is a very logical extension of the previous arguments I just gave.

Q Now, you have prepared a report that has been submitted in this case; correct?

A That's right.
Q And let me just ask you, first, what information or background materials did you use to analyze the effect of metal erosion on flow for the period you studied?
A Well, to summarize on a very high level, I needed the geometries that I was interested in. I needed the description of those geometries in a very precise way. I need information about the fluids that were passing through those geometries. And, finally, I needed information about the presence of sand in that system.
Q I'm going to call up now D-23648, which I think in some ways summarizes what you just shared with the Court.
But, in terms of your approach to the issue that we're talking about today, Dr. Nesic, what was your overall methodology or approach to looking at this issue?
A Your Honor, I know I'm going to talk about these four points in great detail, but I think it's helpful if we summarize now what I have done.
So one of the first things that I had to determine is to find the period of erosion. In other words, to put boundaries on the time that I looked at the erosion and what effects it may have caused and did cause actually to flow.
Then I went on to the geometries that were eroded. So I focused on those geometries that did make a big difference, that did restrict the flow, and then opened up as time went

because of erosion. And, fortunately, we had not only the pre-eroded geometries, the pristine ones that were deployed, but we also had recovered most important components of the eroded geometries. So I used both of those.

And I then finally went to my computational fluid dynamics. It's a complicated technique, as you'll get a glance of in a minute. But we were able -- I was able to get answers as to how restrictive were these geometries exactly one-by-one, and then also able to determine what kind of effect they had on flow before they eroded and after they eroded.

Those are the two important signposts in time I will come back to.

And, finally, the last thing I did was, once I determined those restrictions and how they changed, I answered the question how would the flow then -- flow rate change based on that procedure.

MR. BROCK: Okay. I'm going to call out No. D-23629, which is TREX-11529R.

BY MR. BROCK:

Q I'll ask you if this is the cover page to your report?

A Yes, it is.

MR. BROCK: Your Honor, at this time, we would move Dr. Nesic's report into evidence.

THE COURT: All right. That's admitted.

(Exhibit admitted.)

BY MR. BROCK:
Q Now, Dr. Nesic, have you formed opinions in this case, and will D-23631 on the slide that I have just put up, help you to explain at a high level to Judge Barbier what your opinions are here?
A Yes. I did form opinions, and this slide is a fair summary of that.
Q Just, at a high level, would you walk through your opinions about erosion that took place in the blind shear ram and to the kink riser -- to the BOP and the kink riser?
A Yes.

Your Honor, I've kind of went in very high level at what I set to do, and we are now jumping right to the end. We are going to elaborate. I'm showing you here the main findings that I reached in my work. These are not all the findings, but these are the things that made the biggest difference.

The first bullet point here says that the blind sheer rams and the casing sheer rams were significant restrictions in flow when they were activated and before they were actually eroded. Blind sheer rams more so than the casing sheer rams, but they were both significant restriction to flow.

And I have calculated that, and I'll show you actually some evidence later on.

I've also concluded that this erosion that proceeded over about a five-week period of time significantly changed the flow restrictions in the BOP, and that the resistance they offered has gone down tremendously due to erosion.

Then I've actually been in a position to put numbers to these points that I just described. I was able to calculate how much exactly that this resistance change, by what factor. And, therefore, I was able to say that the flow approximately doubled, with an assumption that the BOP was the main restriction in flow. That was my focus. I did not have focus on the rest of the flow path.

And, finally, what I've determined by my simulations was that this increase from the beginning when everything was in its pristine state to the end was a gradual process. I'm not saying linear, like a straight line process, but it was a gradual process that for the most part it just went progressively from the initial state to the last state.

So that's a high level summary of what I found.

Q Thank you, Dr. Nesic.

I'm going to go now to D-23632. And ask you, Dr. Nesic, to describe for Judge Barbier which geometries you studied to determine the effects of metal erosion on flow rate at the Macondo well.

A Sure.

Your Honor, you've seen probably these name and these images many times. But, just to summarize, after a very careful analysis of what should I look at, I've singled out these four main geometries within the BOP and the kinked riser to be, A, the most restrictive to flow; and, B, the ones that change. Not equally, but the ones that change most over this period of time.

And, there, if you go from bottom up, the casing sheer rams, the blind sheer rams which I already mentioned, then to some upper annular and the kinked riser.

So those were the four geometries that I identified.

Q Why did you select those four geometries?

A Well, there were two main criteria, one which is very obvious. I have gone to Michoud twice. I have seen the pictures. I've seen the actual pieces. Indeed, I did focus on those elements that have shown a high level of erosion. So they became an immediate candidate.

But, on top of that, I had to make sure that I understood and analyzed the flow path to see where was the fluid going at any given point in time.

So, therefore, it wasn't always the case when something eroded a lot that it affected the flow a lot. So I kind of have to have both. That, A, there were restrictions which are important; and, B, that they have eroded.

So, once I've kind of used those two criteria, I

came up with these four geometries that in this period I looked at, April 22nd to May 27th, were more relevant.
Q Now, have you helped us with a demonstrative exhibit that you believe illustrates the event that you believe to be most significant to erosion?
A Yes.
Q I'm going to call out now D-23633-B.
And you see, here, we have a slide titled: Timeline of Significant Erosion Events.
Do you see that?
A Yes.
Q Now, in terms of orienting Judge Barbier to your work, I think you described this just a minute ago. When do you start your analysis and when do you conclude your analysis?
A My analysis starts on April 22nd. And that's because that is the date when the blind sheer rams activated. And they have been designed to be a valve that essentially shuts off the flow altogether, severs everything in its way and shuts off the well.
We all know that that didn't happen. But they did close almost fully, and there was a case that they restricted the flow. And then, as pictures showed and some models I'll show in a second, they severely eroded and opened up in the process.
So that's my starting date.
If we now look here forward, I'm going to kind of

draw your attention to April 29th. That's a week later when the casing shear rams activated. So they're in an intact pristine condition before they were activated, withdrawn in their cavities, and then they were pushed into the flow. They were designed to cut everything in between and severe everything that's in their way, but not to seal the well.

That's what they did. They closed entirely, but they did not seal the well. And they eroded, too.

So we know from that perspective, without any modeling, without any real sophisticated analysis, that since they were only activated April 29th and they eroded, that erosion must have been going on.

Likewise, if we now fast-forward to May 19th, a third hole in the kink riser appeared. I will show some of that footage later on. Another hole appeared just beyond the bend. We knew that was erosion hole. So that was an another signpost for me to say sand production and erosion must have been occurring until May 19th, and surely beyond. Because there was no reason to assume that everything was eroded until May 19th, the hole was made, and then stopped. So I knew it went beyond. I didn't know exactly how far and how long.

And, finally, based on the expert opinions of Dr. Vaziri, who is a sand expert, sand production expert, he suggested that sand production lasted at least until the end of May.

So I've used that and moved it a little forward to be on the safe side, and I picked May 27th as a day when erosion in any significant way has ceased. I don't say it has stopped then, but that's conservative. It lasted at least until May 27th.

Q All right. Thank you very much.

I want to turn now to some of the components of the BOP that you analyzed, and we're going to start with the blind shear ram.

Okay, are you with me?

A Yes.

Q So you've just mentioned to Judge Barbier that they were activated on April the 22nd.

And I've called out now D-23635-A. And I'll ask you first, you mentioned that you traveled to Michoud. Did you actually analyze or look at the rams from the BOP?

A Yes, I have.

Q Now, this is a couple of pictures of the blind shear ram; correct?

A Yes.

Q And can you tell Judge Barbier what you're seeing in these pictures and what is significant to you as an expert in erosion?

A Well, Your Honor, again, these pictures are quite drastic examples of massive erosion. What you see there on the screen are two blocks of the blind sheer rams.

May I pick up the prop at this stage? I think it helps, rather than looking at the pictures, which I'm sure you've seen a million times.

Q Which one are you going to pick up?

A Of the blind shear rams, I'll start with the ones before they eroded.

Q So this would be D-24200, which is a pre-eroded blind shear ram 3D model.

Just tell the judge how this was created; and then, if you have something that will be a good teaching point, please share that.

A Sure. This is a replica, a very realistic replica of the real blocks that were present in the BOP before they have eroded.

So we have obtained detailed design files from Cameron, and then used them to make this model here that I'm going to open up in a second.

The same information from Cameron was used to create the geometries I simulated. So, if you can imagine, I've been able to create these two geometries in their virtual form and pull them into my study. So I operated with exactly the same geometries like these within my computational environment.

Q Go ahead.

A And, in going back to the point, so what you see in front of you, Your Honor, is pretty much these two pieces. But you see them there on the screen after they eroded. This is what they kind of would have looked before they eroded as they were just activated.

So, when they close and tried to seal the well, they didn't go all the way through, and that there was a gap left, and that led to erosion that you can see on your screen.

So that's probably the easiest way to show how massive, just by comparing before -- and if I may pick up the other set, these two are identical as --

Q Just one second. So you're holding up now D-24202, which is the eroded blind shear ram 3D model; correct?

A Correct. Thank you.

So these two are actually virtually identical or totally identical to the ones you see on the picture there.

So you can see there -- actually, anyone can recognize, there was massive erosion that took place here. These were in their closed state, so one can observe immediately without doing any calculations that it must have been much easier for the fluid to push through these holes on the sides even when they push like that than it was the case before they eroded.

Q Now, as an erosion expert, do you have an opinion as to whether this erosion demonstrates that the blind sheer rams were acting as a restriction to flow?

A Yes, I do.

Q What is that opinion?
A Well, again, I will pick up the noneroded version of the blind sheer rams. And they clearly show that, even if they didn't close completely, they closed sufficiently so that the flow could not pass through the middle.

The flow had to swing sideways; because, when you look at the eroded version of them, the damage is pretty much all on the sides. It's not so much in the middle of the blades. So that means that these rams have obstructed the flow in the middle.

And, by the way, that's what our simulations are going to show that I'll stream in a second.

But, even without them, one can conclude that this must have been the restriction in the flow, and therefore the flow kind of pushed its way through the sides.
Q Let's turn our attention now to your analysis of the casing sheer rams. And, very quickly -- I've called up D-23637A -- we show here, consistent with your timeline, that they were activated on April the 29th.

And if you would just speak to Judge Barbier about your findings from your analysis of the casing shear ram.
A Sure, I can.

May I also ask for permission to pick up the physical models?
Q Yes.

A So I'm picking up D-24201, which is --
Q Thank you, by the way.
A My pleasure. I thought this was faster.
And if I can pull them apart. They are not easy to pull apart. Actually, that's realistic, because it takes some force to push these things together, significant force, in reality. So it's not that it's not been a well-made model.
But, going back to our story, this is the version of the pristine uneroded casing sheer rams. Now, you saw how hard it is. I can't push them together in front of you here, but they were designed when they closed to sheer and to cut everything in their way.
Yet, these blades were not so tight so that the flow would not pass through them. There was some flow in between those blades even in a closed arrangement.
Therefore, what you see there on the screen, Your Honor, is what I have on this other prop. It is D-24203, which is identical. If I open it up, these two pieces are identical to the ones you see there on the screen in this arrangement.
Now, again, we see some erosion. Although it's with a naked eye, it's clear that it's not massive like it was in the BSR. And I'll come back to that. But we can clearly see effects of erosion.
Q Now, can you just describe the evidence of erosion that you see there on the casing sheer rams? What do you see?

A   Indeed, the easier one to describe is the so-called top blade. So, if I may orient you here, so that blade was in a horizontal position when it closed on the other one and severed the drill pipe. That was the only thing between the blades.

And so that severed drill pipe was still producing sand, which is clear by this almost circular pattern that was created by the impact of the particles that couldn't make that very sudden and sharp bend. The fluid went like this and then between the blades and out.

The particles didn't -- weren't so quick to turn, so they made an imprint because of these numerous impacts that you see there.

The interesting thing is that that level of damage is much less than what we see on the blind sheer rams, and that is because of that direct impact the particles had.

If you will recall, Your Honor, I described to have the best, quote, unquote, erosion, one needs to come at an angle to chisel out a piece of metal. So just pounding at it more or less directly is not as effective. It does erode, but it doesn't lead to dramatic effects.

Q   Now, the casing sheer rams were activated on April the 29th.

Did they create an obstruction to flow?

A   Yes, they did. If not sealed the well, they definitely posed an obstruction to flow.

Q   Now, let's turn to a discussion of the upper annular preventer, D-23639A.

And, before I go to that, let me just ask one question. From looking at these photographs and the models that you've just shown to Judge Barbier, can you tell the Court whether or not there was sand still being produced in the system as of April the 29th?

A For sure, not on April 29th, because they were activated. They were new, if you want, pristine, when they were activated.

This must have been produced beyond April 29th, because it has happened well into May and I think all the way out to the end of May, this sort of damage. This is sort of unambiguous, I think, in this case.

Q Thank you. Now, let's look at the upper annular preventer, D-23639A.

Did you personally inspect the recovered upper annular preventer and drill pipe?

A Yes, I did.

Q Is this the drill pipe we've referred to in this case as the 1B1?

A I think that's correct.

Q Okay. Now, when we talk about 1B1, what are we referring to?

A Well, Your Honor, we're talking about the first valve, to call it a valve, that closes the upper annular. It squeeze onto the drill pipe, as you've heard probably so many times. The

10:42AM seal that they formed wasn't perfect. It was a leaky seal.

10:42AM The fluid was squeezing by that tool joint, as they call it, that's shown here on that bottom picture, and it was going so intensely through there that it eroded this 1B1 section of pipe.

10:42AM We can see two locations, the one where we have an imprint, and then the completely severed section at the end there.

10:42AM Q Do these photographs that we're looking at here demonstrate that the upper annular preventer was acting as a restriction to flow?

10:43AM A Yes. For the short period that this pipe was held in place, it was a restriction to flow.

10:43AM Q Thank you.

10:43AM Let's now talk about the kinked riser for a few minutes. Just for the record, when we use the term kinked riser, what are we talking about?

10:43AM A It's a term for a bent pipe. But a pipe that went, when it bends, it's sort of neck-down in that section where it was actually turning 90 degrees. So the cross-section was much smaller than the normal full-bore section.

10:43AM Q When the riser kinked on April 22nd, did it create flow restriction?

10:43AM A Yes, it did.

10:43AM Q And why do you say that?

A Well, for the simple fact that I just mentioned: The cross-sectional area right there in that kink, in that 90-degree bend, was much smaller than the cross-sectional area of the pipe, of the riser.

So, therefore, just that restricting of flow was -- and then the fact that it bent. So that, every bend is a restriction as well, even a full-bore bend.

But this was a double restriction from that point of view.

Q Okay. Did your analysis of the photographs and materials indicate whether or not that flow restriction changed over time, that is referring to the kinked riser?

A The kinked riser changed over time somewhat because of the holes that appeared at various points in time that were caused by erosion, and that has changed the hydrodynamics there.

Q Let's look at that D-24452. Do you see, we have here photographs of the kinked riser taken at three time points? Do you see that?

A Yes.

Q Can you describe for Judge Barbier what these photographs demonstrate and why they are important to you in your analysis of this case.

A Yes.

Your Honor, if I may really draw your attention to the big screen, because that's where I can only point with my laser.

You see three very important points in time: April 22nd; there's the kink seen from the back and the fluid is going through and exiting on the other end of the riser, but there's no holes.

Fast-forward to April 28th, so-called first two holes appear. One there in the middle of the pipe just past the bend, which is an erosion-caused hole.

And then another one here that at the very side where there was some squishing and stretching of the pipe which could have been implicated in the erosion hole that formed there.

But the one that's most important is a signpost for everything I did. That third hole, these two on May 19th are the same, even if the color is different, as April 28th. So these two here are the same holes, probably slightly larger.

But this third one right there, so-called third hole, is the one that appeared on May 19th.

So it was critical for us to have that piece of information, as it tells us that sand production and erosion was happening on that date and well beyond that date.

Q Now, I want to talk a little more about this kinked riser and the holes, and I'm going to go to our next call-out which is D-23644B.

Dr. Nesic, the first thing I'd ask you to do is to orient Judge Barbier to what he's looking at here. Probably the best way to do it is if you can sort of describe for him, if he was looking at this, where would it be here in relation to the riser at the top of the BOP.

A So, Your Honor, this picture on the left, the large image, would be obtained if you can imagine standing where it says kinked riser and looking in the direction of the red arrow.

In other words, this photograph is at a 90-degree rotation from what you see there on this sketch. So it is really looking at the kink, where that kink is. Not from the side like on this little animation, but actually looking at it sort of front-on. And that's what you would see.

Q Let me see if I understand this. So the picture that we're looking at here, if we rotated it and put it on the top of the kinked riser there, that's what the orientation would be?

A That is correct.

Now, it looks like --

THE COURT: It would line up with the arrow?

THE WITNESS: Yes. You can imagine yourself standing where it says kinked riser, looking in the direction of the arrow, this is what you would see.

This looks odd because this was taken in Michoud when it was on the ground. The picture is from the bottom-up so it doesn't appear natural. But that's what we're looking at.

BY MR. BROCK:

Q Do you have an opinion as to whether or not these holes are caused by erosion?
A Oh, I know for sure they were caused by erosion.
Q And how do you know that, Dr. Nesic?
A Well, even without looking from the inside of the -- this is just an outside view. There's two important pieces of information that without any doubt tell me that this is erosion.

And let me start first with the orientation of these holes. These holes are aligned with the flow. If you look -- the flow is coming from the bottom, going through, and then continuing upwards in this photograph.

So these holes are exactly -- their shape is oval, and it goes in the direction of the flow.

If these holes were created by anything else, say by cracking, which I heard, the cracks wouldn't be going in that direction. The cracks would be going in the perpendicular direction, sort of across. Cracks would look like that.

This would be where most of the stretching is going on. Which we all know, if we take something and bend, it's going to break like this, not like that. So, to me, that was the sort of the first clue that was very convincing.

There's another one that, if you look at the locations of these two holes, is actually past the bend. The bend, the axis of the bend is somewhere there.

So, again, if it was some sort of

cracking-induced, as I've heard, that's where the cracks would appear. These are not cracks. You will see in a second when we switch this piece around, they don't look like cracks. We know from the place, they are past the middle. That, they've definitely formed beyond where cracking could be occurring.

THE COURT: How many holes do you see in that photo?

THE WITNESS: I see three. I see these two that I focused most of attention. First, this one was shown to appear on May 19th, so that's kind of the most important one for me.

I see another one that appeared on April 28th. And, its sibling here, this one appeared at the same time as the other one.

So I see three holes.

Now, why I've been avoiding to talk about this one, you can see that this hole is roughly in that sort of position where we could have and did have a lot of stretching of the pipe. I can't imagine that this third hole, which is upstream of the other two, could have formed partially by cracking and then aggravated by erosion, or the other way around.

I can't be 100 percent sure.

THE COURT: That's not a fourth hole over on the right corner; is it?

THE WITNESS: There is actually another hole on the --

THE COURT: I see a blue color in middle, it looks like.

THE WITNESS: Yeah. That's where first they cut this. When we took the picture, this was kind of sliced in half, so it was hard to see that properly.

But also, there was additional damage on either side of this picture where pieces were detached. But we don't know exactly when was that done, when they were recovering the piece or when they were cutting the piece. That is not obvious. So I tend not to rely on that information of where there was a lot of damage, mechanical damage to the sides. That's why I focus all my attention on these two middle holes, which were kind of away from all this other stuff that was going on.

BY MR. BROCK:

Q All right. Thank you.

Let's turn now to the issue of the duration of the erosion period. We've talked about the geometries you've selected.

What did you use to define the period of metal erosion?

A I have based my opinions on two main sources. One is the opinions of Dr. Hans Vaziri, who is an expert on sand production. And I relied on his opinions that sand was produced in sufficient quantities between April 20th and end of May. So that was one guiding piece of information.

And indeed, I've also used, as I already mentioned, the appearance of the third erosion-caused hole in the kinked riser on May 19th.

I also relied on Dr. Vaziri for some other opinions. The most important one of them is this issue of half of the sand being produced in the first two weeks and the rest in the other three, three and a half weeks.

Q By your visual observation of the pictures and your understanding of the erosion, were you able to verify Dr. Vaziri's finding that was sand present in the system into May?

A Yes. As I mentioned, that appearance of that third hole on May 19th is the most convincing piece of evidence. I mean, I already mentioned the casing sheer rams that eroded past April 29th.

But this May 19th is the most convincing date when we know that sand was produced and erosion was going on, because it punched a hole in the kinked riser. As I said, it's very reasonable to assume that that went past May 19th and past May 20th.

So I've kind of bounded it with those two key dates that I had at my disposal.

Q Okay.

MR. FIELDS: Could I get D-24723, please.

Thank you.

BY MR. FIELDS:

Q You mentioned to Judge Barbier a minute ago that you had

also looked at the inside of the kinked riser; right?
A That's correct.
Q And can you describe for Judge Barbier what this photograph shows, and if it helps you to understand that erosion was still occurring on May the 19th and beyond.
A Sure.
Your Honor, I know this is kind of hard; these pictures aren't perfect. This is the view of that same piece you saw just a minute ago. A, it's flipped around so that you can see the inside of the pipe.
But what we have is also now the flow is coming, if you can imagine, from the top coming down. So it comes -- that's the way this piece was oriented. So the flow is going apparently in a different direction, but it's really -- the BOP would be now above and then going downwards. That's how this picture is oriented.
And what you see here, again, if you can make out this kind of light area there, that's sort of the most sheering bearing area. So most of the stretching and the bending of the pipe occurred roughly across that axis.
The holes that we saw from the other side, this second and third hole, particularly the third hole, is down here. So it's well past that section of maximum stress and stretch of the pipe.
Now, you've asked me, Your Honor, what about those

holes on the sides. They're better visible from this angle. You can see that there was a hole right there that's caused, again, it looks like erosion by this sort of drawn out surface, that erosion was part of that story.

But it is right in that axis where there was a lot of bending, so I can't rule out some cracking happening before or after erosion. So that's why I'm not basing my analysis on that hole as much as the other holes.

The two holes in the middle are clearly away from any point of maximum stress, so therefore I'm confident that they're erosion-driven.

Again, if you look at the shape of these surfaces, Your Honor, and then I pick any of these props I have and look at the shape of the surfaces on this blind shear ram block, you can see that sort of drawn-out shape.

For example, this one here -- whoops, I apologize -- looks very similar to what you see close to those holes over there.

So I knew, again, beyond any doubt, that this was caused by erosion, those two middle holes were.

Q Thank you.

What date did you use as your end date for erosion in the BOP and the kinked riser, and why did you select the date?

A As I previously mentioned, I bounded it with May 19 when this third hole we just saw appeared. I heard and read what Vaziri, Dr. Vaziri, said, that it lasted at least until the end of May, sand production did.

So therefore, I picked, I think still conservatively, that erosion must have been going on until May 27th. So I have moved it forward a few days compared to Dr. Vaziri's calculation just to be on the safe side.

I think I can say with great confidence that erosion occurred at least until May 27th.

Q Let's turn now to one of your main opinions, and that is that flow rate doubled over the first five weeks of the incident due to erosion.

And I'll ask you first, Dr. Nesic, what metric did you use to evaluate the impact that each of the restrictions that we have talked about had on flow?

A I've used pressure drop, to put it very succinctly. And that's what you've heard a lot here. Pressure drop is the best method, best metric, that we engineers use to describe how hard it is for flow to go through something.

It's not intuitive.

Q Let me stop you just for a second. That's fine.

So you may have been going to this, but why do you use pressure drop to evaluate erosion?

A Because that is a universal metric that is used across all of the engineering branches that deal with fluid flow to describe how hard it is for flow or how easy it is for flow to pass through a given geometry.

Q I'm going to pull up now D-23628A.

This is just a slide showing pressure drop versus flow rate. Judge Barbier has seen the example of the hose. But, in the context of your methodology, can you just use this to describe what you're going to be doing and how you evaluate and use the concept of the pressure drop.

A What one sees in this picture is a very simple analogy that's actually quite, quite accurate of how restriction in the flow results in a pressure drop change.

And what you see, Your Honor, on the left here is a hose that's pinched on the end. So, therefore, the flow cannot really pass with ease through that pinched end there, so it builds up pressure ahead of it.

So, if we then calculate the pressure drop, which is really the pressure in the hose minus the pressure in the atmosphere, which is constant, it's large. It's a large number.

So corresponding to the high restriction is a high pressure drop. That results in a low flow rate. We all know, when we pinch the hose, the flow rate goes down if you really do that effectively.

If I then turn your attention to the other example, if we let go, indeed now the fluid comes out at higher flow rate, but the pressure in the hose is now not as high because the fluid just passes right through. It's almost the same as the pressure outside. So low pressure drop means low restriction and results in a high flow rate.

So that's that I think intuitive example that high restriction means high pressure drop which means low flow rate, and vice-versa.

Q When you talk about pressure drop, you're talking about on either side of the restriction?

A Correct. And that's really how much pressure changes as it pushes through, as the fluid pushes through a given geometry.

Q Now, one of the things you did in this case was to model the restriction to flow that was provided by each component; is that right?

A That's right.

Q All right. So how did you go about doing that?

A Once we obtained the various geometries of interest -- and, just to remind you, the blind sheer rams, the casing sheer rams, upper annular, and kink, we have imported those geometries into our computational environment. That was the first step.

Q And did you use that input to create a model of particles passing through the various components that you analyzed?

A That's right. That's exactly what we did, Your Honor. So we took an electronic version of these geometries that I have just shown you, we moved them into this computerized environment. We put them right against each other the way I did with my hands, and it happened in reality. And then we model how flow goes.

And I will show you some animations to bring that home, but we exactly calculated how flow moved through those geometries before they eroded and after they eroded. We were also able to show how particles move through that same geometry.

Q Now, I'm going to call up a simulation, which is D-24207A1. I think you've just described how you developed this simulation. I'm going to run it.

You want to talk about it a little more?

A If you don't mind.

Q Sure.

A So it's actually not as visible on that screen, but I believe on our small screens it's easier to see.

What you can make out is an outline of the kink. So the white lines are supposed to denote that the boundaries of that riser, that kink there. You can see the kink somewhere roughly in the middle of that screen.

What we did is we've gotten that geometry by laser scan. We then moved it into our computational environment, populated it with million little points inside so we could calculate exactly how the fluid moved.

And, finally, what you will see in this animation, we released a swirl of particles and watched how they moved through this geometry.

So now you can start it now.

Q You ready to do that?

A Thank you.

Q All right. So now describe for Judge Barbier what he sees.

A So, if you imagine, Your Honor, these are solid particles, sand. They're colored blue just to see them better. They're approaching this kink where the cross section is neck-down. There's actually a very tight spot in the middle.

The fluid with the particles then swings left and right. As it has to pass through these narrow passages, of course it accelerates in that process, because now it's a tight spot it passes through.

What you see in red here in this graph are locations where we have predicted very intense impacts of particles coming and going through.

And, indeed, these would be the locations which should result in the highest degree of erosion.

Q What conclusions did you draw from the simulation?

A Well, there were multitude different things. But the ones that stand out, first, I've drawn the number out of this, the exact pressure drop as the fluid went through this geometry.

We also looked at the locations of erosion where they were predicted.

Q I'm going to now call out D-2426A. This may be what you just referenced; but how does your simulation match up with the actual kinked riser? And is that important to you in your analysis here?

A It is very important, because the goal of every mathematical computer-based simulation is to kind of root itself in reality.

And, yes, we were using the exact equations of fluid flow and particle motion, the best possible description of the geometry, but we really didn't have any direct evidence that flow moved exactly like that through the kinked riser. We didn't have any probe in there to measure that.

So the best evidence we had in determining whether this particular flow pattern -- and I'm using this kinked riser -- was right, we compared where we predicted the most intense erosion. These are these red areas on the graph. Then the two holes which are, you know, more or less in the same regions.

So there's good overlap fact. So that told us that these five-alarm mathematical checks and physical checks that these calculations are right, this was an anchor in reality. We call it a reality check.

I was very happy. I think it is remarkable, for such a complicated system, that we got this close.

THE COURT: Let me ask you something.

THE WITNESS: Sure.

THE COURT: Why is it that, when you modeled this or in your opinion when the sand is moving through here and impacting, why is it only making these two holes in these two specific spots and not eroding more or less evenly across that plane, so to speak?

THE WITNESS: That's right. That's a very good question. Because that's what one would imagine, at least when one sees the pictures.

What it is actually is that the cross-section of that plane that you just referred to is actually dog-boned. It looks like that.

So the particles tend to swing sideways because of that tight spot in the middle. That's why you see the attack kind of being focused on more on the sides, not right there in the middle.

Another reason is that, what you don't see in this simulation is there were actually two drill pipes caught inside, which are not here, and they have sort of also channeled the flow to go to a relatively narrow passage. That's where those two holes have appeared.

BY MR. BROCK:

Q Thank you.

Let's go to now one of the other geometries that you looked at, the blind sheer rams. And I'll just call up -- I'm not going to play it yet -- I'm going to call up D-24213A1.

Would you just describe for Judge Barbier what we're looking at here and what you did with this information.

A Sure.

Your Honor, this is one of the thousands, literally thousands, of simulations we did. This shows a flow through a blind shear ram.

Now, I'm going to pick up the prop because I think it's easier. That's why I didn't show this one first. It is somewhat more complicated to appreciate.

So, if I may pick up these blind shear ram blocks before they were eroded, what you're looking at there, Your Honor, is kind of a view exactly from where you sit towards these blocks.

If you would imagine the blocks were made from Plexiglas or something transparent, you would see more or less a picture like that.

So the flow is coming from the bottom, going through these blades which are almost closed - you will see what the animation shows -- and then the flow has to snake through the openings that are left and get out.

Again, the blue on the screen are the particles.

Q So we've got it running now.

If you can describe for Judge Barbier what you see here and what its significance is.

A This is obviously a very slowed down version of the real event.

What you see is then this swirl of particles approaching this partially closed section by the BSR blocks.

And they cannot pass through the middle, as you can imagine, because there's overlapping blades there.

But there's opening on the sides, and the particles make this sudden turn to the right and then sudden turn to the left. On both sides actually there's two like bends right next to each other. Indeed, there's a lot of particle impacting going on there. Not so much head-on. That doesn't cause as much erosion.

But these got an angular impact here on the side. The red color indicates a lot of erosion going on right there.

Another important point I don't know if you can make out, Your Honor, there's actually a drill pipe here that's been caught. It's not easy to see in this complicated case depiction.

So we have the full-blown geometry of the blind shear rams with the drill pipe and particles moving through it.

Q For this simulation, what conclusion did you draw?

A We looked at the location of erosion, obviously, which we can see where saw it on the recovered blocks. But most important information for us was to calculate the pressure drop. In other words, the obstacle that this particular geometry presented to flow.

Q Now, I think you said this, but just to be clear for the record, did you compare the erosion that your model predicted with the recovered blind shear ram?

A Indeed, we did. Again, one of the reality checks was that we predicted locations of erosion where we actually saw physical evidence that erosion happened. That wasn't -- never expected to be, you know, a perfect match, but we wanted to see that areas that were predicted erosion have actually eroded. That was important.
Q Now, did you analyze the other study restrictions with regard to erosion in the same way?
A Yes. So we have repeated this same situation.
But then, if I may pick up the eroded blind sheer rams, we then repeated exactly the same calculation with these precise geometries that I'm holding in my hand. And, indeed, one can imagine, I can put my finger through this now, so there's a large opening there. And the flow now winds with much more ease through these holes.
These are the eroded blind shear rams. I believe we have another animation to show that. I'm not sure if it's coming up.
Q This is D-24201A1, and it's a simulation of particles passing through the eroded blind shear ram. So if you could describe what this is.
A Yeah.
So, in many ways, it's a similar situation. Like with the pre-eroded geometry, you're looking at the flow from the side. The particles are coming from the bottom, and they,

again, seem to do the same thing. But not exactly.

They are swinging to the left and to the right, but now you can see there's no sudden turns. They have already pushed their way and eroded part of the blind shear rams and are coming out with much more ease on the other side.

So the pressure drop we calculated on these blocks was about 20 something times less. The resistance was 20 something times less after erosion than before.

Q Okay. I don't know how long this goes on; let me just stop it.

So, in terms of what we've talked about so far, you looked at the geometries of the BOP in their pristine condition and analyzed, through your modeling efforts, how those obstacles would affect flow in the BOP; correct?

A Yes.

Q And then, as you've described, you were able to look at the components of the BOP at the end of the spill after the components were recovered, and you were able to analyze those to see what change had occurred to those components at the time of recovery?

A Correct.

Q Now, why is it important to you as an expert in erosion, that you're able to know the geometry of the components, both before and after the event?

A That was of huge importance for me. Because, Your Honor, normally, in the work I do, which is sometimes very similar to this situation here, we know, say, how something looks before it eroded.

The industrial partners ask us: Can you predict what something's going look like in 20 years, so that they know how to design for it. In other words, we only know one point in time, and then we're trying to see and predict how something will look at another point in time without ever being able to know what that outcome is going to be. We have to predict it.

In this case, we had a unique privilege which -- to have both before- and after-situation known. We didn't need to guess how much erosion will happen after 35 days; we actually had the eroded components.

So that has anchored my analysis in two points in time, which hugely increases the reliability of everything I concluded from that.

Q Now, after you have that information and the things that we've already talked about, in order to understand how the restrictions affected the flow over time, what did you do next?

A So, if we start from that position, I knew what the restriction was before erosion; I knew what the restriction was after erosion. The last remaining question was, how did it change from that point 1 to that point 2. We had no physical evidence in that interim period before the first and the last day of erosion.

We did not know in the same way what the erosion was, so that's where our computational fluid dynamics models came in to help. We have performed a so-called transient analysis.

Q And describe for Judge Barbier the tool that you used; that is, the transient analysis or simulation that you used, to develop information that will help you describe to the Court how changes occurred over time.

A Your Honor, we started with a virgin geometry, so noneroded geometry. And then used our calculations to predict, if you will, now how those geometries must have looked on the second day and the third day and the fourth day and so on, due to the enormous complexity of this geometry, which now the programs had to modify over time. So they had to distort them as the calculations went on. We had to simply use these geometries. So, they didn't look exactly like this in our transient simulations, but they retained all the key features.

But, for the purpose of this argument, if you can imagine, we would have started with something very similar to this, ran a simulation on the first day. Kind of what you saw, calculated erosion rate, and then went in and modified this geometry ever so slightly to account for other erosion.

Then we simulated the flow again through this partially eroded geometry on day 2. Got the new erosion rate, fed those back in the loop. Moved to day 3. So, essentially, it was a series of calculations from day to day, or even within hour by hour, very intense. Which took us through time to see how the geometries changed.

Q Now, for how many days did you get good information data as a result of that effort?

A That effort was a very intense calculation, something that's rarely been attempted that I know of by anyone. We were able to get 10 good days of data. And, that was very important for us, that we had 10 solid days of data.

Because, remember, we knew the beginning and the end point. We did not need to project into the future and wonder whether it was right or wrong. We knew where this is going to end, so all we needed is enough data points in time so that we could connect that beginning with the end.

We wanted to go for 35 days. That was our goal and hope. But that wasn't possible. But we had enough, 10 good days of simulations.

Q What is your basis for saying that the data that you obtained for those 10 days is reliable? That is, something we can count on.

A Because I have done very similar simulations many, many, many times before, and all of those who have tried something like this know that these simulations are difficult, and there is various reasons and various points in time they stop giving good answers.

But we also know from mathematical and physical criteria when data are good and when they're not. So we looked at every day and every geometry that we got the next day and checked mathematically and physically is it realistic.

When it was, we went to the next day. And then went day 1, 2, 3 through 10. And then, on the 11th and 12th day, things started happening. We saw mathematically, we saw physically and visually that something was wrong. We had to stop there and discard those data.

Q Now, I'm going to call out D-23892. And I'll just ask you, Dr. Nesic, to describe for Judge Barbier what this graph represents and why it is important to you in your evaluation of this case.

A So, Your Honor, you have time on the horizontal axis, and this is pressure drop, or you can think of it as resistance to flow.

The numbers are pressure drop really in pascals, which is an equivalent of the psi. But the actual numbers are not what I needed. I knew what in a real case was my initial and last point. All I needed from this simulation was to know whether to connect my initial and last point with a straight line or some other type of line.

And we did this over and over again. And, for about ten days, we got -- no matter what geometry we looked at -- that the change was linear. So I was very happy with that.

I had no expectation to it being linear or anything else. But, every time we got data like this, you can see, even by the naked eye, that this was a linear change.

So that is the only thing I moved -- I used from this transient simulation and moved them back into my pressure drop analysis. I knew the beginning, I knew the end, and now I was able to draw a line between those two.

Q If you know the beginning and you know the end, are 10 days of good data sufficient for you to reliably form opinions about the way restrictions changed over time?

A Oh, indeed. I mean, we all know that you only need two points to define a line. If three points looked like to be on the line, that's already safer.

To have 10 points that in this case correlate 97 percent with the straight line, I mean, that to me was a case beyond doubt.

Q What did you conclude about the way restrictions changed over time based on your transient simulations?

A Again, I had the privilege of asking these transient simulations a very simple question, asking them just to tell me what was the trend of change of pressure drop.

In other words, was it a straight line or something else? I got an answer that it was a straight line, and that's the only thing I extracted and used it to reach my final conclusions.

Q How did you decide that a linear trend was the best fit for this data?
A As I just mentioned, these data looked straight -- they looked like a straight line. Mathematically, they have a high degree of correlation. They're 97. Something accurate, which is way beyond -- normally, one expects 70 percent, and say everything above 70 percent is a straight line. This was 97 percent.
So my visual intuitive observation was confirmed. So I was very confident to take a straight line as the best representation of this data.
By the way, it suffices to say that, whenever one has multiple options to describe something, in this case a bunch of points, what one chooses is that scientifically acceptable is the simplest fit. And this was, A, a very good straight fit; and, B, it is the simplest of all possible fits.
Q All right. Thank you, Dr. Nesic.
Now, up until this point, we've been talking about your analysis of individual components; correct?
A That's right.
Q The ones you've identified of your subjects of investigation?
A Correct.
Q So let's talk now a little bit about the combined effect of restrictions and how you went about looking at pressure drop

across the BOP system; okay?
A   Sure.
Q   All right.
I'm going to call out now D-23945, and this is one of the charts from your report.
Can you explain to the Court what is represented by this graph and how it is helpful to understanding the changing flow restrictions over time.
A   Sure.
Your Honor, this is one of the two summarizing graphs where everything I did, all those complicated simulations through difficult geometries, which we did thousand times over, everything comes together in these last two graphs that I'm going to show.
So the graph in front of you shows how pressure drops on the vertical axis -- that's really a resistance to flow -- changes over this period of time that I analyze. And these are all calculations. This is not based on my assumptions.
We can see that, if nothing else is important, when you take away method that -- it starts from 3 and a half and goes to 1. That means that the resistance to flow over this period of time changed 3 and a half times.
Q   Let me stop you right there.
A   Sure.

Q Just so that we can orient Judge Barbier to what we're looking at.

Right here, we have April the 22nd, and we have a solid blue line.

Do you see that?

A Yes.

Q All right.

And, over here, you've got the schedule which shows that solid blue is blind shear ram; right?

A That's right.

Q So what are you demonstrating here by this solid blue line here on April the 22nd in relation to what you see at the end point that you're using for erosion May the 27th?

A What we see, Your Honor, is here we've stacked up a number of different elements together. If you take, say, 29th of April --

Q Dr. Nesic --

A Yes.

Q -- focus on this blue line right here. I want you to describe what that is, please.

A Okay.

Q Thank you.

A This blue line is singling out the blind sheer rams. Even if I looked at the whole thing together. So blind shear rams initially offered a high degree of restriction. And then we knew exactly what it was on the 22nd of April because I knew my geometry. We knew exactly what it was, the other blue line, on the 27th of May. We knew it was 20 I think 4 times less.

THE COURT: What's the scale on the left?

THE WITNESS: The scale is pressure drop, but it is --

THE COURT: It's 3.5 what?

THE WITNESS: Times bigger than the pressure drop at the end.

THE COURT: So it's not like --

THE WITNESS: It's a factor.

THE COURT: It's not a 3500 --

THE WITNESS: No.

THE COURT: -- pressure reading.

THE WITNESS: No. That's correct.

And there's a reason for that, Your Honor.

If I used a psi, say, for pressure drop, then if I had a higher flow rate, I would have had more pressure drop in the same geometry. If I had a lower flow rate in the same geometry, I had a lower pressure drop. So it would appear that line would be all over the place if I used the actual psi, if I used the actual pressure drop.

If look at the ratio pressure drop, if you just ask yourself not what was the actual pressure drop but how much does it change from day 1 to day 35, by what factor. It's always by factor 3 and a half overall.

So, no matter whether the flow was low or high, I always get 3 and a half time more pressure drop at the beginning than at the end. And that was so universal within very narrow margins, which is convincing to me that I've singled out only the affected geometry.

Your Honor, with due respect, I didn't know what the flow rate was when I started my analysis, and that wasn't the subject of my work. I didn't try to tell you what was the pressure drop. I just tried to tell you how much does it change.

And that's what this graph shows. It changed by 3 and a half times overall.

Q This describes the restriction at the beginning period that you analyzed in relation to the restriction to flow that is present on May 27th; right?
A Correct.
Q And you know that because you have the components in the pristine condition and you have a calculation and you have pristine and you have the recovered components on May the 27th, and so you know precisely what you have there?
A That's right.
Q And then you've characterized here some of the other events that occur in between. Is one those events on April the 29th the shut-in or the closing of the casing shear ram?
A That's right.

Q And does this column demonstrate restriction to flow based on your analysis that existed as of April the 29th?
A That's right.
Q And, the restriction, the total restriction of the flow that you've calculated at this point is actually a little higher than it was on April the 22nd; correct?
A That is correct.
Q The light-colored boxes -- we see blue here and red here -- what do the light-colored boxes depict on your scale here?
A I was trying to be very transparent in this graph and remind everyone looking at this graph that I had hard numbers for day 1, the beginning of erosion, and day 35, the end of erosion.

That's why they're darker colored. Lighter colors means that these bars in between are obtained by essentially drawing more a less a straight line from beginning to end. So they're what I called less hard or softer numbers. They were obtained by my transient simulations. That's why I've highlighted that for the BSR; it was done that way for the CSR.

The casing shear rams are the same. Beginning and end are hard numbers. In between, I used my transient analysis. I realize that is not as firm a number as the first one, but it's as good as we can get. It was based on calculations.
Q Based on your evaluation of the components that you analyzed, as well as the simulations that you ran, do you have an opinion as to whether or not erosion had concluded in the BOP

and kinked riser within nine hours or a day?

A I think that's impossible.

Q Why do you say that?

A Well, there's many different reasons I can defend that and prove myself correct.

First is we have physical evidence. We know that the kinked riser erosion persisted until May 19th. We know that casing sheer rams such as closed on April 29th continued to erode.

So I just cannot understand how one can make that leap of imagination that from one case of very fast erosion to determine that everything eroded at the same rate.

If I may just take the simplest example, even one individual element which was there all the time eroded differently different locations. So one cannot just take this erosion rate and then apply it to everything else that existed. That's point number one.

And, Your Honor, the other point is not everything that eroded made the same difference. The erosion of the casing sheer rams did not make a big difference on the flow rate. You can see that my red bars are more or less all the same height. That means the casing sheer rams were not perturbed so much by erosion.

So one cannot just take one example and transpose it. That's why I've done this thousand simulations, to catch all this intricate detail and I'm able to stack them up in the right way.

Q Okay. Now, let's go to one final topic, and that is converting the pressure drop conclusions to flow rate conclusions. And I'll just ask you, once you analyzed how restrictions changed over time, were you able to reach conclusions about the effects of metal erosion on flow rate?

A Yes, I was.

Q And what was the technique that you used for that?

A I've used most accepted technique that I know some of the other government experts also used. It's based on the so-called Bernoulli equation.

Q Now, I'm going to -- well, just describe briefly how used the equation here.

A If we take away all the details, it essentially says that pressure drop is directly proportional to velocity squared. In other words, to go from this change of pressure drop to velocity, I have to square root it.

So, while this was a straight line, something that was a straight line will become a curved line in the other block. But it's a simple quadratic or square root relationship.

Q Now, one final graph to sum up your opinions here, Dr. Nesic. I have called up D-23995B, and I'll just ask you if you can use this graph here, or chart here, to explain to Judge Barbier your opinion about how changes in restrictions affected

flow over time.
A Your Honor, this is the ultimate graph, and answers the main charge I had. And that was not what was the flow rate, but how much did the flow rate change over time because of erosion of the BOP.
And what you see here on this chart is the same timeline, April 22nd to May 27th, and kind of an inverse of the previous pressure drop plot, because there is that direct relationship there.
What you see is essentially that, assuming the BOP was the main restriction in the flow, the flow would have doubled over this period of time because of the erosion of the various components.
I would just add very briefly that, again, I don't have an actual flow rate on this axis for the same reason as I had before. I didn't get into this argument what would be the exact flow rate. I only wanted to answer the question by how much would any given flow rate change; what would be the factor.
I came up with a factor of 2 in this case.
Q Does your analysis of the ability of oil and gas to flow through the BOP change based on the initial flow rate?
A No.
Q Why is that?
A Because, the way I've done it, isolated this geometrical affect and separated it out from all the other affects that

effect, say, pressure drop. So nothing else. Either the density of the fluid, the viscosity of the fluid, the actual flow rate do not play into this.

Actually, they do; but, once you divide the flow rate at the beginning and the end, they all cancel out. So you see unambiguously and universally the change of flow that would have been obtained at any given flow rate from 5 to 65,000 barrels a day because these components were eroded.

Q And what is the significance of knowing the geometry at the beginning? That is that, in the pristine condition, versus the geometry after 35 days of flow that includes sand on your analysis?

A Well, it gave me this huge degree of confidence. This is an unusual situation that in a real life problems we know two points in time and are only really asked to connect them in the most intelligent and best possible way.

Usually, we only know one point in time, and then we're asked to predict how something will happen into the future. Or, in the case of failure analysis, we go backward and say, Okay, this is what we know. This is what broke. Go back now and analyze what happened in the past.

But rarely do we know both points in time. This was a privilege to have those two pieces of information. Made my job so much more reliable. I knew the outcome at the beginning and the end. I had quantified it, and then I did the

best possible way to connect the two points in time.
Q Dr. Nesic, what is your ultimate conclusion as to the effect of metal erosion on flow rate, assuming that the BOP and the kinked riser were restrictions to flow?
A I've concluded that this erosion of the elements of the BOP and the kinked riser were so significant, that if the BOP was the sole and the biggest restriction to flow, the flow would have doubled over this period of time that I've analyzed.
Q And the period of time that you have studied is April the 22nd to May the 27th?
A That is correct.
Q And, in terms of the ability of the flow to cause erosion, have you independently verified that erosion would be occurring during that period of time?
A Yes, I have. I have the sand production data and I have the erosion events that happened sort of along this whole timeline.

MR. BROCK: Thank you, Dr. Nesic. That's all we have at this time.

THE WITNESS: Thank you.

THE COURT: All right. Cross examination.

MS. CROSS: Good morning, Your Honor. Anna Cross on behalf of the United States.

CROSS EXAMINATION

BY MS. CROSS:
Q Good morning, Dr. Nesic.

A Good morning, Ms. Cross.
Q Dr. Nesic, you attempted to build a model to determine the rate of metal erosion; right?
A I didn't attempt, I built one.
Q You attempted -- prior to developing a model you showed us here, you tried to develop a model that would predict the rate of metal erosion over time; right?
A No. I did not try to. I actually built one. And I didn't build it prior to this. This was part of the whole exercise.
Q You're not providing an opinion about what the erosion rate was; right?
A That is true.
Q And your model doesn't tell us what the erosion rate was; does it?
A My model didn't need to tell us what the erosion rate was. My model was trying to tell us what the effect of erosion was of flow rate. I was not in the business of predicting erosion rates.
Q Your original intent when you started your work on this case was to calculate the erosion rate, and you found you couldn't do that; right?
A No. I wouldn't agree with that. I actually did calculate the erosion rates.
Q Let's go ahead and take a look at what you said in your deposition.

MS. CROSS: Could we please have page 159, lines 1 through -- and it's going to go through 162.

BY MS. CROSS:

Q I asked you: Before the break you said that the erosion rate calculated by your model had no material consequences on your findings. What did you mean by that?

Answer: If you will allow me to explain that, I need to offer a little bit of a historical perspective, historical as it refers to my work.

Okay.

Our original intent when we started this work and were charged with the task was to try to take the geometries of interest within the BOP and the kinked riser and calculate the erosion as accurately as we can, use that information to describe how that geometry eroded and changed, keep calculating the erosion rate in a transient sense, and in the end arrive with the geometry of those elements as they were found and recovered. Okay.

So, in order to do that, one needed at least two things to work really well: That the erosion model, particularly the very high erosion rates part of it -- continuing on to the next page it -- the very high erosion rates --

THE COURT: Wait, wait, wait. You're not going to read this whole page, are you? What was your original question to him? What are you trying to prove here?

BY MS. CROSS:

Q Your model does not calculate an erosion rate that you presented in your report; right?

A Ms. Cross, I've never presented erosion rates in my report as related to the real geometries, because I didn't need that information. I knew the geometry at the beginning and the end.

I will agree that it was difficult to work with the real geometries and their erosion process over time, but I did calculate the erosion rates. I've actually even calibrated them with a laboratory study. So I did do that.

It was difficult to apply those erosion rates and modify a very complicated geometry, and that's the only pathway that we didn't follow compared to what we intended from the beginning.

That's what I say in my deposition as well.

Q Okay. And so my question was simply, your opinion is not that there was a certain erosion rate based on your modeling?

A That is true. That wasn't my thrust, that's right.

Q All right. In your modeling, you looked at scans of various parts of the BOP and the riser showing erosion that were recovered after the response; right?

A That's right.

Q Now, you're not providing your own opinion about the duration of erosion; are you?

A Oh, yes, I am.
Q In your report, you said you assumed the period of erosion; right?
A What that word means is that I formed an opinion as to what it was; and, based on that, I used the assumed period in my other calculations.
That doesn't mean I guess it. In our scientific world, the word assume doesn't mean that I'm just wildly guessing what it was.
Q You assumed the flow rate based on Dr. Vaziri's estimate of the duration of sand production; right?
A Would you please repeat that question?
Q You based your assumptions that the end of the erosion period was May 27th on Dr. Vaziri's opinion about the duration of sand production?
A That is only partially true, so you got one of the two important pieces of information. I did base my opinion on what Dr. Vaziri said about sand production, and I extended that saying, Well, if there was sand until the end of May, I can safely assume that there was some erosion until the end of May.
But, as I have just testified in the direct, the other compelling piece of evidence which I had which is totally independent from Dr. Vaziri and what he thought, is with a third hole in the kinked riser that appeared on May 19th.
So, here, we are now really debating how long past

May 19th and before the end of May erosion stopped, and I stopped it conservatively on May 27th.

Q You can't say for certain that erosion didn't stop on, say, May 26th; can you?

A Well, I'm not ready to speculate about, you know, a day forward or backward. I thought May 27 best reflects a compromise where I knew that it went beyond May 19th, and I took it that it stopped some time before the end of May.

I think May 27th was a good measure. I don't know of any reasons why I would now speculate about a day forward, a day backward. In the end, it wouldn't make any big difference on my analysis.

THE COURT: Tell me again where the May 27 came from. What's his name, the other --

THE WITNESS: Vaziri.

THE COURT: He said that's when the sand production ended?

THE WITNESS: He actually said end of May, so it means a few days beyond. He had based it on a model he ran for sand production and obviously his expertise.

THE COURT: And the 27th, you --

THE WITNESS: I moved it forward.

THE COURT: Sort of an average or something.

THE WITNESS: Well, no. It wasn't really --

THE COURT: Not an average, but what was your thinking there?

THE WITNESS: I was thinking to be a little more conservative. He said at least the end of May. I said, Well, I don't want to stretch it that long because I know there's arguments. We don't have physical evidence it was end of May. We have May 19th. So I thought May 27th is a sensible one.

I had no reason, Your Honor, to say May 20th, because I knew it was --

THE COURT: It is also the case, if you know, that the sand production would be sort of declining?

THE WITNESS: That's right.

THE COURT: So that could be another factor.

THE WITNESS: That could be. It's not my area of expertise, but that could definitely be another factor.

THE COURT: Go ahead.

BY MS. CROSS:

Q You didn't check Dr. Vaziri's work; right?

A I did not.

Q You didn't independently do any analysis to confirm that sand production lasted until May 27th?

A No. I had all reasons to rely on Dr. Vaziri's opinions were correct. I'm not a sand production expert, and I was never attempting to perform such an analysis.

Q And you understand that Dr. Vaziri is not being called by BP in this case; right?

A That, I understand, yes.
Q Let's talk about the pre-erosion geometries that you looked at. You assign those pre-erosion geometry pressure drops to April 22nd; right?
A That is true for the case of the blind sheer rams. And I do the same for the casing shear ram a week later when they close, which was April 29.
Q So, for the blind shear ram, the upper annular and the kinked riser, you assume that the pristine geometry, the pre-erosion geometry as you called it, was still, in fact, the geometry on April 22nd; right?
A Well, I took each one separately, so I don't think it's fair to lump them together. But what is true in a sort of big picture is that, on April 22nd, the blind shear rams were activated and started eroding.

They were by a long shot, which everybody agrees, the biggest resistance in that stack. So, therefore, you can call it the day of the erosion -- or the erosion started in the BOP, from my perspective.

So I wouldn't fully agree with your statement, but there's elements of truth in that.
Q When Mr. Brock asked you about the period of erosion, you said it was from April 22nd to May 27th; right?
A That's the integral view of the whole process, the certain thing activated with delayed. The CSR was activated a week

later. I have lumped the other three together. So, in that sense, you were correct, that they all started on the same day. In my analysis.

Q Right. So you assumed that there was no erosion of the upper annular or the kinked riser between April 22nd, the blowout, and April 22nd when your modeling started; right?

MR. BROCK: I'd just object. I think you used April 22nd twice. I don't know what you meant to say.

THE COURT: You said April 22nd and April 22nd.

MS. COOK: Sorry.

THE COURT: Thought were you referring to different times of that day.

THE WITNESS: Erosion was fast, but not that fast.

THE COURT: Why don't you restate your question.

BY MS. CROSS:

Q You assumed, Dr. Nesic, that April 22nd was the beginning of erosion for the blind shear ram, the upper annular, and the kinked riser; right?

A That is how I've lumped them together, that is correct.

Q So any erosion that happened in the upper annular or the kinked riser, erosion to the drill pipe, for example, you assumed none of that happened until April 22nd?

A Not entirely. If I may just explain.

When I look at something, whether something eroded or not, if you will recall, Your Honor, I had two criteria:

Whether something eroded or not and whether it had an effect, that erosion had an effect on the change of flow rate.

So, therefore, the only qualifying -- the major qualifying geometry on April 22nd that fits both those criteria were the blind shear rams. The kinked riser, if you look at how they stack up, was a negligible -- it was only 1 or 2 percent, the same as upper annular.

So I was not concerned with whether they were little eroded before the blind shear rams closed. I was looking at the big events, not every detail in the sense that you asked.

Q You didn't have any data between April 22nd and May 27th for the blind shear ram; right?

A That's correct. We had the geometry at the beginning, April 22nd, and at the end, which is May 27th.

Q And you present in figure 33 -- and Mr. Brock asked you about this -- what you called the hard numbers for the blind shear ram; right?

A Well, it's not only me calling it that. When one has that degree of accuracy and scientific knowledge about what happened, I think that's a fair characterization of calling it hard data. I think it's not fair to call it anything else.

Q What was the final pressure drop in your post-erosion modeling for the blind shear ram?

A Can you please repeat the question?

Q Sure. What was the final pressure drop in the blind shear

ram for your post-erosion geometry?
A It was 20 something times less than what it was in the pre-erosion geometries.
Q What was it in terms of pascals?
A Well, that would depend on whether you took any given flow rate that you would assume. Since I was not trying to guess the flow rate and then guess the pressure drop, I only looked by how much it changed. And this 20 something factor, I believe it was 22 or 24, that big factor was the same whether I started with 5,000 stock barrels per day or 65.
When you divide the beginning with the end, you always got about the same factor. That's why I don't remember the actual pressure drop for any given flow rate. And, actually, it's not important for my analysis.
Q You didn't present the actual pressure drops for your pre-erosion geometry or your post-erosion geometry in your report; right?
A No. Because, as I just argued, the actual numbers were not important for the main conclusion. However, it is fair to say that, in the produced files that I handed over, the actual simulations for high flow rate and low flow rate and every geometry were in actual units, pascals or psi, whatever you want, so that the hard data in terms of units were there.
That just didn't affect my overall conclusion when all those things came together in the graphs I've shown.

Q The post-erosion geometry pressure drop for the blind shear rams in the files as you produced them was about 6 psi for the high flow rate case, and between 0 and 1 psi for the low flow rate case; right?
A Honestly, I have done thousand of simulations. At least a few hundred of those were related to the blind shear rams. I have no recollection of any individual number and what are you exactly referring to. You may well be right, but that doesn't stick in my memory.
MS. CROSS: Could we please have D-22820.
BY MS. CROSS:
Q Now, Dr. Nesic, this is a version of your figure 33 that takes out everything except what you call the hard numbers for the blind shear ram.
Do you agree that this accurately depicts the blind shear ram numbers that you had April 22nd and May 27th?
A Yes, it looks right. I have haven't seen this graph in any great detail before. But, yeah, it looks right.
Q And you used your transient modeling to try to figure out how to connect those two dark blue blocks; right?
A That's true.
Q Okay. And you decided based on your transient modeling that there was a straight line between those two blocks; is that right?
A There was a straight line that connects. But there is a

straight line which best characterizes the change of pressure drop with time due to erosion, that is correct.
Q Nothing in between April 22nd and May 27th is, in fact, a calculation for the blind shear ram as you present your results in figure 33; right?
A I'm sorry, but I have to disagree. I didn't just wave my hands or use some guess or even just experience to connect the points on the 22th of April to the 27th of May.
I've actually made the best possible attempt to calculate what the nature of that line should be.
Now, I've known of many examples when people have two points and no physical evidence in between, they just connect them with a straight line.
But that's not what I did. I've actually performed transient simulations, which you just referred to, and they have indicated that the best possible line and the simplest possible way to connect these two known states would be a linear line.
So it doesn't mean that I just did it without calculations.
Q And it's fair to say that there's only one line that would connect these two points; isn't that right?
A If we assumed that the rate of sand production was constant, that would be the case. We would only use one line to connect these points.

Q Now, let's turn to your transient modeling. Your transient modeling crashed after 10 to 12 days; right?

THE COURT: Ms. Cross, if you're moving to another topic, I think we're going to break for lunch now.

You're going to be a while?

MS. CROSS: I am.

THE COURT: All right, let's break for lunch. We'll come back at 1:15.

(Proceedings in Recess.)

CERTIFICATE

I, Susan A. Zielie, Official Court Reporter, do hereby certify that the foregoing transcript is correct.

/S/ SUSAN A. ZIELIE, FCRR

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Susan A. Zielie, FCRR

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